Mortality Risk Valuation in Environment, Health and Transport Policies

OECD

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Foreword

The idea of associating a monetary value with human life is very challenging and can seem insensitive or harsh. Life is indeed priceless, at least when considered from the complex perspective of an individual. However, policy makers are regularly devising policies and regulations that affect people's risk of death and that seek to protect lives in society, and require methodologies for comparing the costs of reducing risk with the expected benefits in terms of lives saved. The analysis presented in this report will help policy makers get a better measure of such benefits.

The report takes stock of surveys from around the world where people have been asked about their willingness to pay for a small reduction in mortality risk, and analyses the variation in the estimates resulting from differences in study designs (including the way risk changes are displayed), characteristics of risk (type and size of risk changes, baseline risks, etc.), socio-economic characteristics (age, income, gender, health status, etc.), and other variables.

The report offers guidance on how the findings of the analysis can be included in future assessments of policies that affect mortality risks. Such assessments will need to take into account the income level in the given country, as well as characteristics of the risk change in question and the population affected by it. Such guidance will help to improve the information base upon which important decisions are taken on mortality risks faced by society.

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The work was undertaken under the auspices of the former Working Party on National Environmental Policies under OECD's Environmental Policy Committee (superseded in 2011 by the Committee's Working Party on Integrating Environment and Economic Policies).

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The project also benefitted from comments made by participants at a workshop held 17-18 September 2009 in Prague, the Czech Republic; from participants at a workshop held 19 October 2010 in Brussels, Belgium; and from consultations with staff of the National Center for Environmental Economics, of the United State's Environment Protection Agency, in January 2011.

Many of the authors of the original studies on which the present meta-analysis was based have kindly provided additional results of their analyses and additional information regarding the sample they surveyed. Many of them have also provided advice on which of their estimates would be suited for inclusion in a meta-analysis intended as a basis for policy assessments. OECD extends a warm thank for all the help received.

All the data used in the analyses are freely available at *www.oecd.org/env/policies/vsl*.

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Acronyms

AC	Averting Costs
AIC	Actual Individual Consumption
ATE	Absolute Transfer Error
BT	Benefits Transfer
CAFE	Clean Air for Europe
CBA	Cost-Benefit analysis
CE	Choice Experiments
CEA	Cost-Effectiveness Analysis
CM	Choice Modelling
CPI	Consumer Price Index
CUA	Cost-Utility Analysis
CV	Contingent Valuation
DALY	Disability Adjusted Life Year
DEFRA	Department for Environment, Food and Rural Affairs (in the United Kingdom)
GDP	Gross Domestic Product
HW	Hedonic Wage
MA	Meta-Analysis
MA-BT	Meta-analysis for Benefits Transfer
NOAA	National Oceanic and Atmospheric Administration (in the United States)
PCB	Polychlorinated Biphenyls
PPP	Purchasing Power Parity
PV	Present Value
QALY	Quality-Adjusted Life Years
RP	Revealed Preference
SE	Standard Error
SEPA	Swedish Environmental Protection Agency
SP	Stated Preferences
TE	Transfer Error

VERHI	Valuation of Environment-Related Health Impacts
VOLY	Value of a Statistical Life Year
VPF	Value of Prevented Fatality (= VSL)
VSL	Value of a Statistical Life
WTA	Willingness-to-Accept
WTP	Willingness-to-Pay

Executive summary

The idea of associating a monetary value with human life is very challenging and can seem insensitive or harsh. Life is indeed priceless, at least when considered from the complex perspective of an individual. However, policy makers are regularly devising policies and regulations that affect people's risk of death and that seek to protect lives in society, and require methodologies for comparing the costs of reducing risk with the expected benefits in terms of lives saved.

The benefits of prevented mortalities can be expressed in terms of a "Value of a Statistical Life" (VSL), which represents the value a given population places *ex ante* on avoiding the death of an unidentified individual. VSL is based on the sum of money each individual is prepared to pay for a given reduction in the risk of premature death, for example from diseases linked to air pollution.

It is important to keep in mind that even if these mortality risk changes are not valued explicitly, they will still be valued implicitly through the policy decisions that are ultimately made. For example, if a policy that has a cost of USD 5 million per prevented fatality (and this is the only benefit) is implemented, this implies a VSL of at least USD 5 million. However, such implicit values tend to vary a lot from case to case, depending on the level of information among the decision makers and the specifics of the political processes. Whilst people object sometimes on ethical grounds to explicit valuations, the use of implicit values is pervasive and is the default situation, even if it is not so visible. Explicit values derived from carefully conducted valuation techniques will improve the information base for decision makers and can yield more consistent policy making and lead to more efficient allocation of scarce resources across sectors.

One important tool to promote consistency in policy making is cost-benefit analysis (CBA). CBA compares the total expected costs of a given action against the total expected benefits, to see whether the benefits outweigh the costs, and by how much. The effects of a policy or business decision on human life are obviously a major concern: car air bags, speed limits, water quality standards and vaccinations are just a few of the cases where costs of improving safety are measured against the number of lives saved.

CBA is now an important element in project and policy evaluations in many OECD countries, including the United States, Canada, Australia, the United Kingdom and the Nordic countries, as well as the European Commission. CBAs are widespread in the transportation, energy and environment sectors. Such analyses have, for example, been made of the European Commission's Clean Air for Europe programme, and of the Clean Air Act Amendments in the United States.

However, the method used to establish a VSL number for policy making vary widely between countries, and even between agencies within a country. The main difference is the reliance on Revealed Preference (RP) methods in terms of wage risk studies in the United States (where most such studies have been conducted), while Europe, Canada and Australia rely more on Stated Preference (SP) methods, eliciting people's willingness-to-pay (WTP) for changes in mortality risks. The focus in this report is on VSL values derived from SP studies.

The report summarises the results of a four-year effort to compile and analyse the largest database to date containing all SP studies that have been prepared around the world and that estimate adult VSL in environmental, health and transport risk contexts. The objective is to summarise this literature to answer two broad questions of relevance for both policy and research communities:

1. What are the main factors explaining people's WTP for reductions in mortality risks in the environmental, health and transport contexts, and the VSL derived from SP studies?
2. Based on the current knowledge, which VSL estimates should be used in analysis of environmental, health and transport policies?

The methodological approach used to answer the two questions is a meta-analysis (MA). MA is a body of statistical methods that have been found useful in reviewing and evaluating empirical research results from a variety of sources. It is used here to show how, and explain why, VSL estimates vary with different characteristics of the SP valuation methodology employed, characteristics of the change in mortality risk (*e.g.* type of risk, latency, cancer risk etc.), socio-economic characteristics of the respondents, and other variables.

Deriving a VSL value from a willingness-to-pay survey

VSL can be derived in the following way from a SP survey: The survey finds an average WTP of USD 30 for a reduction in the annual risk of dying from air pollution from 3 in 100 000 to 2 in 100 000. This means that each individual is willing to pay USD 30 to have this 1 in 100 000 reduction in risk. In this example, for every 100 000 people, one death would be prevented with this risk reduction. Summing the individual WTP values of USD 30 over 100 000 people gives the VSL value – USD 3 million in this case. It is important to emphasise that the VSL is not the value of an identified person's life, but rather an aggregation of individual values for small changes in risk of death.

The VSL is often used in CBA of policies as follows: the analyst first estimates the number of deaths expected to be prevented in a given year by multiplying the annual average risk reduction by the number of people affected by the programme. Then the VSL (either a single number or a range) is applied to each death prevented in that year in order to estimate the annual benefit. Annual benefits are then summed over the life time of the policy as a present value, using the national social discount rate.

There is a large and growing literature of SP studies worldwide valuing small changes in mortality risks. However, few syntheses of the results from these studies have been available. Such syntheses can help researchers and policy makers to better understand people's preferences for small mortality risk changes. On the basis of an improved understanding of people's preferences, one can better select appropriate VSL numbers for use when assessing the benefits of prevented mortalities in public policy analysis.

While in some cases, a new primary valuation study, tailored for the specific policy in question, might be needed in order to carry out an appropriate CBA, in many situations benefit transfer (BT) can be used instead. Benefit transfer is where VSL values that have been estimated in one context are – with appropriate adjustments – used in policy assessments in another context. This will generally be less time- and resource-consuming than undertaking new primary valuation studies. To facilitate BT, the report outlines an eight-step procedure for how to transfer VSL estimates from existing SP studies for use in a regulatory policy analysis or CBA. A simple unit value transfer, with income adjustment in terms of GDP per capita, is recommended when transferring VSL estimates from other countries to establish a domestic VSL base value.

The book proposes a range for the average adult VSL for OECD countries of USD (2005-USD) 1.5 million – 4.5 million, with a base value of USD 3 million. For EU-27, the corresponding range is USD 1.8 million – 5.4 million (2005-USD), with a base value of USD 3.6 million. These base values and ranges should be updated as new VSL primary studies are conducted.

Table 0.1 summarises the recommendations for when the values for a country (or group of countries) should be adjusted or not. These recommendations should be updated as new primary valuation studies become available, providing further evidence on these potential adjustments.

Table 0.1. **Recommendations for adjusting VSL base values**

Adjustment factor	Recommendation
Population characteristics	
Income	No adjustment within a country or group of countries the policy analysis is conducted for (due to equity concerns). For transfers between countries VSL should be adjusted with the difference in Gross Domestic Product (GDP) per capita to the power of an income elasticity of VSL of 0.8, with a sensitivity analysis using 0.4 (see equation (1) in chapter 2.1.)
Age	No adjustment for adults due to inconclusive evidence. Adjust if regulation is targeted on reducing children´s risk. VSL for children should be a factor of 1.5 – 2.0 higher than adult VSL.
Health status of population and background risk	No adjustment (due to limited evidence)
Risk characteristics	
Timing of risk (Latency)	No adjustment (due to limited evidence)
Risk perception (source or cause)	No adjustment (due to inconclusive evidence). Sensitivity analysis for lower values in the environment sector than in health and traffic.
Cancer or dread (Morbidity prior to death)	No adjustment if the regulation is targeted on cancer risks and/or risks that are dreaded due to morbidity prior to death. Morbidity costs prior to death should be added separately.
Magnitude of risk change	No adjustment. However, since the magnitude of the risk change clearly affects the VSL, a sensitivity analysis based on VSL calculated from a risk change similar in magnitude to the policy context should be conducted. A risk change of 1 in 10 000 annually is suggested for calculating a VSL base value.
Other adjustments	
Altruism and Public vs. Private risk	No adjustment (due to limited evidence and unresolved issues). Use “Private risk” to calculate a VSL base value. Provide illustrative adjustments in sensitivity analysis.
Discount for hypothetical bias in SP studies	No adjustment (due to limited evidence).
Correction for inflation	Adjustment based on the national Consumer Price Index (CPI).
Correction for increased real income over time	Adjust VSL with the same percentage as the percentage increase in GDP per capita.

Chapter 1

The valuation of mortality risk

Environmental, health and transport polices often reduce mortality risks substantially. It is necessary to value such risk changes in monetary terms in order to compare them to costs in cost-benefit analysis. This report uses meta-analysis methods to take stock of stated preference studies that estimate the value of a statistical life (VSL) for adults, with the aim to explain people's preferences for mortality risk reductions and to recommend specific VSL estimates that may be used in policy analyses. Current regulatory practices vary considerably even between agencies within the same country. Hence, there is considerable scope for more consistent and efficient treatment of the benefits of mortality risk reductions.

1.1. Background and objectives

Why valuation of mortality risks is important

Cost-Benefit Analysis (CBA) of public policies to reduce risks to human health and safety, and assessment of health impacts in project evaluation, require mortality risk reductions to be valued in economic terms. Policies and projects in the environmental, transport, energy, food safety and health sectors all involve changes in public mortality risks. When assessed in economic terms, the value of these changes tend to dominate estimates of the benefits of environmental and other policies (for air pollution, see *e.g.* US EPA, 1999; European Commission, 1999; Friedrich and Bickl, 2001; Watkiss *et al*., 2005).

Available estimates of how the public-at-large, in different circumstances, value a prevented fatality – or a statistical life (VSL) – varies significantly. This can strongly influence whether or not the estimated benefits of a given policy measure exceed the cost of that measure. Gaining a better understanding of what explains the differences in available estimates of the value of a statistical life can hence be of vital importance for policy making. CBA is increasingly being required and used in project and policy evaluations in OECD countries, *e.g.* the United States and Australia (where CBAs are termed Regulatory Impact Assessments), the United Kingdom and the Nordic countries. The European Commission conducts CBAs for all new EU Directives, and the World Bank and the regional development banks in Asia, Africa and Latin America use CBAs in their project evaluations. Most of the applications to date have been in the transportation, environment (including water and sanitation) and energy sectors. Within the environmental sector, the US Environmental Protection Agency and DG Environment of the European Commission have taken a leading role in using VSL estimates to assess the benefits of mortality risk reductions in their CBAs.

To avoid placing a monetary value on human lives, Cost-Utility Analysis (CUA), rather than CBA, has dominated economic assessments in the health sector. CUA can be considered as a special case of Cost-Effectiveness Analysis (CEA). In health impact assessments, CUA estimates the ratio between the cost of a health-related intervention and the benefit it produces in terms of the gained number of years lived in full health by the beneficiaries. This is usually expressed as a cost per QALY[1] (Quality-Adjusted Life Year), where the "gained" number of life years are converted to QALYs (*e.g.* if an intervention allows a patient to live for five additional years, but only with a quality of life weight of 0.5, then the intervention confers 5 x 0.5 = 2.5 QALYs to the patient). However, the costs per QALY could be very high, and the CUA does not tell whether the benefits in terms of "gained" life years exceed the costs. This comparison can only be achieved putting monetary values on gaining life-years and preventing premature deaths, by performing a new primary valuation study using non-market valuation techniques, or transfer values from existing primary valuation studies using benefit transfer (BT) techniques.

Even if these mortality risk changes are not valued *explicitly*, they will still be valued *implicitly* through the decisions that are made. For example, if a policy that has a cost of EUR 5 million per prevented fatality (and this is the only benefit) is implemented, this implies a VSL of *at least* EUR 5 million. However, such implicit values tend to vary a lot from case to case, depending on the level of information among the decision makers, the specifics of the political processes and other aspects of the decisions on which they are based. A review of 76 US regulations by Morrall (2003) showed that the implicit cost of a prevented fatality from different policy decisions ranged from 100 000 (childproof lighters) to 100 billion (solid waste disposal facility criteria) in 2002 US dollars.[2] Thus, explicit values derived from non-market valuation techniques will yield both more transparent and consistent values, and potentially lead to more efficient allocation of scarce resources across sectors.

There are two main methodological traditions to value mortality risk changes, and VSL, in monetary terms: revealed and stated preference methods. *Revealed Preference (RP)* methods are based on individual behaviour in markets where prices reflect differences in mortality risk (*e.g.* a labour market, where wages reflect differences in workplace mortality risks), and markets for products that reduce or eliminate mortality risks (*e.g.* buying bottled water to reduce mortality risk from contaminated tap or well water, and buying motorcycle helmets to reduce mortality risks in traffic accidents). These two RP approaches, termed the "hedonic wage" (HW)/wage risk (see *e.g.* Viscusi and Aldy, 2003) and "averting costs" (AC) methods (see *e.g.* Blomquist, 2004), respectively, depend on a set of strict assumptions about the market and the respondents' information and behaviour which are seldom fulfilled.

Stated Preference (SP) methods, *e.g.* contingent valuation (CV) or choice modelling (CM), instead construct a hypothetical market for the mortality risk change in question and ask respondents directly in surveys for their willingness-to-pay (WTP) to reduce their mortality risk, from which the VSL can then be derived. Both RP and SP methods have their strengths and weaknesses, but there has been a growing emphasis on SP methods in recent years. Important reasons for this is that many environmental, transport and health policies affect the youngest or the oldest part of the population the most (rather than the workers in occupations that involve risk, whom wage risk studies are based on), and that mortality often results from long-term risk exposure and exacerbation of pre-existing medical conditions (rather than accidental deaths in the workplace).

Objectives of this book

There is a large and growing literature of SP studies worldwide valuing small changes in mortality risks. However, there is little systematic or synthesised knowledge of the results from these studies, or analysis of how the accumulated knowledge can further ongoing research to understand people's preferences for small mortality risk changes, and on this basis select appropriate VSL numbers for assessing the benefits of prevented mortalities in public policy analysis.

This report summarises the results of a four-year effort to compile and analyse the largest database to date containing all SP studies globally estimating adult VSL in environmental, health and transport risk contexts. The objective is to summarise this literature to answer two broad questions of relevance for both policy and research communities:

1. What are the main factors explaining people's WTP for changes in mortality risks in the environmental, health and transport contexts, and the VSL derived from SP studies?
2. Based on the accumulated knowledge, which VSL estimates should be used in analysis of environmental, health and transport policies?

Both questions are of research and policy interest. It should be noted that the first-best strategy to assess the economic value of mortality risk reductions is to conduct a primary valuation study, tailored for the specific policy in question. However, in many instances, this may be too time- or resource-consuming, or not strictly necessary for conducting a meaningful CBA. The analysis done in this report to answer question 2 above is for the situation in which such a primary valuation study is not possible or necessary, *i.e.* when so-called benefit transfer (BT) is used instead.

The primary methodological approach used here to answer the two questions is to conduct a meta-analysis (MA). MA is a body of statistical methods that have been found useful in reviewing and evaluating empirical research results (Stanley, 2001). It is used here to show how, and explain why, VSL estimates vary with different characteristics of the SP valuation methodology employed, characteristics of the change in mortality risk (*e.g.* type of risk, latency, cancer risk etc.), socio-economic characteristics of the respondents and other variables. The study follows the recommendation of the US EPA Work group on VSL meta-analysis (US EPA, 2006) to conduct MA of stated and revealed preference studies of VSL separately, as the two methods are too different to be combined.

In addition to providing a quantitative literature review, MA may also be useful for BT purposes. The idea is that when the effect of each policy-relevant factor on VSL can be quantified based on the literature in a meta-regression function with an acceptable degree of certainty; this function can be transferred to a policy context in need of a VSL estimate. The values of the variables at the relevant policy context (*e.g.* income of the population, type of risk, etc.) can be inserted into this function to generate an appropriate VSL estimate. There are methodological hurdles involved in this process, but this method for BT is analysed in this report along with simpler techniques. Of course, the MA results are primarily descriptive in terms of explaining how people actually do value risks. When assessing how society should value risks, concerns other than efficiency (*e.g.* equity) must also be taken into account.

The report is an updated compilation of several outputs from this project over the last few years. The report aims to reflect the most important findings from this rich body of work, and build on what has been learnt in the process of grappling with the large database of SP studies. Readers that are interested in delving into the studies behind this report are referred to the source studies: Braathen *et al.* (2009), Biausque (2010), Lindhjem *et al.* (2010, 2011) and Navrud and Lindhjem (2011).

Outline of the book

An important aim of the project has been to arrive at specific recommendations of VSL numbers that can be used to assess benefits of mortality risk reductions in environmental, health and traffic policies. The book is therefore organised around several successive and necessary steps to conduct benefit transfer (BT):

1. Assemble a database of VSL estimates from which to transfer (Chapter 2)
2. Assess good practice guidelines for valuation methods, screening and conduct meta-analysis (Chapter 3)
3. Assessment of benefit transfer techniques and accuracy (Chapter 4)
4. Follow good-practice benefit transfer guidelines (Chapter 5)
5. Conduct benefit transfer – recommend VSL for different contexts (Chapter 6)
6. Draw conclusions and recommendations (Chapter 7)

First, it is necessary to get an overview of the literature and assemble a database of VSL values that can be used to transfer values from. The procedure of compiling the database and the characteristics of studies and VSL estimates contained in it (step 1), are discussed in detail in Chapter 2. Chapter 3 in turn assesses the quality of studies in the database, screens out VSL estimates from studies that do not reach a certain level of quality, conducts MA to investigate how different factors affect VSL and checks the sensitivity of results to different methodological choices (step 2). Chapter 4 discusses some important issues in using MA for BT, and assesses and compares the accuracy of MA compared to other, easier-to-apply BT techniques (step 3).

To conduct a BT, step 4 requires the use of a good-practice BT guideline. This and the other BT steps are discussed in detail in Chapter 4, assessing how and which VSL estimates can be transferred to different contexts. Step 5 makes an actual transfer, following the guidelines. Chapter 6 discusses and recommends appropriate base VSL estimates (or ranges) and goes through the main factors that should be considered when adjusting this base value upwards or downwards depending on the policy context. Finally, Chapter 7 summarises the main results and concludes.

Before moving into the specific steps of the BT process, the rest of this chapter first explains the underlying concepts of VSL and mortality risk valuation more thoroughly. Section 1.3 then provides an overview of current regulatory practices internationally in valuing mortality risks. These practices vary widely not just between countries, but also between regulatory authorities with the same countries. A more consistent approach in many countries could lead to welfare gains.

1.2. Issues in the valuation of mortality risk

Risk reductions and value of statistical life (VSL)

The first step in valuing a statistical life is to understand the WTP for a risk reduction that will extend that life. First, WTP is defined as the maximum amount that can be subtracted from an individual's income to keep his or her expected utility unchanged. Individuals are assumed to derive well-being, or utility, from the consumption of goods.

To derive the WTP for a risk reduction, let U(y) denote the utility function expressing the level of well-being produced by the level of consumption, y, when the individual is alive. Further, let R denote the risk of dying in the current period, and V(y) the utility of consumption when dead (*e.g.* the utility derived from leaving bequests). Expected utility is then expressed as EU = (1-R) U(y) + R V(y). This expression is simplified to EU = (1-R) U(y) if it is further assumed that the utility of income is zero when the individual is dead.

The VSL is a summary measure of the WTP for a mortality risk reduction, and a key input into the calculation of the benefits of policies that save lives. The mortality benefits are computed as VSL×L, where L is the expected number of lives saved by the policy.

The VSL is the marginal value of a reduction in the risk of dying, and is therefore defined as the rate at which people are prepared to trade off income for risk reduction:

$$VSL = \frac{\delta WTP}{\delta R} \tag{1.1}$$

where R is the risk of dying. The VSL can equivalently be described as the total WTP by a group of N people experiencing a uniform reduction of 1/N in their risk of dying. To illustrate, consider a group of 10 000 individuals, and assume that each of them is willing to pay EUR 30 to reduce his, or her, own risk of dying by 1 in 10 000. The VSL implied by this WTP is EUR 30/0.0001, or EUR 300 000.

The concept of VSL is generally deemed to be an appropriate construct for *ex ante* policy analyses, when the identities of the people whose lives will be saved by the policy are not known yet. As shown in the above example, in practice VSL is computed by first estimating WTP for a specified risk reduction ΔR, and then by dividing WTP by ΔR.

How people value mortality risk changes and how it is measured

Mortality risks are most often valued in terms of VSL, which is the rate at which people are prepared to trade-off income for a reduction in their risk of dying. As briefly mentioned above, there are two basic non-market valuation approaches suggested for identifying the WTP of an individual for mortality risks.

First, the Hedonic Wage (HW) approach (a revealed preference (RP) method) analyses actual behaviour in the labour market. If a person is working in a job with above-average mortality risk, he will normally require a higher wage to compensate for this risk. By observing the wage premium, one can see what value they attach to that risk. One drawback of hedonic wage studies is that they provide estimates of VSL for only a small (working-age) segment of the population. A second shortcoming is that these studies value current risk of accidental death, whereas environmental hazards (*e.g.* asbestos or PCBs), are likely to cause death only after a latency period, with the eventual cause of death being cancer or chronic respiratory illness. Wage-risk studies also face the problem of separating between actual and perceived risks, as well as other factors that cause variation in wages.

Second, Stated Preference (SP) studies explicitly ask individuals how much they would be willing to pay (or willing to accept) to compensate for a small reduction (increase) in risk. SP methods can be divided into direct and indirect approaches. The direct Contingent Valuation (CV) method is by far the most used method, but over the past few years the indirect approach of Choice Modelling (CM) (or "Conjoint Analysis") has gained in popularity. The main difference between these two approaches is that the CV method typically asks the respondent for their WTP for a public programme that would reduce their mortality risk directly as an open-ended maximum WTP question, or as a dichotomous choice (referendum; yes-no) approach. CM, on the other hand, asks respondents to make a series of choices between health risks with different characteristics and monetary costs. The main appeal of SP methods is that, in principle, they can elicit WTP from a broad segment of the population, and can value causes of death that are specific to environmental hazards. The main drawback of the SP methods is that it is *hypothetical*, so that the amounts people say they are willing to pay may be different from what they actually would have been willing to pay, if faced with the given situation.

Another approach to valuing (both) mortality (and morbidity) risk is the Averting Cost (AC) or self-protection approach. Here, expenditures people make to reduce either the probability of a bad outcome or severity of the bad outcome are usually assumed, under certain plausible conditions, to be a lower bound on the *ex ante* value people assign to reduced risks. However, recent analysis (Shogren and Stamland, 2005) have found that VSL estimated from this method is not in general a lower bound on the population average WTP for mortality risk reduction. Situations arise in which these expenditures are upper bounds, and situations exist when this "lower bound" is a severely deflated lower bound. The economic circumstances describing these situations, unfortunately only partly depend upon things one can observe and correct for (*e.g.* the fraction of the population who purchases self-protection and the price-setting in the market for self-protection). The impacts of these observable factors are "tangled" with the impacts of elements one cannot directly observe (*e.g.* the heterogeneity of both skill to cope with risk and risk preference among people). Thus, more research is still needed to define and broaden the case where one can at least say whether self-protection expenditures are a lower-bound of true value, or one is confident of the direction bias (*i.e.* relatively invalid) in a given value (Bishop, 2003).

How people value mortality risks, and hence the derived VSL from RP and SP studies, depend on a number of factors. Some of these factors are related to context of the risk, *e.g.* including *(1)* the cause of death (respiratory illness, cancer, road traffic accident), *(2)* the beneficiary of the risk reduction (adult vs. child, oneself vs. household), and *(3)* the mode of provision of the risk reduction (public programme vs. private good) (Alberini and Ščasny, 2011). Other factors relate to when the risk reduction sets in (*i.e.* latency vs. immediate), whether people have some degree of (perceived) control and whether there is perceived dread. These are all factors or attributes of the mortality risk in question. Characteristics of the respondent may also be important for how he values the risk change. The perhaps most important factors in this category include age, health status, gender and income. The most important factors for mortality risk valuation will be reviewed later in this report, in relation to the MA (where many of the variables are tested) and in the review of the wider literature as basis for recommending adjustments to derived base VSL estimates.

Before moving to the review of current regulatory practices in the next section, two issues that are not considered explicitly in this report, *i.e.* VSL for children and value of a life year (VOLY) for adults (and children) are reviewed briefly.

Value of children versus adults and altruism

OECD (2004) reviewed the evidence on economic valuation of mortality among children, and concluded that children have neither the cognitive capacities nor financial resources to state reliable preferences in SP surveys. Thus, society's perspective is the best perspective from a policy point of view, but it is not applied to children's preferences – due to difficulties in distinguishing between paternalistic[3] and non-paternalistic altruism (and thus the problem of double-counting due to altruism). With paternalistic altruism, it would be appropriate to add-up WTP across individuals. Therefore, parents are asked about the value they attribute to their children's mortality risk. Some studies find the values of children's health benefits to be higher than those of adults, while others find the two values to be similar, and one study even finds the value to be less. For further information on SP surveys of parents WTP to reduce mortality risks for their children, see *e.g.* Alberini, Chiabai and Tonin, 2009; Ferrini *et al.,* 2009; and Ščasny, Alberini and Chiabai, 2009. Based on existing reviews of the US and European empirical evidence, it is recommended using a higher VSL for children than for adults (see Chapter 6.2).

Value of a life year (VOLY)

A concept related to VSL is the value of a statistical life year (VOLY). Specifically, assume that a VOLY is constant over the rest of a person's remaining lifetime, and let T be the number of expected remaining life years. VOLY and the VSL are then related as follows:

$$VSL = \sum_t^T VOLY \cdot (1 + \delta)^{-t}$$

where δ is an appropriate discount rate. VOLY is sometimes used in policy analyses in addition to (or instead of) of VSL, but, depending on the age of the people whose lives are saved by the policy, VOLY can lead to recommendations in conflict with those obtained by using VSL. Consider for example two alternative public programmes, and suppose that both save 100 lives. But suppose that with one, the lives saved are those of young adults, whereas the other saves the lives of the elderly. As long as the VOLY is constant with respect to age, the policy that saves young adults, who have a longer life expectancy, would be concluded to offer greater benefits if the VOLY is used. By contrast, if the VSL is used, and a single figure is applied to people of all ages, the two policies would be concluded to provide the same benefits. See Annex 1.A1 for a further discussion of VOLY and the SP literature that attempts to value VOLY directly.

1.3. Current regulatory practices valuing mortality risks

The aim of this section is to give a brief and up-to-date overview of the existing VSL regulatory practices. The focus is on environment, transport and health policies, but VSL for other uses (*e.g.* terrorism risks in the United States) will also be discussed briefly. An example of how VSL have been used in policy assessments is presented in Annex 1.A2.

Introduction

Concentrating on the EU and individual countries leading the way in establishing unit values for VSL, this section discusses:

- What are the base values they are using? What are this values based on (average, meta-analysis, fitting distributions, etc.)?
- What kinds of adjustments are currently made for differences in risk characteristics and affected population?
- Are there differences in practices between different departments/sectors?
- Status on any processes to update/revise current estimates (including simple adjustments for inflation and income increases).

United States

Robinson and Hammitt (2010) summarise the base VSL estimates used by the major US regulatory agencies (see Table 1.1). They note that most agencies use central values somewhat above the middle of the range (expressed in 2007 USD) suggested by the US Office of Management and Budget 2003 guidance for regulatory analysis, of roughly USD 1 million to USD 10 million. Of these agencies, the US Environmental Protection Agency, or EPA (using a recommended central estimate of USD 7.5 million), has been responsible for the majority of the regulations using VSL estimates, and has devoted considerable attention to valuing these mortality risks (Robinson, 2007). The US Department of Transportation, the US Food and Drug Administration and the US Department of Homeland Security have also conducted a number of regulatory analyses involving the use of VSL estimates.

US EPA recommends that the same values are to be used in all benefit analyses regardless of age, income or other population characteristics.[4] The only adjustments that are made are due to expectations of increased real income over time, delays between exposure and changes in mortality incidence (*i.e.* latency), and some external costs (*e.g.* insured medical costs) not likely to be included in estimates of individual WTP. The same practice is followed by the other US agencies, but they differ in how they implement these adjustments.

Note that the estimates vary between the US agencies although they are all based on the same studies in terms of selected literature reviews and meta-analyses, dominated by hedonic wage (wage-risk) studies in the US and other high-income countries. However, the differences across agencies reflect particular estimates they chose from these literature reviews, rather than tailoring of the values to the particular populations or risks each agency addresses (Robinson and Hammitt, 2010).

Table 1.1. **Base VSL estimates in US regulatory analyses**

Agency	Reported VSL Estimates (range, dollar year)[a]	Basis
Office of Management and Budget 2003 guidance	USD 1 million – USD 10 million (no dollar year reported	Available research, allows agency flexibility
Environmental Protection Agency 2000 guidance[b]	USD 7.5 million (USD 0.9 million – USD 21.1 million, 2007 USD)	Viscusi (1992, 1993) literature review
Department of Transportation 2008 guidance	USD 5.8 million (sensitivity analysis: USD 3.2 million, USD 8.4 million; probabilistic analysis: standard deviation of USD 2.6 million, 2007 USD)	Mrozek and Taylor (2002), Miller (2000), Kochi *et al.* (2006), Viscusi and Aldy (2003) meta-analyses; Viscusi (2004) wage-risk study
Food and Drug Administration 2007 analyses[c]	USD 5 million, USD 6.5 million (varies, no dollar year reported)	Viscusi and Aldy (2003) meta-analysis
Department of Homeland Security 2008 analyses[d]	USD 6.3 million (USD 4.9 million – USD 7.9 million, 2007 USD)	Viscusi (2004) wage-risk study
Other agencies	Economically significant rules addressing mortality risks infrequent, approaches generally similar to the above	

Notes: Estimates presented in 2007 dollars because some agencies have not yet updated their estimates for subsequent years.

a. The US DOT and US DHS base estimates include the effects of income growth over time as well as inflation as of the year 2007. The US EPA adjusts for income growth separately in each analysis depending on its target year; the value in the table reflects the effects of inflation only.

b. The US EPA estimates are reported in 1997 dollars and inflated to 2007 dollars by the authors using the US Consumer Price Index (*www.bls.gov/data/inflation_calculator.htm*). The US EPA is now updating its guidance.

c. As reported in US FDA 2007.

d. Based on Robinson (2008). Previous US DHS analyses use VSL estimates of USD 3 million and/or USD 6 million.

Source: Robinson and Hammitt (2010).

Since the scenarios in the policy analyses (such as air pollution and road traffic accidents) differ in many aspects from the risks analysed in the wage risk studies (which are based on job-related accidents) unit value transfer with adjustments for differences in population and risk characteristics is needed. However, as Robinson and Hammitt (2010) point out, only in a few cases have analysts been able to quantitatively adjust unit values from the primary study to fit the context of the policy analysis. The most frequent approach is for them to explore the implications of the resulting uncertainties of the transfer qualitatively due to the limited research available for making these corrections quantitatively.

In those cases where age-differentiated VSLs have been applied in sensitivity analyses, there has sometimes been considerable controversy about their use. For instance, in the United States, the use of age-differentiated weights in an EPA analysis of the Clear Skies Initiatives resulted in a spate of newspaper articles.[5] Specifically, a 37% lower VSL was applied for those over 65. The US EPA has now abandoned this adjustment due to new studies not showing a clear decline in VSL at high age.

Another controversy arose from US EPA adjusting their VSL estimate *downwards* based on improved methodology for wage-risk studies, and new meta-analyses taking account of these methodological improvement (Viscusi, 2009)

The United States is currently reviewing evidence on VSL to update their values.[6]

Canada

While US agencies generally do not adjust their VSL estimates for differences across population subgroups, despite *some* evidence that individuals' WTP for their own risk reduction varies with age, Canadian agencies have included age adjustments in some regulatory analyses without the sort of public outcry that resulted in the US (and in spite of the fact that the current Canadian guidance on impact assessment does not discuss age adjustments [Treasury Board, 2007]).

Chestnut and De Civita (2009) updated the extensive literature review of previous VSL studies by Chestnut *et al.* (1999) with the aim of recommending a new VSL base value and range for Canada.

Chestnut and De Civita (2009) found that the mean VSL estimates from Canadian wage-risk studies averaged CAD 7.8 million and ranged from CAD 6.2 million to CAD 9.9 million (all amounts in 2007 CAD). The mean VSL estimates from Canadian stated preference studies averaged CAD 5.0 million and ranged from CAD 3.4 million to CAD 6.3 million. The US stated preference studies using the *same* instruments as the Canadian studies obtained very similar results. The average of the mean US results in these studies is CAD 5.1 million, almost identical to the average of the Canadian estimates. Chestnut and De Civita *op. cit* state that this, and the similarity of results between Canadian and US wage-risk studies, supports the use of results from US studies to help inform the selection of estimates for use in Canadian policy analysis.

A recent meta-analysis of wage-risk studies in the United States provides somewhat different perspectives about the best estimates from this literature. Viscusi and Aldy (2003) reported a mean VSL of CAD 10.8 million. When they included all the estimates from studies worldwide, the mean became CAD 7.9 million. About 65% of these studies are from the United States and most of the rest are from Canada, Australia, and European countries.

