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The value of statistical life in road safety: a meta-analysis

Arianne de Blaeij*, Raymond J.G.M. Florax, Piet Rietveld, Erik Verhoef

Department of Spatial Economics, Master-Point, Free University, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands

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Abstract

Costs of accidents make up an important part of the total external cost of traffic. A substantial proportion of accident costs is related to fatal accidents. In the evaluation of fatal accident costs the availability of an estimate of the economic value of a statistical life is pivotal. We present an overview of the empirical literature on the value of statistical life in road safety (VOSL), and use meta-analysis to determine variables that explain the variation in VOSL estimates reported in the literature. We show that the magnitude of VOSL estimates depends on the value assessment approach (particularly, stated versus revealed preference), and for contingent valuation studies also on the type of payment vehicle and elicitation format. We explain that VOSL estimates cannot simply be averaged over studies. The magnitude of VOSL is intrinsically linked to the initial level of the risk of being caught up in a fatal traffic accident and to the risk decline implied by the research set-up.

Keywords: Transport safety; Value of statistical life; Meta-analysis

1. Introduction

Traffic accidents are a major issue in transport policies around the world. In Europe, for example, approximately 40,000 fatalities occur in traffic accidents every year. The number of additional non-fatal accidents amounts to a multiple of this figure. Over the past few decades, the long-run trend in casualties related to road accidents shows a decreasing trend, even though transport volumes increased substantially. The introduction of a broad range of safety enhancements in vehicles, infrastructure and traffic behavior probably goes a long way in explaining this relative increase in road safety. Obviously, there is no guarantee for these improvements in accident rates to continue, in particular because the introduction and adoption of additional safety enhancements imposes an increasing burden on household and government budgets. A cost–benefit analysis can help to better understand the economic efficiency of additional spending on policies targeted at road safety improvement.[1]

Costs of accidents, comprising fatal and non-fatal damage costs, make up an important part of external costs of traffic. Damage costs include a variety of expenses related to, for instance, medical treatment, material and immaterial damage, legal assistance, law enforcement and loss of time. Some of these costs can be measured in monetary terms, because goods are marketed. Some costs cannot be given a value, owing to lack of trading opportunities. Some costs are borne by society as a whole (i.e. the taxpayer), whereas others merely constitute a financial burden to the traffic participant involved in an accident (Haight, 1994).

Governments play an important role in the development of safer transport systems. This is independent of whether monetary or non-monetary externalities are concerned, and whether strictly economic or related political, cultural and moral arguments prevail. It is desirable to base decision-making on a robust and reliable measure of the monetary value of road safety. In particular, the valuation measure should be appropriately defined and empirically assessable (Jones-Lee et al., 1995a,b).

The European Union currently uses a value of 1 million euros per human life in safety cost–benefit analyses. This is generally referred to as the 'one-million-euro rule' (Despontin et al., 1998). The value is determined by means of an approach focusing on output, implying that the value of life is estimated as gross output loss. As a result, policy measures bringing about the saving of lives up to a cost of 1 million euro per person can be justified on rather narrowly defined economic grounds. The use of this specific value also implies that a policy measure or project leading to a reduction of 1 fatality, results in a reduction of 8 serious

* Corresponding author. Tel.: +31-20-44-46029; fax: +31-20-44-46004.
E-mail address: ablaeij@feweb.vu.nl (A. de Blaeij).
*URL:*http://www.feweb.vu.nl/re/master-point

[1] The current paper is concerned with a strict economic approach to the issue of road safety. Obviously, there are also social, cultural and moral dimensions to this issue, but they are discarded in the current analysis.

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injuries, 26 slight injuries and 211 damage-only accidents. The one-million-euro test does, however, not take into account the willingness to pay for avoiding pain and suffering (Despontin et al., 1998).

It is obvious that the monetary valuation of traffic safety is not an easy task, because it requires an estimate of the economic value of a statistical life (VOSL). Although various methods and approaches for estimating VOSLs have been put forward, some scholars argue that valuing fatal injuries, and hence human life, is virtually impossible. They maintain that people do not nearly have sufficiently accurate preferences to make a sensible trade-off between road safety and money. The (perceptions of) changes in risk levels are so small that making the trade-off is very difficult, if not virtually impossible (Hauer, 1994).

We draw attention to the fact that value-of-life studies refer to the value of a *statistical* life. Valuation of a statistical life is concerned with valuation of changes in the level of risk exposure rather than the valuation of the life of a specific individual. Operationally, this translates into statements in terms of risk exposure. When the risk of involvement in a fatal accident is 1:100,000, the implication is that statistically there is 1 death per 100,000 people per year. Changes in the risk level imply changes in the number of statistical lives saved, and can be given an economic value. The economic value is essentially the marginal rate of substitution of wealth for risk of death, due to any specific cause. The statistical value of life is then merely the average of a series of observations on the marginal rate of substitution, where the latter is taken as an appropriate estimator of the underlying (unobserved) population mean.