Mrozek and Taylor (2002) argued that many wage-risk studies do not sufficiently control for inter-industry differences in wages that they state are correlated with risk levels and thus can lead to an over-statement of the risk premium. They incorporated an adjustment for this into their mean result and obtained a VSL of about CAD 3.7 million for US studies. Without this adjustment, their mean result was CAD 9.7 million, very similar to Viscusi and Aldy's result for US studies. Chestnut and De Civita (2009) stated that this was quite a substantial difference, and it is not clear which is more accurate. Viscusi and Aldy argued that using industry dummy variables to control for inter-industry differences in wages can cause a downward bias in the risk coefficient, because these dummy variables could pick up some wage differences that are actually due to differences in risks. On the other hand, Mrozek and Taylor made the argument that using no controls for unaccounted for differences in wages across industries could lead to an upward bias in the risk coefficient.

Chestnut and De Civita (2009) argue that the truth is somewhere in between, which is also where the stated preference results fall. The midpoint between the two wage-risk meta-analyses is about CAD 7 million. This is close to the average of the mean stated preference result and the mean revealed preference result from the Canadian studies, which is about CAD 6.5 million. This is the recommended central estimate for policy analysis. It gives equal weight to results from the two types of studies. The recommended low value is CAD 3.5 million, which is close to the adjusted estimate from Mrozek and Taylor (with the inter-industry adjustment) and to the lower of the Canadian stated preference results (Alberini *et al.*, 2004). The recommended high value is CAD 9.5 million, which is representative of the wage-risk meta-analyses results without the inter-industry adjustment, and is in the range of the highest wage-risk results obtained in Canada (CAD 9.0 million and CAD 9.9 million). Chestnut and De Civita (2009) conclude that these values represent a reasonable range for policy analysis. Higher and lower estimates exist in the literature, so these are not lower and upper bounds. Arguments could be made to defend each of these estimates as a reasonable base value although the central estimate is the best choice if a single VSL base value is used. The recommended estimates are about the same as the previous recommendation for working-age adults (central of CAD 6.5 million) and higher than the previous recommendations for adults ages 65 and over (central of CAD 4.9 million).

Canada is currently reviewing this evidence on VSL to update their values.

United Kingdom

The United Kingdom has a long tradition for SP surveys of VSL, and the WTP results from these studies have been used in their Cost-benefit Analysis guidelines for the *transport* sector since 1993 to establish VSL estimates in order to value both fatal and non-fatal accidents. The U.K. Department of Transport (U.K. DfT) 2009 uses the midpoint from a range of GBP 750 000 to GBP 1 250 000 (1997-GBP) produced by the most recent U.K. SP study to establish a VSL mid-point value of GBP 1 million. They then update this to 2007-GBP, yielding a central VSL estimate of GBP 1 080 760. Then they add lost output/productivity loss of GBP 555 660 and medical and ambulance costs of GBP 970 to get the estimate currently used for the social benefits of preventing a fatality: GBP 1 638 390.

In the *environmental* sector, the U.K. Interdepartmental Group on Costs and Benefits (IGCB, 2007) presented a literature review of both wage risk and SP studies of VSL worldwide.[7] In order to decide which papers to consider in detail, the IGCB narrowed down the number of studies according to whether they had the following characteristics:

- The study was based in the United Kingdom using a representative U.K. sample of respondents;
- The study used an air pollution context;
- The study elicited people's WTP to reduce the risk of their death brought forward by air pollution; and
- The study also estimated the value of a life year, which could be applied to the quantified health effects expressed in terms of life years lost.

Thus, these IGCB criteria for benefit transfer adhere quite closely to the benefit transfer guidelines presented in Chapter 5, with the exception of the focus on value of a life year (VOLY) to value impacts from air pollution. IGCB (2007, Annex 2) states that although there were are a number of wage-risk studies and contingent valuation studies that elicit people's WTP for mortality risks, the only two studies that specifically tried to value mortality risks associated with air pollution in the United Kingdom were Chilton *et al.* (2004) and Markandya *et al.* (2004). However, only Chilton *et al.* (2004) valued VOLY directly, whereas Markandya *et al.* (2004) derived VOLY from the VSL their SP survey produced. Chilton *et al.* (2004) specifically asked respondents to consider extensions in life expectancy in poor and normal health. Hence, IGCB (2007) argue that these values are more relevant for valuing acute effects, as they value changes in life expectancy (life years saved) and take explicit account of the fact that the increased life expectancy occurs in poor health. The proposed value of a VOLY applied to acute mortality was therefore GBP 15 000 (2004-GBP); based on the Chilton *et al.* (2004) *poor health* VOLY (based on the WTP for a 1-month increase in life expectancy). The guidelines recommend sensitivity analysis to be carried out to account for the smaller number of life years saved that can be considered as being in normal health, based on the Chilton *et al.* (2004) *normal health* VOLY of GBP 29 000 (2004-GBP). This estimate was based on their 1-month sample, and is consistent with a VOLY derived from the U.K. DfT (2009) VSL estimate for a prevented fatality cited above.

Thus, Defra uses VOLY, not VSL, from SP studies to value a 2-6 months loss in life expectancy for every death brought forward due to air pollution (which is the impact documented by epidemiological studies). The UK, however, seems to be the only country that currently uses VOLY as the main approach to value mortality impacts from air pollution. The European Commission DG Environment in their CBAs of air quality policies, however, use VOLY for sensitivity analysis; see Annex 1.A1 for an example. Note, however, that DG Environment used the VOLY estimates derived from the VSL estimates from Markandya *et al.* (2004), as this SP survey in three European countries was considered to be more representative of the European population than the Chilton *et al.* (2004) study of the U.K. population only.

European Union

The European Commission 2009 *Impact Assessment Guidelines* discuss a number of different approaches to valuation, and suggests using the methodology that is appropriate to the circumstances. The Guidelines indicate, however, that the VSL has been estimated at EUR 1-2 million in the past (no year indicated) and EUR 50 000 – EUR 100 000 for VOLY, and suggest that these range are used "if no more context specific estimates are available" (European Commission, 2009, Annexes, p. 43).

The EUR 1-2 million estimate seem to stem mainly from the European Commission (EC) DG Environment's (2001) "Recommended Interim Values for the Value of Preventing a Fatality in DG Environment Cost Benefit Analysis' (2000).[8] Based on a review meeting of US and European mortality valuation experts, three values were provided for the environmental context where someone is old – a best estimate of around EUR 1 million (2000), with a lower estimate of EUR 0.65 million and an upper estimate of around EUR 2.5 million. It was suggested that these values be adjusted for latency, carcinogenic pollutants (due to dread) and age. However, such adjustments do not seem to be been applied in practise.[9] These values were based on contingent valuation studies of the value of preventing a statistical transport fatality indicating a value of around EUR 1.5 million. Adjusting for the age of mortality victims usually associated with environmental pollution produces a figure of *around EUR 1.0 million* (2000 prices) recommended for cost-benefit analyses of environmental regulations; primarily dealing with air pollution. An interesting observation is that the US experts, some of whom were also part of the advisory board for the US EPA, which base their VSL value on wage risk studies; recommended using Stated Preference studies to determine a VSL for Europe. This was probably due to the lack of European wage risk studies, and the fact that Stated Preference studies better cover the affected population.

VOLY was used for sensitivity analysis in the Commission's DG Environment's CBAs of air quality policies; see Annex 2 for an example.

Other countries

Apart from the countries mentioned above, few countries have "advanced" practice in this area. However, the Australian Government (2008) did an extensive literature review of VSL studies, and recommends that willingness-to-pay (*i.e.* Stated Preference studies) is the appropriate way to estimate the VSL. Based on international and Australian research, a credible estimate of the VSL is AUD 3.5 million, and of VOLY AUD 151 000.

Norway can be used as an example of countries that rely on transfer of VSL estimates from other countries since no primary valuation study had been conducted until just recently.[10] The Norwegian Ministry of Finance (2005) in their guidelines for regulatory analyses recommend a VSL of 11 million 2005-NOK for environmental policies and NOK 15 million for accidental mortality risks.[11] These numbers were based on a rough unit value transfer of the recommended VSL estimates from the European Commission DG Environment (2001); based on PPP-adjusted exchange rates and converted to 2005-NOK, using the Norwegian CPI *(i.e.* adjustments made in accordance with the guidelines for benefit transfer outlined in Chapter 5). The Norwegian Directorate for Public Roads (2006), however, in their guidelines for CBA, use a VSL of 26.5 million 2005-NOK, which was based on a meta-analysis performed nearly 20 years ago of both wage risk and SP studies (but dominantly wage risk studies from the US), and adjusted to 2005-NOK using the CPI (after finding that their general use of a national building cost index for large construction project to update all costs and benefits, including VSL, could not be justified theoretically). This VSL estimate does also include productivity loss, medical costs, vehicle damage costs and administrative costs. 18.3 million 2005-NOK constitutes the mortality risk welfare loss (from valuation studies), and 12.5% is added to account for the welfare loss of the close family (*i.e.* altruism). Thus, there is some inconsistency with the Ministry of Finance (2005) guidelines. However, the Directorate for Public Roads is the agency with the longest experience in using VSL estimates in CBAs in Norway, and their guide has served as a guide to CBA guidelines prepared for the other transportation modes and for other sectors. The Norwegian Ministry of Finance (2005) also recommends a VOLY of NOK 425 000, which was based on unit value transfer of an EU population-weighted average VOLY of EUR 40 000 (2005-EUR) from a 9-country Contingent Valuation survey of people's WTP for a 3 and 6 months increase in life expectancy (Desaigues *et al.,* 2011).

Summary and comparison

This overview shows that different countries, and different sectors within a country, use different VSL values. This is partly due to the fact that different valuation methods dominate mortality risk valuation on different continents; notably hedonic wage/wage risk studies in the United States and Stated Preference studies in Europe. However, research also indicates that VSL values should differ, since their preferences differ with differences in population and risk characteristics.

Robinson and Hammitt (2010) note that the use of standardised estimates across agencies in a country, or a group of countries, like the European Union, is a second-best option that results from deficiencies in the research base and other concerns. While increased harmonisation may be desirable as long as the agencies rely on a similar approach to estimate VSL, standardisation means that the economic analyses will fall short of the goal of reflecting the preferences of those affected by the regulations. In the US, as in other countries, empirical research suggests that VSL is likely to vary by population and risk characteristics, but neither in the US nor other countries have agencies tailored their estimates to reflect these differences.

Notes

1. QALYs (Quality Adjusted Life Years) are calculated from weights on a scale from 0 to 1, where 1 is a life year in "perfect health", as evaluated by the beneficiaries, and 0 is premature death. The concept of DALYs (Disability Adjusted Life Years) was developed by the World Health Organization and is calculated from a scale from 0 ("perfect health") to 1 (death), based on evaluations by medical experts. QALY and DALY estimates might differ for the same illness as they are based on individual preferences and expert estimates, respectively. Different techniques to elicit QALY could also produce different results, but both QALY and non-market valuation techniques are based on individual preferences, which also underpin economic welfare theory and its applied tool, CBA.

2. See also US Office of Management and Budget (2010a, b) for more recent assessments.

3. "Paternalistic" altruism occurs when a person only cares about other people's consumption of a public good. "Non-paternalistic" (or "pure") altruism occurs when a person cares about the general utility levels of others.

4. See *http://yosemite1.epa.gov/ee/epa/eed.nsf/pages/MortalityRiskValuation.html*.

5. See Viscusi and Aldy (2007) for a discussion.

6. See *http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0563-1.pdf/$file/EE-0563-1.pdf*.

7. IGCB (2007) also reviewed the few existing Value of a Life Year (VOLY) studies, including Chilton *et al.* (2004) which had been commissioned by the Department for Environment, Food and Rural Affairs (Defra). This was done because the only study they found valuing VOLY directly was a Swedish study, Johannesson and Johansson (1996) that they were reluctant to transfer from; partly since it was conducted in another country and partly due to low sample size.

8. See *http://ec.europa.eu/environment/enveco/others/pdf/recommended_interim_values.pdf*.

9. Adjustments based upon health status are not suggested given continued uncertainty in this area. Interestingly, adjustments for differences in average income across member states are not recommended for both methodological (uncertainty) and political (subsidiarity) reasons. However, lower values could be used for what were Accession States at that time.

10. The Norwegian transportation departments for roads, railways, aviation and marine transport recently jointly funded a Stated Preference survey for valuing VSL and VOLY from mortality risks from accidents and transport-related air pollutants. Final reports are expected in 2011. The aim is to produce improved and consistent VSL estimates within the transportation sector and consistent with the environmental sector; and to revise their respective handbooks for CBA.

11. PPP-corrected exchange rate in 2005; 1 USD = 8.89 NOK.

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Annex 1.A1

Value of a statistical life year (VOLY)

In the absence of direct empirical estimates, the method used to derive VOLYs has been to take an estimate of the VSL and to convert it to a discounted stream of annual life year values over the remaining lifetime of the subject, based on population data on survival probabilities (European Commission, 1999). For acute effects the following relationship was used:

$$VSL = VOLY_r \cdot \sum_{i=a+1}^{T} {}_aP_i (1+r)^{i-a-1}$$

where a is the age of the person whose VSL is being estimated, ${}_aP_i$ is the conditional probability of survival up to year i having survived to year a, T is the upper age bound, and r is the discount rate.

The following relationship was derived for quantification of the VOLY for chronic effects:

$$VOLY^r_{chronic} = \sum_{i=1}^{i=T} \frac{YOLL_i}{YOLL_{tot}} \cdot \frac{VOLY^r}{(1+r)^{i-1}}$$

where $YOLL_i$ = the number of years of life lost as a result of an increment in the hazard in year I in each future year, and $YOLL_{tot}$ = the total number of years of life lost in the population.

In recent years, there have been several attempts to value VOLY directly (*e.g.* Chilton *et al.*, 2004 and Desaigues *et al.,* 2011). The first effort to value VOLY directly was Johannesson and Johansson (1996), who found a very low VOLY. The Defra study (Chilton *et al.* 2004) performed a CV survey of gains in life expectancy of 1, 3 and 6 months, in order to come up with an estimate of a VOLY (and at "poor" and "good" health). This study did not pass a scope test,[1] but the authors argued for using the one month subsample to construct a "best" estimate for VOLY of GBP 27 630. Krupnick (2004) also argued that, because this study specifically evoked air pollution as the cause, this may have reduced WTP, since people may have questioned whether it should be their responsibility to pay for air pollution reductions. Desaigues *et al.* (2011) improved on the Defra CV survey instrument and performed the same CV survey in 9 European countries – France, Spain, UK, Denmark, Germany, Switzerland, Czech Republic, Hungary, and Poland – with a total sample size of 1463. The CV survey mentioned air pollution specifically as the reason for a reduced life expectancy of 3 and 6 months (*i.e.* split sample), and asked for WTP for a programme that reduces air pollution and avoids this reduction in life expectancy. The estimated VOLY varied between countries, but the sample size for each country was small, and the authors recommended using estimates separately for EU-15 (plus Switzerland)

and the New Member States at EUR 41 000 and 33 000; respectively; and a population-weighted EU-25 average VOLY value of EUR 40 000.

Krupnick (2004) noted that the VOLY measure did not have the "lineage" enjoyed by VSL, but it had risen in prominence because it is undeniable that most avoided premature deaths due to environmental policies would be to the elderly. Treating elderly and non-elderly people as equivalent for valuation purposes seemed inappropriate, because much fewer life-years are lost when the elderly die. At the same time, the epidemiological literature is not as robust in life-years lost, and the VOLY literature is very thin, involving only a few studies that directly ask for WTP for additional life expectancy, *e.g.* Johannesson and Johansson (1996), Hammitt and Liu (2004) and Chilton *et al.* (2004). Therefore, Krupnick (2004) was critical to the suggestion to use VOLY in the main analysis, with VSL for a sensitivity analysis, in the CBA of the Clean Air for Europe (CAFE) initiative (Holland *et al.,* 2004); see also Annex 1.A2.

Although the database used for this report does contain VOLY studies and estimates, they are few. US EPA has also recently cautioned against using VOLYs that are assumed to be constant with respect to age, due to the limited evidence underlying this assumption, US EPA (2007). Therefore, this report analyses only the VSL estimates.

Note

1. A much-used test in valuation research – where people in split samples are asked for their WTP for two different risk levels, to see if people's stated WTP vary with the scope (size) of the good they are valuing.

Annex 1.A2

An illustration of how VSL estimates have been used

An example of how VSL estimates have been used in policy assessments is presented below.

In its guidelines for the estimation of the benefits of environmental policies (US EPA, 2000), the US Environmental Protection Agency recommended using a VSL of USD 6.1 million (1999 dollars). To arrive at this figure, the Agency compiled VSL values from 26 studies, mostly compensating wage studies. The US EPA does not adjust the VSL for age, futurity of the risk, and cancer, but it does adjust it for growth in income.

The European Commission used a working group set up by DG Environment (2000) to debate valuation of mortality end-points and define "interim" values. The working group's firm preference was for estimates based on the VSL, given the absence of direct empirical estimates of VOLYs. The working group considered evidence on the VSL from wage-risk studies and contingent valuation studies, and considered the latter to be the more robust for defining society's willingness to pay to reduce risk. The group agreed on an upper limit defined by the VSL identified in the ExternE research (*www.externe.info*) – EUR 4.1 million in 2005 prices. The group was, however, persuaded that recent methodological advances in non-market valuation should be taken into account in establishing a VSL for DG Environment use. On this basis, the value of EUR 1.5 million (2005 prices) was identified as a baseline figure. This provided a best estimate of EUR 1.1 million for the VSL after adjusting down to account for the age of those likely to be affected, using a factor of 0.7. A lower estimate of EUR 0.75 million was based on research by Krupnick *et al.* (2002) in North America. A number of other adjustments relating to potential air pollution-specific valuation issues were considered, but not adopted. Table 1.A2.1 presents a summary of adjustments made by DG Environment.

Table 1.A2.1. **EC Policy guidance on unit values in 2000 (2005 prices)**

Adjustment factor	EC Guideline
Baseline VSL	Central: EUR 1.5m; Range: EUR 0.75 – EUR 3.75m
Context	50% premium for cancer
Age	Multiplier of 0.7 (applies to central value only)
Health	No adjustment
Cultural	No adjustment
Income	No adjustment
Final Unit Values	Central: EUR 1.1m; Range: EUR 0.75 – EUR 3.75m
Futurity	Discount rate: 4%

Subsequently, however, the European Commission funded a new empirical study of mortality risk valuation. This study, reported in Markandya *et al.* (2004), later published as Alberini *et al.* (2006), had as its objective the derivation of unit values to account in monetary terms for the incidence of premature death estimated to result from air pollution in Europe. Values were derived from three surveys undertaken simultaneously in UK, France and Italy, using a common survey instrument previously developed in North America (Krupnick *et al.*, 2002).

The Clean Air for Europe (CAFE) CBA, undertaken by DG Environment as part of the Air Quality Thematic Strategy, on behalf of the European Commission (Watkiss *et al.*, 2005), applied the results of Markandya *et al.* (2004). Emphasis was given to the results of this study over the study undertaken in the United Kingdom by Defra that valued extensions in life expectancy (and so, VOLY) directly (Chilton *et al.*, 2004). This preference was *a)* on the basis that Markandya *et al.* was more representative of the EU population, covering three EU Member States compared to one, and *b)* that it had a much larger sample size. On the basis of Rabl (2002), the study derived the changes in remaining life expectancy, and therefore the corresponding VOLY, associated with the 5 in 1 000 risk change over the next 10 years (*i.e.* an annual risk reduction of 5 in 10 000) using empirical life-tables. Thus, both VSL and VOLY could be used in the health impact assessment.

The CAFE CBA considered an adjustment for the quality of the life lost. The Markandya *et al.* study found that the fact that a respondent has a chronic heart or lung condition does not influence WTP *per se*. However, those persons who have been hospitalised for cardiovascular or respiratory illnesses over the last 5 years had WTP amounts that were, everything else being the same, roughly twice as large as those of all others. Therefore, as a sensitivity test, a multiplier of two was applied. The WTP was not found to be age-dependent, so no adjustment was made for age.

Table 1.A2.2. **Values for use in CAFE CBA: Effects of chronic exposure on mortality**

(EUR, 2005 prices)

	VSL	VOLY	Derived from:
Median (NewExt)	1 109 000	59 200	Median WTP for an annual risk reduction of 5 in 10 000
Mean (NewExt)	2 280 000	143 000	Mean WTP for an annual risk reduction of 5 in 10 000

Source: Watkiss *et al.* (2005).

Chapter 2

Meta-database on stated preference studies of mortality risk valuation

This chapter describes the database that was used in the meta-analyses described further in Chapter 3. First, an account is given of how the value of statistical life (VSL) estimates were collected. Next, various characteristics of the estimates, and of the surveys they stem from are illustrated. The variations in the estimates in the unscreened sample across risk contexts, countries covered, survey implementation method, types of elicitation questions, etc., are described.

2.1. Compilation of the meta-dataset

The aim when compiling the data for the analysis presented in this report was to be as comprehensive as possible in (at least) two dimensions: Within the boundaries chosen, as many original valuation surveys as possible were included, and as much comparable information as possible was extracted from the studies – regarding the sample surveyed, the risk change that the sample valued, the method used in the surveys, etc.[1]

A priori, the aim was to cover *all* SP-based valuation studies that provide one or more VSL estimates – or sufficient information so that the implied VSL values could be calculate. Some studies make estimates of the "Value of a Statistical Life Year" (VOLY) – either in addition to, or as an alternative to, VSL estimates. Information also about such studies has also been collected, but the analysis in this report only addresses VSL estimates.[2]

The analysis includes surveys published in academic journals and books; prepared for various ministries or other public institutions; issued as discussion papers or similar from research institutes, etc., and studies forming part of PhD theses, etc. Surveys (only) forming part of Master theses, etc., have, however, *not* been included.

The analysis focuses on VSL estimates stemming from *stated preferences* studies in an environment, health or traffic context.[3] Information regarding revealed preference studies was not collected for this project, for reasons discussed in Chapter 1.

The focus has been on surveys where the respondents have been asked to place a value on a change in (a private or public) risk to *themselves* (or their household). This means, *inter alia*, that surveys where parents were asked to value a change in the risks facing their children are *not* included.[4]

Some of the surveys also include estimates of changes in morbidity risk – the risks of getting ill – but most of them only focus on mortality risk changes. A separate variable in the dataset reflects whether a morbidity estimate is also collected in the survey, but the present report focuses only on valuations of changes in *mortality* risks.

The hunt for relevant surveys started with a number of searches[5] in the EVRI database (operated by Environment Canada). The reference lists of previous meta-analyses, and of each of the valuation studies that came to light, were carefully studied. Similar searches were made in the databases of a number of scientific publishers, covering a large number of scientific journals, such as ScienceDirect (*www.sciencedirect.com/science*), SpringerLink (*www.springerlink.com/home/main.mpx*), IngentaConnect (*www.ingentaconnect.com*), Wiley InterScience (*http://www3.interscience.wiley.com/cgi-bin/home*) and Cambridge Journals (*http://journals.cambridge.org/action/login*). The EconLit database, the Swedish ValueBase database (*www.beijer.kva.se/valuebase.htm*), and Google Scholar (*http://scholar.google.fr/*) were also searched.[6]

No survey was excluded for being "too old" – and the oldest survey included here was carried out in 1970. In order to make the estimates comparable over time and between countries, the estimates expressed in national currency have been adjusted to national 2005 price levels, using the consumer price index, and converted to US dollars, using purchasing power-adjusted exchange rates (PPPs).[7]

Other than price developments, improvements in the survey methods, etc., over time could make it difficult to compare estimates prepared at different points in time. The meta-analysis takes a number of factors in this regard into account, through variables reflecting the elicitation method used, the type of visual aid being used (if any) to help explain the magnitude of the risk changes to the sample, etc.

Most of the studies present not just one, but several different, VSL estimates – based, for example, on sub-samples with different age or income, different magnitudes of the risk-changes valued, different risk contexts (environment, health, and traffic), different assumptions made about the distribution of WTP values collected from each person asked, etc. As many estimates as possible from any given study have been included – generally with some variations in the explanatory variables from estimate to estimate.

2.2. Characteristics of the surveys collected and VSL estimates used

This section gives a descriptive overview and characterisation of the VSL estimates on which the meta-analysis (MA) is based. This is an essential first step of any MA. The next section will use regression analysis to investigate further how different variables (some of which are included in the descriptive analysis in the current section) are related to the VSL estimates.[8]

Figure 2.1 gives the frequency distribution of the 856 mean VSL estimates of the unscreened sample of this MA. Each vertical bar represents *an interval*. About 280 of the estimates fall in the range USD 0-1 million,[9] about 210 estimates in the range USD 1-3 million, and so on. About 40 VSL estimates were larger than USD 20 million. While the largest part of the estimates based on health-related risk changes are lower than USD 3 million, the distribution of the estimates stemming from traffic- and environment-related risk changes are more evenly distributed across the selected intervals.

Figure 2.1. **Frequency distribution of VSL estimates, by risk category**

Number of estimates in each interval, 2005-USD, PPP adjusted

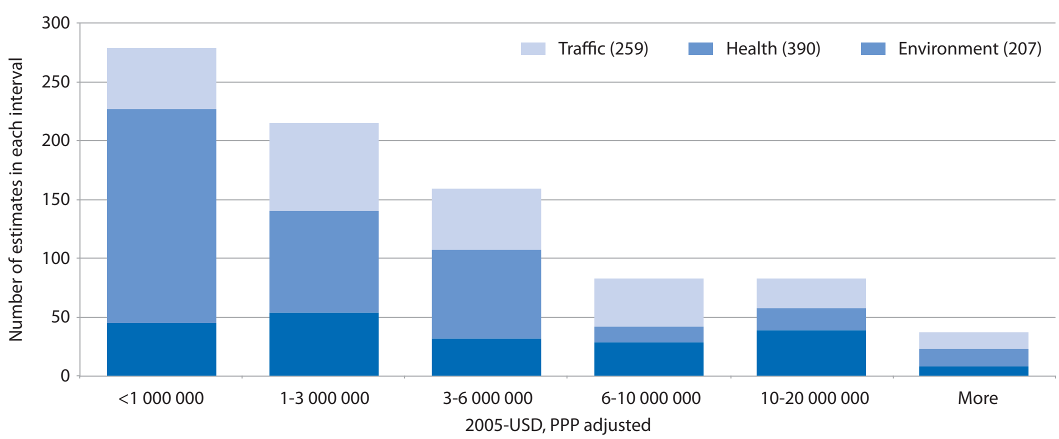


Figure 2.2 illustrates how the VSL estimates are split according to the risk context in which they were made, which almost half of them being made with respect to a change in a health-related mortality risk. Figure 2.2 also shows that the share of all the *surveys* addressing health-related mortality risk changes is a bit lower, and that slightly more surveys address changes in traffic-related mortality risks.[10]

Figure 2.2. **The number of VSL estimates and surveys according to risk category**

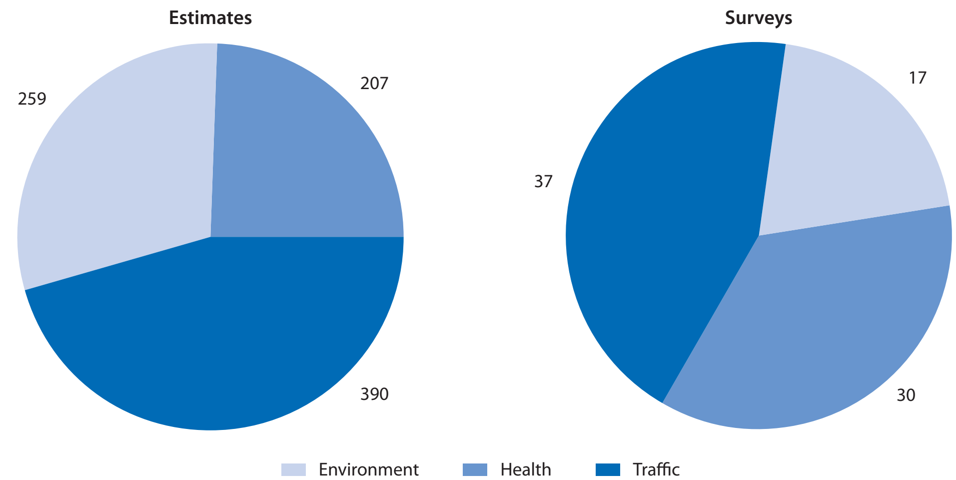


Figure 2.3. **Mean, median and standard error of mean VSL estimates according to risk category**

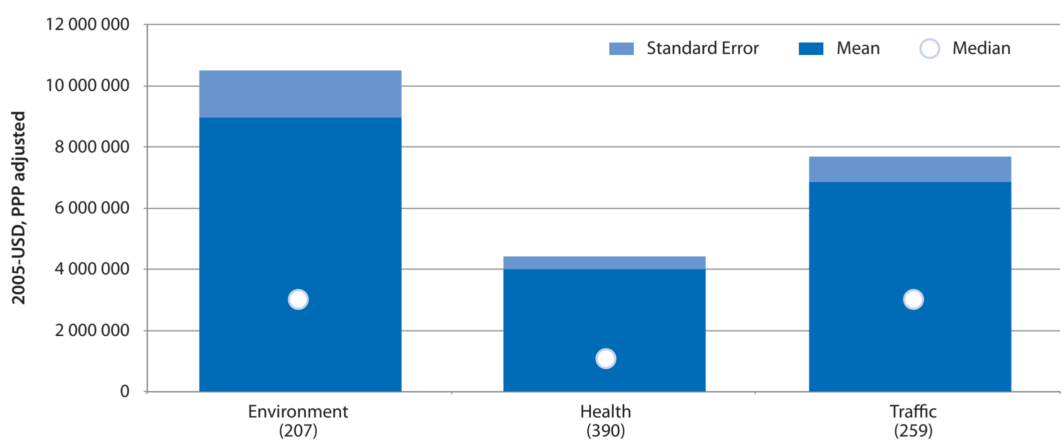
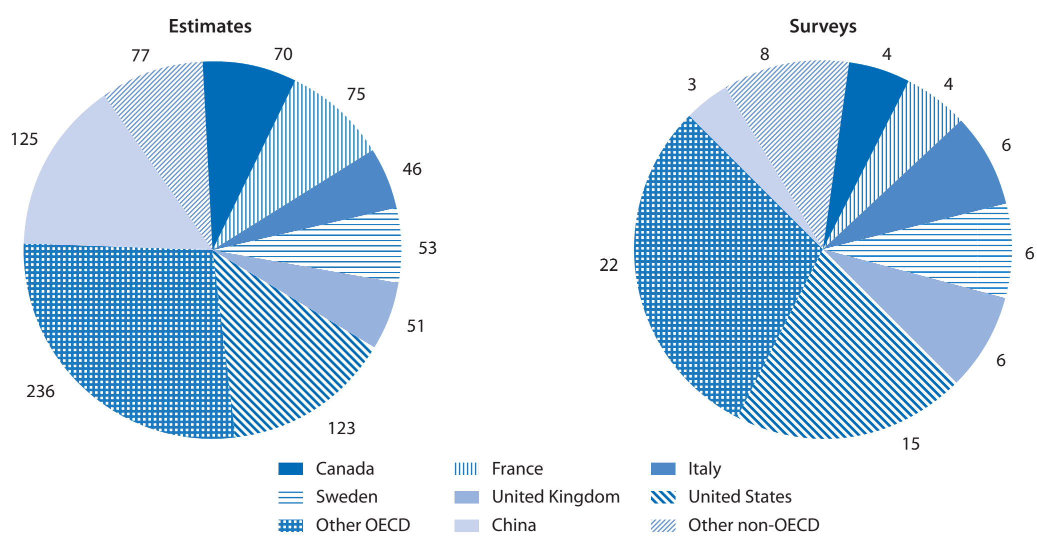


Figure 2.4. **The number of VSL estimates and surveys, according to country**



Note: "Other OECD" includes Austria, Belgium, Chile, Czech Republic, Denmark, Japan, Korea, the Netherlands, New Zealand, Norway, Poland and Switzerland. "Other non-OECD" includes Bangladesh, Brazil, India, Malaysia and Thailand.

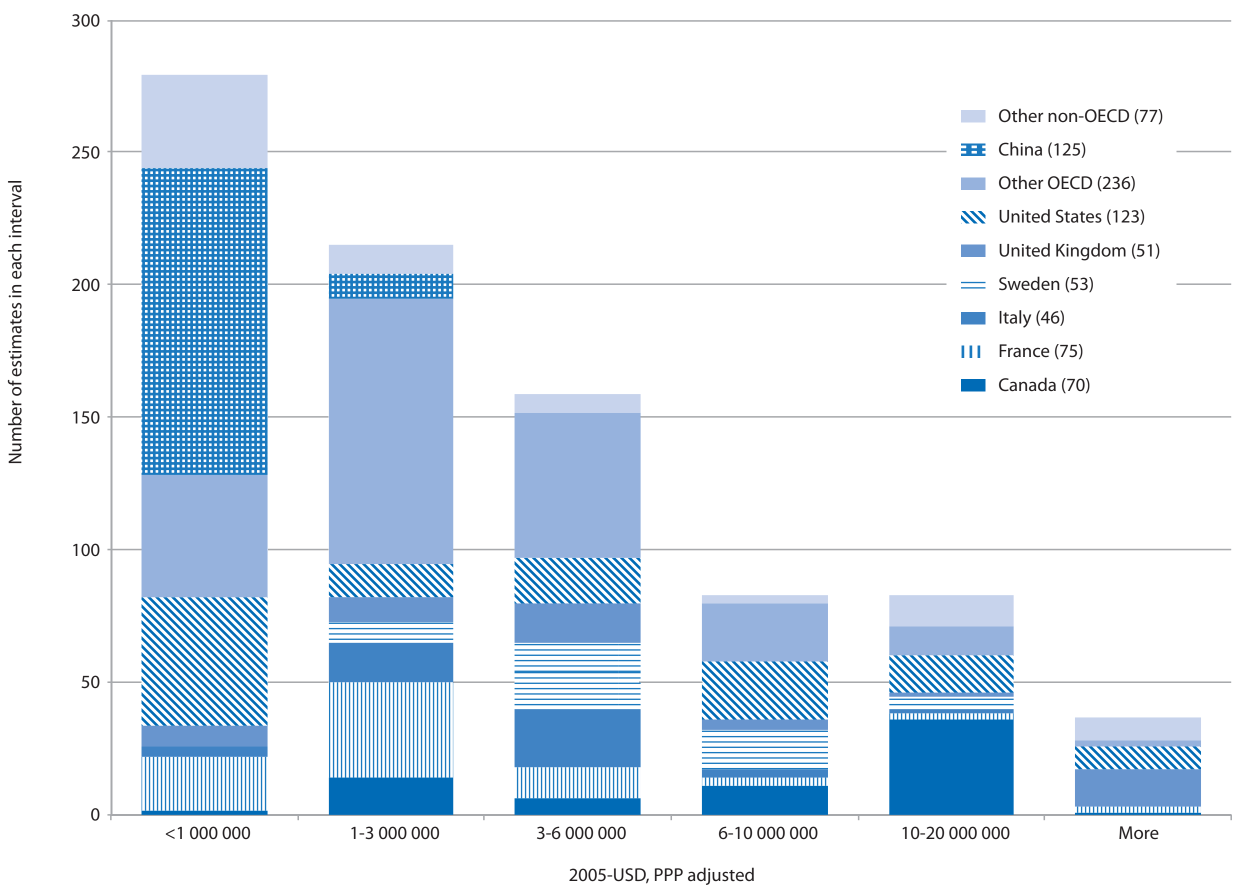
Figure 2.3 shows mean, median and standard error for the mean VSL estimates stemming from the different risk contexts in focus in this analysis. One can notice that the median value is much lower than the mean values in each case; reflecting the long right-hand tails of the distributions.

Figure 2.4 illustrates from which countries the surveys and VSL estimates are stemming. While almost a quarter of all surveys providing a mean VSL estimate has been conducted in the United States, the largest number of VSL estimates stem from China. A significant number of surveys and mean VSL estimates are also available from the United Kingdom, France, Italy, Sweden and Chile.

Figure 2.5 describes the distribution of mean VSL estimates by country. As could be expected, the estimates elaborated in Chine are in the lower ranges. More surprisingly, there are quite a few estimates from "Other non-OECD" in the two upper ranges. There are also a number of very high estimates from the "Other OECD" category. One can also notice a number of very high estimates from the United Kingdom.

Figure 2.6 shows developments over time in the data collection methods used in the surveys. Face-to-face surveys dominated for a long time, but self-administrated surveys with PCs (where the respondents fill in their replies themselves on PCs placed at central locations) and web-based surveys (with pre-recruited "panels" of respondents, often managed by professional market survey firms) have increased in recent years.

Figure 2.5. **Frequency distribution of mean VSL estimates, by country**



Note: "Other OECD" includes Austria, Belgium, Chile, Czech Republic, Denmark, Japan, Korea, Netherlands, New Zealand, Norway, Poland and Switzerland. "Other non-OECD" includes Bangladesh, Brazil, India, Malaysia and Thailand.

Figure 2.6. **Accumulated number of surveys according to data collection method**

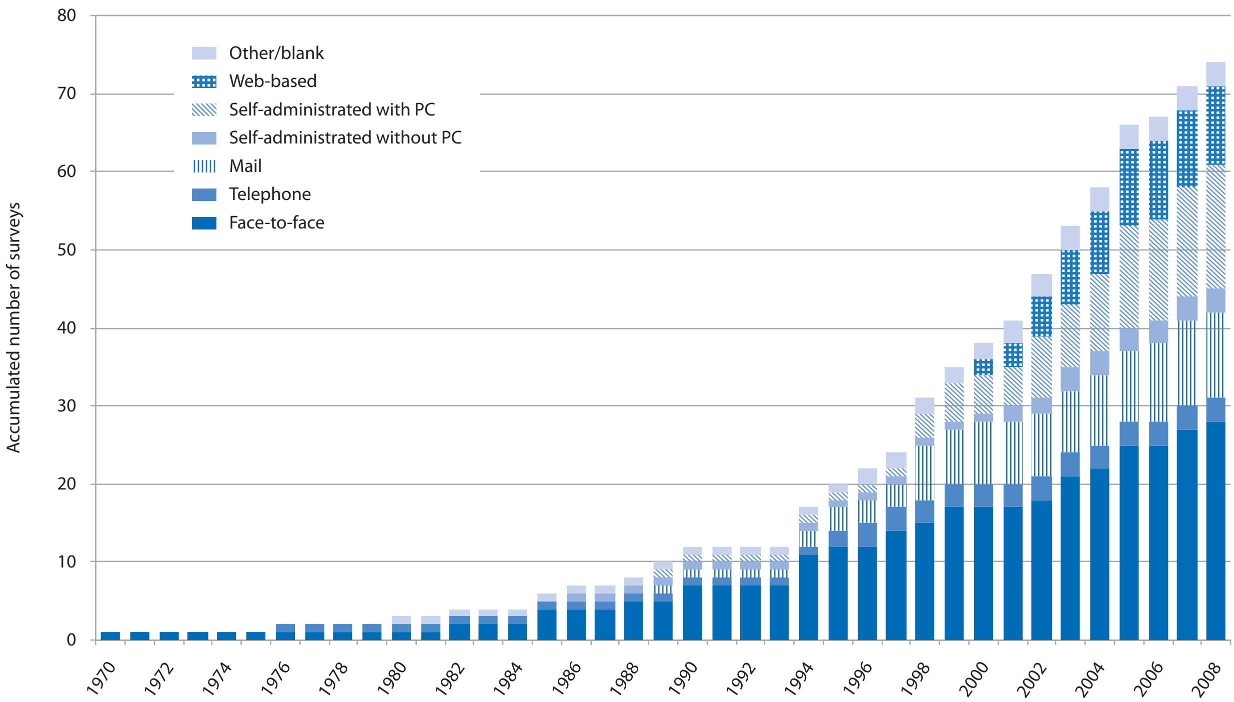


Figure 2.7 illustrates mean, median and standard error of the VSL estimates according to the data collection method used. The differences in standard error of the estimates collected using different methods is quite striking, and the differences in means and medians are also noticeable. There is a particularly large variation in the mean estimates collected through face-to-face interviews, mail surveys and "other" methods[11] (*e.g.* a combination of several approaches).

Figure 2.7. **Mean, median and standard error of VSL estimates, according to collection method**

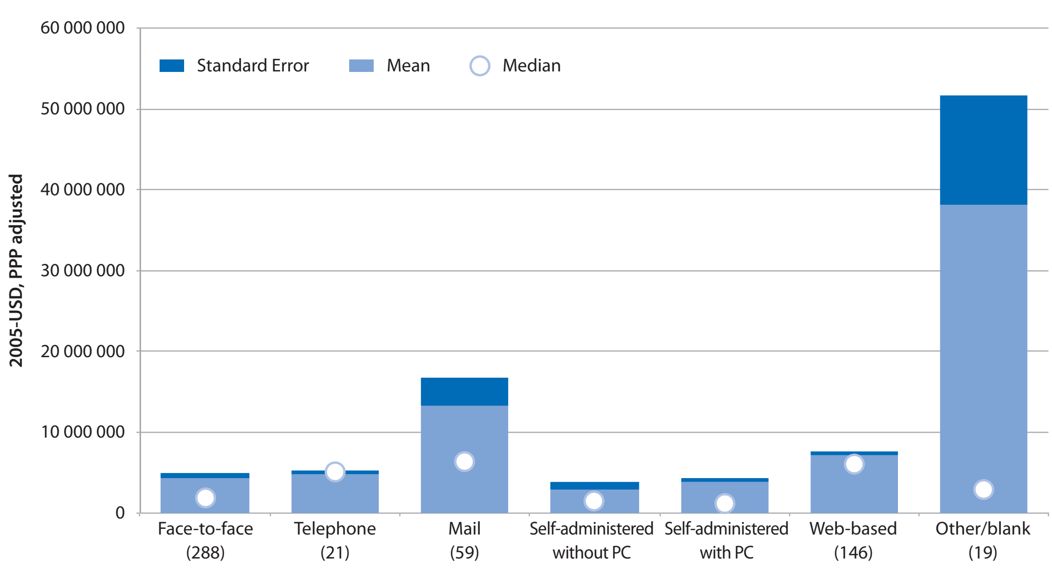


Figure 2.8 illustrates changes over time in the method used to elicit the WTP for a given change in risk. It is clear that while open-ended questions dominated for many years, in particular dichotomous choice questions (where respondents are asked to say "yes" or "no" to paying a specified amount for achieving a given risk reduction) have taken over a large part of this "market" since the turn of the century – and almost half of all VSL estimates have now been "produced" in this way.

Figure 2.8. **Accumulated number of surveys providing mean VSL estimates, by elicitation method**

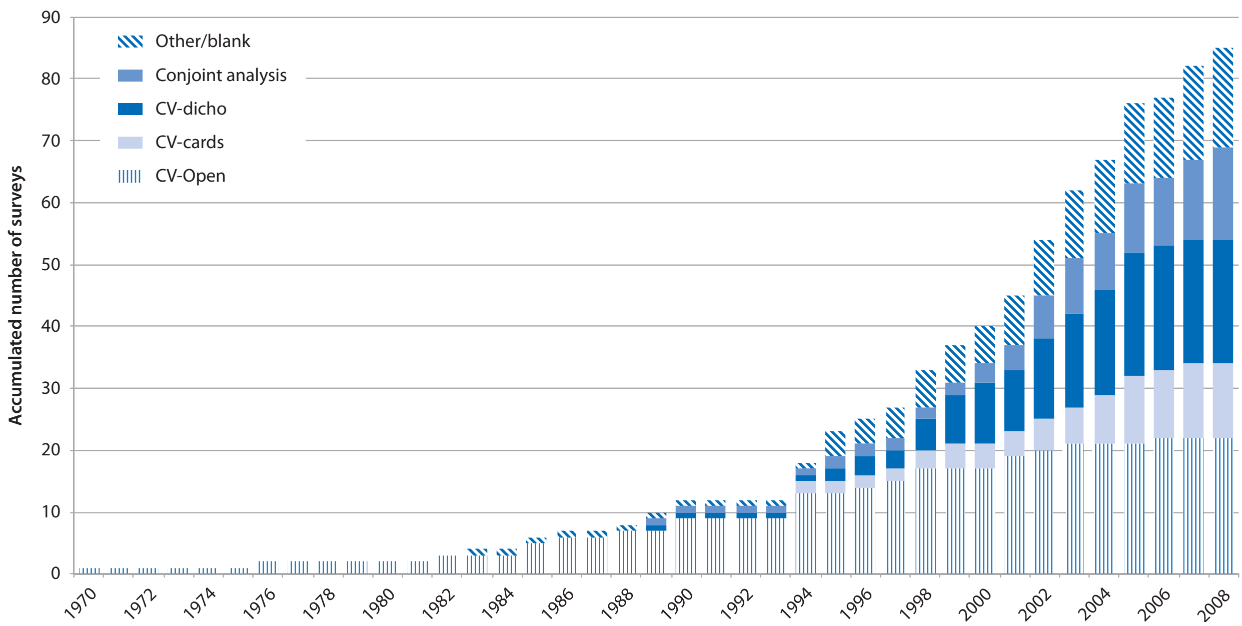
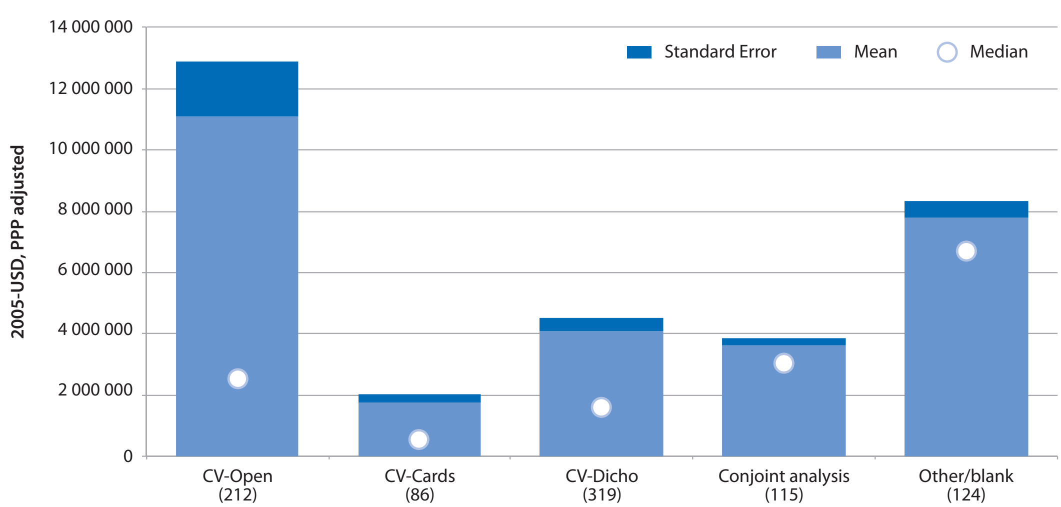


Figure 2.9 illustrates mean, median and standard errors of the VSL estimates according to the different ways of eliciting the WTP that was used. It is clear that both the mean and the standard error tend to be much higher when open questions or "other" elicitation methods are used, than when payment cards, dichotomous questions or conjoint analysis is applied.

Figure 2.9. **Mean, median and standard error of VSL estimates, by elicitation method**



A major issue in all VSL surveys is whether or not the respondents understand the magnitude of the risk changes they are being asked to value. Figure 2.10 illustrates developments over time in the use of various forms of visual tools to help the respondents better understand the risk-changes of relevance. The category "Other visual tool" includes cases where several different visual aids have been used, and the category "Other/Blank" includes cases with various types of written or oral explanation of risk change magnitudes, plus cases where information is lacking. Since the late 1990s, it has become popular to use a grid with 1 000 squares, where a few squares are coloured to represent baseline risk and the change in risk in question, cf. Figure 2.11. The graph illustrates a 1 000 squares grid, where the risk of death changes from to 10 to 5 in 1 000 over 10 years, *i.e.* the annual risk changes from 10 to 5 in 10 000.

Figure 2.10. **Accumulated number of surveys providing mean VSL estimates, by use of visual aids**

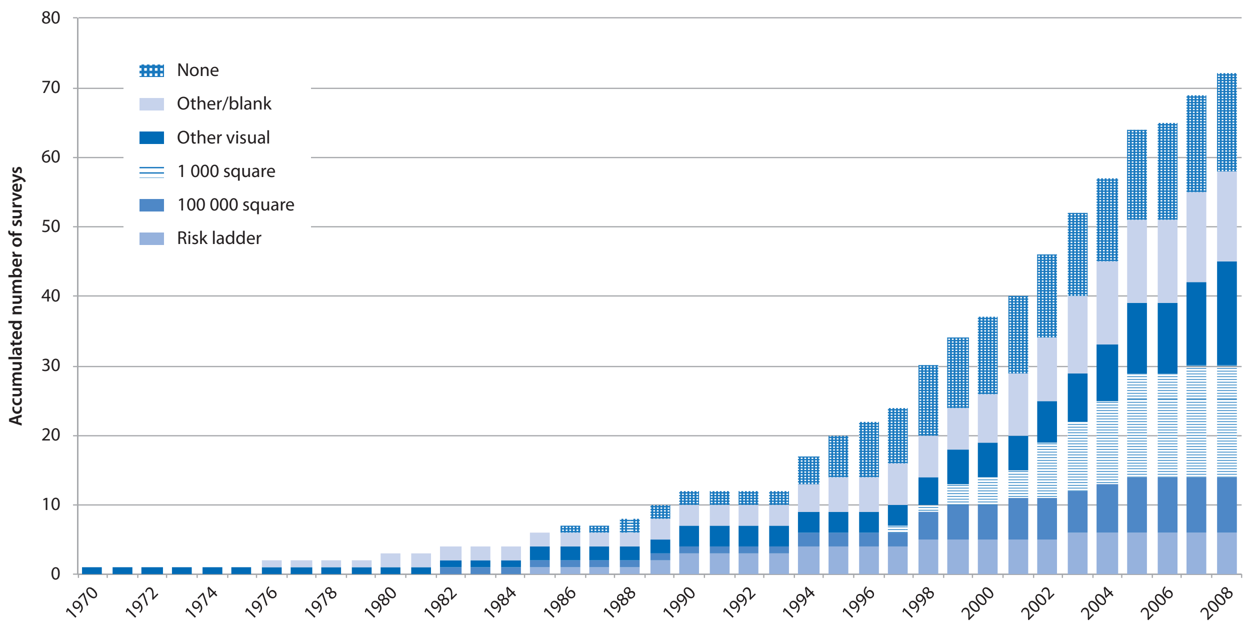
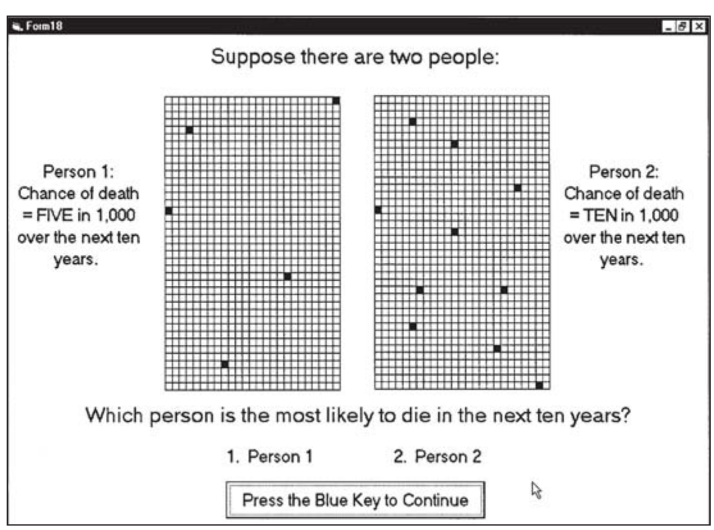


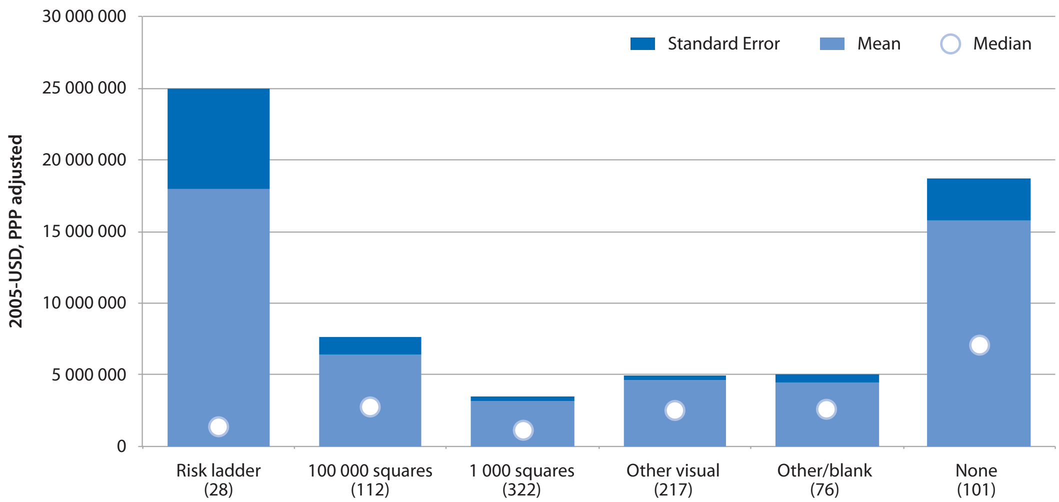
Figure 2.11. **Example of a risk communication tool**



Source: Krupnick *et al.* (2002).

Figure 2.12 illustrates the mean, median and standard deviation of the VSL estimates, according to the use of visual aids. The differences in the means and the standard deviations of the estimates from surveys where a risk ladder or a 100 000 square grid have been used, on the one hand, and, on the other hand, estimates where *e.g.* a 1 000 square grid have been used, are quite striking.

Figure 2.12. **Mean, median and standard error of VSL estimates, according to use of visual aids**



Notes

1. “Study” here means any publication where results are reported, while “survey” is used to describe a “field application” of a questionnaire.

2. All the information collected is freely available at *www.oecd.org/env/policies/vsl*. One can there also find information regarding 15 estimates that were based on willingness to accept (WTA) compensation for a risk increase, rather than WTP for a reduction (or to avoid an increase), which were excluded from the analyses here.

3. The distinction between the environment and health categories is not always obvious, in part because some health risks are caused environmental problems – *e.g.* air or water pollution. In the classifications made here, the focus has been on whether or not an *explicit* reference to an environmental problem was made in the valuation-question posed to the sample. If that was not the case, the survey was classified as being “health-related”. This is, for example, the case with some well-known surveys using a questionnaire developed by Krupnick, Alberini and Cropper *et al.*, which in several cases refer to environmental problems in the titles of the papers presenting the surveys.

4. Such studies were covered by OECD’s VERHI project, cf. *www.oecd.org/env/social/envhealth/verhi*.

5. Searches have, *inter alia*, been made for the terms “VSL”, “VOSL” (value-of-a-statistical-life), “VOLY”, “VPF” (value of a prevented fatality) and “statistical life”.

6. The OECD Library was very helpful in getting hold of the relevant articles. A number of authors kindly provided additional studies and/or information regarding the samples they surveyed.

7. The PPPs are taken from the World Bank's International Comparison Program, 2008 edition. This publication provides *i.a.* PPP estimates based both on *i*) all of GDP; and *ii*) on only the part of GDP used for Actual Individual Consumption (AIC). For most countries, these two different PPP measures are very similar, but for some countries – *e.g.* some developing countries – the differences are considerable. The analyses presented in this report are based on the AIC-related PPPs.

8. Table 6.1 provides some summary information on the mean VSL estimates used in this project, regarding the full sample, a "trimmed" dataset, where the highest and lowest 2.5% of the sample have been deleted, and for various quality-screened samples used in the meta-regressions.

9. All estimates refer to USD in 2005 money value.

10. The meta-analysis covers in all 74 surveys that provide *mean* VSL estimates. However, some surveys covered more than one risk contexts. Hence, the total number of surveys in Figure 2.2 (84) is larger than 74.

11. "Blank" indicates that we do not have information on the data collection method.

Chapter 3

Meta-regression analysis of value of statistical life estimates[1]

The chapter presents the main results of a meta-analysis (MA) of stated preference (SP) surveys of mortality risk valuation. The variation in VSL is explained by differences in characteristics of the SP methodologies applied, the population affected and characteristics of the mortality risks valued. The most important variables explaining the variation in VSL are GDP per capita and the magnitude of the risk change valued. According to theory, however, VSL should be independent of the risk change. A range of quality screening criteria are used in order to investigate the effects of limiting the MA to high-quality studies. Mean VSL from studies that pass both external and internal scope tests tend to be less sensitive to the magnitude of the risk change. For many of the screened models, an income elasticity of VSL of 0.7-0.9 is found.

3.1. Introduction

Chapter 2 gave a descriptive overview of the database of value of statistical life (VSL) estimates. To discern patterns in the data, *i.e.* which factors explain the variation in VSL estimates, formal statistical meta-analysis (MA) is required. Such analysis is also an important step when using meta-analysis for benefit transfer (BT), as further discussed in Chapters 4 and 5. Meta-regression is a type of meta-analysis that uses quantitative statistical techniques to analyse how the so-called effect-size, the variable to be explained (in this case, estimates of VSL) vary with a set of explanatory variables derived based on information from studies. Definition and coding[2] of the variables depend on theoretical expectations, previous empirical results and the availability of necessary information in studies.

The aim of this chapter is to summarise meta-regression results particularly related to two main questions:

1. How do characteristics of the population surveyed, the risk type and context, and methodological aspects of the surveys affect mean the VSL estimates?
2. How sensitive are the results to common methodological challenges and choices faced by the meta-analyst, especially related to procedures for screening VSL estimates on the basis of quality criteria from the Stated Preferences (SP) literature?

The answers to these questions are relevant to the ongoing research attempting to better understand people's preferences for (small) risk changes and, on the basis of people's preferences, select appropriate VSL numbers that can be used when assessing the benefits of prevented mortalities in public policy analysis. The latter part is a particular concern of this report and will be discussed further, especially in Chapters 5-7. During the course of this project, several meta-regression analyses have been conducted, *e.g.* as described in Braathen *et al.* (2009), Lindhjem *et al.* (2010) and Biausque (2010). Those works reflect some progression and learning as the project has evolved. Some highlights from preliminary analysis are presented here, though the main emphasis is on the most recent results. The presentation of these results draws heavily on Lindhjem *et al.* (2011).

The Chapter starts in Section 3.2 with a discussion of the trade-offs encountered in conducting a MA of the VSL estimates, and how some of these issues may be alleviated for example by screening out estimates from studies that do not pass fundamental quality criteria for stated preference surveys.

Further, Section 3.3 highlights some of the results and steps of the extensive process of preliminary analysis conducted during the full length of this project. More comprehensive accounts are given in Braathen *et al.* (2009), Biausque (2010) and Lindhjem *et al.* (2010).

Section 3.4 briefly presents the statistical issues related to the choice of meta-regression approach, while Section 3.5 discusses the results from the meta-regression results when applying different quality screening criteria. Section 3.6 summarises the main results from the meta-regression analyses and concludes.

3.2. Meta-data and screening considerations

MA trade-offs and sensitivity of choices

There is a trade-off between the number of possible and interesting variables that can be included to explain variation in VSL estimates and the information actually available about these variables in the studies collected. Choosing a smaller number of variables will give a dataset with fewer holes, as it is more likely that the information is found across more studies. This balancing of the number of studies and variables to arrive at a final dataset for analysis is to some extent more art than science. There is little guidance on these issues in the MA literature, although some newer studies have begun to explore such questions and the sensitivity of results to such choices (see *e.g.* Johnston and Rosenberger (2010); Nelson and Kennedy (2009); Lindhjem and Navrud (2008), Rosenberger and Johnston (2009)).

A related issue is that even if the VSL one tries to understand and explain is consistently defined across studies, the VSL estimates may vary due to a number of factors, such as differences in econometric estimation approaches, country-variation, risk types valued, etc. There is a limit to how much variation (or heterogeneity) in a meta-dataset that can be meaningfully modelled in meta-regressions with a limited range of explanatory variables. There is no agreement in the literature on what this limit is. US EPA (2006) represents perhaps the most conservative view, while there are several examples of published studies where the analysed effect size is very ambiguously defined, and the heterogeneity in possible explanatory factors is great.

Many MA studies are not explicit about their protocol for collecting, coding, including and analysing studies in final meta-analyses. There is also little in the way of sensitivity analyses of results to such protocols and choices made during the process of collecting and coding data. Hence, the approach taken here has been to start by including as many studies as could be found and code a rich set of variables from each study (inevitably creating some holes in the dataset). Further, data from studies have been supplemented with information from official statistics, from the authors of the original studies and, to some extent, calculations based on information reported in the studies. This makes the database very detailed and rich, as described in Chapter 2, but it also makes it necessary to decide on some protocols for screening data when conducting analysis. This will depend on the objective of the analysis. Further, the need for sensitivity analysis following such choices is emphasised here.

Some initial sensitivity analyses were conducted in Braathen *et al.* (2009), demonstrating the challenge of estimates being dropped when various models and explanatory variables are used. The basis for that analysis was a fairly comprehensive set of potential explanatory variables, reproduced here in Table 3.1. Column two describes how the variables have been defined and coded (mostly into so-called binary or dummy variables). The third column indicates the hypothesised relationship with VSL.

A procedure was adopted to make the data analysis manageable, to avoid excessive loss of estimates from studies not reporting information for all variables and to alleviate concerns over quality of studies. This procedure consisted of making a short-list of the most important explanatory variables from Table 3.1 based on theory and preliminary meta-regression analyses (as discussed in Section 3.3 below) and screening out estimates based on quality criteria.

Table 3.1. **Meta-analysis variables and expected relationships with VSL**

Variable	Description	Sign
Dependent variable		
lnvsl_aic	Natural logarithm of VSL in USD 2005 (mean, annual WTP divided by annual risk change, aic adjusted)	….
Risk valuation context variables:		
lnbaserisk*	Continuous: Log of ex ante (baseline) mortality risk (risk of "dying anyway")	0/(+)
baseriskhigh*	Binary: 1 if baseline risk is > 0.0005; 0 if otherwise	0/(+)
lnrchange	Continuous: Log of change in mortality risk on an annual basis (normalised per year from study info)	0/-
decrease	Binary: 1 if WTP for a decrease in mortality risk; 0 if WTP to avoid a risk increase	-
rchangehigh*	Binary: 1 if risk change is > 0.0005; 0 if otherwise	-
year1*	Binary: 1 if risk change for 1 year or shorter; 0 if > 10 years (incl. life-time or forever)	?
year510*	Binary: 1 if risk change for 5 or 10 years, 0 if > 10 years (incl. life-time or forever)	-
private	Binary: 1 if private good (risk affects only the individual asked or her household); 0 if public good	+
environ	Binary: 1 if environment-related risk change; 0 if traffic-related (by definition acute)	+?
health	Binary: 1 if unspecified health risk reduction; 0 if traffic-related (by definition acute)	-
acute*	Binary: 1 if the risk is acute; 0 if chronic	+?
latent*	Binary: 1 if risk is latent; 0 if not	+/-
grid1k*	Binary: 1 if a 1000 square grid was used in risk explanation; 0 if oral/written or no explanation.	-
grid100k*	Binary: 1 if a 100 000 square grid was used in risk explanation; 0 if oral/written or no explanation	?
anyvisual	Binary: 1 if any type of visual risk explanation tool has been used; 0 if oral/written or no explanation	?
control	Binary: 1 if the risk is voluntary (can be controlled/avoided by individual); 0 if involuntary	-
specific	Binary: 1 if survey includes a description of degree of suffering; 0 if more abstract	+
cancer	Binary: 1 if reference to cancer risk in survey; 0 if otherwise	+
Methodological variables:		
cvdc	Binary: 1 if dichotomous choice CV; 0 if other (payment card, bids, conjoint analysis, ranking)	+?
cvoe	Binary: 1 if open-ended max WTP CV question; 0 if other (payment card, bids, conjoint analysis, ranking)	-?
individ	Binary: 1 if WTP is stated as an individual; 0 if stated on behalf of household	-
monthly	Binary: 1 if WTP was stated per month (and converted to annual WTP); 0 if otherwise	+
lump	Binary: 1 if WTP was stated as a one-off lump sum; 0 if otherwise	+
donation	Binary: 1 if payment vehicle used donation; 0 if otherwise	+
tax	Binary: 1 if payment vehicle used tax; 0 if otherwise	-
wta	Binary: 1if willingness to accept compensation for a risk increase; 0 if WTP for risk reduction	+
telephone	Binary: 1 if telephone survey; 0 if otherwise (*i.e.* mail, web)	+?
f2f	Binary: 1 if face-to-face interview survey; 0 if otherwise	+?
resphigh*	Binary: 1 if response rate was > 65 percent; 0 if lower	-
parametric	Binary: 1 if WTP was estimated using parametric (typically WTP lower-bound); 0 non-parametric	+
Socio-economics, time and space:		
lnincome	Continuous: Log of mean annual income as reported in study, USD 2005, AIC-adjusted	+
lnincomeest*	Continuous: Log of mean annual income as estimated by us, USD 2005, AIC-adjusted	+
aic20000*	Binary: 1 if AIC per capita 2005 USD PPP > USD 20000; 0 otherwise	+
lnage	Continuous: Log of mean age of sample	+/-
lnage_60	Ln of the share of ample older than 60	?
lnyear	Continuous: Log of year of data collection. Range ln3 – ln40 (1967 to 2007)	+/-
carowner	Binary: 1 if car owner; 0 if otherwise	?
seloccu	Binary: 1 if only selected occupations in sample; 0 if otherwise	
oecd	Binary: 1 if OECD; 0 if non-OECD country	+
usa*	Binary: 1 if United States; 0 if other country	+
europe*	Binary; 1 if Europe; 0 if otherwise	+
rural	Binary: 1 if survey was conducted in rural area; 0 otherwise	-
national	Binary: 1 if survey nation-wide; 0 otherwise	?
hdi09	Binary: 1 if survey year in a country with human development index >0.9; 0 otherwise	+

Table 3.1. **Meta-analysis variables and expected relationships with VSL** *(continued)*

Variable	Description	Sign
lifeex70	Binary: 1 if country of survey has life expectancy higher than 70 years; 0 otherwise	+
lnremlife*	Continuous: Log of difference between life expectancy in country of survey and average age subsamble	?
Study quality and other variables:		
journal	Binary: 1 if study published in a journal, 0 if otherwise	?
samp200*	Binary: 1 if sample had more than 200 respondents; 0 if otherwise	?
krupalber	Binary: 1 if survey instrument of Krupnick/Alberini/Cropper was used; 0 otherwise	?
vslsource	Binary: 1 if VSL estimate was reported in the study; 0 if calculated by us based on study information	+?

Note: * indicates that variable was included in the preliminary data analysis, but not in the meta-regression models shown in the main section of Braathen *et al.* (2009).

In the following, several potential criteria for excluding certain studies or estimates from the analysis, based on subjective and more objective factors, are discussed. In MA generally, it is a controversial issue to screen out studies based on quality, as there is no general agreement about what constitutes quality in general, and required quality for a certain purpose, specifically. Still, there are good reasons to explore ways to do this, since good studies provide better information that is closer to the "truth" in some sense. As mentioned, this is also a priority raised by the US EPA's 2007 Science Advisory Board review (Morgan and Cropper, 2007).

In order to increase the reliability and test the sensitivity of our MA, several possible screening criteria and arguments for choosing a subset of these are discussed for the sensitivity analyses of the meta-regression models used here.

Screening based on quality criteria

There are many survey characteristics that may indicate low quality in SP research in particular and in survey research in general. If a survey has a high share of respondents expressing some type of protest behaviour in their responses to the risk change valuation question, it is likely that aspects of the scenario description, or other weaknesses of the questionnaire, have contributed to this. However, it is difficult to judge what would be an acceptable level of protest behaviour, and whether, and how, protesting varies across cultures. This is therefore a type of quality criterion which is probably too ambiguous to use, in addition to the fact that not all studies report such information. No estimate has therefore been excluded from the present analysis based on this criterion.

Another potential screening criterion is to exclude surveys that do not pass an internal and/or external "scope test", or where such tests have not been performed. An "internal scope test" means that the same individual have been asked to value two or more mortality risk changes of different magnitude to test whether they are willing to pay (proportionally) more to get a large, rather than a small, risk reduction. The stricter test of "external scope" means that independent samples of individuals have been asked to value different mortality risk changes, to test whether different respondents' WTP vary positively with the risk change valued (Hammitt and Graham, 1999). According to economic theory, the relationship between the size of the risk change and WTP should be positive and approximately proportional (see *e.g.* Corso *et al.,* 2001). Complete scope insensitivity would mean that respondents state the same or not significantly different WTP for risk reductions of different magnitudes, indicating that they are either indifferent to the size of the risk, or do not understand the differences in probability. The scope test criterion originates from the NOAA panel's recommendations for SP research (Arrow *et al.*, 1993). It was applied by Krupnick (2007) to screen studies in a literature review of the relationship between VSL and age. However, it is difficult to apply this criterion in practice to exclude studies, as not all studies conduct such a test, or report the results in a consistent way. As this is an important criterion with regards to economic theory, and thus theoretical validity, several meta-regression models have nevertheless been run applying this criterion to test how it affects results, and especially VSL sensitivity to the risk change (see Section 3.5 below). In addition, the regressions also control for the way the risk change has been explained to respondents and the size of the risk change.

Whether or not a study is published in a peer-reviewed journal or similar is often used as a quality criterion. In the MA literature, it is generally not recommended to exclude studies on the basis of this. Published studies may not always provide the most suitable information needed for the purpose of the MA (*e.g.* since the aim of a study often is to provide new methodological advancements, not to report VSL estimates *per se*), and working papers and reports may often be better than papers published in low-quality journals.[3] Further, published studies may be systematically different in some way than unpublished studies, *e.g.* studies with few statistically significant results may be harder to publish. To reduce this potential publication bias, it can be better to "err on the side of inclusion" (Stanley and Jarrel, 2005). A recent study shows that such publication bias may be important (Doucouliagos *et al.*, 2011), so screening out studies that have not been published may not be advisable.

Three criteria that might be more objective related to the quality of survey research more generally are:

1. high response rate,
2. new studies (which may use improved methodology, as well as better reflect changing preferences), and
3. large sample size.

If the response rate of the survey is low, this may increase the risk of self-selection bias, leading to higher VSL estimates, as demonstrated by Lindhjem (2007). Using this criterion can be supported in principle, but in practice, few studies are thorough enough in providing their net response rates, and the ways response rates are calculated and reported are not standardised (*e.g.* for web-based surveys from pre-recruited panels *vs.* in-person interviews).

More recent studies may be of higher quality, if they reflect the gradual methodological innovation and refinement that has occurred. They may also reflect changes in preferences within the surveyed population over time. Instead of choosing an arbitrary year (*e.g.* a year some time after the NOAA panel recommendations, cf. Arrow *et al.*, 1993) and exclude older studies, survey year is typically included in regressions to control for such effects.[4] The latter approach is used for some of meta-regressions to follow.

Larger samples give statistically more precise estimates and are generally associated with larger budgets and (one would hope) higher quality of surveys. This criterion is used in the screening conducted here. In some of the regressions, all VSL estimates from surveys where the number of respondents in the full sample was smaller than 200 were excluded (admittedly somewhat arbitrary). Further, VSL estimates based on a sub-sample of fewer than 100 respondents are also excluded. Sample size was also used as a criterion by Krupnick (2007).