Despite problems with valuation, an abundant empirical literature on the subject of VOSL in road safety exists. As shown in Table 1, the magnitude of VOSL estimates reported

Table 1
Annotated overview of studies with empirical estimates of the value of statistical life in road safety, in 1997 US dollars (×1000)[a]

Authors	Country	Year of		Study type	No. of estimates	Range of VOSL estimates in 1997 US dollars[b]		
		Publication	Data			Single estimate	Lowest estimate	Highest estimate
Atkinson and Halvorson (1990)	US	1990	1986	Revealed	1	4538		
Baker (1973)	US	1973	1973[c]	CPLS	4		826	12,385
Beattie et al. (1998)	UK	1998	1996	Stated	4		1344	15,187
Blomquist (1979)[d]	US	1979	1988	Revealed	1	1506		
Blomquist and Miller (1992)	US	1996[e]	1987	Revealed	3		1444	5,588
Carthy et al. (1999)	UK	1999	1997	Stated	4		4031	5,246
Cohen (1980)	US	1980	1974	CPLS	1	380		
Corso et al. (2000)	US	2000	1999	Stated	8		2336	5,548
Desaigues and Rabl (1995)	France	1995	1994	Stated	6		882	20,510
Dreyfus and Viscusi (1995)	US	1995	1987	Revealed	1	4056		
Ghosh et al. (1975)[d]	UK	1975	1973	Revealed	1	1692		
Hansen and Scuffham (1995)	New Zealand	1994	1994[c]	CPLS	1		637	727
Jara-Díaz et al. (2000)	Chili	2000	1999	Stated	1	4348		
Johannesson et al. (1996)	Sweden	1996	1995	Stated	4		5242	6,312
Jondrow et al. (1983)[d]	US	1983	1988	Revealed	1	1903		
Jones-Lee et al. (1983)	UK	1983	1982	Stated	11		594	10,149
Kidholm (1995)	Denmark	1995	1993	Stated	3		745	1,110
Lanoie et al. (1995)	Canada	1995	1986	Stated	2		1739	3,111
Maier et al. (1989)	Austria	1989	1989[c]	Stated	6		1557	4,297
McDaniels (1992)	US	1992	1986	Stated	3		8327	29,933
Melinek (1974)	UK	1974	1974[c]	Revealed	1	784		
Miller and Guria (1991)	New Zealand	1991	1990	Stated	5		1101	1,760
				Revealed	1	1434		
Morrall (1986)	US	1986	1984	CPLS	4		143	1,864
Persson and Cedervall (1991)	Sweden	1991	1987	Stated	10		1224	25,949
Persson et al. (1995)	Sweden	1995	1993	Stated	2		4262	4,866
Persson et al. (2001)	Sweden	2001	1998	Stated	1	2307		
Schwab Christe (1995)	Switzerland	1995	1993	Stated	1	906		
Schwab Christe and Soguel (1995)	Switzerland	1995	1994	Stated	2		816	981
Viscusi et al. (1990)	US	1991	1991[c]	Stated	1	9116		
Winston and Mannering (1984)[d]	US	1984	1988	Revealed	1	1903		

[a] Many studies are taken from Elvik's (1995) literature review.

[b] The VOSL estimates are expressed in local currencies and current prices (applying to a specific year), so that spatial and temporal adjustments are necessary for comparison of estimates. VOSLs in current prices are transformed to constant prices of 1997 using a GDP deflator, and subsequently transformed into 1997 US dollars using 1997 purchasing power parities (PPP). Both the GDP deflators and PPPs are taken from *World Development Indicators* (World Bank, 2000).

[c] Refers to year of the study rather than year of the data, because the latter is unavailable.

[d] Estimates taken from Miller (2000).

[e] The value of statistical life estimates are taken from the 1992 working paper.

in the literature is vastly different, and they range from less than 200,000 to almost 30 million US dollars in 1997 prices (Cohen, 1980; Persson and Cedervall, 1991). The apparent lack of agreement among economists as to an appropriate estimate of VOSL obviously enhances the difficulty of establishing consensus among policy makers, and therefore complicates decision-making (Despontin et al., 1998). We therefore explicitly address the issue of variation in VOSL estimates reported in the international literature. In this paper, we confine ourselves to VOSL estimates for road safety, because there is evidence that VOSLs depend on the context of the value assessment (such as road safety, wage-risk, or health; see Miller, 2000). We will use meta-analysis to attain insight into the literature. As will be explained in more detail below, meta-analysis is a methodology for the systematic analysis of differences between outcomes of empirical studies, and comprises a vast array of statistical techniques.

The remainder of the paper is organized as follows. We introduce the concept of the value of statistical life in Section 2. This section also contains a discussion of various methodological aspects of the VOSL concept. In Section 3, we describe the meta-analysis technique and we explain the suitability of assessing the degree of heterogeneity of effect size indicators weighted by their estimated standard error. In Section 4, we present the results of a meta-regression analysis of 95 estimates of the value of statistical life. We also use a subset of the dataset for which sample sizes of the original studies are available, in order to weight the VOSL estimates according to the precision with which they have been estimated. Section 5 contains the results of a meta-regression for a subset consisting of 54 VOSL estimates obtained using the contingent valuation technique. This enables us to take the initial risk level and changes in the level of risk into account. Section 6 winds up this paper and presents conclusions and directions for future research.