There are also other characteristics of SP research that could be considered as screening criteria, but which are difficult or controversial to use in practice. These include *i)* WTP question formats (dichotomous choice recommended by the NOAA panel *vs.* other formats, such as open-ended questions aided by a payment card with dollar amounts), and *ii)* whether a study used debriefing protocols, and found results consistent with economic theory in regression analysis, *i.e.* theoretical validity (see *e.g.* Krupnick, 2007, and SEPA, 2006).

An additional option that has been applied here is to ask as many as possible of the authors of the original studies themselves to assess whether a particular estimate should be included in the MA or not.[5] This process yielded opinions from the authors regarding slightly fewer than 60% of the estimates. For one of the model runs, all estimates were removed from the sample if the authors had answered "No". There were too few of the authors who wanted to recommend one specific VSL estimate to use that information. Hence, their opinion regarding exclusion was used instead.

Heterogeneity considerations and screening based on other criteria

To maintain a sufficient degree of homogeneity, only sample *mean* VSL estimates were included. Sample *medians* that some studies report were excluded. Further, surveys that asked individuals' willingness to accept (WTA) compensation for risk increases were excluded, as such a question is conceptually different from a question regarding the WTP for a risk reduction (or, less commonly, to avoid an increase in mortality risk). WTA is not bounded by income – meaning that respondents could provide unrealistically large responses – and there is often a large share of "don't know" and protest responses when respondents are asked to accept an increase in mortality risk.

Some surveys only address particular occupational or other groups (*e.g.* students, health personnel, people working at a nuclear power plant, commuters of a certain type, etc.). Only studies which had relatively representative samples of the broader population of the geographical area in question have been included in the present analyses. There is, however, some variation concerning which age groups are targeted by different surveys. No attempt was made to differentiate between surveys aimed at different age groups. Instead, it was controlled for the age of respondents in preliminary regressions (as reported in Section 3.3 below). Reported VSL estimates for subgroups from the samples with regards to *e.g.* age and income were also included.

In Section 3.5, the final screening criteria are introduced one by one for different meta-regressions to investigate the robustness of the results. In one of the model runs, the methodological heterogeneity is limited by analysing only estimates from studies that use variations of the same VSL survey questionnaire, initially developed by Krupnick, Alberini and co-authors (see *e.g.* Krupnick *et al.*, 2002; Alberini *et al.*, 2004). The idea is that if the methodological variation in the surveys is reduced, more of the variation in the VSL estimates can be explained by risk and population characteristics. These variables are more relevant for policy analysis than the methodological variables.

For each of the subsets of meta-data generated by the screening criteria used, several meta-regressions were run, including a short-list of the explanatory variables in Table 3.1 that have been found to be important from theory and from extensive preliminary statistical analysis on the dataset.

3.3. Preliminary analysis, choice of variables and relationships with VSL

The explanatory variables used in the meta-regression analysis are of three main types:

1. Characteristics of the risk change and the context in which it is valued (type of risk, controllability of risk, size of risk, etc.);
2. Characteristics of the methods applied in the different surveys (ways the WTP question is asked, survey mode, econometric estimation procedures, etc.), and
3. Characteristics of the population asked to value the risk change (socio-economics, such as income and age).

In addition, meta-analysts sometimes include variables that cover quality dimensions of the surveys or other types of variables. For many variables there are *a priori* expectations of the relationship with VSL from theory or empirical studies, while other variables are typically more explorative.

The (many) variables in the four categories listed in Table 3.1 were used in preliminary analyses in Braathen *et al.* (2009). Further explorative analyses have also been carried out since that paper was published. In particular, more combinations and recoding of variables were tested in different subsamples.[6] Annex 3.A2 displays some meta-regression analyses based on full and screened datasets including some alternative explanatory variables, as listed in Table 3.1. Based on those analyses, a short-list of variables was selected for the meta-regressions to follow, cf. Table 3.2. The table also indicates the relationship with VSL that is expected from economic theory, and mean and standard error of the variables in the sample that was used here.

The mortality risk change presented to respondents in the SP surveys was normalised to an annual risk change, in order to ensure commensurability between the VSL estimates. The risk change in question affects a private individual, her household or also the general public. The definition of "private" used here includes risk changes that affect an individual or her household. Dummy variables were included to separate these effects (see variables "public" and "household" in Table 3.2) rather than making adjustments to the risk change variable itself, *e.g.* based on average household size or similar. The effect of whether the risk change only affects the individual or her household members, versus the public at large, is complex and depends among other things on the degree and type of altruism. The prevailing resource allocation model determining expenditures for mortality risk reductions and other goods within households is also important (see *e.g.* Lindhjem and Navrud, 2009, and Strand, 2007). Respondents are usually believed to value risk reductions affecting their household more than risk reductions affecting themselves only, likely due to altruistic motives. However, perhaps contrary to common belief, SP studies often find that WTP is lower for public risk reductions compared to private (individual or household) risk reductions of equal magnitude (see *e.g.* Svensson and Johansson, 2010). The reasons for this are unclear, but a set of possible explanations include: i) respondents may not believe the public programmes will benefit them, ii) respondents may not believe public programmes to be effective, or iii) respondents may have their attention focused on the public nature and be less attentive to the benefit to themselves. See also Bosworth *et al.* (2010) for a recent discussion of possible reasons why WTP for private risk reductions may be different from public risk reductions.

Of the risk context variables, no consistent relationships were found in the data between the magnitude of the VSL and the duration of the risk change, whether the risk was acute or chronic, whether the degree of suffering was mentioned in the survey or the individual had control over the risk. Some significant effects were found related to whether or not the risk

Table 3.2. **Meta-analysis variables, expected VSL relationships and descriptive statistics**

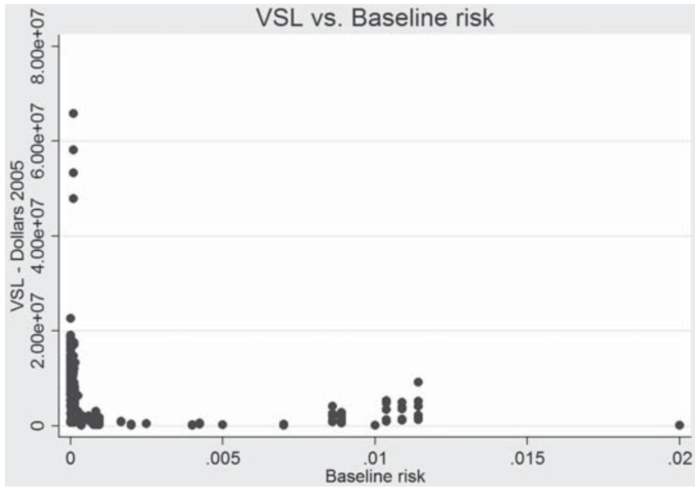
Variable	Description	Sign	Mean (SE)[#]
Dependent variable			
lnvsl	Natural logarithm of sample mean VSL in PPP-adjusted USD 2005 (mean, annual WTP divided by annual risk change, PPP-adjusted based on AIC*).		14.50 (1.59)
Risk valuation context variables:			
lnrchrisk	Continuous: Log of change in mortality risk on an annual basis per 1000 (normalised per year from study info).	0	-8.48[§] (2.13)
public	Binary: 1 if public good; 0 if private (risk affects only the individual asked or her household).	+/-	.30 (.46)
envir	Binary: 1 if environment-related risk change; 0 if health-related.	?	.24 (.42)
traffic	Binary: 1 if traffic-related risk change; 0 if health-related.	?	.30 (.45)
latent	Binary: 1 if risk change occurs after a certain time; 0 if the risk change is immediate.	+/-	.14 (.35)
cancerrisk	Binary: 1 if reference to cancer risk in survey; 0 if not.	+	.13 (.34)
household	Binary: 1 if WTP is stated on behalf the household; 0 if WTP is only for the individual asked.	+	.29 (.45)
Methodological variables:			
noexplan	Binary: 1 if no visual tool or specific explanation of the risk change was used in survey; 0 if otherwise.	+/?	.14 (.33)
turnbull	Binary: 1 if WTP was estimated using Turnbull, non-parametric method; 0 parametric method.	-	.04 (.20)
Income and survey year:			
lngdp	Continuous: Log of GDP/capita, USD 2005, PPP-adjusted based on AIC.*	+	9.65 (.86)
lnyear	Continuous: Log of year of data collection, adjusted to start at log2 for earliest survey included from 1970.	+/-	3.41 (0.32)

Notes: * PPP: purchasing power parity. AIC: Actual Individual Consumption. # Mean and standard error (SE) are for sake of brevity given only for the whole, unscreened dataset of 856 estimates. § 625 estimates contain information about the risk change valued.

change was latent or immediate, whether it affected private individuals or their household members, as opposed to the public at large, whether the risk change was related to cancer, and related to the size of the risk change itself. Variables capturing these dimensions were therefore included in the main meta-regressions reported in the Section 3.5.

The baseline risk (*i.e.* the existing, underlying risk levels) affected the VSL estimates in some regressions, but this result was not robust. Theoretically, baseline risk should affect VSL positively, but not very much for low risk levels (see *e.g.* Eeckhoudt and Hammitt, 2001). The empirical evidence is ambiguous: the papers by de Blaeij *et al.* (2003) and Persson *et al.* (2001) suggest that baseline risk affects VSL positively, but Andersson (2007) and Viscusi and Aldy (2003) find the opposite result. In the present analyses, a choice was made to exclude the baseline risk variable from the regressions because the information was unavailable for 25% of the final sample. In the data, there seems to be a non-monotonic relationship between this variable and the VSL, as Figure 3.1 indicates – looking at only baseline risks below 0.05.

Figure 3.1. **VSL vs. baseline (underlying) risk**



Cancer risk may be associated with considerable dread, which can be expected to influence WTP for such risk reductions positively (van Houtven *et al.* 2008). The way cancer is referred to in the surveys, and defined here, this type of risk may incur immediately or be latent. The effect of latency on WTP is theoretically undetermined: Even though people are known to discount the future at a positive rate, their utility will also vary with different periods of life in a way that can make WTP to reduce future mortality risks higher than their WTP to reduce immediate risks (see *e.g.* Hammitt and Liu, 2004). As mentioned, the relationship between the size of the risk change and WTP should be positive and approximately proportional. This implies that VSL should largely be unaffected by the change in risk, at least for small changes and for low baseline risks (Hammitt and Graham, 1999). However, it is often found in primary SP studies that people's WTP is relatively insensitive to the size of the risk change; *i.e.* they fail internal and/or external scope tests. This means that questions involving smaller risk changes tend to result in higher VSL estimates. This result has not, to our knowledge, been documented across many studies in a MA before.

The type or category of risk was also included in the analysis, *i.e.* environment, health or traffic risks.[7] There is some evidence in the literature that characteristics of typical risks under each of these categories may give different WTP, and correspondingly different VSL estimates. However, the categories themselves may be too general to give clear indications in the data. In the preliminary analysis, different results were found, and it was decided to include them in the main meta-regressions presented here, as they are highly policy-relevant variables.

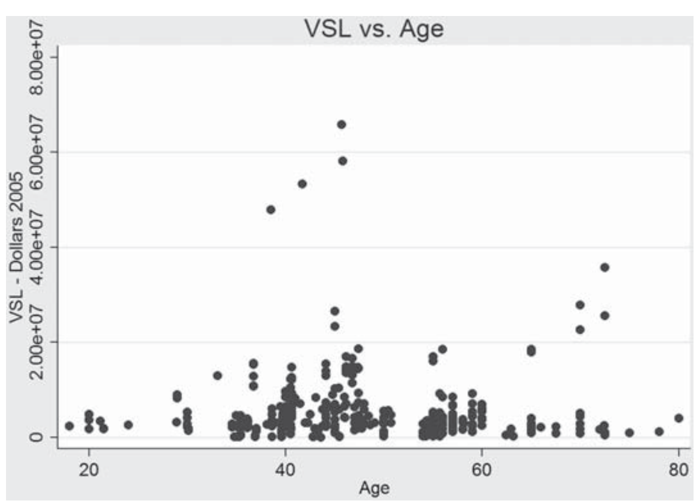
Of the methodological characteristics, a number of variables typically included in MA studies were tested in preliminary analysis, such as survey mode, type of WTP elicitation method (*e.g.* dichotomous choice, open-ended), type of payment vehicle, etc. No clear relationships with VSL were found for these variables. However, some patterns related to the way the risk change was displayed to respondents were found. Especially if there was no proper explanation of the size of the risk change in writing, orally or by the aid of visual tools (such as square grids or life expectancy graphs), WTP tended to be higher. In other words, respondents seem to overrate risk changes that are not carefully explained and displayed. Hence, a variable capturing this dimension was included in the main regressions (variable "noexplan" in Table 3.2). The variable "Turnbull" is also included. It indicates if the authors used a non-parametric estimation approach, typically giving a conservative, lower-bound estimate of WTP, and therefore a low VSL estimate.[8] These are the two methodologically related variables retained from Table 3.1 in Section 3.2 above.

Of socio-economic and other variables, it was decided to retain only GDP per capita (adjusted using AIC-based PPP-correction factors, in the same way as the VSL estimates) and the year of the survey (for a subset of the regressions). Most studies report mean (household or individual) income from the total sample, but not for subsamples from which many of the VSL estimates are derived. In order not to lose these estimates, and those where no sample income was reported at all, GDP per capita was used instead as a proxy for individual wealth. The correlation between log of GDP per capita and log of reported sample income was found to be very high (higher than 0.9). Thus, it can be considered a good proxy.[9] The relationship between GDP per capita and VSL can be expected to be positive.

The relationship between survey year and VSL is theoretically undetermined. New studies may use more appropriate methodologies (*e.g.* reducing known biases), potentially yielding more reliable and lower estimates, an argument sometimes found in the MA literature. Increased wealth over time, which is not appropriately accounted for in the income variable may, on the other hand, be captured in the survey year variable and lead to increasing VSL estimates over time.

Some investigations were conducted of the relationship between different characterisations of the age of the samples from which VSL estimates were drawn, but no clear relationships were found in the data. Most studies find either an empirical relationship with an inverted U-shape or a certain degree of independence (cf. Alberini *et al.*, 2004; Andersson, 2007; Hammitt and Liu, 2004; Viscusi and Aldy, 2007; and Krupnick, 2007). For a subset of our data, there were indications of an inverted U-shaped relationship between VSL and mean age of the sample (see Figure 3.2). But this result was not robust. The information on age is only available for ca 75% of the sample; the initial descriptive statistics (and even the preliminary regressions) suggest that there is little correlation with the VSL, even if Figure 3.2 illustrates an approximately inverse-U-shaped curve. Hence, this variable was for simplicity excluded from further analysis.

Figure 3.2. **VSL vs. Age**



Braathen *et al.* (2009) checked for differences in VSL between countries and groups of countries (such as OECD *vs.* non-OECD) other than due to income, but found no clear patterns. Further analysis for this report did not reveal any clear patterns either. Hence, of the variables included in the database, GDP per capita appears to be the most useful for differentiating between countries. Some negative correlation between the degree of risk reduction and level of GDP per capita was found for a screened subset of the data (see Section 3.5). This may be because studies in lower-income countries use larger risk reductions in their surveys, perhaps to reflect more realistic risk changes given the relatively higher baseline risks there.

Finally, it was decided not to include additional variables from Table 3.1 in Section 3.2 related to study quality and other factors, for example related to whether studies are published or not, as justified by the previous discussion on screening criteria.

3.4. Meta-regression approach

A number of meta-regression models were considered and tested. The following model, based on fairly standard practice in the MA literature, was used:

$$\mathrm{lnvsl}_{si} = \beta_0 + \beta_1 \mathrm{lngdp}_{si} + \Sigma_k\, B_k X_{si}(k) + \varepsilon_{si}$$

where lnvsl_{si} is the natural logarithm of VSL (equals WTP divided by the annualised risk change) for estimate i from survey group s; lngdp_{si} is the natural logarithm of per capita GDP and X_{si} is a vector of other explanatory variables, as outlined in Table 3.2. This model was estimated using ordinary least squares (OLS). However, since the number of estimates varies widely across survey groups *s*, the OLS is weighted by the reciprocal of the number of estimates in each group, so as to weight each survey group equally (as opposed to giving equal weight to each individual VSL estimate). For example, the study by Krupnick *et al.* (2006) gives a fairly large number of estimates compared to other studies (see Annex 3.A3).

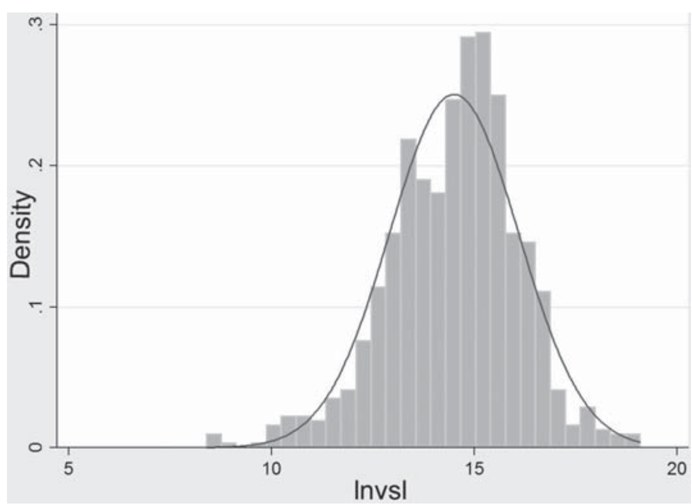
There seems to be no general agreement on what is the best strategy in the case where there are many estimates from a given survey. Mrozek and Taylor (2002) apply the weighting scheme used here, as do other MA studies in the environmental and health economics field. There are also alternative econometric approaches to deal with this issue, as discussed by for example Nelson and Kennedy (2009). The sensitivity of the results to the choice of weighting scheme in is presented in the supplementary Appendix B of Lindhjem *et al.* (2011).

Weights based on the precision of the estimates are also used for the subset of the data that is derived from surveys using the VSL questionnaire initially developed by Krupnick, Alberini and co-authors, to explore the effect of this choice. The inverse of the standard deviation of the mean VSL is used as reported in the study or as calculated by us, based on t-values or other information. This is the weighting scheme recommended by US EPA (2006), but it is difficult to apply in practice, since many studies do not report the necessary information. That is why this analysis was limited to the mentioned surveys, which to a larger extent report such information. We also multiply the precision weights with the survey estimate weights, for purposes of comparison. This latter approach was for example used by van Houtven *et al.* (2007).

Moreover, a "cluster" option is used for estimating robust standard errors, in order to account for the correlation between different estimates within the same survey group. This is also a common strategy in the MA literature (Nelson and Kennedy, 2009). A random effects model was used in Braathen *et al.* (2009), but a simpler, and more transparent approach for interpretation, was chosen here for the final analysis.[10] A technical reason for this choice was the concern that the random effects model involves stronger assumptions than a clustered OLS and may introduce some bias into the estimations. Clustered OLS (with or without some kind of weighting) is still the most common approach in the MA literature. It is also more transparent and easier to interpret when using the meta-regression models for benefits transfer, as discussed in Chapter 4.

A log-log model, which transforms the risk change, GDP per capita and survey year variables and leaves the dummy variables unchanged, was applied since this provided the best fit to the data. As shown in Chapter 2, the VSL distribution is highly skewed, with a long right tail, and transformation makes the distribution closer to normal (see Figure 3.3). Using double-log has the additional advantage that the estimated coefficients for GDP per capita and the risk change have natural interpretations as elasticities. Note that a "risk change elasticity" of -1 implies that WTP is independent of the risk change, indicating preferences that are completely insensitive to scope. An elasticity equal to zero implies that WTP increases proportionally with the risk reduction, as predicted by economic theory. This issue is discussed further below.

Figure 3.3. **Transforming the VSL estimates using natural log creates a more normal distribution**



3.5. Results of meta-regressions for different screening criteria

In this section, the data-screening criteria discussed in Section 3.2 are introduced one by one and the sensitivity of results to these criteria, and to the inclusion of different types of explanatory variables in the regression models, is analysed. The motivation is to better understand how risk context, methodological, socio-economic and other variables determine the observed VSL estimates. In addition to illustrating how VSL depend on these variables, it is the first step in the search for models that can potentially be used to derive VSL estimates for policy analysis in different contexts, *i.e.* in benefit transfer (BT) applications as discussed in Chapters 4 and 5. If there, for example, are few or no policy-relevant variables that show robust relationships with VSL, there is no basis in the data to argue that mortality risks should be valued differently, and VSL be adjusted, based on these variables. References and key information about the studies and number of estimates included in the different data subsets used in the meta-regressions in this section can be found in Annex 3.A3. There the mean VSL for the different data subsets are also given.

Full dataset – no screening

For the sake of comparison, this section starts by reporting results for the full dataset where no screening criteria have been applied. Five regression models were run, gradually increasing the number of explanatory variables, see results in Table 3.3. The GDP per capita and Turnbull variables are retained through all models here and in subsequent sections, as both variables have *a priori* very clear relationships with VSL. Note that the risk change variable is not included here, since many studies do not report this information. We include this variable in the next section.

Starting with Model I, it can be seen that including only log GDP per capita and the Turnbull variable explains 40% of the variation in the VSL estimates (R-squared equals 0.4). Despite the fact that it is a full and unscreened dataset, the R-squared compare favourably with many MA studies in the literature. The number of estimates (856) is the same for all five models, so the results are comparable across models.

Table 3.3. **Meta-regression results, full sample**

	Model I	Model II	Model III	Model IV	Model V
lngdp	1.265***	1.241***	1.306***	1.276***	1.173***
	(0.215)	(0.210)	(0.204)	(0.207)	(0.212)
turnbull	-0.450	-0.289	-0.282	-0.0398	0.0313
	(0.501)	(0.492)	(0.475)	(0.464)	(0.492)
envir		0.169	0.427	0.218	0.268
		(0.448)	(0.458)	(0.351)	(0.347)
traffic		0.729**	0.768**	0.878**	0.631**
		(0.287)	(0.297)	(0.337)	(0.309)
public			-0.349	-0.412	-0.421
			(0.388)	(0.383)	(0.356)
household			-0.294	-0.222	-0.172
			(0.305)	(0.294)	(0.279)
cancerisk				0.850**	0.946***
				(0.369)	(0.355)
latent				-0.467	-0.414
				(0.435)	(0.392)
noexplan					1.010***
					(0.321)
Constant	2.372	2.247	1.739	1.913	2.727
	(2.092)	(2.059)	(2.017)	(2.045)	(2.096)
Estimates	856	856	856	856	856
R-squared	0.405	0.441	0.456	0.486	0.529
Root mean squared error	1.361	1.320	1.305	1.270	1.216

Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Increasing the number of variables increases the explained variation to around 53% in Model V. The GDP per capita is highly significant for all five models, yielding an elasticity of GDP to VSL of between 1.1 and 1.3.[11] However, this drops considerably when controlling for the size of the risk change, as expected from the discussion in Section 3.3, and as discussed in the next section. Estimates based on traffic risk changes lead to significantly higher VSL across the four models where the variable is included, compared to the "hidden" category of health risks (*i.e.* risks from unspecified causes) (the coefficient on "traffic" is significant and positive). There is a significant cancer premium in Models IV and V where this variable is included. Model V also shows that in surveys where respondents have not been carefully explained the magnitude of the risk change by the use of visual tools or proper explanation, the estimated VSL tends to be higher (variable "noexplan").

Latent risks seem to be valued in the same way as immediate risks, and the Turnbull, household and public variables are also not significant.

First-level screening

For the next subsets of the data, the size of the risk reduction reported in the surveys is included as an explanatory variable. Some estimates are lost, as this information is not always reported (though it should be), but something is gained as the model is more appropriate. The screening criteria used are:

- If no value for the risk change has been reported, the study is excluded (231 estimates dropped).
- Estimates from subsamples smaller than 100 observations and main survey samples less than 200 observations are left out (319 estimates dropped).
- Samples that are not representative of a broad population are left out (179 estimates dropped).[12]

Compared to the full dataset used above, this dataset is likely to be of higher quality. Results of five regression models using the same explanatory variables as above, with the addition of the risk change variable, are reported in Table 3.4.

The number of estimates has now been reduced by more than half, from 856 to 405. As before, the GDP per capita is highly significant, though the elasticity has dropped below unity, to between 0.7 and 0.9. This is around the same range as other studies (typically based on individual surveys rather than on MA), though new estimates show elasticities equal to unity or above (see *e.g.* Viscusi, 2010). As mentioned above, the risk change was found to be negatively correlated with the level of GDP per capita for this dataset (-0.4). Running Model V from the unscreened sample for the 625 estimates where the risk change information is given (results not displayed here) yields an income elasticity of 1, as does Model V in Table 3.4 if we run the regression excluding the risk change variable. Hence, controlling for the risk change in the regressions helps explain around half of the reduction in the income elasticity. This means that some of the effect on VSL is not due to increase in GDP per capita, but due to the fact that surveys in higher-income countries tend to present lower risk changes for respondents to value.

The coefficient on the risk change variable is between -0.57 and -0.45 for the five models. This means that respondents' WTP is not very sensitive to the size of the risk change and, hence, WTP does not increase in proportion to the risk reduction, as predicted by economic theory. Since VSL is defined as WTP divided by the risk change, VSL therefore decreases when the risk change to be valued increases. This finding can be seen as a potential problem for both policy and research, as using lower risk change levels in the surveys would ensure higher VSL estimates. The next section investigates whether this result changes if a scope sensitivity criterion is applied.

Table 3.4. **Meta-regression results, first-level screening**

	Model I	Model II	Model III	Model IV	Model V
lngdp	0.768*** (0.205)	0.841*** (0.193)	0.882*** (0.184)	0.850*** (0.186)	0.783*** (0.193)
lnchrisk	-0.450*** (0.0940)	-0.528*** (0.103)	-0.552*** (0.101)	-0.572*** (0.0826)	-0.577*** (0.0849)
turnbull	-0.948 (0.825)	-0.384 (0.653)	-0.109 (0.630)	0.0160 (0.654)	-0.0774 (0.677)
envir		-1.097*** (0.352)	-0.433 (0.275)	-0.650* (0.348)	-0.606* (0.335)
traffic		-0.310 (0.278)	-0.0814 (0.308)	-0.126 (0.267)	-0.288 (0.231)
public			-1.002*** (0.260)	-0.917*** (0.263)	-0.913*** (0.249)
household			-0.0198 (0.277)	0.01 54 (0.232)	0.0159 (0.225)
cancerisk				0.407 (0.314)	0.475 (0.308)
latent				-0.369 (0.381)	-0.326 (0.371)
noexplan					0.668*** (0.214)
Constant	2.882 (2.422)	1.784 (2.313)	1.205 (2.230)	1.319 (2.263)	1.846 (2.386)
Estimates	405	405	405	405	405
R-squared	0.720	0.767	0.806	0.817	0.833
Root mean squared error	0.886	0.810	0.740	0.721	0.691

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

It can also be observed that the traffic variable is no longer significant, though the environment variable is negative and significant for three out of four models where it is included (negative coefficient for the variable "envir"). Note that while mean VSL is higher for the environmental risks in the full dataset (see Table 3.3), results may differ when controlling for important covariates as done here. The "public" variable is now significant and negative, meaning perhaps that the effect of altruism is outweighed by other factors, as discussed earlier. Finally, the "noexplan" variable is still positive and significant.

The R-squared is high for all models. It is interesting to observe that the combination of only the risk change, GDP per capita and Turnbull variables explains 72% of the variation in VSL estimates. Adding the other explanatory variables increases the R-squared to 83%, which is high by any measure in the MA literature.

Estimates from scope sensitive studies

In the database, information exists about whether external and/or internal scope tests have been conducted and whether the surveys have passed the test(s) or not. When mean WTP is found in statistical tests to be significantly higher for respondents faced with risk change A compared to risk change B, and A is larger than B, the test is normally interpreted as passed in the literature. Note that in the interpretation here, the stricter requirement that WTP should be proportional to the risk change, *i.e.* that WTP_A/WTP_B and A/B should be equal, is not applied. Information about proportionality is not always reported in studies conducting scope tests. Further, due to differences in reporting practices, no other information about the degree of sensitivity found in the studies was coded. Still, this information may be able to shed some light on whether VSL estimates from surveys that passed scope tests display lower sensitivity to the risk change magnitude in meta-regressions. Note that since proportionality of WTP with the risk change is not required for the scope tests to be considered passed, the coefficient on the risk change variable should not be expected to be zero (even in this case), but to be closer to zero than for regressions based on estimates from surveys that did not pass scope tests.

The starting point is the screening criteria from the first-level screening discussed above, where there for each estimate is information about the risk changes that were the basis for deriving VSL. Of the 405 estimates included in Table 3.4, 199 come from studies that conducted an external scope test (85 passed, 114 did not pass). 206 come from studies that did not conduct such a test, or did not report results. Regarding internal scope, 318 estimates come from studies that conducted such a test (291 passed, 27 did not pass), the remaining 87 did not conduct such a test, or report such results. Further, of the 187 estimates that come from studies that conducted both external and internal tests, 107 passed only the internal test, 79 estimates passed both, and 1 estimate passed neither tests. Hence, the external test is much harder to pass.

For simplicity, results from only two types of models are displayed: One where GDP per capita, risk change and Turnbull variables are included (like Model I in Table 3.4) and one where the full set of covariates are included (like Model V in Table 3.4). The dataset is divided into three (results are displayed in Table 3.5):

- VSL estimates from studies that did not pass neither external nor internal scope tests (Models I and II, 108 estimates)
- VSL estimates from studies that passed either internal or external tests (Models III and IV, 297 estimates); and
- VSL estimates from studies that passed both internal and external tests (Models V and VI, 79 estimates).

It seems that passing just one of the tests does not significantly reduce the sensitivity of the VSL estimates to the magnitude of the risk change valued, as this coefficient is strongly significant and not much closer to zero in Models III and IV compared to Models I and II, respectively. These two pairs of models divide the dataset from the first level screened dataset above into two along the scope dimension, and results can be compared with Models I and V in Table 3.4.

Estimates that pass both tests, however, seem to yield a larger reduction in the risk change coefficient, even making it insignificant in Model VI. Note that the "noexplan" variable is dropped in this model, as all the estimates come from studies that provided visual tools and specific explanation of the risk change. There are some changes in other results, most notably: The latency variable is a bit unstable, GDP per capita and "public" are no longer significant in Model V, while the Turnbull variable only turns negative and significant for the no-scope dataset and for Model V. Even if these results should be interpreted with caution due to the low number of estimates, there seems to be some indication that VSL estimates from more scope-sensitive surveys are slightly less affected by the magnitude of the risk change in meta-regressions. However, more research is required,

Table 3.5. **Meta-regression results for subsets of the data screened according to results of scope tests**

	No scope		Internal or External		Internal & External	
	Model I	Model II	Model III	Model IV	Model V	Model VI
lngdp	0.753*** (0.174)	0.811*** (0.116)	0.692** (0.318)	0.745** (0.293)	0.249 (0.158)	0.336** (0.134)
lnchrisk	-0.475*** (0.0814)	-0.608*** (0.0895)	-0.443*** (0.114)	-0.551*** (0.102)	-0.290*** (0.0573)	-0.245 (0.135)
turnbull	-1.982*** (0.435)	-0.714** (0.333)	0.600 (0.903)	0.850 (0.866)	-0.705* (0.370)	-0.476 (0.299)
envir		-0.0285 (0.222)		-0.241 (0.355)		0.130 (0.294)
traffic		-0.360 (0.215)		-0.179 (0.385)		-0.190 (0.197)
public		-0.999*** (0.244)		-0.768** (0.312)		-0.0143 (0.331)
household		0.512* (0.243)		-0.486 (0.358)		0.0845 (0.332)
cancerisk		0.0965 (0.299)		0.484 (0.311)		0.0188 (0.125)
latent		1.186*** (0.338)		-0.384 (0.293)		-0.695** (0.245)
noexplan		0.648** (0.227)		1.051*** (0.291)		
Constant	3.032* (1.521)	1.162 (1.402)	3.556 (3.623)	2.366 (3.439)	9.395*** (1.572)	9.192*** (1.659)
Estimates	108	108	297	297	79	79
R-squared	0.898	0.952	0.629	0.775	0.637	0.756
Root mean squared error	0.545	0.386	0.971	0.765	0.528	0.451

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

for example finding ways to classify the degree of scope sensitivity in original surveys, to draw firm conclusions. It may also be the case that surveys that did not conduct scope tests would have passed them, if they had been conducted – hence, potentially dampening the expected effect from the classification used above.

Estimates from surveys using a similar questionnaire

This section limits the dataset to studies using variations of the mentioned questionnaire initially developed by Krupnick, Alberini and co-authors (*e.g.* Krupnick *et al.*, 2002; and Alberini *et al.*, 2004). The idea is that if the methodological variation can be eliminated or significantly reduced, the effects of other variables, more relevant for benefits transfer and policy use, will come out more clearly.

This questionnaire values health risk reductions only (with no reference to specific causes of the risk), using a 1000-square grid for displaying and training respondents to understand the magnitude of the risk changes, etc. In some ways, the surveys using this approach can be regarded as good practice compared to many other approaches, although further refinement and innovation in this area is still desirable. Another advantage is that variations of the questionnaire have been used in several countries, ensuring variation in some of the policy-relevant variables (such as income). The screening criteria used here were otherwise the same as for the first-level screening above. The risk reductions portrayed in the surveys are privately experienced (to eliminate altruistic concerns), and affecting only an individual (rather than a household). The variables "household", "envir", "traffic", "cancerrisk", "public", and "noexplan" drop out, as the values of these are the same for all estimates. The log of survey year was added to the regression models.

Results of three meta-regression models are displayed in Table 3.6. In order to investigate the effect of the weighting strategy, one model (Model I) was run using the same approach as for the meta-regressions above, *i.e.* weighting by the inverse of the number of estimates from a given survey, so that each survey counts equally. Second, the same model was run with only precision weighting, *i.e.* using the inverse of the standard deviation of the mean VSL estimates reported (as recommended by US EPA, 2006) (Model II). Finally, the two weights were combined into one in the final model (Model III). This comparison is made here, since the studies using this particular questionnaire also have much reporting related to standard deviation, providing a more complete dataset.

Table 3.6. **Meta-regression results for surveys using similar questionnaire**

	Model I	Model II	Model III
lngdp	0.435***	0.301**	0.372***
	(0.0811)	(0.0888)	(0.0909)
lnchrisk	-0.507**	-0.834***	-0.578**
	(0.166)	(0.0716)	(0.195)
turnbull	-0.591*	-0.686**	-0.485*
	(0.249)	(0.234)	(0.246)
latent	-0.227***	-0.0151	-0.0286
	(0.0536)	(0.0299)	(0.0662)
lnyear	4.222**	2.456	1.928
	(1.254)	(1.845)	(1.684)
Constant	-8.903	-4.076	-0.955
	(4.924)	(7.198)	(6.633)
Estimates	169	155	155
R-squared	0.815	0.848	0.879
Root mean squared error	0.359	0.252	0.282

Robust standard errors in parentheses.

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

The number of estimates drops to 169 for Model I. This model explains around 81% of the variation in VSL estimates. It can be seen that both risk change and income again are highly significant. The income elasticity has dropped to below 0.5, compared to 0.7-0.9 in the first-level screened sample models previously displayed. VSL tends to be lower for risk reductions that are latent and for estimation procedures using the lower-bound, conservative, non-parametric Turnbull estimator (the latter of which is expected from theory). It can also be noted that newer studies tend to give higher VSL estimates, unclear for which reasons. One possibility may be that the "lnyear" variable picks up differences between countries not explained by the GDP per capita. However, the coefficient is not robust across the three models.

The precision weighting in Model II yields similar results as the first model. Note that a few (14) estimates have been dropped, as there is no information about standard deviation for these estimates, so Model I is not strictly comparable with Models II and III. The GDP per capita and risk change variables are still highly significant. The income elasticity of VSL drops to a low 0.3 and the coefficient for the risk change is fairly close to -1, the level at which WTP is independent of the risk reduction. The Turnbull variable is still significant. The variables regarding the year of the survey and latency are no longer significant. Combining both precision and sample weighting in Model III leaves the results very similar (*i.e.* somewhere in between the other two weighting strategies, as expected).

For these subsets of the data using variations of a good practice questionnaire, it is possible to explain a fairly large part of the variation in VSL estimates by a small number of variables. However, the concern remains for these estimates that the VSL is still highly sensitive to the magnitude of the risk change; there is no improvement for this questionnaire compared to the dataset undergoing first-level screening.[13]

Excluding estimates based on author recommendations

The final sample uses author recommendations to exclude certain estimates, as explained in Section 3.2. Hence, in addition to the first-level screening criteria, screening was done based on authors' recommendations to exclude a particular estimate from further analysis (which causes an additional 55 estimates to be dropped compared to the models in Table 3.4). It is worth noting that many of the estimates that the authors recommended for exclusion were screened out anyway based on the other criteria used here. Results are displayed in Table 3.7.

The same variables as for the first-level screened sample were used again for five different meta-regressions. As can be seen, the R-squared is again very high, and between 71 and 84%. The "envir" variable is significant for all four models where it is included; reflecting lower VSL estimates when they are based on environment-related risk changes compared to unspecified, health-related risk changes. "Traffic" variable is negative this time, but significant only in Model V. The variable "public" is highly significant and negative in all three models where it is included. The size of the risk change and income are still significant, the income elasticity again increasing to between 0.74 and 0.88. There is a cancer premium in Model V, but not in Model IV. The latency and Turnbull variables are not significant. The "noexplan" variable is again significant. Compared to the first-level screening results, the results from the author recommended dataset are strikingly similar. All the same variables are significant and coefficient values are not much different. This may reflect that there is much overlap between the first-level screening criteria and those used by authors to recommend screening out certain estimates.

Table 3.7. **Meta-regression results for sample where author recommendations are used**

	Model I	Model II	Model III	Model IV	Model V
lngdp	0.752***	0.823***	0.885***	0.832***	0.741***
	(0.206)	(0.190)	(0.186)	(0.185)	(0.192)
lnchrisk	-0.461***	-0.588***	-0.561***	-0.590***	-0.612***
	(0.101)	(0.120)	(0.111)	(0.0897)	(0.0909)
turnbull	-0.941	-0.305	-0.142	-0.00910	-0.129
	(0.826)	(0.626)	(0.632)	(0.649)	(0.671)
envir		-1.303***	-0.566*	-0.857**	-0.855**
		(0.374)	(0.306)	(0.367)	(0.345)
traffic		-0.533	-0.204	-0.230	-0.464*
		(0.333)	(0.327)	(0.287)	(0.246)
public			-0.879***	-0.744**	-0.684***
			(0.255)	(0.272)	(0.228)
household			-0.166	-0.150	-0.203
			(0.290)	(0.248)	(0.238)
cancerisk				0.516	0.620*
				(0.332)	(0.326)
latent				-0.320	-0.272
				(0.385)	(0.371)
noexplan					0.746***
					(0.221)
Constant	2.923	1.511	1.154	1.358	1.950
	(2.441)	(2.290)	(2.255)	(2.271)	(2.360)
Estimates	350	350	350	350	350
R-squared	0.717	0.779	0.814	0.827	0.845
Root mean squared error	0.905	0.803	0.739	0.714	0.677

Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

3.6. Conclusions

Overall, through the different screening procedures, the following main results can be summarised from the meta-regressions:

- The explanatory power and fit of the models seems to gradually increase as stricter screening criteria are applied (since root mean square errors generally drop) and as more explanatory variables are included (as expected). Heterogeneity is gradually reduced in the data.
- The main regression results are fairly robust across models and screening criteria. Effects of income (GDP per capita) and the size of the risk change presented to respondents are strongly positive and negative, respectively. These two variables are by far the most important variables to explain the variation in global VSL estimates. The income elasticity of VSL seems to be in the range 0.7-0.9 for most of the regressions applying screening criteria. This range is, however, substantially lower; 0.3-0.4, for some subsets of the data that satisfy scope tests or use the same high-quality survey approach.

- There is a strong indication from the screened models that public mortality risk changes that affect people beyond the respondent's own household are valued *lower* than private risk changes only affecting the respondent or her household members.
- There is a strong indication from most of the screened models that environment-related risk changes are valued *lower* than risk changes from unspecified causes (categorised as health-related in this paper).
- There is mixed evidence regarding the valuation of traffic-related risk changes compared to health-related risk changes.
- There is strong indication that if a visual tool or a specific oral or written explanation was used to explain the risk changes to the respondents in the survey, the estimated VSL tends to be lower.
- There is no clear evidence of a cancer premium in the VSL estimates; *i.e.* VSL does not seem to be systematically higher when respondents were asked to value cancer-related risk changes.
- There is mixed evidence regarding the effect of other variables, such as latency of risk changes, the year of the survey and the use of the non-parametric Turnbull estimator.
- Using only estimates that come from surveys that have passed either an internal or external scope test (but not requiring proportionality of WTP to the risk change), does not seem to reduce the degree of sensitivity of VSL to the risk change. However, estimates that pass both tests seem to yield a reduction in the risk change coefficient, even making it insignificant in one of the models (although this model is based on relatively few estimates, so results should be interpreted with caution).
- For the subset of the data based on a common questionnaire initially developed by Krupnick, Alberini and co-authors, the results are fairly robust to the type of weighting procedure used in the regressions (*i.e.* by precision, by number of estimates from a survey or combining both).
- The results above are generally fairly robust to removing the weighting procedure (making each individual estimate count equally in regressions) and to the trimming of the 2.5% highest and lowest VSL estimates relative to GDP capita in each of the meta-regression models. A full account of this sensitivity analysis is given in supplementary appendices of Lindhjem *et al.* (2011).

Many of the results follow predictable patterns from economic theory and previous studies. For example, VSL should increase with income and the income elasticities found are plausible and within the range of other studies. On the other hand, it is a concern for stated preference research, and policy, that all but one of the models shows a very robust, strong and negative relationship between stated VSL and the magnitude of the risk change valued by the respondents. There are indications from the meta-regressions that estimates from more scope-sensitive survey applications, where the magnitude of the risk change is typically better explained to respondents, yield survey responses more in accordance with economic theory and VSL estimates that are less sensitive to the risk change. This is an important point in the consideration of theoretical validity of SP surveys used to value risks. The findings seem to point to a need for further research to improve SP methods for estimating VSL, but not to discard SP methods for this purpose altogether.

Further discussion and interpretation of the results are given in Lindhjem *et al.* (2011). The results from the meta-regressions in this chapter are used in Chapters 5 and 6 in combination with other evidence from the literature when considering how to derive VSL estimates for policy purposes. The next chapter demonstrates how estimated meta-regression functions may be used for benefit transfer purposes. The accuracy of such approaches is compared with other, simpler BT techniques.

Notes

1. This chapter draws heavily on Lindhjem *et al.* (2011).
2. "Coding" means that information from studies expressed as numbers or as text is transformed into variables for statistical analysis. Typically, much of the information is coded as binary (0-1) variables – see Table 3.1.
3. Working papers may of course later be published in a journal or similar, which is a practical reason why excluding working papers may miss the mark.
4. There may of course be other time trends captured in this variable, *e.g.* effects of wealth increases not reflected in GDP numbers.
5. Our request to authors was phrased in the following way: "It would be excellent if you could indicate if you think that a given VSL estimate ought to be included in our analysis. We would like you to distinguish between four 'options': "Only", "Yes", "Perhaps" and "No". Please use "Only" to indicate the preferred estimate from a given survey (if any), "Yes" to indicate that the estimate is one among several estimates that ought to be included, "Perhaps" to indicate that you are in doubt and "No" if you think that a given estimate definitively should not be included in the meta-analysis." It should be mentioned that authors may have invoked different criteria in their recommendation to exclude estimates (and these criteria may depend on the exact use of the estimates). The approach used here could be strengthened in future work by developing more objective criteria for making such author judgements or by utilising more formal expert elicitation techniques.
6. See Braathen *et al.* (2009) for preliminary MA results and Annex 3.A1 for some additional meta-regression analyses conducted by Biausque (2010).
7. The distinction between the environment and health categories is not always obvious, in part because some health risks are caused by an environmental problem. In the classifications made here, the focus was on whether or not an explicit reference to an environmental problem was made in the valuation question posed to the sample. If that was not the case, the survey was classified as being "health-related".
8. SP surveys frequently return interval-censored data on respondents' WTP, *i.e.* that the exact WTP is not elicited through an open-ended question of maximum WTP. Turnbull is an algorithm that can be used to derive a lower-bound estimation of the population's expected WTP from such interval-censored data, without the use of parametric assumptions regarding the population's distribution of WTP (see *e.g.* Haab and McConnell, 2002).
9. It is acknowledged that individual income and GDP per capita are different measures. The difference may be quite large for *e.g.* resource rich countries. However, it is a proxy often used in MA studies (see *e.g.* Brander *et al.*, 2006).
10. This approach was chosen also to simplify the use of the models for deriving VSL estimates for policy, as shown in Lindhjem *et al.* (2010).

11. Caution should be exercised when interpreting the income elasticity, as it is not possible in a MA like this to adjust for the potential effect of real income growth on VSL over the long time period the data cover (see *e.g.* Costa and Kahn, 2004). Adjustment of VSL and GDP per capita using consumer price indices to a common base year is the most transparent and commonly used method.

12. Number of estimates dropped from the full unscreened dataset for each criterion, *i.e.* the number of estimates indicated dropped does not depend on which order the criteria are introduced.

13. It is worth noting that, even though estimates from the same survey are weighted down, there is quite a large share of the estimates in this section from a specific study conducted in China, which found a low degree of external scope sensitivity (Krupnick *et al.*, 2006). See Annex 3.A3.

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Annex 3.A1

Additional meta-regressions

This annex uses the available information regarding variability in the estimates of the value of statistical life (VSL) to assign greater weight to those estimates that are more accurate. It is based on Biausque (2010), and the analysis is done on a slightly different sample of VSL estimates than what was used in the final regressions described earlier in Chapter 3.

Description of the method

Consider n studies that measure a parameter of interest y (in our case, this is the logarithm of the VSL). However, as discussed, a certain number of covariates may affect the "true" parameter values $y_1, \ldots, y_n$. Thus, we have a standard regression of the form

$$y_i = x_i'\beta + \varepsilon_i$$

where x_i designates a vector of covariates from study i and ε_i is an error term denoted the "inter-study heterogeneity term". It is assumed that the ε_i are independent and identically distributed $N(0, \tau^2)$. While one do not exactly observe the "true" values $y_1, \ldots, y_n$, estimates, $\hat{y}_1, \ldots, \hat{y}_n$ are available. Thus, for each i one can write

$$\hat{y}_i = y_i + \delta_i$$

where δ_i is an "inter-study heterogeneity term". It is assumed that δ_i is independent and identically distributed $N(0, \upsilon^2)$. Note that, generally, one have estimates for the values $\upsilon_1, \ldots, \upsilon_n$. Therefore, the model is of the type:

$$\hat{y}_i = x_i'\beta + \delta_i + \varepsilon_i$$

where the parameters β and τ^2 are to be estimated.

There are many methods which can be used to estimate β and τ^2, including empirical Bayesian techniques. However, these techniques are all extremely demanding computationally and would make the running the simulations in the next section very long. A simpler method involving the method of moments is therefore used to estimate the "inter-study" variance term. Formally, an ordinary least squares regression weighted by the reciprocals of the estimated variances $\upsilon_1, \ldots, \upsilon_n$ is estimated. This yields an initial estimate for β that can be written

$$\hat{\beta}_1 = (X' V^{-1} X)^{-1} X' V^{-1} \hat{Y}$$

where $X_i = (x_1, \ldots, x_n)$, $\hat{Y} = (\hat{y}_1, \ldots, \hat{y}_n)$, and $V = diag(\upsilon_1, \ldots, \upsilon_n)$. $X' = (x_1, \ldots, x_n)$.

Thus, the average of the residual sum of squares, $RSS = \Sigma_{i=1}^{n} (\hat{y}_i - x_i'\beta_1)/v_1$, is

$$E(RSS) = (n - m) + \tau^2 \{Tr(V^{-1}) - Tr[V^{-1}X(X'V^{-1}X)^{-1}X'V^{-1}]\}$$

where m is the number of covariates (including the constant). This yields a natural estimator for τ^2 by the method of moments:

$$\hat{\tau}^2 = \max \left\{ \frac{RSS - (n - m)}{Tr(V^{-1}) - Tr[V^{-1}X(X'V^{-1}X)^{-1}X'V^{-1}]}, 0 \right\}$$

This information is used to obtain a second estimate of β.

$$\hat{\beta}_2 = (X'\tilde{V}^{-1}X)^{-1} X'\tilde{V}^{-1}\hat{Y},$$

with $\tilde{V} = \text{diag}(v_1 + \hat{\tau}^2, \ldots, v_n + \hat{\tau}^2)$.

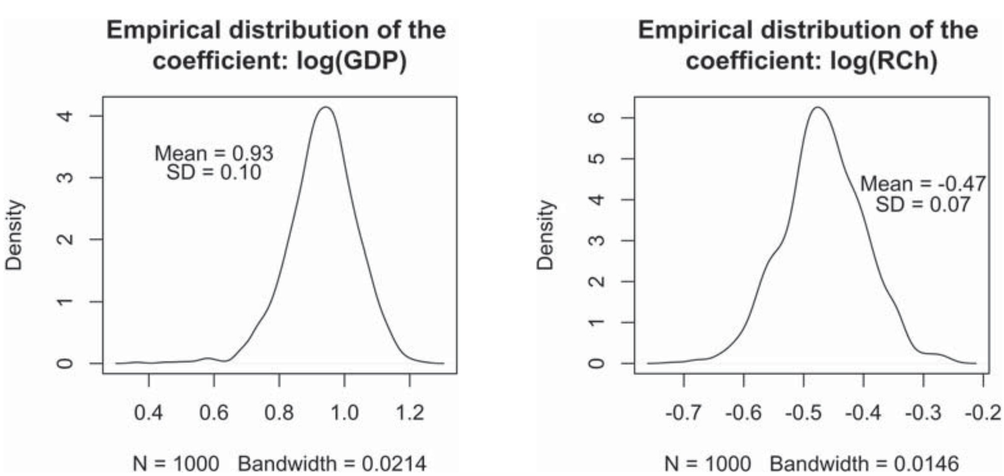
Adapting the method to the data

The method presented above only works for independent observations of $y_1, \ldots, y_n$. Consequently, it cannot be directly applied to the present data. The approach used below therefore involves taking a random sample consisting of a single observation from each study group and then performing a meta-regression on this "small sample". This process is repeated 1000 times so as to obtain an empirical distribution of the parameters to be estimated.

However, the required information about the estimated variances is only available for 254 observations from 21 study groups. Table 3.A1.1 presents the descriptive statistics for this sample. Each "small sample" includes 21 observations only. For this reason, only two regressors were chosen: the logarithm of per capita GDP and the logarithm of the risk reduction proposed in the survey. The logarithm of the VSL remains the dependent variable. For each iteration of the process described above, an estimate of the model's coefficients was obtained. Figure 3.A1.1 illustrates the empirical distributions of the estimates of the model's coefficients (elasticity of wealth and of risk reduction).

$$\log(VSL)_i = \beta_0 + \beta_1 \log(PIB)_i + \beta_2 \log(RCh)_i + \delta_i + \varepsilon_i.$$ [1]

Figure 3.A1.1. **Empirical distributions of the coefficients of the regressions**



It can be seen that the empirical distributions of the calculated coefficients are fully consistent with the results obtained in the regressions in the main models of Chapter 3.

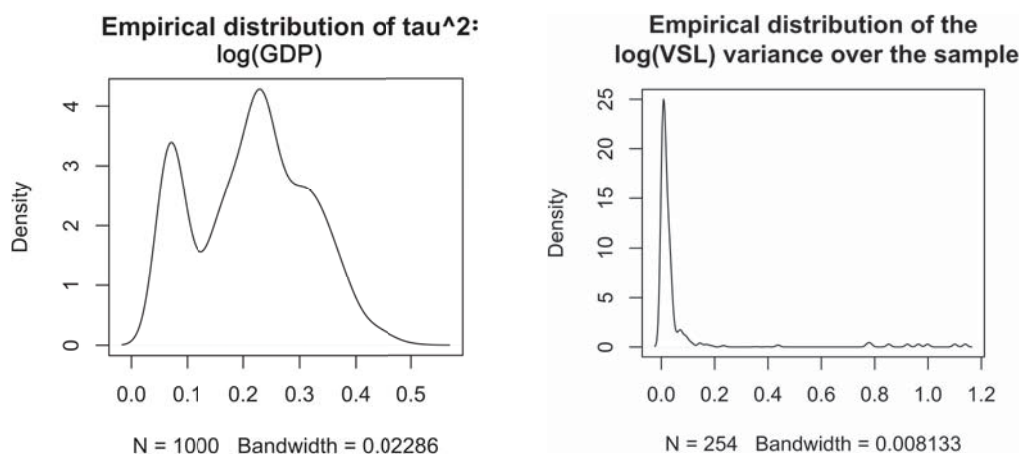
Table 3.A1.1. **Descriptive statistics, sample with standard deviations**

Paper	No. Obs.	Publication year	Country	Average VSL	Range	Per capita VSL/GDP ratio
Alberini *et al.*	2	2004	United States	1 421 025	1.1 – 1.7	34
Alberini *et al.*	3	2007	Italy	3 598 485	1.4 – 6.3	130
Alberini *et al.*	2	2006	Canada – United States	1 036 062	0.8 – 1.2	27
Chestnut *et al.*	12	2009	Canada – United States	5 142 629	2.5 – 9.4	134
Desaigues *et al.*	6	2004-07	Denmark	2 651 682	1.1 – 4.9	79
Gibson *et al.*	1	2007	Thailand	659 955	##	96
Giergiczny	3	2006	Poland	795 082	0.2 – 1.7	59
Hakes & Viscusi	2	2004	United States	6 247 816	6.1 – 6.4	150
Hammitt & Zhou	12	2006	China	115 515	0.02 – 0.4	28
Itaoka *et al.*	19	2007	Japan	1 280 220	0.5 – 2.8	42
Johannesson, Johansson & O'Conor	4	1996	Sweden	4 652 973	2 – 7.1	145
Jones-Lee, Hammerton & Philips	4	1985	United Kingdom	5 226 967	3.9 – 7.2	166
Krupnick *et al.*	8	2002	Canada	1 758 343	1.1 – 3.6	50
Krupnick *et al.*	110	2006	China	562 225	0.1 – 1.7	137
Leiter & Pruckner	24	2008-09	Austria	3 021 948	1.9 – 5.2	89
Leiter & Pruckner	4	2008	Austria	2 445 736	2.1 – 2.8	72
Mahmud	4	2006	Bangladesh	5 248	0.04 – 0.07	4
Leung *et al.*	8	2009	New Zealand	2 870 491	1.8 – 4.4	117
Rheinberger	2	2009	Switzerland	4 362 827	4.2 – 4.5	123
Schwab Christe & Soguel	6	1995	Denmark	13 600 000	9 – 17.5	404
Svensson	14	2009	Sweden	7 693 884	3 – 9.6	240
Vassanadumrondgee & Matsuoka	4	2005	Thailand	1 555 256	1.3 – 1.8	226

This corroborates the finding that the elasticity of the value of statistical life with respect to wealth is approximately 0.95, with a 95% confidence interval between 0.73 and 1.13 for this last method.

To assess whether the inter-study heterogeneity term plays an important role in the results obtained from the methods described above, one can look at the empirical distribution of $\hat{\tau}^2$ obtained from the 1000 iterations previously performed. This distribution is then compared with that of the variance of $\log(VSL)$ from the sample of 254 observations, again weighting them with the reciprocal of the number of observations in each study group. These distributions can be seen in Figure 3.A1.2. It can be seen that inter-study heterogeneity appears to play an important role in the weighting, because the empirical probability that the factor $\hat{\tau}^2$ is greater than 0.1 exceeds 0.75, while the distribution of the logarithm of the value of statistical life is largely concentrated between 0 and 0.1. This indicates that the various components of heterogeneity (heterogeneity from the estimates of the VSL in study *i* and heterogeneity from inter-study differences) are essentially attributable to inter-study heterogeneity.

Figure 3.A1.2. **Distribution of inter-study heterogeneity and of the variance of log(VSL)**



Quantile regressions

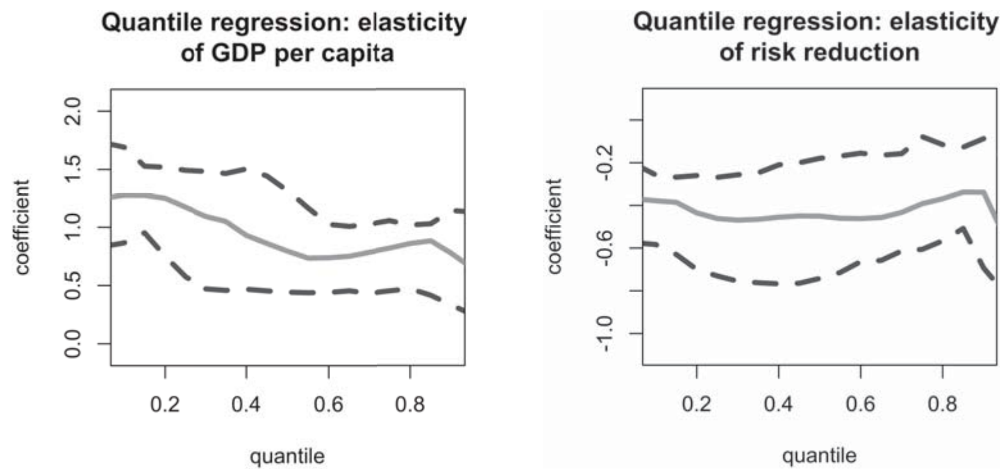
In order to probe a little deeper into the data, quantile regressions are used here to assess whether the calculated elasticities differ by quantile. To this end, simulation techniques that involve drawing a random sample of a single observation from each study group are again used (in order to obtain independent observations). This time, each sub-model assumed is expressed as follows:

$$\log(VSL)_i = \beta_0(q) + \beta_1(q)\log(PIB)_i + \beta_2(q)\log(RCh)_i + \varepsilon_i(q).$$

where q is a quantile between zero and one and $\varepsilon_i(q)$ is an error term such that its q-quantile equals zero. As in the previous section, greater weights were assigned to more accurate observations, and an inter-study heterogeneity term was included. However, the techniques described above for estimating the term $\hat{\tau}^2$ were not designed for quantile regressions. These estimates are nevertheless used on an experimental basis. For each quantile and each sub-sample, this parameter was estimated and a quantile regression was performed, using the weights $w_i = 1/(v_i + \hat{\tau}^2)$. In practical terms, for each quantile q, 1000 sub-samples were randomly selected according to the protocol explained above, and the empirical distribution of the coefficients $\beta_1(q)$ and $\beta_2(q)$ were calculated. Figure 3.A1.3

depicts the median and the 2.5% and 97.5% quantiles of the two empirical distributions as a function of quantile *q*. The two solid lines represent the median and the dashed lines represent the 2.5% and 97.5% quantiles.

Figure 3.A1.3. **Quantile regressions**



One can first observe that the results obtained by this technique are consistent with the coefficients estimated above; namely, the elasticity of VSL with respect to wealth is approximately 1, and its elasticity with respect to risk reduction is approximately -0.4. However, one can now see that the elasticity associated with risk reduction is fairly constant across quantiles, while that of per capita GDP appears to decrease with the quantile. In other words, the explanatory power of wealth for the value of statistical life appears greater for low values of VSL. One should therefore be prudent when using the elasticity of wealth. In countries considered to be rich, differences in terms of wealth or disposable income seem to play a muted role in explaining variations in the VSL. In developing countries, on the other hand, these variations seem more straightforward.

Non-parametric regressions

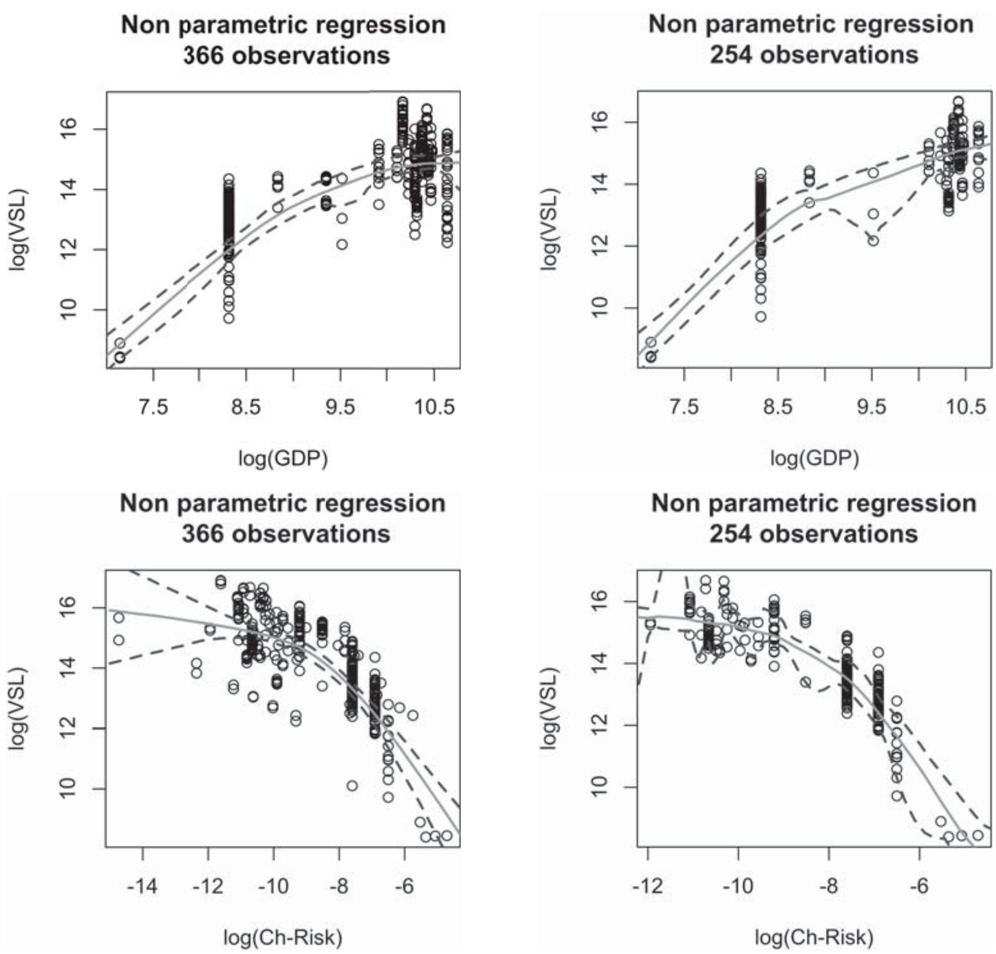
In order to view these effects differently, non-parametric regression techniques were also used. Here, the objective is to estimate the influences that the logarithm of per capita wealth and the logarithm of risk reduction exert on the logarithm of the value VSL, while making the fewest possible prior assumptions as to the form of the model. Once again, the complexity and heterogeneity of the data preclude direct application of standard methods. In particular, the problem of dependency between observations arises once again. Therefore, as in the two previous sections, simulation methods will be used. The following operations were repeated 1 000 times:

- A single observation for each group of studies was selected.
- A non-parametric penalised cubic-spline regression was performed on this small sample.
- This model was used to obtain a sequence of the form $[E(\log(VSL) \mid \log(PIB) = x_k)]_k$, $[x_k]_k$ being a size 100 sequence equispaced between seven and 11 (values related to our data).

Thus, for each value of x_k, 1 000 different values of $E(\log(VSL) \mid \log(PIB) = x_k$ were obtained. Then the 2.5%, 50% and 97.5% quantiles were selected, in order to construct a 95% confidence interval for $E(\log(VSL) \mid \log(PIB) = x_k$.

Figure 3.A1.4 shows the results of these simulations on samples of 366 and 254 observations. As on the quantile regression graphs, the solid line refers to the median value of the nonparametric regression, whereas the dotted lines refer to the lower and upper boundaries of this type of regression.

Figure 3.A1.4. **Parametric regression by simulation techniques**



Note: See Biasque (2010) for an explanation of the difference between the samples of 254 and 366 observations.

The effects that had been noted when using quantile regressions in respect of the influence of the logarithm of per capita GDP can in fact been seen in these graphs; *i.e.* the influence of wealth on the statistical value of human life seems less substantial in countries that are already rich. Further, the influence of risk reduction is also greater when this risk reduction is fairly substantial. These findings are indicates that when per capita GDP is high, the proposed risk reduction in stated preferences surveys is generally rather low (*i.e.* there is a negative correlation between per capita GDP and the proposed risk reduction).

Note

1. PIB: Produit Interieur Brut – GDP. RCh: Risk Change.

Annex 3.A2

A selection of regressions with additional variables

This Annex presents a selection of additional meta-regression analyses, for the full dataset and the first-level screened datasets discussed in Section 3.5. The main purpose is to introduce some additional variables compared to those that are listed in Table 3.1 and investigate their effects. Much work was carried out in the preliminary analysis stage, some of which are documented in Braathen *et al.* (2009) and in Annex 3.A1 above. However, the dataset has been changed slightly and updated since those analyses were carried out. Hence, some of the regressions have been rerun and the results are displayed here.

Given the vast range of variables available in the database, and the challenge discussed above that data is missing for some variables, this annex is not meant to be exhaustive of such alternative regression models. It will be topic for further work to investigate how to utilise the full breadth and depth of the material, something it is hoped that may be spurred by the free access to the full dataset – at *www.oecd.org/env/policies/vsl*. Below a few alternative regression models are presented and briefly discussed.

The following additional variables are included in the meta-regressions to follow:

- **Voluntary:** if the risk is voluntary (can be controlled/avoided by individual), the variable is equal to one; 0 if involuntary. It is likely that people are willing to pay more to reduce mortality risks they cannot control.
- **Baseline risk** ("lnblrisk"): the "risk of dying anyway". The relationship with VSL should be weak positive. The logarithm of this variable is used.
- **Self-administered survey** ("selfadmin"): This is a variable indicating 1 if the survey was completed without the assistance of an interviewer, *e.g.* a web-survey or on a PC. Some studies find that the survey mode may be important for the result, especially the presence of an interviewer that could lead to so-called social desirability bias.
- **Year of the survey** ("lnyear"): higher number indicating more recent survey. This variable was included in the regressions for the good practice questionnaires (see Table 3.6). The logarithm of this variable is used.
- **Age** ("lnage"): The logarithm of the mean age of the sample is included. It is an empirical question how age relates to VSL. Some have hypothesised an inverted U-shaped curve.

Combinations of these variables are displayed for the full and the screened dataset in the following. To reduce the total number of explanatory variables and not get (too) over-specified models, the variables "household" and "Turnbull", which were rarely significant in the main regression models in Section 3.5, have been excluded.

Full dataset

A few new models were run and the results are displayed in Table 3.A2.1. The first model is simple, only including GDP per apita for sake of comparison. Compared to earlier meta-regression models on the full dataset (see Table 3.3), the "selfadm" and "voluntary" variables have been introduced in Model II, survey year in Model III, and baseline risk and mean age of the sample in Models IV and V, respectively. The GDP per capita coefficient is very similar to earlier models. The "voluntary" variable is only significant in Model IV (with the perhaps opposite sign of what is expected). The coefficient on survey year is positive in the same model. It is interesting that the self administration mode seems to influence the VSL estimates positively in two out of four models where it is included. This is not as expected, as it is normally though that self administration would lead to more conservative statements of WTP. It is difficult to come up with an explanation for this result.

Table 3.A2.1. **Meta-regression for full dataset with alternative explanatory variables**

	Model I	Model II	Model III	Model IV	Model V
lngdp	1.298*** (0.206)	1.219*** (0.183)	1.293*** (0.210)	1.346*** (0.217)	1.130*** (0.204)
voluntary		0.191 (0.349)	0.0848 (0.365)	-0.580** (0.255)	0.0145 (0.405)
envir		0.220 (0.431)	0.247 (0.426)	-0.858** (0.357)	0.373 (0.293)
traffic		0.799*** (0.278)	0.860*** (0.316)	0.179 (0.443)	0.685** (0.275)
selfadm		0.617** (0.272)	0.501 (0.328)	0.231 (0.237)	0.836*** (0.283)
public			-0.101 (0.342)	-1.292*** (0.408)	-0.351 (0.382)
lnyear			36.76 (56.67)	142.7*** (39.69)	68.83 (55.17)
cancerisk				0.270 (0.348)	0.552** (0.251)
latent				0.184 (0.240)	-0.295 (0.309)
noexplan					0.954*** (0.287)
lnage					0.259 (0.419)
lnbrisk				-0.246*** (0.0703)	
Constant	2.030 (1.997)	1.932 (1.696)	-278.0 (431.7)	-1.085*** (302.0)	-521.7 (420.0)
Estimates	856	856	856	462	592
R-squared	0.403	0.474	0.479	0.744	0.696
Root mean squared error	1.363	1.281	1.277	0.836	0.987

Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Note that the first three models have the full number of estimates (856), while the introduction of the baseline risk and age variables reduce the datasets to 462 and 592 estimates, respectively. This is because many studies do not report this kind of information. The baseline risk variable is significantly negative, which is unexpected. However, in the next section the change in risk is also included. There is no effect of the "age" variable the way it is used here. The size and significance of coefficients included in the model runs in Table 3.1 do not change substantially. The explained variation and root mean square errors are also similar. Note, however, that the models are not strictly comparable, as some of the models lose many estimates from regressions.

First-level screening

The models in this section are identical to the models in the section above, except that the regressions are carried out on the datasets that have undergone first-level screening and the risk change variable is included. Since many of the studies do not report the risk change, the dataset is, as has been noted, reduced by almost half. In addition, Models IV and V have now less than 300 estimates. The voluntary variable is now significantly positive in Model II, while the survey year variable is no longer significant. The self administration variable is now significantly positive in three out of four models. When in Model IV the risk change variable is included, the baseline risk variable ceases to have an effect on VSL. This is not unexpected. Finally, the age variable has again no effect on VSL.

Overall, the results found for the key variables (GDP per capita and risk change) are robust across different models. Further research is required to investigate effects of other variables listed in Table 3.1 and not included here. However, challenges remain in interpreting and choosing variables – based both on theory and empirical work.

Table 3.A2.2. **Meta-regression for screened dataset with alternative explanatory variables**

	Model I	Model II	Model III	Model IV	Model V
lngdp	0.866*** (0.188)	0.790*** (0.137)	0.869*** (0.183)	0575*** (0.157)	0.567*** (0.140)
voluntary		0.617** (0.271)	-0.198 (0.342)	-0.0924 (0.419)	0.101 (0.304)
lnchrisk	-0.454*** (0.0905)	-0.545*** (0.0840)	-0.545*** (0.110)	-0.519*** (0.0942)	-0.858*** (0.123)
envir		-0.690** (0.323)	-0.436 (0.333)	-0.374 (0.479)	-0.825** (0.314)
traffic		-0.0898 (0275)	0.0723 (0.387)	-0.108 (0.336)	-1.095*** (0.346)
selfadm		0.427* (0.251)	0.356 (0.264)	0.427* (0.241)	0.514** (0.200)
public			-1.093*** (0.378)	-0.503 (0.421)	-0.677** (0.312)
lnyear			18.73 (58.84)	-26.35 (40.13)	-78.82 (72.96)
cancerisk				-0.192 (0.338)	0.0605 (0.206)
latent				-0.159 (0.192)	-0.0257 (0.226)
noexplan					0.653** (0.278)
lnage					-0.0776 (0.330)
lnbrisk				-0.0797 (0.0613)	
Constant	1.878 (2.065)	1.258 (1.619)	-141.0 (447.5)	204.0 (305.3)	600.7 (553.7)
Estimates	405	405	405	268	292
R-squared	0.707	0.803	0.819	0.810	0.901
Root mean squared error	0.905	0.745	0.717	0.579	0.576

Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Annex 3.A3

Studies included in the main meta-regressions

Table 3.A3.1. **Study characteristics, references and number of estimates included for different meta-regressions in Chapter 3**

Study	Country	Survey Year	Risk change valued – Unscreened data (1×10^{-4})[b]	Risk[c] context	Un-screened data	First-level screening data	Scope sensitive studies: No scope data	Scope sensitive studies: Internal or external scope	Scope sensitive studies: Internal and external scope	Similar survey	Author recom.	VSL range – Unscreened data (Mill. USD 2005)[b]
Acton (1973)	United States	1970	10 - 100	H	4							0.04 - 0.2
Adamowitz *et al.* (2007)	Canada	2004	n.a.	E	18							7.2 - 18.5
ADB (2005)	Malaysia	2004	2 - 5	T	4	4	4				4	0.3 - 0.8
Aimola (1998)	Italy	1994	0.3 - 2	H	12							0.5 - 12.6
Alberini & Chiabai (2006)	Italy	2004	1 - 6	H	8	7		7			7	1.0 - 5.6
Alberini & Ščašny (2009)	Czech Rep. & Italy	2008	n.a.	H, T	28							0.9 -2.5
Alberini *et al.* (2004)	United States	2000	1 - 5	H	2	2		2		2	2	1.1 - 1.7
Alberini *et al.* (2006a)	Czech Republic	2004	1 - 12	H	12	11		11			11	0.7 - 5.4
Alberini *et al.* (2006b)	Canada & United States	1999	5	H	2	2		2	2	2	2	0.8 – 1.2
Alberini *et al.* (2007)	Italy	2005	0.2	E	3	3		3	3		3	1.3 - 5.6
Andersson & Lindberg (2008)	Sweden	1998	n.a.	T	4							2.3 - 10.3
Andersson (2007)	Sweden	1998	0.1 - 0.4	T	8	8	8				8	3.0 - 15.4
Bateman *et al.* (2009)	UK	2007	1 - 800	H	6							0.2 - 4.6
Bhattacharya, Alberini & Cropper (2007)	India	2005	0.4 - 3	T	18							0.02 - 0.1
Buzby, Ready & Skees (1995)	United States	1994	0.5	E	2	2	2				2	5.4 - 7.6
Carson & Mitchell (2006)	United States	1985	0.0004 - 9	E	12	12		12			12	0.2 - 6.4
Carthy *et al.* (1999)	UK	1997	n.a.	T	12[a]							1.6 - 6.0
Chanel & Luchini (2008)	France	2001	n.a.	E	12							1.2 - 3.0
Chanel, Cleary & Luchini (2006)	France	2001	n.a.	E	8							1.4 - 1.8
Chestnut *et al.* (2010)	Canada & United States	2003	1 - 5	E, H, T	34[a]	34[a]		34[a]	34[a]		12	1.2 - 9.3
Choi, Lee & Lee (2001)	Korea	2000	n.a.	E, T	2							3.5 - 5.7
Cookson (2000)	UK	1996	0.0004	E, H, T	6							59.0 -197.0
de Brabander (2009)	Belgium	2005	0.03 – 1	T	19							4.1 - 14.7
Desaigues & Rabl (1995)	France	1994	0.002 - 4	T	12	12	12				4	0.3 - 26.5
Desaigues *et al.* (2007)	France	2002	1 - 5	H	43	20	20			6 - 20	20	0.2 - 9.8
duVair & Loomis (1993)	United States	1989	10 - 30	E	3	3		3			3	0.2 - 0.5
Ghani, & Faudzi (2003)	Malaysia	1999	0.2 - 0.5	T	8	8	8				8	0.7 - 1.9
Ghani, Faudzi & Umar (2004)	Malaysia	1997	0.005 - 0.01	T	6							0.6 - 1.0
Gibson *et al.* (2007)	Thailand	2003	2	H	1	1	1				1	0.7

Table 3.A3.1. **Study characteristics, references and number of estimates included for different meta-regressions in Chapter 3** *(continued)*

Study	Country	Survey Year	Risk change valued – Unscreened data (1×10^{-4})[b]	Risk[c] context	Un-screened data	First-level screening data	Scope sensitive studies: No scope data	Scope sensitive studies: Internal or external scope	Scope sensitive studies: Internal and external scope	Similar survey	Author recom.	VSL range – Unscreened data (Mill. USD 2005)[b]
Giergiczny (2006)	Poland	2005	1 - 10	H	3	3	3				3	0.2 - 1.7
Guo, Haab & Hammitt (2006)	China	2003	5	E	1	1	1				1	0.02
Guria *et al.* (2003)	New Zealand	1998	0.3 - 0.5	T	8[a]	8[a]		8[a]			8[a]	1.8 - 4.4
Gyrd-Hansen *et al.* (2008)	Norway	2005	n.a.	H	3							4.3 - 8.5
Hakes & Viscusi (2004)	United States	1998	1	T	3	2	2				2	4.7 - 6.4
Hammitt & Zhou (2006)	China	1999	15	H	12	12	12				12	0.02 - 0.3
Hojman, Ortúzar & Rizzi (2005)	Chile	2003	n.a.	T	6							0.3 - 0.6
Hultkrantz, Lindberg & Andersson (2006)	Sweden	2004	n.a.	T	2							2.2 - 5.8
Iragüen & Ortúzar (2004)	Chile	2002	n.a.	T	4							0.3 - 0.6
Itaoka *et al.* (2007)	Japan	1999	1 - 5	H	30	19	3	16		19	19	0.5 - 4.1
Johannesson, Johansson & Löfgren (1997)	Sweden	1996	2	H	14	14	14				14	2.8 - 5.5
Johannesson, Johanss'n & O'Conor (1996)	Sweden	1995	0.4	T	4	4		4			4	2.0 - 7.0
Jones-Lee, Hammerton & Philips (1985)	UK	1982	0.3 - 0.7	T	18	10		10	10		4	0.7 - 75.4
Kidholm (1995)	Denmark	1994	0.2 - 0.3	T	6	6		6			6	9.0 - 17.5
Krupnick *et al.* (2002)	Canada	1999	1 - 5	H	10	8		8	8	8	8	1.1 - 3.6
Krupnick *et al.* (2006)	China	2005	5 - 10	H	112	110	1	109	16	110	110	0.1 - 1.7
Krupnick *et al.* (2008)	Canada	2004	n.a.	E	20							7.7 - 22.6
Lanoie, Pedro & Latour (1995)	Canada	1986	4	T	1							2.1
Leiter (2010)	Austria	2005	n.a.	E	6							2.4 - 3.4
Leiter & Pruckner (2008)	Austria	2005	0.2 - 7	E	4	4		4			4	2.1 - 2.8
Leiter & Pruckner (2009)	Austria	2005	0.2	E	32	32		32			24	2.0 - 6.0
Mahmud (2006)	Bangladesh	2003	40 - 90	H	4	4		4			4	0.03 - 0.04
Maier, Gerking & Weiss (1989)	Austria	1988	0.3 – 0.7	T	6							2.1 - 40.9
McDaniels, Kamlet & Fischer (1992)	United States	1986	0.5	T	2							11.0 - 11.1
Miller & Guria (1991)	New Zealand	1990	3	T	20	3	3					0.7 - 2.4
Muller & Reutzel (1984)	United States	1980	0.3	T	1							16.1
New Ext (2004)	Italy & UK	2002	1 - 5	H	14	8		8		8		0.7 - 8.5
O'Conor & Blomquist (1997)	United States	1995	0.1 - 0.4	H	5							10.7 - 15.5
Ortiz, Markandya & Hunt (2009)	Brazil	2003	1 - 5	H	32							2.8 - 35.7

Table 3.A3.1. **Study characteristics, references and number of estimates included for different meta-regressions in Chapter 3** *(continued)*

Study	Country	Survey Year	Risk change valued – Unscreened data (1×10^{-4})[b]	Risk[c] context	Un-screened data	First-level screening data	Scope sensitive studies: No scope data	Scope sensitive studies: Internal or external scope	Scope sensitive studies: Internal and external scope	Similar survey	Author recom.	VSL range – Unscreened data (Mill. USD 2005)[b]
Perreira & Sloan (2004)	United States	1998	0.2	T	8							13.5 - 21.8
Persson *et al.*(2001)	Sweden	1998	0.2 – 0.5	T	7	7		7			7	1.6 - 4.3
Rheinberger (2009)	Switzerland	2007	0.07	T	2	2		2	2		2	4.2 - 4.5
Rizzi & Ortúzar (2003)	Chile	2000	n.a.	T	6							0.6 - 2.1
Robertson (1977)	United States	1976	0.3 - 0.8	T	3							5.0 - 9.5
Ščašný & Skopckova (2009)	Czech Republic	2008	n.a.	H	4							01. - 0.4
Schwab Christe & Soguel (1995)	Switzerland	1994	0.75	T	1							13.3
Smith & Desvousges (1987)	United States	1985	10 - 160	E	48							0.09 - 11.2
Strand (2005)	Norway	1995	n.a.	E, H, T	12							4.1 – 10.5
Svensson (2009)	Sweden	2006	0.2	T	14	14	14				14	3.0 - 10.3
Tonin, Turvani & Alberini (2009)	Italy	2007	n.a.	E	4							2.6 - 5.4
Tsuge, Kishimoto & Takeuchi (2005)	Japan	2002	1	H	1	1		1			1	2.7
Vassanadumrondgee & Matsuoka (2005)	Thailand	2003	0.3 - 6	E, T	4	4		4	4		4	1.3 - 1.8
Viscusi, Magat & Huber (1991)	United States	1989	n.a.	T	1							12.9
Weseman, de Blaeij & Rietveld (2005)	Netherlands	2001	n.a.	T	29							1.5 - 6.4
Williams & Hammitt (2000)	United States	1998	0.6 - 5	E	6							9.6 - 137.8
Zhang *et al.* (2006)	Canada	2004	n.a.	E	8							6.5 - 18.9
Zhu (2004)	Norway	1995	n.a.	E, H, T	6							0.7 - 12.2
Total number of estimates					856	405	108	297	79	155-169	350	
Mean (st. error) VSL (million US 2005)[d]					7.41 (.88)	3.12 (.25)	3.27 (.48)	2.91 (.26)	2.16 (.28)	1.49[e] (.12)	2.97 (.25)	

Notes: a. Includes new estimates provided by the authors.

b. Range of risk change valued and VSL range only shown for the unscreened data, as this range may vary depending on which estimates are screened out for different subsets.

c. H = health (unspecified cause), E = Environment-related, T = Traffic-related.

d. Weighted so that each survey counts equally, rather than each estimate.

e. Mean for the subset of 169 observations. For the subset of 150 observations mean (st.error) is 1.45 (.14).

Chapter 4

Using meta-analysis for benefit transfer: Issues and examples

There are many ways to conduct benefit transfer (BT), where a VSL estimate is transferred from the available literature to a policy context in need of a VSL estimate. One such method utilises meta-regression analysis to estimate how different policy-relevant factors affect VSL, in order to improve accuracy in BT. This chapter discusses issues to consider when using meta-analysis in BT and goes through a comprehensive example where the accuracy of simple and more advanced BT methods are compared. The example shows that the use of meta-analysis for BT may achieve accuracy gains over other methods in some situations.

4.1. Introduction

The previous chapter discussed several ways to screen the dataset and run meta-regression models on subsets of the data. The next question is how to choose from these models for predicting values that could be used for policy purposes. By "predicting" it is meant first running the regressions which estimate the coefficients determining the influence of each variable (as done in Chapter 3) and then inserting variable values corresponding to a policy situation of interest (*e.g.* a public programme giving a risk change of 1/10 000 for a country with certain GDP per capita) and adding up the individual effects of each variable to an overall VSL estimate. In a particular benefit transfer (BT) situation, the values for methodological variables will have to be chosen based on some "best practice" consideration or set equal to the mean of the variable in the dataset, or similar.

This procedure of using the estimated meta-function to predict or estimate a value for policy purposes is sometimes called meta-analytical benefit transfer (MA-BT). It is one of several methods that can be used for BT, as discussed in Chapter 5. Here the aim is to discuss and demonstrate how meta-analysis can be used for BT. Since accuracy of such transfers is also an important concern, this chapter also goes through a comprehensive example where several different BT techniques are used (also ones discussed in Chapter 5) to transfer values and investigate transfer accuracy.

The more explanatory power (the higher R-squared) the meta-models have, the more accurate they generally are in predicting values. The more significant variables influence VSL, the higher generally is the R-squared and the explanatory power of the model. The next section therefore assesses this accuracy for a selection of meta-regression models presented in Chapter 3. The models here are not used directly to derive specific VSL estimates for policy. That is discussed in later chapters.

There is generally no one single, most appropriate or correct meta-model for policy use. There is no such agreement in the literature or among practitioners. As has been shown in Chapter 3, the results vary between model specifications and subsets of the data. And even if some results are fairly robust, coefficient values will not be identical. These differences in coefficients may have fairly large impacts on the estimated VSL in a particular context. However, based on the analysis in Chapter 3, more confidence can be had in the models where estimates have been screened out than in the models run on the full, unscreened dataset.

The final section of this chapter illustrates the use of MA-BT compared to other BT techniques (such as choosing a value from a similar study, making simple adjustment based on GDP differences, taking a raw average from studies in the same country or the whole sample, etc.).

4.2. Accuracy of benefit transfer: Out-of-sample transfers

This section compares the accuracy of the different meta-regression models. A measure frequently used to assess the accuracy of benefit transfers is transfer error (TE), defined as:

$$TE = \frac{|VSL_T - VSL_B|}{VSL_B} * 100\%,$$

where T = Transferred (predicted) value from study site(s), B = Estimated true value ("benchmark") at policy site.

TE is a measure of how many percent the estimated and transferred value "missed" the true value for a particular policy context, assuming that one could know what this "true" value is. When a VSL estimate is needed for assessing value of mortality risk changes from a certain policy proposal, the true VSL value is of course not known in practice. Studies testing transfer errors often use a "benchmark" value for this true value, often the VSL estimate from a good study, and then test how different BT techniques perform when predicting this value.

Validity has traditionally required "that the values, or the value functions generated from the study site be statistically identical to those estimated at the policy site" (Navrud and Ready, 2007), *i.e.* that TE is statistically indistinguishable from zero. More recently, BT validity assessment has shifted focus somewhat to the concept of reliability for policy use, which requires that TE is relatively small, but not necessarily zero. This shift comes from the realisation that BT can be considered valid even if the standard hypothesis of TE=0 is rejected – in fact, the most appropriate null hypothesis is that TE is larger than zero since environmental and other benefits from theory should be assumed to vary between contexts for many reasons (Kristofersson and Navrud, 2005). However, there is no agreement on maximum TE levels for BT to be reliable for different policy applications, though 20 and 40% have been suggested (Kristofersson and Navrud, 2007). This issue is discussed more in the context of general BT guidelines in Chapter 5.

To utilise the measure of TE to assess BT accuracy of meta-regression models, a data splitting technique, or BT simulation, is used. N different MA-BT functions were estimated using N-1 of the data for each run, since the VSL estimate predicted is taken out. The one VSL estimate taken out for each run represents the "true" value, *i.e.* the benchmark used to assess how close the MA models can predict. Then the overall mean and median TE for all the N models taken together, sometimes termed the mean and median Absolute Percentage Error, is calculated (Brander *et al.*, 2006).

In the following, this procedure is carried out for a selection of the estimated meta-regression functions from Chapter 3.5. Simple and comprehensive versions of the meta-regressions are used for the BT tests for the full sample and for the first-level screened sample, and the comprehensive version of the author recommended sample, respectively. One of the models is also used for which the data is derived from studies applying the same good practice questionnaire initially developed by Krupnick, Alberini, Cropper and others (see *e.g.* Krupnick *et al.,* 2002). Specific reference to the models from Chapter 3 is made for each BT simulation below, for readers who are interested in the regression details. The point here, however, is not so much the results as such, but the use of the estimated meta-regression functions for BT, and to investigate how different screening criteria and model types affect MA-BT accuracy.

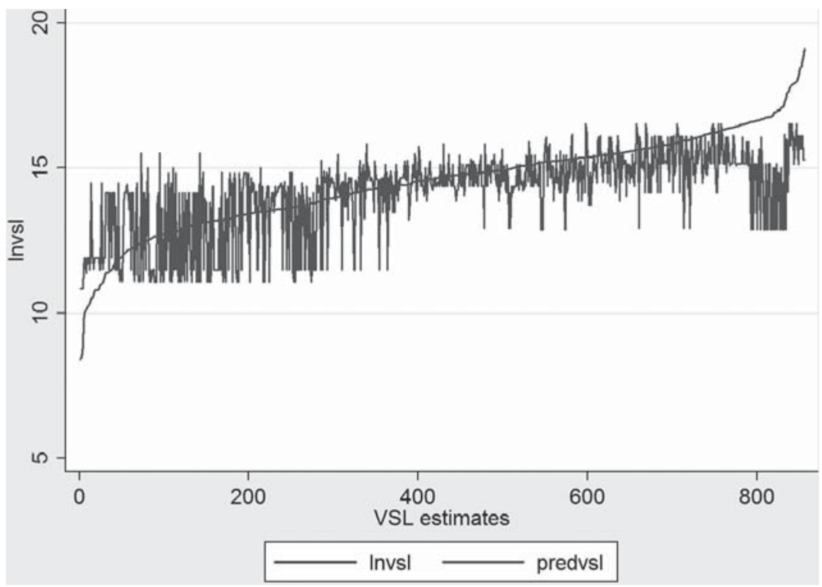
Results are also displayed graphically, *i.e.* the predicted values (zigzag line in the figures) and the VSL estimates that are predicted (rising graph in the figures) are compared in ascending order from the lowest to the highest VSL estimates in the dataset. The difference represents the absolute transfer error (ATE) for each VSL value.

Full dataset – no screening, Models I and V

Figure 4.1 shows the results for Model V from the unscreened sample from Table 3.3 in Section 3.5. This model includes all the explanatory variables. Mean and median TE are 134% and 68%, respectively. That means that on average the values transferred miss the "true" benchmark value, the value to be predicted, by 134%. That result is quite high and as expected with a full model of the unscreened sample. As can be seen from the figure, the predictions particularly miss at the high and the low ends of the values, *i.e.* the further out in the tales of the distribution. This is as expected.

Simpler models including fewer explanatory variables would be expected to have even higher TE. The mean TE for Model I of the unscreened sample, for example, where GDP/Capita and Turnbull are the only explanatory variables included, is 260% (diagram not displayed). The mean TE was also estimated for a trimmed full Model V where the 2.5% highest and lowest VSL values were taken out. This version of the model reduced the TE somewhat to 107%.

Figure 4.1. **LnVSL and predicted lnVSL from Model V of the unscreened sample**



First-level screening – simple Model I

Two accuracy simulations were conducted for Models I and V of the sample that underwent first-level screening, see Table 3.4 in Section 3.5). The overall mean TE for Model I (only variables risk change, Turnbull and GDP per capita included) was found to be 104% and the median 57%. The trimmed version reduced mean TE to 75% (diagram not displayed). Hence, screening reduces the TE somewhat compared to the full sample. However, the TE level is still quite high.

First-level screening – Full Model V

Figure 4.3 shows the second BT accuracy simulation for the full Model V on the sample that was screened. Overall mean TE was found to be 96% and the median 57%. Accuracy increases as expected when the explanatory power increases and when more explanatory variables are included. A TE of 96% is still fairly high and in the upper range compared to other such tests in the literature (see *e.g.* Lindhjem and Navrud, 2008).

Figure 4.2. **LnVSL and predicted lnVSL from Model I of the first-level screened sample**

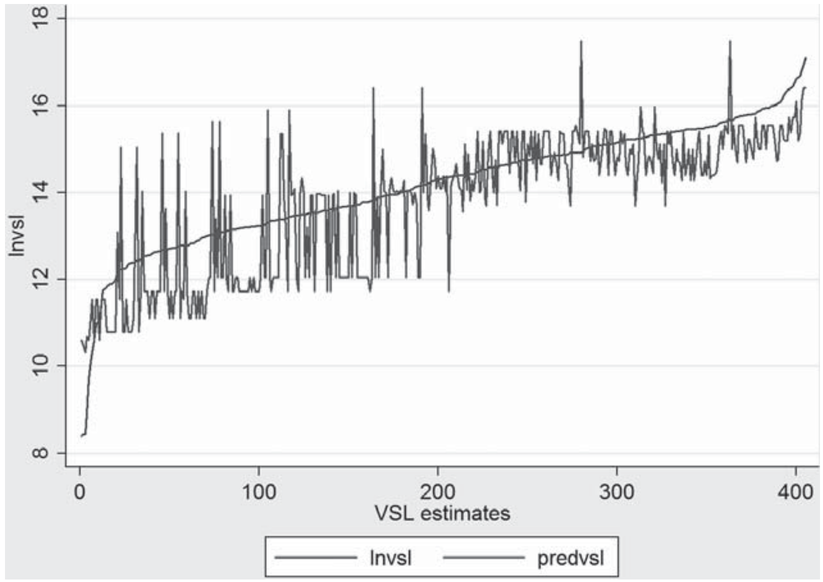
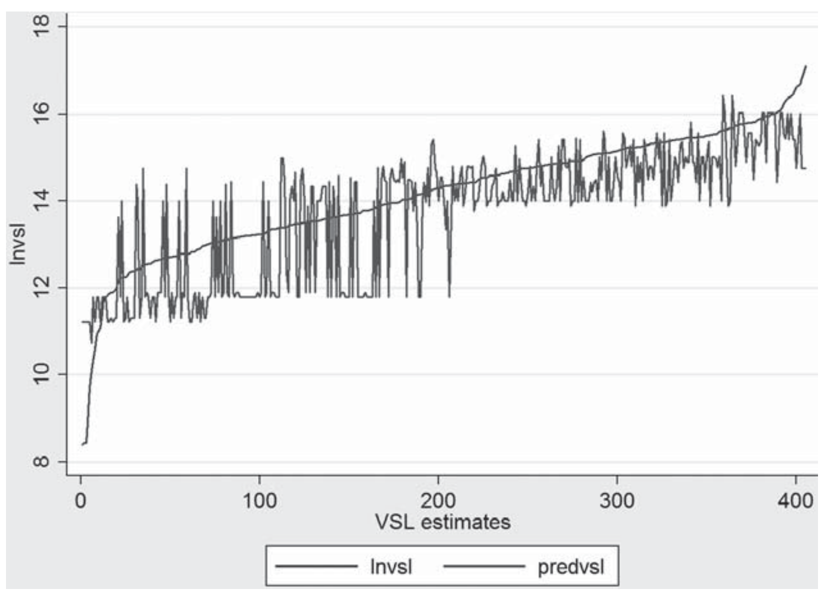


Figure 4.3. **LnVSL and predicted lnVSL from Model IV of the first-level screened sample**



First-level screening – Full Model V, trimmed

When trimming the same model displayed in Figure 4.3 (*i.e.* removing the highest and lowest 2.5% of the VSL estimates), TE is reduced to 46% (median 38%) (See Figure 4.4). An unweighted version of this model was also tried: mean TE remained the same, at 46% (median reduced to 31%).

Figure 4.4. **LnVSL and predicted lnVSL from a trimmed Model V of the first-level screened sample**

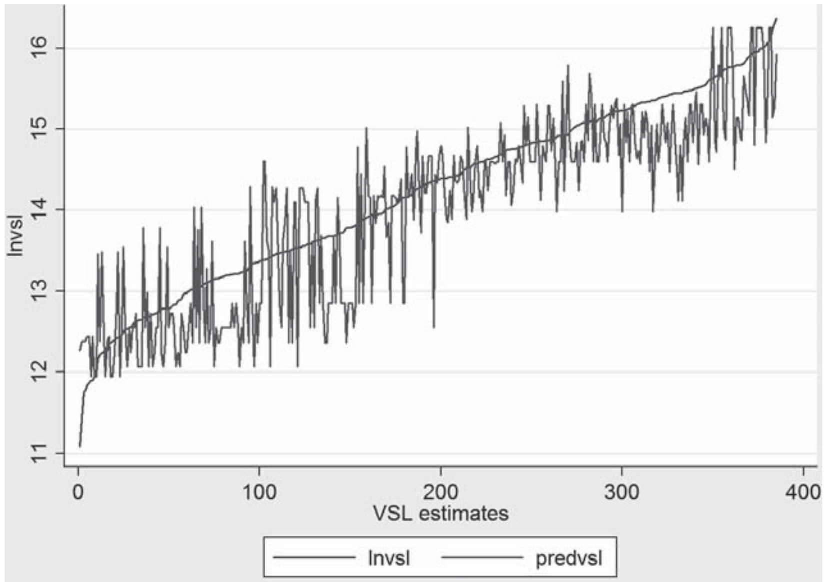
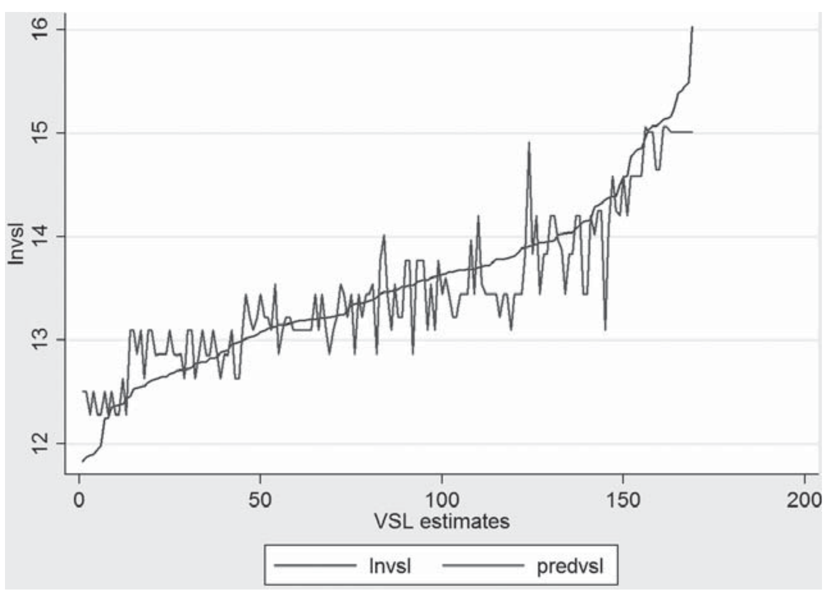


Figure 4.5. **LnVSL and predicted lnVSL from Model I of the "good-practice" questionnaire sample**



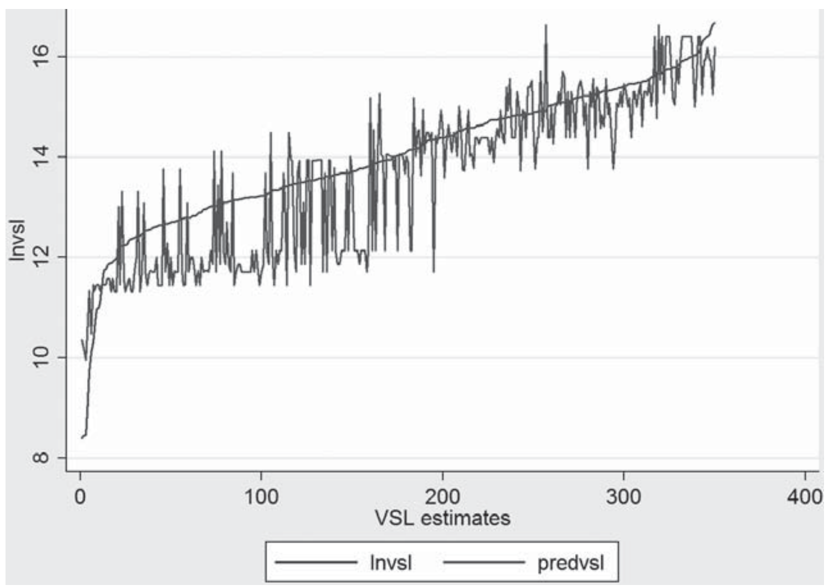
Estimates from surveys using same "good-practice" questionnaire – Model I

The same test was done for the studies that use a similar good practice questionnaire, *i.e.* Model I in Table 3.6 in Section 3.5, which has five explanatory variables (excluding the constant). In this case, much variation and heterogeneity has been eliminated by focusing on studies that are methodologically similar. One would therefore expect the model to predict out-of-sample estimates with higher accuracy than the previous models. This is also what is observed: overall mean TE is 26% and median TE 22%. The trimmed version of this experiment yields a mean TE of 25% (median 22%). That is high accuracy, approaching the low level suggested above by Kristofersson and Navrud (2007) of 20%.

Estimates recommended by authors – Model V

Finally, the same procedure was carried out for the full model for the sample where authors recommended values to be excluded, *i.e.* Model V from Table 3.7 in Section 3.5. Note that many of the estimates authors advised to exclude were eliminated by the other screening criteria used for previous models. It is not clear what to expect in this case. Results show that mean TE is lower compared to the first-level screened sample, at 65%, while the median is 51%. Trimming this model reduces the mean and median to 60 and 38%, respectively, approaching the high end of the accuracy interval discussed above (diagram not displayed here).

Figure 4.6. **LnVSL and predicted lnVSL from Model V of the author recommended sample**



Summary points

An accuracy test was carried out for the four main types of screening criteria applied to the data. Removing VSL estimates one by one and estimating MA models on the remaining data to predict the out-of-sample estimate (representing the "true" benchmark value for a hypothetical policy context), yielded the following main results:

- The unscreened dataset, with meta-regression models with the highest heterogeneity and lowest explained variation, yielded the highest overall mean absolute transfer error of around 130%.
- The mean absolute transfer error dropped to 96% for the most comprehensive model when the first-level screening criteria are applied.
- Choosing the most methodologically similar studies, where values have been derived based on the same "good practice" questionnaire, yielded an overall mean absolute transfer error at a very low level of 20%.
- Following author recommendations of excluding observations seems to reduce the transfer error. The mean TE is 65%.

- The more complete models (larger number of variables included) yielded lower transfer errors than the simple models (only 1-2 key variables included).
- Trimming high and low values reduced transfer errors.
- Weighing estimates down if there are many included from one survey, does not seem to influence transfer errors much in the case where this was tried.

4.3. Comparison of BT techniques: Which one to choose?

To more closely resemble an actual BT situation, a single VSL estimate is drawn randomly from one study to represent a benchmark, unknown VSL value for a policy or programme under assessment. This is assumed to be the "true" value for this context. The next step is to use the other studies to transfer a best VSL estimate to that policy context, based on simple and more sophisticated BT techniques. Transfer errors from the simple BT techniques are compared with the use of five MA-BT models, based on those estimated in Chapter 3. The choice of the latter is partly based on the accuracy assessment in the previous section.

This is a simple comparison based on one example of a BT situation. A comprehensive assessment for all VSL estimates in the dataset was not conducted, as for example done by Lindhjem and Navrud (2008) and Johnston and Thomassin (2010). Even so, this example illustrates that the choice of BT method is not an easy one. Even if one chooses to go for a MA-BT approach, the choice of screening procedure (and other methodological choices) will influence the results. Further discussion of how to conduct BT is given in Chapter 5.

Table 4.2 gives an overview and explanation of different possible BT choices an analyst has when in need of a suitable VSL estimate to assess a particular mortality risk reduction policy. The first six BT techniques (N1-N6) are based on naïve transfers of mean VSL estimates that are adjusted or chosen in a certain way (unit transfers). The next five BT techniques (MA1-MA5) utilise the meta-regression models estimated in Lindhjem *et al.* (2010) (reproduced in Table 4.1 above) and initially tested in section 4.2, to estimate and transfer VSL estimates. Note that all estimates used here have been adjusted for inflation to the same year and currency: USD 2005.

Below is presented a short description of how each of the BT methods is used to derive a VSL estimate. At the end, the estimated values derived from each BT approach and the overall accuracy is summarized. But first a particular benchmark value to represent the true value in a particular policy context is chosen which will serve as the example through this exercise.

Choice of "benchmark value" for comparison of accuracy

It was decided to choose a study from Japan as the source for a benchmark value to be approximated through BT techniques (Itaoka *et al.*, 2007). The study used the "good practice" questionnaire developed by Krunpick and colleagues, and should represent a good-quality estimate of VSL. The study reports several estimates and a VSL value of *USD 2 795 978* was here chosen randomly**.**

The study valued a 1 in 10 000 risk change related to health (rather than environment or traffic); the risk change was assumed to be immediate (not latent), chronic and private (affects the respondent and his household only) and was explained to respondents using a 1000 square grid. Further, the survey was conducted in 1999, using self-administration on a PC asking a dichotomous choice WTP question. In the following we take out the 31 estimates from Japan (30 of which are from the study from which we choose our benchmark value) to simulate a real BT situation.

N1 – Take VSL estimate from most similar studies

A commonly used BT strategy is to search for a domestic study, which has valued a similar risk change and then pick one or take the mean of the most suitable or similar VSL estimates reported from that study. If a suitable national study does not exist (as is the case for our example for Japan), an option is to choose a similar international study. It is not straight-forward to decide which "similarity criteria" should be applied (and in which order), as the analyst may typically not find one, unique study that match all the risk and population characteristics that define the policy context of interest.

Table 4.1. **Common BT methods tested**

#	BT method for VSL	Description/Model used
N1	Naïve unit BT: mean of most similar international studies [a]	Pick VSL estimate from most similar study
N2	Naïve unit BT: mean of unscreened international studies	Adjusted by currency, not GDP.
N3	Naïve unit BT: mean of international studies, simple screening and GDP-adjustment	Same screening as for MA2 below. Adjusted by currency and GDP. Income elasticity set to unity.
N4	Naïve unit BT: mean of international studies with same risk change, simple screening and GDP-adjustment	Same screening as for MA2 below. Only for the studies with the same risk change. Adjusted by currency and GDP. Income elasticity set to unity.
N5	Naïve unit BT: mean of similar "best practice" studies	Same screening as for MA3 below. Adjusted by currency, not GDP.
N6	Naïve unit BT: mean of similar "good practice" studies adjusted with GDP	Same screening as for MA3 below. Adjusted by currency and GDP. Income elasticity set to unity.
MA1	Meta-analytic BT: unscreened	Model V, Table 3.3
MA2	Meta-analytic BT: simple screening	Model V, Table 3.4
MA3	Meta-analytic BT: similar "good practice" studies	Model V, Table 3.6
MA4	Meta-analytic BT: author recommendation	Model I, Table 3.7
MA5	Meta-analytic BT: simplified trimmed model	Trimmed version of Model I, Table 3.3.[b] (Only risk change and GDP included)

Notes: a. Very few countries have enough studies domestically. Therefore the search is done for international studies.

b. The same model as is displayed in Annex 2 of Lindhjem *et al.* (2010).

One would perhaps think that the risk reduction should be the same. This reduces the number of potential VSL estimates from the full dataset of 825 (when all the Japanese estimates have been removed) to 84 eligible estimates. Further, if we think that the type of risk should be the same ("health"), this leaves 74 potential estimates. Of these, 69 estimates are for chronic risk changes. Further, of these estimates, 66 describe a private risk change which is immediate (not latent). Adding the remaining variables from Table 3.2 in Chapter 3 (the main explanatory variables), that the risk change affects the individual (rather than the household) and is not related to cancer, leaves finally 58 candidate VSL estimates. This search process can go on until a sufficiently similar study is found. However, it would be difficult to decide which variables should be used to judge similarity, in which order and when to stop the screening process.

The weighted mean VSL of the final 58 estimates is *USD 5 394 902*. Weighting ensures (as explained in Chapter 3) that each study counts equally, rather than each estimate. The calculated VSL estimate using this BT procedure is around double that of the benchmark value above.

N2 – Take mean of full VSL sample

A simpler method than picking a single study or do a detailed matching of variable characteristics with the policy context to arrive at a shortlist of similar VSL estimates would be instead to take a raw mean of VSL estimates of all collected studies. A weighted mean VSL (where more estimates from the same survey is weighted down) for this procedure is *USD 7 567 595*.

N3 – Take mean of screened VSL sample, adjust by GDP difference

Screening estimates according to the procedure discussed in Chapter 3 reduces the number of estimates. For our example, and as shown in Table 3.4, the number of estimates is reduced from 856 to 405. The weighted mean VSL from this sample is USD 3 192 369. AIC-adjusted GDP per capita for Japan for this year was USD 20 438 while the weighted mean of the GDP per capita for the sample was USD 17 860. Assuming an income elasticity of VSL of 1 for simplicity (and as a rough approximation to what is found in the meta-regressions in Chapter 3), leaves a simple, income adjusted transferred VSL estimate to Japan of *USD 3 653 171.*

N4 – Take mean of screened VSL sample for same risk change, adjust by GDP difference

Doing the same exercise as for N3, but only including studies that have the same risk reduction as the Japanese study of 1/10 000, reduces the number of estimates to 35. The weighted mean of these estimates is USD 4 108 583. Since the remaining estimates actually come from countries with higher mean GDP per capita (USD 23 029), income adjustment yields a transferred VSL estimate for Japan of *USD 3 646 325*, when the income elasticity is set to unity.

N5 – Take mean VSL of "good practice" studies

Taking the mean of the estimates using the "good practice" approach to VSL valuation implied by the questionnaire developed by Krupnick, Alberini and co-authors (see *e.g.* Krupnick *et al.,* 2002), yields a VSL estimate of *USD 1 530 351*, based on 150 estimates This is a bit less than half of the benchmark value.

N6 – Take mean VSL of "good practice" studies, adjust by GDP difference

Adjusting the N5-estimate by differences in GDP between the average of the sample and Japan, yields a VSL estimate of *USD 1 645 776.*

MA1 – MA-BT, unscreened

If an overall meta-regression analysis was carried out with no concern regarding screening based on objective or subjective criteria of quality, one could take as a starting point Model V in Table 3.3. When removing the Japanese estimates, the estimated meta-regression function of this model is:

lnVSL = 2.665964 + 1.182646* lngdp + 0.2190166*envir + 0.6100854* traffic -0.4374794*public – 0.1879115*household + 1.006378* cancerrisk – 0.394941*latent +0.9939775*noexplan – 0.0299846*Turnbull

First, this equation is used to estimate and transfer a VSL value to the policy context in Japan. Since the methodological values are unknown at the policy site (in reality), common practice is to set the values of the methodological variables equal to some best practice value. In this case, it is good practice to use thorough explanation in explaining risk changes (hence "noexplan" is set to zero). Similarly, since the Turnbull approach typically yields a lower bound on VSL, this variable is also set to zero. The issue of whether variables that are not significant should be excluded (normally in BT they are not) is disregarded here.

Further, since the risk is related to health, for an individual (not a household), a private risk programme, immediate and not related to cancer, all these variables are set to zero. That leaves the following simple equation:

lnVSL = 2.665964 + 1.182646* lngdp

Inserting log of the GDP per capita for Japan of USD 20 438 and taking the antilog (inverse) of lnVSL[1] yields an estimate of VSL of USD *1 801 093*.

MA2 – MA-BT, first-level screening

Instead of using the unscreened model above, the first-level screening of observations was applied (*i.e.* Model V of Table 3.4). Inserting values for log of the risk change (1/10 000) and GDP per capita yielded an estimated VSL of *USD 3 311 838*.

MA3 – MA-BT, picking "good practice" studies

Conducting the same procedure as above, except using Model I of the good practice studies in Table 3.6, yielded an estimated VSL of USD *2 228 216*. Compared to the MA-BT models above, this model also included the variable "year" (of data collection). In the same way as for the previous MA-BT functions, all other variables except GDP, the risk change and study year, were set to zero to fit the policy context the estimate was to be transferred to.

MA4 – MA-BT, author recommendation

Finally, utilising the last screening procedure, Model V of the author-recommended sample of Table 3.7, inserting values for the risk change and GDP for Japan, yielded a VSL estimate of *USD 3 421 554*.

MA5 – MA-BT, simplified, trimmed model

A simple MA-BT option is to follow the first-level screening procedure, estimate the simplest model including only the variable risk change and GDP (which we know are important for explaining the variation in the VSL estimates). Further, to eliminate the impact of very high and low values, the sample can be trimmed. Using the trimmed version of Model I in Table 3.4[2] (where the Turnbull variable is excluded) yielded a VSL estimate of USD *2 278 488*.

Comparison of BT methods summarised

The estimated VSL values are repeated in Table 4.2 for the 11 BT methods applied here. The second column represents the benchmark value; the true value for the Japanese policy context that is approximated by the use of different BT methods. The third column is the estimated and transferred value. Comparing these two values, it can be seen from the table that the simple, naïve BT methods generally yielded higher VSL estimates and that all had higher transfer errors than the MA-BT methods, varying from 30% to 171% (column four). The highest TE came from taking the raw mean from the full, unscreened sample of VSL estimates. This result is as expected. Following a searching procedure to find the most similar subset of studies (N1) also yield fairly high TE at 93%. More elaborate transfer of mean VSL in methods N3-N6 produced transfer errors that approximate acceptable levels (around 30-45%).

Table 4.2. **Comparison of simple methods with meta-analytic BT for an example scenario**

Method	A: "Benchmark value", policy context (USD 2005)	B:Estimated/transferred value (USD 2005)	C: Transfer error (TE, %)*	Rank in terms of TE
N1	2 795 978	5 394 902	93.0	10
N2	2 795 978	7 567 595	170.7	11
N3	2 795 978	3 653 171	30.7	6
N4	2 795 978	3 646 325	30.4	5
N5	2 795 978	1 530 351	45.3	9
N6	2 795 978	1 645 776	41.1	8
MA1	2 795 978	1 801 093	35.6	7
MA2	2 795 978	3 311 838	18.5	1
MA3	2 795 978	2 228 216	20.3	3
MA4	2 795 978	3 421 554	22.4	4
MA5	2 795 978	2 278 488	18.5	2

* C = (B-A)/A*100%, cf. the definition of transfer error in Section 4.2.

The MA-BT methods had lower transfer errors than the simple BT methods (with the exception of MA1), at around 18-22%. The lowest errors came from using the good-practice data and the simple, screened and trimmed sample model (MA2 and MA5) in this example. The rank of the different BT techniques in terms of BT accuracy for the example is given in column five.

Summary points

A simple example was explained where an estimate of VSL from Japan was randomly picked to represent an unknown, true VSL value at a policy site or context. Different benefit transfer techniques were next used to derive a VSL value that could be transferred to the Japanese context. Six simple BT methods were compared with five versions of our MA models. Though no general conclusions can be drawn based on this example, the example demonstrated that:

- Transferring a raw, unadjusted mean VSL value from a full sample or a sample that has been reduced based on screening for similarity with the policy site (methods N1 and N2) produces relatively high transfer errors (92-171%).
- The transfer error for simple mean transfers can be reduced to (almost) acceptable levels (around 30%) by using the first screening procedure applied in Chapter 3.
- The five different MA models produce on average lower transfer errors (from 18-35%) than just transferring mean VSL estimates.
- The lowest errors came from using the good practice data and the simple, screened and trimmed sample model in this example
- The example, though just illustrative, demonstrates that with two highly significant variables in the MA models of risk change and GDP, the transfer process may be simplified by including only those two variables in adjustments.

Notes

1. Along with Stapler and Johnston (2009) – and to make the calculations simpler and more transparent for non-experts – no correction is made for so-called "econometric error" when converting from log, cf. Bokstael and Strand (1987). Such correction would in most cases only have a relatively small impact on the estimated VSL values, when considering the overall sensitivity of results in this example.
2. This model is given in Annex 2 of Lindhjem *et al.* (2010).

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Chapter 5

How to derive Value of a Statistical Life numbers for policy analysis

There are four requirements for establishing value of statistical life (VSL) numbers for use in cost-benefit analyses based on transfers from the existing primary SP studies: i) *A database of SP studies;* ii) *Criteria for assessment of the quality of primary SP studies,* iii) *Benefit transfer (BT) techniques, and* iv) *Benefit transfer guidelines. Here the two last requirements are described in more detail. Two main groups of BT techniques are described: unit value transfer and function transfer; which includes meta-analyses. The BT guidelines for VSL are based on an eight-step procedure which establishes a base value with a value range.*

There are four requirements for establishing value of statistical life (VSL) numbers for use in cost-benefit analyses based on transfers from the existing primary SP studies: *i)* A database of SP studies; *ii)* Criteria for assessment of the quality of primary SP studies, *iii)* Benefit transfer (BT) techniques, and iv) Benefit transfer guidelines. Here the two last requirements are described in more detail. Two main groups of BT techniques are described: unit value transfer and function transfer; which includes meta-analyses. The BT guidelines for VSL are based on an eight-step procedure which establishes a base value with a value range.

5.1. Introduction

To comply with the theory underpinning CBA, different value of statistical life (VSL) numbers for different groups within society could be advocated. However, in practice, countries in their cost-benefit analyses of *e.g.* road safety projects tend to use a single VSL that is independent of the per capita income level, or indeed other personal characteristics, of the sub-group in society to which the safety improvement will actually apply. Baker *et al.* (2008) present a theoretically justified application of a "common" VSL for any particular hazard within a given society, to be compatible with a cost-benefit analysis (CBA) decision-making approach. To be coherent across policy areas, one can also argue in favour of using a "common" VSL.

There are also *equity* arguments for using the same VSL within an individual country, and even within a group of countries, like the European Union, when performing CBAs of EU-wide policies, like *e.g.* new EU Directives (for which CBAs are routinely performed).

In this report, the *individual country* is used as the decision unit, but the guidelines presented in this chapter could also be used to establish VSL values for CBAs of EU-wide policies, international environmental problems, like *e.g.* long-range transported air pollutants (acid rain, heavy metals, environmental toxics), and even for global environmental problems, like emission of greenhouse gases and their global warming potential. Then population-weighted overall mean VSL would have to be constructed based on primary valuation studies from all the affected countries, or an equity-weighted VSL value based on generalisation/benefit transfer from one (or the mean of many) high quality studies, or a meta-analysis of many studies.

In the following section, the main steps in conducting benefit transfer is presented and discussed.

5.2. Approaches for deriving VSL numbers for policy analysis

Below is presented a step-by-step guide on how to determine a VSL estimate that can be used in a CBA of a policy or project involving changes in mortality risks in an individual country. The guide is based on existing guidelines for benefit transfer (especially Navrud, 2007) from a *study site* (where the original/primary valuation study was performed) to the *policy site*, but adapted specifically to mortality risk valuation. Since the variation in VSL will relate to risk and population characteristics other than location, it often makes sense to use the concepts study and policy "context" rather than "sites" when we talk about benefit transfer of mortality risks rather than environmental goods.

In order to perform benefit transfer for VSL we need:

1. A database of primary valuation studies (to transfer from);

2. Best practice guidelines for valuation methods/surveys; including criteria for the assessment of the quality of primary valuation studies, in order to screen studies to transfer from and/or include in a meta analysis;
3. Benefit transfer techniques (unit value transfer, and function transfer including meta analysis) and an assessment of accuracy of transfers;
4. Benefit transfer guidelines.

The first prerequisite for benefit transfer is a *database for primary valuation studies,* with enough detail to judge similarity between the primary studies and the policies benefit transfer is used to evaluate (usually in a CBA context), and enough detail to perform meta-analyses. For SP studies of VSL worldwide, the OECD has now prepared a publicly available database of primary valuation studies with the detailed information needed for all benefit transfer techniques (see Braathen *et al*., 2009 and Lindhjem *et al*., 2010, 2011). The database was reviewed in Chapter 2, and is freely available at *www.oecd.org/env/policies/vsl*.

The second prerequisite, *best practice guidelines for valuation methods*, do not exist specifically for mortality risk valuation but the Swedish Environmental Protection Agency (Söderqvist and Soutukorva, 2006) provides criteria for assessment of the quality of revealed preference (RP) and stated preference (SP) studies in general.

The third and fourth prerequisites for reliable benefit transfer, *Benefit transfer techniques* and *Benefit transfer guidelines* applied to mortality risk reductions, are described further below. The aim is that the guidelines should be practical and simple to use, and show in a transparent and step-by-step manner how one can arrive at economic values for mortality risk changes. For other practical general guides to value transfer for environmental goods in general; see the Danish EPA Guidelines (Navrud, 2007) and the U.K. Defra Guidelines (Bateman *et al*., 2009).

Benefit transfer techniques

There are two main groups of benefit transfer techniques:[1]

1. Unit Value Transfer
    - i. Simple (naïve) unit value transfer
    - ii. Unit value transfer with income adjustments
    - iii. Unit value transfer for separate age groups
2. Function Transfer
    - i. Benefit Function Transfer
    - ii. Meta analysis

Simple (naïve) unit value transfer (from one study, or as a mean value estimate from several studies) is the simplest approach to transferring benefit estimates from a study context (or as a mean from several study contexts) to the policy context. This approach assumes that the utility (or wellbeing) gained from a mortality risk reduction experienced by an average individual in the study context is the same as will be experienced by the average individual in the policy context. Thus, it is assumed that we can directly transfer the benefit estimate in terms of VSL from the study context to the policy context.[2]

For the past few decades, agencies like the European Commission's DG Environment, the US Environmental Protection Agency (US EPA), Health Canada, and Ministries of

Transportation and Treasuries/Ministries of Finance in many countries have conducted literature reviews to establish VSLs to be used in their CBAs (see *e.g.* Chestnut and De Civita, 2009, for a recent such review for the Canadian Treasury and Health Canada). The selection of the VSL value(s) are often based on estimates from one or a few valuation studies considered as being of high quality and close to the policy context, both geographically (to avoid cultural and institutional differences) and in terms of similarity of the population characteristics and mortality risk characteristics (especially what causes the mortality risk, and the magnitude and direction of mortality risk change).

The obvious problem with simple unit value transfer between countries is that the average individual in the policy context may not value mortality risk changes the same as the average individual in the study contexts. There are two principal reasons for this difference. First, people in the policy context might be different from individuals in the study contexts in terms of income, education, age, religion, ethnic group or other socio-economic characteristics that affect their mortality risk valuation. Second, even if individuals' preferences for mortality risk reductions in the policy and study contexts were the same, the mortality risk context (*e.g.* degree of suffering, dread, latency, voluntariness, etc.) and the magnitude of the risk change considered, might not be similar (and the size of the mortality risk change valued will affect the size of the VSL in SP studies).

The simple unit value transfer approach should not be used for transfer between countries with different income levels and costs of living. Therefore, *unit transfer with income adjustments* has been applied. The adjusted VSL estimate, VSL_p' at the policy site can be calculated as

$$VSL_p' = VSL_s\,(Y_p/Y_s)^{\beta} \tag{5.1}$$

where VSL_s is the original VSL estimate from the study context, Y_s and Y_p are the income levels in the study and policy context, respectively, and β is the income elasticity of VSL (in terms of WTP for reducing the mortality risk). Mortality risk reductions is a "normal" good with a positive income elasticity which meta-analyses of RP studies of labour markets indicate is in the range 0.5-0.6 (Viscusi and Aldy, 2007). However, Viscusi (2010) argues this is just for the restricted age spectrum covered in RP studies, and that it should be around 1.0 for the general public. If the income elasticity β is unity, equation (1) would be simplified to multiplying VSL at the study site by the percentage the income at the policy site constitute of the income at the study site. When we lack data on the income levels of the affected populations in the policy and study contexts, Gross Domestic Product (GDP) per capita figures can be used as proxies for income in international benefit transfers.

Using the official exchange rates to convert transferred estimates in US dollars to the national currencies does not reflect the true purchasing power of currencies, since the official exchange rates reflect political and macroeconomic risk factors. If a currency is weak on the international market (partly because it is not fully convertible), people tend to buy domestically produced goods and services that are readily available locally. This enhances the purchasing powers of such currencies on local markets. To reflect the true underlying purchasing power of international currencies, the World Bank's and OECD's International Comparison Program (ICP) has developed measures of real GDP on an internationally comparable scale. The transformation factors are called Purchasing Power Parities (PPPs).

Even if PPP-adjusted GDP figures and exchange rates can be used to adjust for differences in income and cost-of-living in different countries, it will not be able to correct for differences in individual preferences, baseline levels of risks and magnitude of risk changes, risk contexts, and cultural and institutional conditions between countries. Thus, population and risk characteristics should be as similar as possible between the study and policy sites.

The other most common adjustment of unit values for VSL is for *age*. While there is a growing empirical case for the use of a differentiated VSL for children in cost-benefit analysis, it must be recognised that the use of age-differentiated VSL (in general) in policy analysis is the exception and not the rule. Indeed, adjustments of any kind to a central value are not commonly applied, except in sensitivity analyses.

Transferring the entire *benefit function* is conceptually/theoretically more appealing than just transferring unit values, because more information is effectively taken into account in the transfer. However, the evidence for transfer of values for respiratory illnesses across countries indicate that function transfer does not perform any better (in terms of transfer error) than simple unit value transfer (Ready *et al.,* 1997). The benefit relationship to be transferred from the study context(s) to the policy context could be estimated using either revealed preference (RP) approaches like the hedonic wage (HW) method, or stated preferences (SP) approaches, like the contingent valuation (CV) method. For a CV study, the benefit function can be written as:

$$WTP_{ij} = b_0 + b_1 G_j + b_2 H_i + e \tag{5.2}$$

where WTP_{ij} is the willingness-to-pay of household *i* for mortality risk reduction *j*, G_j is the set of characteristics of the mortality risk reduction (including the size of the mortality risk reduction), and H_i is the set of characteristics of household *i*, and b_0, b_1 and b_2 are sets of parameters and e is the random error.

To implement this approach, the analyst would have to find a study in the existing literature with estimates of the constant b_0 and the sets of parameters, b_1 and b_2. Then the analyst would have to collect data on the two groups of independent variables, G and H, at the policy site, insert them in equation (5.2), and calculate households' WTP at the policy context, and calculate VSL by dividing the WTP by the mortality risk reduction.

The main problem with the benefit function approach is due to the exclusion of relevant variables in the WTP (or bid) function estimated in a single study. When the estimation is based on observations from a single study of one or a small number of mortality risk changes or a particular mortality risk context, a lack of variation in some of the independent variables usually prohibits inclusion of these variables.

Thus, instead of transferring the benefit function from one selected valuation study, results from several mortality risk valuation studies can be combined in a *meta-analysis* (MA) to estimate one common benefit function. MA has been used to synthesise research findings and improve the quality of literature reviews of valuation studies in order to come up with VSL unit values, cf. Chapters 3 and 4. In a meta-analysis, several original studies are analysed as a group, where the result from each survey is treated as a single observation in a regression analysis. If multiple results from each survey are used, various meta-regression specifications can be used to account for such "panel effects".

The MA makes it possible to evaluate the influence of a wider range in characteristics of the mortality risk change, the features of the samples used in each analysis (including characteristics of the population affected, like age and income), and the modelling assumptions. In practice, however, detailed characteristics of the mortality risk change and the population are often not reported in the primary studies (especially not if they are published journal papers, which often focus on methodological tests of valuation methods rather than on reporting monetary estimates and the data needed in a meta-regression analysis), and it requires a large effort to find them (if at all possible). The resulting regression equations explaining variations in VSL can then be used together with data collected on the independent variables in the model that describes the policy context to construct an adjusted unit value. The regression from a MA would look similar to equation (5.2), but a set of variables reflecting differences in the valuation method applied need to be added; *i.e.* C_s = characteristics of the methodology applied in study *s*; as meta-analyses typically find that differences in valuation methodologies account for a significant part of the variation in mean willingness-to-pay across studies *s;* WTP_s. (Sometimes, and in the present meta-analyses, these variables are regressed on the estimated VSL rather than WTP, in order to get adjusted VSL estimates directly from the meta-analysis).

Meta-analysis (MA) of RP studies only (*i.e.* HW/wage risk studies) have been performed by *e.g.* Mrozek and Taylor (2002) and Viscusi and Aldy (2003), of both RP and SP studies (Kochi *et al.*, 2006), and recently of only SP studies (cf. Chapter 3, Braathen *et al.*, 2009; Biausque, 2010; Lindhjem *et al.* 2010, 2011). Conducting meta-analyses of only RP, or only SP, studies usually increases the explanatory power of the analysis, as the heterogeneity (variation) in methodology is less. Thus, limiting the methodological scope of the meta-analysis usually provides more reliable estimates from the studies analysed.

As HW studies of wage differentials between jobs with different mortality risk levels may not be appropriate to assess the value of very different mortality risks from transportation, environmental and health policies which affect the general population, the MA reported here is based solely on the growing stock of SP studies on adult mortality risks. Thus, the scope of the analysis is limited, compared to previous MAs of VSL which usually included either just RP or both RP and SP studies (*e.g.* Viscusi and Aldy, 2003; Mrozek and Taylor, 2002; Kochi *et al.*, 2006). This limitation was imposed in order to gain a lower degree of heterogeneity (variation) in the VSL estimates and to be able to account for and explain these differences. Doing separate meta-analyses for RP and SP studies was also a clear recommendation of an US EPA expert group which reviewed the use of MA to synthesise VSL estimates (US EPA, 2006).

Guidelines for benefit transfer

There are few detailed guidelines on benefit transfer. In the United States, there are guides that cover the key aspects of conducting benefit transfer, notably Desvouges *et al.* (1998), aimed at transfer for valuing environmental and health impacts of air pollution from electricity production, US EPA (2003) on benefit transfer for valuing children’s health, and recently Bateman *et al.* (2009b), providing guidelines for value transfer of environmental goods in general in a CBA context. Adapted to the economic valuation of mortality risks for CBA and other policy uses, the following eight-step guidelines are proposed:

1. Identify and describe the change in mortality risk to be valued in the policy context
2. Identify the affected population in the policy context (size and socioeconomic characteristics)
3. Conduct a literature review to identify relevant primary studies (preferably based on a database; but supplemented by journal and general web search)
4. Assessing the relevance/similarity and quality of study context values for transfer
5. Select and summarize the data available from the study context(s)
6. Transfer value estimate from study context(s) to policy context

7. Calculating total benefits or costs
8. Assessment of uncertainty and transfer error/Sensitivity analysis

Step 1: Identify the change in mortality risk to be valued in policy context

There is evidence (Chapter 3, Braathen *et al.,* 2009) that people could be willing to pay less for certain types of mortality risks than others, *e.g.* if there is a time lag between when they are exposed and experience the risk change, when they (feel they) have more control over the risk themselves, and when the risk change occurs in older age. Also, the estimated VSL seem to be lower when they are exposed to higher risks prior to the change (*i.e.* higher baseline risks), lower when people value larger risk changes, and lower if they are asked to pay for a reduction in risk rather than pay to avoid an increased mortality risk (due to loss aversion). Therefore, in this first step it is important to identify the characteristics, magnitude and direction of the risk change (see also Chapter 5 for a more detailed discussion):

1. Identify the type of mortality risk
    i. latency (*i.e.* time between exposure/measure to reduce exposure and impact)
    ii. dread (especially related to cancer)
    iii. degree of control
    iv. age group affected (Children vs. adults vs. elderly)
    v. other risk and population characteristics
2. Describe (expected) change in mortality risk
    i. baseline level (from which the changes takes place)
    ii. magnitude and direction of change (*i.e.* gain vs. loss)

Step 2: Identify the affected population in the policy context

Desvousges *et al.* (1998) used this as the last step in their benefit transfer guide. However, it is important to identify the size of the affected population in the policy context before reviewing the valuation literature and evaluating the relevance of selected studies. The transferred value should come from the same type of affected individuals. Population characteristics also need to be similar, in order to ensure they share the same type and level of welfare determinants.

For mortality risks, the number of individuals should be the unit of aggregation at the relevant geographical scale (*i.e.* community, regional/county, national, EU, international or global level).

Step 3: Conduct a literature search to identify relevant primary studies

The next step is to conduct a literature search to identify relevant primary studies; preferably based on a database, but supplemented by journal and general web search. General databases like EVRI *www.evri.ca*, can be used, but specialised databases, like the OECD database of SP studies of VSL worldwide (see *www.oecd.org/env/policies/vsl*) is preferred in order to identify *similar* studies from the same country or other closely located countries (*i.e.* which share the same type of institutional and cultural context). This recommendation is based on value transfer validity tests showing that spatially closer studies tend to have lower transfer errors. Studies closest in time should be selected for the same reason. The current practice of using the Consumer Price Index (of the country of the policy context considered) is at best a crude approximation of how people's preferences and values for mortality risk reductions change over time (as this good in not included in the basket of goods on which the CPI is calculated). While there are several studies testing transferability in space, only a few studies tests transferability over time

Journal articles and databases of valuation studies often do not have all the data needed for the relevance of the study context to be evaluated, and the full study report should be collected. Thus, existing databases for primary valuation studies can often only be used for screening potential candidate studies for transfer. Then, authors of the identified candidate primary studies can be contacted in order to collect all information needed to judge the "similarity" of the mortality risk and population characteristics of these study contexts versus the policy context.

Meta-analyses could also be consulted, bearing in mind the limitations for value transfer of meta-analyses with a broad scope (*i.e.* too large variation in methods included). However, when there is a sufficient number of studies using the same type of valuation methodology with very detailed information about most studies and high explanatory power (as in the case of the MA reported here) MA can be a potentially very powerful tool for benefit transfer, and even preferable to unit value transfer techniques.

Step 4: Assessing the relevance/similarity and quality of study context values for transfer

Here, the quality of the relevant valuation studies is assessed in terms of scientific soundness and richness of information. Desvousges *et al.* (1998) identified the following criteria for assessing the quality and relevance of candidate studies for transfer:

- *Scientific soundness* – The transfer estimates are only as good as the methodology and assumptions employed in the original/primary studies
  - Sound data collection procedures (for Stated Preference surveys, this means either personal interviews, or mail/internet surveys with high response rate (>50%), and questionnaires based on results from focus groups and pre-tests to test wording and scenarios)
  - Sound empirical methodology (*i.e.* large sample size; adhere to "best practice"-guidelines guidelines for SP and RP studies; *e.g.* Bateman *et al.* (2002) for a manual in Stated Preference studies, and Söderqvist and Soutukorva (2006) for a guideline in assessing the quality of both RP and SP primary valuation studies).
  - Consistency with scientific or economic theory (*e.g.* links exists between end-points of dose-response functions and the unit used for valuation, statistical techniques employed should be sound; and CV, Choice Experiments (CE) and HW functions should include variables predicted from economic theory to influence valuation).
- *Relevance* – the original studies should be similar and applicable to the "new" context
  - Magnitude (and direction) of mortality risk change.
  - Baseline level of mortality risk.
  - Risk characteristics should be similar (latency, dread, degree of control etc).
  - Duration and timing of the impact should be similar.

- Socio-economic characteristics (including age and income) of the affected population should be similar.
- Cultural, religious and institutional setting should be similar.

- *Richness in detail* – the original studies should provide a detailed dataset and accompanying information
  - Identify full specification of the primary valuation equations, including precise definitions and units of measurements of all variables, as well as their mean values.
  - Provision of standard errors and other statistical measures of dispersion.

All three criteria and their components are equally important for assessing the relevance and quality of the study. Based on these three criteria, *a check list for judging the similarity* of characteristics of the mortality risk change and population at the study sites versus policy site for mortality risk valuation studies has been developed:

- Characteristics of the good
  - Similar *baseline, size* and *direction* of mortality risk change? (To avoid scaling-up and -down values according to the size and direction of the mortality risk valuation, as it can depend on these factors).
  - Similar mortality risk characteristics? (Dread, cancer, latency, level of control, and environmentally related, transport-related or health-related)
- Population characteristics
  - Similar average *income* level (and income distribution)? (If not, income adjustments should be made when performing the value transfer.)
  - Similar *gender, age and educational* composition of the affected population?
  - Similar *size* of affected population? Is the policy analysed local, regional, national, international or global?
  - Similar preferences for mortality risk changes? Are the attitudinal, religious and cultural factors the same?
  - Domestic study? The general recommendation is to choose a domestic study, or as close as possible geographically, to avoid differences in institutional context with regards to *e.g.* public health care systems.

Step 5: Select and summarise the data available from the study context(s)

Several parallel approaches should be applied, and the results from these should be used to present a range of values.

Search the studies to provide low and high estimates, which can define a lower and upper bound (not statistically speaking) for the transferred estimate, respectively. Collect data on the mean estimate and standard error, and specific spatial transfer errors if available.

Consult relevant meta-analyses to see if the scopes of these are narrow enough to provide relevant information about the estimate to be transferred; as a check on the unit value transfer performed. The scope of the meta-analysis could be too wide to produce reliable estimates if the meta-analysis consists of studies which vary a lot in terms of methodology, and the characteristics and size of the mortality risk change considered.

Compare the magnitude of the value from the meta-analyses, when methodological parameters in the meta-function are set according to the best practice guidelines and the policy context. Methodological variables in meta-analyses that reflect best practice guidelines include survey mode (preferable in-person interviews or web and mail surveys with high response rates), studies should preferably be conducted after the NOAA Panel guidelines to CV (Arrow *et al.,* 1993) (The year of study is often used as a proxy variable for quality in some meta-analyses), as similar as possible in magnitude and direction of change, characteristics of the population; and use a realistic and fair payment vehicle (*i.e.* not voluntary contribution without a provision point mechanism, and not payment vehicles that create a large degree of protest behaviour).

Step 6: Transfer value estimate from study context(s) to policy context

a) Determine the transfer unit

The recommended unit of transfer for mortality risk changes is VSL, as there are still very few primary studies estimating Value of a Life Year (VOLY) directly. US EPA (2007) also cautions against using VOLYs, and specifically a VOLY that is independent of at what age it is gained, due to the limited evidence underlying this assumption.

b) Determine the transfer method for spatial transfer

If the policy context is considered to be very close to the study sites in all respects, *unit value transfer* can be used. If there are several equally suitable study contexts to transfer from, they should all be evaluated and the transferred values calculated to form a value range.

For unit transfers between countries, differences in currency, income and cost of living between countries can be corrected for by using Purchase Power Parity (PPP) corrected exchange rates; see *e.g. www.oecd.org/dataoecd/53/47/39653689.pdf.* Within a country, one should use the same VSL value out of equity concerns, in spite of income differences within the country. The same applies to a group of affected countries, if an EU-wide policy, international policy or global policy is the subject of a CBA.

Function transfer can be used if value functions have sufficient explanatory power[3] and contain variables for which data is readily available at the policy site. Most often the "best" model is based on variables where new surveys have to be conducted for the policy context to collect data. Then one could just as well perform a full-blown primary valuation study. If models are constructed based on variables for which there exist data for the policy context, they very often have low explanatory power.

If relevant *meta-analyses* are identified (see previous step), estimates from these should be used in a comparison of several transfer methods. Sensitivity analysis should be performed to see how much the transferred value estimate could vary. The constructed upper and lower values should be used to bound the transferred estimate.

To conclude, *unit value transfer* with income adjustment (where necessary) is recommended as the simplest and most transparent way of transfer between countries. This transfer method has in general also been found to be just as reliable as the more complex procedures of value function transfers and meta-analysis. This is mainly due to the low explanatory power of willingness-to-pay (WTP) functions of Stated Preference studies, and the fact that methodological choices, rather than the characteristics of the context and the affected populations, has a large explanatory power in many meta-analyses.[4] However, meta-analyses can be a very powerful tool when detailed data for each study is available, the included studies have little methodological variation, and the explanatory power of the meta-regression is high. This is the case with the MA presented in this report.

c) Determine the transfer method for temporal transfer

The standard approach for adjusting the value estimate from the time of data collection to current money value is to use the Consumer Price Index (CPI) for the policy context country. If values are transferred from a study site outside the policy-site country, one should first convert to local currency in the year of data collection; using PPP-corrected exchange rates in the year of data collection, and then use the national CPI to update to current currency values.

VSL could also increase more or less in value than the goods the CPI is based on, and the increase in value could be very country-specific. There is, however, very little evidence on this for VSL. When data on the relative increase in VSL over time becomes available, this temporal adjustment would of course come in addition to the spatial transfer which this eight-step benefit transfer procedure mostly concerns.

Step 7: Calculating total benefits or costs

The transferred VSL estimate should be multiplied by the expected number of avoided fatalities within the area analysed (which could be local, regional, national international or global) to estimate the social benefits of a new policy or project.

The general equation for calculating the present value of the benefits, PV (B) is:

$$PV\,(B) = \sum_{t}^{T} B_t/(1 + r)_{\mathrm{t}} \tag{5.3}$$

where B_t is the total benefits in year t, T is the time horizon (for the policy/project) and r is the social discount rate (*e.g.* r = 0.04 *i.e.* 4% p.a.). With regards to the analyses carried out by the European Commission of its own proposals (such as the *Thematic Strategy on Air Pollution*), a 4% real discount rate was used. This rate is "recommended" in the Commission's Guidelines for Impact Assessment, and applies to all Commission proposals.[5] Benefits and the discount rate are stated in real terms, *e.g.* 2010 USD, and the discount rate is a real rate of return (*i.e.* corrected for inflation, and not a nominal rate).

Annual benefits B_t equals the VSL value multiplied by the expected number of reduced (or increased) fatalities, n.

$$B_{\mathrm{t}} = n \times VSL_i \tag{5.4}$$

When aggregating damages and costs of *e.g.* mortality and morbidity cases, two main issues need to be considered: The first is whether the risk assessment (*e.g.* the dose-response or concentration-response modelling) provides a clear separation between fatal and non-fatal cases of a particular illness or health impairment. The second is whether the VSL study includes or excludes (implicitly or explicitly) morbidity prior to death. The analyst will need to carefully consider the link between the risk assessment and valuation to avoid double-counting. This is more of an issue when adding together non-fatal and fatal cases that are linked to the *same* illness (*e.g.* non-fatal and fatal cases of heart disease), and less problematic when considering *different* illnesses (*e.g.* non-fatal cases of asthma and fatal cases of heart disease).

Step 8: Assessment of uncertainty and transfer error/Sensitivity analysis

Validity tests of benefit transfer (*e.g.* Navrud, 2004) indicate that the transferred economic estimates should be presented with error bounds of ±40%. However, if the contexts are very similar, or the primary study was designed with transfer to contexts similar to the policy context in mind, an error bound of ±20% could be used. If the study and policy contexts are not quite close, unit transfer could still be used, but arguments for over- and underestimation in the transfer should be listed, and the unit value should be presented with error bounds of ±100% (based on the large variation in individual estimates observed in validity tests). Ready and Navrud (2006) summarised the experience from international validity studies on valuation of morbidity and found that these transfer errors are not different from those observed for transfers within a country. They found that the average transfer error for international benefit transfers based on unit and benefit function transfers tends to be in the range of 20% to 40%, but individual transfers have errors as high as 100-200%.

Based on the above studies and the benefit transfer error test literature specifically for health valuation, four categories of how good the fit is between the study context and the policy context can be distinguished. The level of fit is based on the check list for judging the similarity between the study and policy contexts in Step 4 of the Guidelines.

Each category has a corresponding approximate transfer error that should be used to perform sensitivity analysis when conducting unit value transfer; see Table 5.1. The transfer errors in Table 5.1 refer to the transfer error of *mean* WTP, or in this case, mean VSL, estimate. Thus, a transfer error of ±20% indicates that the VSL estimate could be 20% higher or lower than the mean VSL base estimate.

Table 5.1. **Transfer errors**

Category	Level of fit between primary study and policy context	Percentage transfer error of mean estimate in unit value transfer (%)
1	Very good fit	+ 20
2	Good fit	+ 50
3	Poor fit	+ 100
4	Very poor fit	Discard primary study for unit value transfer (Meta analysis is the only option)

It is important to note that these transfer errors should be added to the uncertainty in the primary studies due to sampling procedures, survey mode, valuation methods, etc.

The table lists four categories of how similar the primary study (study context) is to the policy context (to which one would like to transfer values to), and corresponding approximate transfer errors when performing unit value transfer. These indicative transfer errors are based on a review of transfer errors from the benefit transfer validity test literature. The judgment of similarity should be based on the check list of context and population characteristics presented in Step 4 of the Guidelines.

Whereas Table 5.1 presents transfer errors for unit value transfer, accuracy tests of transfers based on the MA reported here (see Section 4.2) show that the best models in the MA yield transfer errors comparable to category 2 and 3; and some models even report transfer errors close to category 1. This clearly shows the great potential for MA to supplement unit value transfer even in cases when there is a good or very good fit in terms of similarity between the primary study and the policy application in a unit value transfer exercise.

There is no agreement on what the maximum acceptable transfer error is for benefit transfer to be reliable for cost-benefit analyses, although levels of ±20 and 40% have been suggested (Kristofersson and Navrud, 2007). However, two decision-rules can be used as a rough test of whether benefit transfer has acceptable transfer errors for policy analysis, or whether a new primary study of VSL should be conducted.

i. When performing a CBA of a new project or policy, the estimated Present Value (PV) of benefits should be compared with the corresponding PV of costs. The effect on total annual benefits (costs) of the expected transfer error (from Table 5.1) should be evaluated in order to see if this reduces the PV of benefits (increases the costs) to a critical level; meaning that the PV of net benefits becomes negative (from positive). If this is the case, the transfer errors are large enough to change the outcome of the CBA, and a new primary study should be considered.

ii. When there is a need for national VSL estimates for policy purposes and no such primary study exist, a CBA of conducting a new primary valuation study should be performed in order to determine whether the costs of a new primary study is worth the benefits in terms of lower probability of making the wrong decision. One should also consider whether it is sufficient to increase the accuracy of the transferred estimate by conducting a small small-scale primary VSL study to better calibrate the transfer

Policy decisions frequently need to be made quickly, and there is no time (and often no money) for new primary valuation studies. Given that the goal of benefit-cost analysis is typically to *provide information* (rather than being the sole basis for the policy decision), it can still be useful to present the results to policy makers using benefit transfer. Even if uncertainty in the transfer leads to uncertainty regarding whether benefits exceed costs, it is useful for decision makers to know this, so that they can take this uncertainty into account in their decision-making. Thus, informing the decision maker that net benefits could cover a wide range (including negative values), and that uncertainty in the transferred VSL contributes significantly to the uncertainty regarding net benefits, is more useful than providing no information at all on the potential magnitude.

Notes

1. In addition, there is the little used preference calibration transfer method; suggested by Smith *et al.* (2006).

2. Recent applications of the simple unit value transfer approach to mortality risks are, however, less naïve and involve transfer of ranges rather than point estimates; see *e.g.* Robinson (2008) for a review of practices in the US.

3. Roughly said to be having a higher adjusted R^2 than 0.5, *i.e.* explaining more than 50% of the variation in value.

4. This is partly due to the fact that meta-analyses often lack detailed data on the characteristics of the good, because the primary studies lack these data.

5. Also of relevance is the use of discounting related to the environment in regional policy within the European Union. In particular, the Structural Funds finance environmental protection through projects as varied as the development of renewable energy in Germany and waste management in

Greece and Portugal. The Cohesion Fund is specifically earmarked for transport and environment projects in the poorest States of the Union. As is often the case for such projects, the Commission distinguishes between the financial discount rate used for financial analysis and the economic discount rate applied to socio-economic cost-benefit analysis. The two rates can be different. The financial discount rate is limited to 6% in real terms for all projects (for the current programming period). For example, the United Kingdom uses 3.5% whilst the Czech Republic uses 6%. In exceptional and duly justified cases, the rate applied to certain projects in the new member states and the current candidate countries could be raised up to 8% in real terms, where they would encounter important difficulties of bank finance, or where there is a particular interest with respect to Community policies and guidelines. In contrast, the social discount rate will be chosen by the beneficiary state, but must remain consistent from one project to another.

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Chapter 6

Recommended Value of a Statistical Life numbers for policy analysis

Two benefit transfer techniques, meta-analysis and unit value transfer with income adjustment, are used to establish adult VSL base values and ranges for assessing policies for the OECD and EU-27 areas. These base values and ranges should be updated as new VSL primary studies are conducted in OECD/EU-27-countries, so that more countries are represented in the meta-analysis. Country-specific VSLs should be used in CBAs of national policies. Empirical evidence from the literature and the meta-analysis are used to establish a guide to adjustments of base VSL values for different policy contexts.

6.1. Base VSL values for regulatory analysis

Methods and sources of base VSL values

Chapter 5 outlined an eight-step procedure for benefit transfer to establish base value of statistical life (VSL) values. Unit value from domestic studies valuing mortality risks as similar as possible to the policy context is recommended; see Section 5.2 (Step 4) for a list of similarity criteria. However, Lindhjem *et al.* (2010) show that a meta-analysis with very high explanatory power based on more than 1 000 observations of mean VSL from SP studies worldwide, can produce transferred VSL estimates with an uncertainty below ±50%, when screening procedures are applied (see also Section 4.2).

A simple unit value transfer (with no adjustment) to establish an OECD base value is to take the overall mean VSL of all SP studies in the database constructed for the meta-analysis. For a single country, however, the mean VSL from the most similar study, rather than the mean of all studies, would be the preferred procedure. Since there is no SP study covering all OECD-countries, nor all EU-27 studies, all studies within these blocks of countries need to be considered. Table 6.1 shows a mean of the mean VSL estimates of about USD 6.1 million (2005-USD) from the full sample, which increase to about USD 7.4 million when each study is given equal weight. Trimming, by removing the 2.5% highest and 2.5% lowest estimates, results in a VSL of about USD 5 million. However, this sort of standard trimming procedure of the sample is rather arbitrary. Screening the studies based on a quality assessment of the valuation methodology applied should rather be used (see Lindhjem *et al.* (2010, 2011) and Chapter 3 for details).

For the quality-screened sample of studies from the meta-analysis, the median of the mean VSLs from the valuation studies is less sensitive to high VSL estimates values than the mean of the mean VSLs, and also gives equal weight to each estimate. Based on this type of simple value transfer approach, Table 6.1 shows a VSL estimate for the OECD countries of about USD 3 million (2005-USD). This means that 50% of the mean VSL estimates from OECD countries are lower than USD 3 million and 50% higher than USD 2.9 million. For EU-27, the corresponding VSL estimate is USD 3.6 million. If applying a mean transfer error of ±50% (which Lindhjem *et al.*, 2010, found for the best meta-analytic models), one gets a VSL base value range for OECD countries as a whole of USD 1.5–4.5 million, and USD 1.8–5.4 million for EU-27. Note that these ranges overlap with the weighted mean of mean VSLs of about USD 4 and 4.7 million for OECD and EU-27, respectively.

Chapter 4 provides an example of different meta-analytic transfer approaches for a national VSL (Japan was used as an example). The results show that using the raw, unadjusted mean VSL from the full sample of studies could produce transfer errors of more than ±100%. Thus, the VSL base range could be even larger. Also, this range is not a confidence interval in a standard statistical sense, nor does it cover the minimum and maximum values in the database of SP studies of VSL, but is the result of applying a simple unit value transfer procedure to get an overall OECD value. It is worth noting in Table 6.1 that weighted mean VSL (*i.e.* giving all studies equal weight and correcting for the varying number of estimates from each study) have less of an impact on the mean VSL in the quality-screened samples than in the full and trimmed samples.

Another way to derive a base value VSL for all OECD countries is to apply the best meta-analytic models and insert the average GDP for OECD countries, which is about USD 30 000 (2005-USD, PPP-adjusted), and values for the other population and risk characteristics included in the more comprehensive models. Applying the five meta-analytic transfer models used in the example in Section 4.3 yields a mean VSL estimate of USD 2–3 million. This is based on the following assumptions about risk characteristics: risks related to *health* (environment and transport would give lower and the same VSL, respectively), a *private* risk programme (as this provides "cleaner" measure than public risk), an *immediate* risk, *not* related to *cancer*. Methodological variables are set to "best practice". Applying a mean transfer error of ±50% (which might be on the high side, judging from the example which gave transfer errors of +18–35%) gives an average OECD VSL base value range of USD 1–4.5 million. This is about the same range as provided by the simple unit value transfer described above. Note, however, that this meta-analytic transfer is just *one* example.

Table 6.1. **Summary of the estimates of value of statistical life (VSL)**

2005-USD

	Full sample	Trimmed sample [b]	Quality-screened sample [c]	OECD countries (screened) [c]	EU-27 (screened) [c]
Mean VSL (standard error)	6 064 679 (490 985)	4 959 587 (315 688)	2 792 963 (169 443)	4 007 900 (229 931)	4 704 038 (329 474)
Weighted mean VSL [a] (standard error)	7 415 484 (885 235)	6 314 696 (301 182)	3 123 538 (255 835)	3 981 851 (289 793)	4 893 216 (439 370)
Median	2 377 592	2 377 592	1 680 571	3 012 558	3 614 506
Observations	856	814	405	261	163

Notes: a. Weighted by the inverse of the number of observations from each SP survey.

b. Highest and lowest 2.5% of the values taken out of the sample.

c. First-level quality-screening used the following procedure: *i)* If no value for the risk change was reported, the study was excluded; *ii)* Sub-samples smaller than 100 observations and main survey samples less than 200 observations were left out; and *iii)* Samples that are not representative of a broad population were left out. See Section 3.5.

Recommended base values

Base values for VSL are difficult to establish also for a single country. Thus, in the United States, the Office of Management and Budget provides a range, rather than a base value, as guidance to US agencies to use in their CBAs (see Section 1.3, Table 1.1). A base value for all OECD countries is difficult to estimate, and one should also rather use a range than a base value in order to take account of the uncertainties of the benefit transfer and generalisation needed to establish this value. Also, a base value or range for all OECD-countries is not very useful, as it should only be used for CBAs of OECD-wide policies. Base values and ranges for individual OECD-countries, however, are of great interest, as most CBAs are conducted at the national level. CBAs of EU Directives and EU policies, however, take place at the European level. Thus, for the EU, EU-wide values are needed.

As discussed above, one can recommend the following VSL ranges and base values: USD 1.5–4.5 million (2005-USD) with a base value of USD 3 million for the OECD; and USD 1.8–5.4 million (2005-USD), with a base value of USD 3.6 million, for EU27. These base values and ranges should be updated as new VSL primary studies are conducted in OECD/EU-27-countries, so that more countries are represented in the meta-analysis. Updating from 2005 to 2010-USD could be approximated using the average Consumer Price Index (CPI) for OECD and EU-27, respectively. Also, the value range should be adjusted for increased real income in OECD and EU-27 over time and by using equation (6.1) to calculate the percentage change in mean GDP per capita in OCED/EU-27 to the power of the income elasticities of VSL suggested below.

To derive VSL base value ranges for *individual countries* within the OCED and EU-27, a unit value transfer with income adjustment (in terms of GDP per capita) of VSL from a study site with population characteristics as similar as possible to the policy site should be undertaken, using equation (6.1) below.

$$VSL'_p = VSL_s\ (Y_p/Y_s)^{\beta} \qquad (6.1)$$

For the income elasticity of VSL, β equal to 0.7-0.9 (found in Chapter 3, in most of the quality-screened models) is recommended.[1] For income Y_p and Y_s at the policy site and the study sites, respectively; the most current GDP per capita numbers (PPP adjusted, preferably by AIC[2]) should be used. This will yield VSL_p' in 2005-USD, which should then be converted to national currencies using PPP-adjusted exchange rates for 2005 (see *e.g. http://stats.oecd.org/Index.aspx* for GDP numbers and PPP-corrected exchange rates). To adjust VSL to current in individual countries, the domestic Consumer Price Index should be used. To correct for increased real income over the same period, VSL should be adjusted with the percentage increase in GDP per capita (in real terms/constant prices), to the power of the income elasticities cited above. If national VSL estimates for a *specific* policy analysis is needed, one should rather use the eight-step procedure for benefit transfer, conduct unit value transfer from a study with risk and population characteristics as similar as possible to the policy site, add the uncertainty bounds, and then use the meta-analysis to calculate and validate the value range for VSL needed in the specific policy context. This would be the best way to adjust the base value for the factors discussed in Section 6.2.

6.2. Adjustments to base values: Review and recommendations

Introduction

When should a VSL base value be used and when should one try to adjust that base value to improve the accuracy of the VSL estimate? This section addresses this important question of how the transfer of a VSL base value to another policy context should take account of differences in population and risk characteristics and other differences which could potentially affect appropriate VSL estimate to use.

In her comprehensive review of RP and SP studies, Robinson (2008) provided a summary of the empirical evidence for adjustments of the VSL base value for population and risk characteristics, and the implications for Department of Homeland Security regulatory analysis of measures to prevent terrorism attacks. This summary is reproduced in Table 6.2.

Robison (2008) argues that recent wage-risk studies (particularly Viscusi, 2004) provide the most appropriate source for VSL estimates for application in the homeland security context, as terrorists are most likely to target major urban areas with high concentrations of workers. Thus, the averted mortality risks may accrue somewhat disproportionately to working-age individuals, similar to those included in the wage-risk studies.

For the environment, transportation and health sectors, policies would often affect the general public, and thus Stated Preference studies based on surveys of the general public would be more appropriate. In the next sections, literature reviews and the meta-analysis of SP studies (Chapter 3) are used to shed light on the same characteristics as presented in Table 6.2. For most issues, the empirical evidence from SP studies is similar to RP studies, and thus the recommendations for adjustments are also similar (but one cannot rule out that adjustments might vary depending on the baseline in terms of whether one adjust job-related risks versus food-related risks). Note that this review also addresses adjustments in VSL *between* countries, whereas Robinson (2008) only addresses adjustments for differences *within* one country (*i.e.* the United States).[3]

Table 6.2. **Empirical evidence and recommendations for adjusting VSL base values**
Evidence from Revealed Preference (*i.e.* wage risk) studies

EFFECTS OF SCENARIO DIFFERENCES		
Characteristic	Empirical Evidence	Implications for Homeland Security Rules
Population Characteristics		
Income	Many studies; VSL increases as real income increases.	Adjust VSL to reflect real income growth over time.
Age (life expectancy)	Many studies; results inconsistent.	No adjustment.
Underlying Health Status	Limited; uncertain effect.	No adjustment.
Background Risks	Limited; uncertain effect.	No adjustment.
Self-selection	Limited; uncertain effect.	No adjustment.
Risk Characteristics		
Latency and Morbidity	Limited; magnitude of effect uncertain, simple adjustments possible.	Adjust if regulation is targeted on risks with significant latency periods or morbidity prior to death.
Altruism	Limited; uncertain effect.	No adjustment.
Risk Perception (source or cause)	Limited; averting homeland security risks may be valued more highly than averting the risks commonly studied.	Provide illustrative adjustments in sensitivity analysis.

Source: Robinson (2008, exhibit 4.5).

Adjustments for population characteristics

This section uses the evidence from the literature reviews and meta-analysis of Stated Preference studies in Chapter 3 to suggest adjustments of VSL based on differences in the following population characteristics:

1. Income: Adjustments across space (not within the same country) and time.
2. Age: Is there evidence for adjusting VSL for adult age groups? How should VSL for children be valued?
3. Health status of the population and background risks

Income

Empirical evidence as well as the meta-analysis in Chapter 3 show, as expected from economic theory, that people's WTP increases with income, and thus VSL increases with income. Ethical concerns, however, could prevent the use of different VSL estimates for different income groups within a country. The same is true for a group of countries, like the European Union, when performing CBAs of new EU directives involving changes in mortality risks. Even for global environmental problems, like climate change, one can see increased use of equity-weighting in CBAs in terms of using the same VSL for poor as for rich countries (Tol, 2005; Stern, 2008; and Anthoff *et al.,* 2009). However, for CBAs on the national level, which is the most common level for regulatory analyses, national VSL estimates should be used (to reflect the preferences of the national population). These national VSL estimates could, however, differ with respect to risk characteristics and population characteristics other than income.

Viscusi (2010) argues that even if meta-analyses of wage risk studies show an income elasticity of 0.5–0.6, this is just for the restricted age-spectrum covered in wage risk studies, and that it should be around 1.0 for the general public. The meta-regressions in Chapter 3, however, find an income elasticity of 0.7–0.9 for most of the quality-screened models of SP studies of the general public. Since this meta-analysis is based on studies of the general public, it is suggested using an elasticity of 0.8 (*i.e.* the midpoint of 0.7 and 0.9) in Equation 6.1 when conducting a CBA at the national level, and there is a need to transfer a VSL estimate from another country. As a sensitivity analysis, it is recommended to use an elasticity of 0.4, this lower elasticity was found for a subset of studies in the meta-analysis that used the same high-quality survey instruments or satisfied the scope test (*i.e.* where it was shown that people were willing to pay significantly more for a larger risk reduction than for a smaller one).

Age

The reluctance to make age adjustments of VSL in the United States stems from the significant controversy that erupted over the so-called "senior discount", where the US EPA used a lower VSL for older individuals in sensitivity analyses conducted for air pollution rules prior to 2004, including the Clear Skies Initiative, where benefits to senior citizens constituted the majority of the policy benefits (Robinson, 2007). Because environmental policies often reduce risks to the very young or the very old, the age differentiation with regards to VSL arose first in this sector. Aldy and Viscusi (2007) note that negative direction of the change in valuation of older people's lives, rather than recognition of heterogeneity in VSL, may have accounted for the public uproar that the benefit assessment created. If the US EPA had instead placed a premium on the lives of children whose risks would be reduced by the policy, it is likely that few would have objected. Aldy and Viscusi *op. cit.* also point out that whether VSL should vary by age is not a matter of equity or political expediency, but should rather be grounded on estimates of how people's WTP for risk reductions vary with age. As people age, their life expectancy shortens, but their economic resources vary as well, giving rise to a theoretical indeterminacy in the age-VSL relationship (see also Viscusi, 2009).

While there is some empirical evidence that VSL declines at older age, recent work suggest this relationship is uncertain (Hammitt, 2007; Aldy and Viscusi, 2007; Krupnick, 2007). Thus, determining the VSL at different ages requires more research. Age differentiation in VSL will facilitate better prioritisation of mortality risk reduction efforts for populations of various ages. Two US expert panels have advised against making VSL age adjustments due to inconclusive evidence (Cropper *et al.*, 2007; National Academy of Sciences, 2008).

The meta-analysis of SP studies of *adult* VSL in Chapter 3 found no clear relationship between age and VSL, although for a subset of the data, indications of an inverted U-shape relationship between VSL and mean age of the sample was found (meaning that VSL increase with age to about 40-50 years of age and then decline, see Annex 3.A1).

VSL appears to be *higher for children*, due to parents' altruistic concerns for their children, with results from the United States and Europe indicating VSL for children being as high as a factor of 2 that of their parents/adults (US EPA, 2003; OECD, 2010). More generally, in cases where the policy intervention particularly affects children, due to the nature/scope of policy (*e.g.* pesticides in school grounds) or because children are particularly vulnerable to this particular hazard (*e.g.* lead in drinking water), then child-specific values are likely to be particularly helpful in ensuring that resources and policy efforts are allocated efficiently. According to OECD (2010), it is likely that the introduction of a "premium" for children would raise less controversy than a "discount" for seniors. Since "children" were not included in the studies used to determine baseline VSLs, the "premium" could be simply added to the baseline estimate. Moreover, there is a stronger political case. While the interests of children are usually defended by parents (and other care-givers), policy makers in OECD governments have always had a special role in protecting the interests of children with respect to risks in general. In some cases (*i.e.* negligence or abuse), this role may supersede that of their parents. As such, there is, at least, a distinct obligation with respect to children's risks to determine whether or not a premium should be applied.

Based on literature reviews and the SP meta-analysis of Chapter 3, *no adjustment for age is recommended.* However, when the policy that is analysed targets children specifically (or affects mainly children), a higher VSL for children is recommended, based on the available empirical evidence from the United States and Europe (US EPA, 2003; OECD, 2010). *VSL for children* should be *1.5–2.0 times higher* than the mean adult VSL.

Health status of the population and background risks

The SP evidence is very limited and inconclusive regarding any relationship between health status and VSL. The principal studies that have explored this linkage are Johannesson and Johansson (1996) and Krupnick *et al.* (2000). Johannesson and Johansson found that WTP values declined with poorer health status, while Krupnick *et al.* found no significant evidence of such a relationship.

Since few SP studies contain information about health status of the population and the background/baseline risks, these variables were not included in the final version of the meta-analysis described in Chapter 3. There were some indications that baseline risks may affect VSL in some earlier regressions, but theoretically the baseline risk is not expected to affect WTP and VSL very much, at least not for small levels of risks.

Based on the literature review and the SP meta-analysis *no adjustment for health status of the population and background risks* is recommended.

Adjustments for risk characteristics

This section uses the evidence from the literature reviews and the meta-analysis of Stated Preference studies in Chapter 3 to suggest adjustments of VSL based on differences in the following risk characteristics:

Timing of risks (Latency)

As expected from theory, there is empirical evidence that people value mortality risk where there is a time lag between the measure and the impact lower than immediate mortality risk reductions. The analyses in Chapter 3 provide mixed evidence for latency, but regressions only including estimates from surveys using the same high-quality survey instrument, and surveys that pass both internal and external scope tests (*i.e.* where it was shown that people were willing to pay significantly more for a larger risk reduction than for a smaller one), indicate that latent risk reductions lead to lower VSL values.

Based on the literature review and the meta-analysis, no adjustments should be made for latency in base VSL values.

Risk perception (source or cause)

Some research suggest that risks that are viewed as less controllable, voluntary and familiar may be valued up to twice as high as other risks (Robinson *et al.*, 2010). Jones-Lee and Loomes (1995) compared events that differ in magnitude, but found little evidence of a scale premium. They suggest that, in the case of rare catastrophic events, aversion to ambiguity may be counterbalanced by doubts about whether programmes can be designed to effectively avert such risks.

The meta-analyses described in Chapter 3 indicates that while in the full, unscreened dataset, transport-related mortality risks are valued higher than health and environmental risks, in the quality-screened models, VSL estimated from SP surveys explicitly mentioning that the mortality risk is environmentally related is valued *lower* than health and transport sector studies. However, as the types of risks valued within these categories seem heterogeneous, one should be cautious in interpreting these results.

Based on the literature review and the SP meta-analysis, VSL should *not be adjusted* for whether the regulatory analysis considers measures in the health, environment or transport sectors. However, sensitivity analysis for lower values in the transport and environment sectors than health should be carried out.

Cancer/Dread (Morbidity prior to death)

WTP to reduce the risk of cancer death may be greater than for accidental death, *e.g.* because of the lengthy and painful illness and treatment process that frequently precedes death from cancer. In their literature review, Chestnut and De Civita (2009) pointed to studies indicating that this effect exists. However, they concluded that the available valuation research is not sufficient at this time to determine the direction and the magnitude of applying available VSL estimates to cancer death. On-going Stated Preferences studies in EU-projects, like EXIOPOL and HEIMTSA, will shed more light on this adjustment factor.

In the meta-analyses described in Chapter 3, a cancer premium was found in analyses of the full, unscreened dataset, but not in the analyses of the quality-screened models.

The literature review and the meta-regressions do not support adjusting VSL upwards if the regulation is targeting cancer risks. Thus, it is *not* recommended to adjust VSL for cancer risks, but to account for the costs of morbidity prior to cancer deaths separately.

Adjustments of VSL in space and time

VSL estimates vary in space (*i.e.* between countries) and over time. For transfer between countries, Purchasing Power Parity (PPP) adjusted exchange rates should be used to also correct for how differences in the costs of living affect VSL (which is not reflected in the market exchange rates for different currencies).

To update VSL estimates over time, the same VSL study repeated over time would be needed to establish a price index for VSL. In lack of such empirical evidence and a specific price index for VSL, the Consumer Price Index (CPI) is frequently used to update VSL estimates over time. This practice assumes that how people value mortality risks over time follows the same pattern as their willingness-to-pay for the basket of consumer goods the CPI is based on. A research programme repeating the same best practise stated preference study of mortality risk for many years in several countries would provide more reliable estimates for how the general population value mortality risks in space and time.

Even if the income elasticity of VSL is not used to adjust VSL for income differences within a country, it is frequently used to adjust VSL over time to take account of an increase in income (often in terms of GDP per capita) in real (not nominal) terms over time.

As there is a lack of empirical evidence on how VSL estimates develop over time, the Consumer Price Index of the policy country is recommended for conversion of VSL to the current price level. An income elasticity of 0.8 is recommended for adjusting VSL for changes in real income over time within the OECD and EU-27 countries; which means that a 1% increase in real GDP per capita will result in a 0.8% increase in VSL. A sensitivity analysis for an income elasticity of 0.4 should be performed (as some of the quality-screened models in Chapter 3 show this lower income elasticity).

"Discount factor" for hypothetical bias in Stated Preference studies?

Compared to meta-analysis of wage risk studies, the meta-analyses described in Chapter 3 provide "conservative", lower estimates. The issue of hypothetical bias in SP studies is still a concern, but there is no general agreement of a "discount factor" to account for this potential difference in stated and "true" willingness-to-pay. SP studies have the great advantage over wage risk studies in that they can reflect preferences of the *general* population for different risk contexts rather than just job related risks for workers in a restricted age group (excluding children and the older adults).

Adding other social costs of the fatality

Average private and public costs of dealing with a fatality (treatment, hospital costs, etc.) should be added to the VSL to estimate the total social value of preventing a fatality. One should, however, be aware of the possible double-counting of morbidity and mortality effects when summing of all health effects in a CBA. Also, there are no widely-accepted standards for estimating these costs, and different studies might result in significantly different estimates (see *e.g.* Akobundu *et al.*, 2006; Blom *et al.*, 2001; and Yabroff *et al.*, 2009). Since these costs are generally very small relative to VSL, ignoring these costs may not noticeably affect the analytic results.

Altruism and private vs. public risks

Valuation of private risk changes is the most common scenario in both wage risk and SP studies. Thus, altruistic concerns need to be added for policies affecting public mortality risk like *e.g.* air pollution policies. According to Strand (2004);

"whenever paternalistic altruism dominates (respondents attach "considerably more" weight to other persons' survival probabilities than to their general consumption), it may be legitimate to include altruistically expressed values as part of "true" VSL. Elicitation of VSL as a purely private good may then be misleading in public policy contexts where mortality risk reductions almost always are of the public good kind".

Strand (2003) argues that the altruism expressed by adults for their children does not cease to exist once children are older than 18 and are asked to value risk in SP studies. Despite lower income for young adults, their VSL is much higher due to the fact that many people have altruistic values for them. Older people typically have higher income themselves (and higher WTP for risk changes), but the altruistic values from others may be less strong than for young adults.

However, no general adjustment factor for altruism for studies valuing private risk can be found in the literature. On the contrary, several SP studies find significantly *lower* WTP for public risks than for private risks (Svennson and Vredin Johansson, 2007), and so does the present meta-analysis of SP studies. Svennson and Vredin Johansson (2007) find, based on the results from a purpose-made survey, that part of the discrepancy can be explained by the individuals' age and his/her attitudes towards privately and publicly provided goods in general. Due to differences in attitudes, they argue that public and private goods are in fact perceived as a two different goods, even if the risk reductions are of equal magnitudes. However, one cannot fully exclude that methodological issues of the SP method might have influenced their results. Thus, the difference in valuation when the risk change affects the individual or her household members versus the public at large is still unexplained.

Altruism would pull in the direction of higher WTP and VSL for public risk changes. On the other hand, private risk changes are typically something the family or individual controls through buying a helmet or a product that reduces risk. In other words, the risk change is more concrete and direct when it is private compared to a public risk programme. Thus, one can argue that SP studies of private risks provides "cleaner" estimates of VSL, and should be the main basis of VSL estimates until this difference can be fully explained.

Notes

1. For transfer of VSL from high-income to low-income countries, Hammitt and Robinson (2010) show that income elasticities larger than 1 should be used. However, transfers between OECD-countries or between EU 27 countries, could apply the elasticities (below 1) found in the present meta-analysis of studies from these countries. Transfers from developed to developing countries (outside the dataset described in Chapter 3) should, however, use income elasticities larger than 1.
2. While GDP per inhabitant is often used as an indicator of countries' level of economic welfare, it is not necessarily a suitable indicator for households' actual standard of living. For the latter purpose, a better indicator may be actual individual consumption (AIC) per inhabitant; for further explanations, see: *http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/GDP_per_capita,_consumption_per_capita_and_comparative_price_levels*.
3. Although the base values in Robinson (2008) were derived from a HW study, much of the work cited on adjustments is based on SP work. The most significant difference between this report and Robinson (2008) is that she focused on homeland security and did not include the more recent research.

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Chapter 7

Recommendations for use of Value of a Statistical Life figures in policy assessments

For OECD as a whole, the recommended VSL range (in 2005 USD) is 1.5–4.5 million, with a base value of USD 3 million. Corresponding values for EU-27 are USD 1.8–5.4 million and 3.6 million, respectively. These base values and ranges should be updated as new VSL primary valuation studies are conducted in OECD/EU-27-countries, so that more countries are represented in the meta-analysis. For CBAs of national policies, country-specific VSLs should be derived using unit value transfer with income adjustment, unless good national primary SP studies exist. Recommendations for adjustments of base VSL values to fit different policy contexts are provided.

Regulatory practices with regards to how to establish the value of a statistical life (VSL) varies widely between countries, and even between agencies within a country. The main difference between the United States and Europe is the reliance of Revealed Preference (RP) methods in terms of wage risk studies in the United States (where most such studies have been conducted), while Europe more relies on Stated Preference methods, eliciting people's willingness-to-pay (WTP) for changes in mortality risks. Two other countries in the forefront of mortality valuation, Canada and Australia, also increasingly rely on SP studies.

VSL from a SP survey can be derived in the following way: A survey finds an average WTP of USD 30 for a reduction in the annual risk of dying from air pollution from 3 in 100 000 to 2 in 100 000. This means that each individual is willing to pay USD 30 to have this 1 in 100 000 reduction in risk. In this example, for every 100 000 people, one death would be prevented with this risk reduction. Summing the individual WTP values of USD 30 over 100 000 people gives the number referred to as value of statistical life. The VSL estimate in this case is USD 3 million. It is the aggregate WTP for the group in which one death would be prevented. It is important to emphasise that the VSL is not the value of an identified person's life, but rather an aggregation of individual values for small changes in risk of death.

The VSL is often used in cost-benefit analysis (CBA) of policies as follows. One first estimates the number of deaths expected to be prevented in a given year by multiplying the annual average risk reduction by the number of people affected by the programme. Then the VSL (either a single number or a range) is applied to each death prevented in that year in order to estimate the annual benefit. Annual benefits are summed over the life-time of the policy as a present value using the national social discount rate.

An eight-step procedure for transferring VSL estimates from existing SP studies for use in a regulatory policy analysis is outlined. A simple unit value transfer with income adjustment in terms of GDP per capita, using equation (7.1), is recommended when transferring VSL estimates from other countries to establish a *domestic* VSL base value.

$$VSL'_p = VSL_s\ (Y_p/\mathrm{Y_s})^{\beta} \tag{7.1}$$

For the income elasticity of VSL, a β equal to 0.8 (found in most of the quality-screened models described in Chapter 3) is recommended. Since some of the quality screened models showed lower income elasticities, a sensitivity analysis using a β equal to 0.4 should be performed. For the incomes Y_p and Y_s at the policy site and the study sites, respectively; the most current GDP per capita numbers (PPP adjusted, preferably by AIC) should be used. This will yield $VSL_p{}'$ in 2005-USD, which should then be converted to national currencies using PPP-adjusted exchange rates for 2005 (see *e.g. http://stats.oecd.org/Index.aspx* for GDP numbers and PPP-corrected exchange rates). To adjust VSL to current in individual countries, the domestic Consumer Price Index should be used. To correct for increased real income over the same period, VSL should be adjusted with the percentage increase in GDP per capita (in real terms) to the power of the income elasticities cited above.

The OECD database for SP studies of VSL[1] should be used to identify SP studies that are as similar as possible with respect to the population and risk characteristics listed in Table 7.1 below. An uncertainty factor (transfer error) of ±20–100% should be added to the VSL base value dependent on the similarity between the study transferred from (termed *study context*) and the policy analysed (termed *policy context*). The quality-adjusted/screened meta-analysis results should be used to increase the validity of the unit transfer. When there is no similar study to transfer VSL estimates from, meta-analysis is the only possibility, but then a transfer error of ±100% should be added according to the eight-step guidelines (see Section 5.2). However, the meta-analysis of SP studies in Chapter 3 indicates that adding an error bound of ±50% to the calculated mean value would cover the uncertainty of the transfer.

Literature reviews and the present meta-analysis indicate a base range for the average VSL for OECD countries of USD 1.5–4.5 million (2005-USD), with a base value of USD 3 million. For EU-27, the corresponding base range is USD 1.8–5.4 million (2005-USD), with a base value of USD 3.6 million. Table 7.1 summarises the recommendations for when the base value range for a country (or group of countries) should be adjusted or not.

Table 7.1. **Recommendations for adjusting VSL base values**

Adjustment factor	Recommendation
	Population Characteristics
Income	No adjustment within a country or group of countries the policy analysis is conducted for (due to equity concerns). For transfers between countries VSL should be adjusted with the difference in Gross Domestic Product (GDP) per capita to the power of an income elasticity of VSL of 0.8, with a sensitivity analysis using 0.4.
Age	No adjustment for adults due to inconclusive evidence. Adjust if regulation is targeted on reducing children´s risk. VSL for children should be a factor of 1.5 – 2.0 higher than adult VSL.
Health status of population and background risk	No adjustment (due to limited evidence)
	Risk Characteristics
Timing of risk (Latency)	No adjustment (due to limited evidence).
Risk perception (source or cause)	No adjustment (due to inconclusive evidence). Sensitivity analysis for lower values in the environment sector than in health and traffic.
Cancer or dread (Morbidity prior to death)	No adjustment if regulation is targeted on cancer risks and/or risks that are dreaded due to morbidity prior to death. Morbidity costs prior to death should be added separately.
Magnitude of risk change	No adjustment. However, since the magnitude of the risk change clearly affects the VSL, a sensitivity analysis based on VSL calculated from a risk change similar in magnitude to the policy context should be conducted. A risk change of 1 in 10 000 annually is suggested for calculating a VSL base value.
	Other adjustments
Altruism and Public vs. Private risk	No adjustment (due to limited evidence and unresolved issues). Use “Private risk” to calculate a VSL base value. Provide illustrative adjustments in sensitivity analysis.
Discount for hypothetical bias in SP studies	No adjustment (due to limited evidence).
Correction for inflation	Adjustment based on the national Consumer Price Index (CPI).
Correction for increased real income over time	Adjust VSL with same the percentage as the percentage increase in GDP per capita.

Note

1. See *www.oecd.org/env/policies/vsl*.

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