2. The value of statistical life

There is a widely shared opinion among economists that the monetary value of safety in public sector cost–benefit analyses should reflect the preferences of those affected by the policy measure. The monetary value of safety should be expressed as the aggregate of the individuals' willingness to pay (WTP) for safety improvements or, alternatively, the willingness to accept (WTA) compensation for increased risk levels. WTP (and WTA) values are individual trade-offs in terms of expenditures for improving safety versus alternative types of consumption. We can therefore conclude that WTP (and WTA) values are explicitly intended to reflect preferences, perceptions and attitudes toward risk of those affected by the decisions in which the values are to be used. This implies that the WTP for a risk decrease can differ among different hazardous situations.

Fig. 1 shows that the marginal WTP for a given reduction in the probability of involvement in a fatal accident is an increasing function of the initial risk level.[2] Fig. 1 assumes that preferences can be represented by continuous and smooth utility functions, an assumption that has been questioned in the context of road safety (e.g. Dubourg et al., 1994), but that nevertheless often implicitly or explicitly underlies empirical work on the VOSL. The function can conveniently be interpreted as a demand function for safety.[3] Risk levels can be measured as the percentage safety or, equivalently, as the probability of a fatal accident per 100,000 inhabitants. The WTP to avoid death with a probability of one equals the area under the marginal WTP curve. The VOSL is often calculated as the marginal willingness to pay for reductions in risk multiplied by the inverse of the risk reduction considered. At initial risk level P_0 this yields the VOSL represented by the shaded rectangle.[4] Typically, the VOSL estimate depends directly on the initial risk level. It is only under the assumption of a constant marginal WTP (for all risk reductions measured along the horizontal axis), that this would not be the case. With a declining demand function, the willingness to pay to avoid a fatal accident will probably be larger than the VOSL, given that the marginal WTP will often be evaluated at levels represented at the right hand side of Fig. 1.[5]

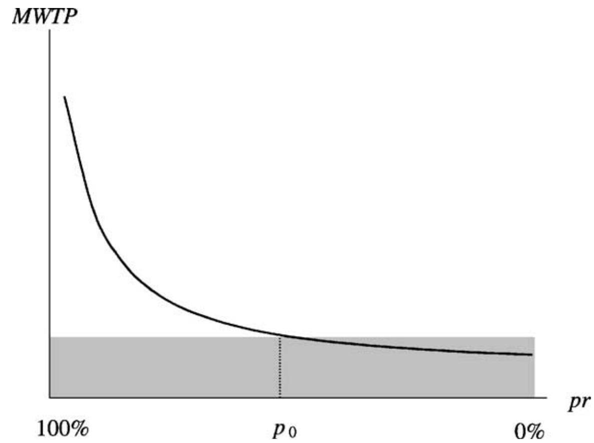

Fig. 1. The relationship between marginal willingness to pay and risk of being caught up in a fatal accident.

[2] A referee pointed out that Guria et al., 1999 found the opposite result.

[3] This is the standard hypothesis regarding the relation between an individual's marginal rate of substitution, in most cases estimated by either WTP or WTA, and the size and nature of the risk reduction. More specifically, the total WTP is an increasing, strictly concave function of the reduction in probability of death during a forthcoming period. Weinstein et al. (1980, p. 382) state that "[f]or a standard individual (for whom life is preferable to death and for whom the marginal utility of assets is greater alive than dead), the selling or buying prices for a [given] reduction of the mortality probability are greater, the greater the base probability of mortality." Consequently, the marginal WTP for reductions will be declining when the risk level declines.

[4] Note that the VOSL is the population mean of the marginal rate of substitution.

[5] Strictly speaking, the type of relationship depicted in Fig. 1 should hold for the total risk encountered by an individual. As traffic related risks are often a substantial part of total risks (at least for people younger than 40), one can expect a similar pattern to apply also to traffic risk in isolation.

In the literature on road safety valuation, the initial probability of a fatal accident is typically low, between 5 and 50 fatal injuries per 100,000 inhabitants per year (McDaniels, 1992; Persson and Cedervall, 1991). At low risk levels, the demand function may be close to horizontal, implying that small differences in initial risk levels among studies will not have an impact on estimated VOSLs. This is a crucial assumption in the empirical VOSL literature, although oftentimes it remains implicit.

The WTP (or WTA) can be empirically assessed by means of revealed or stated preference methods (Carthy et al., 1999; Jones-Lee and Loomes, 1995; Jones-Lee et al., 1995b). In the case of stated preference methods, the so-called contingent valuation method (CVM) is often used. CVM boils down to, more or less directly, asking individuals of a representative sample of the population at risk to state their willingness to pay for a (typically small) hypothetical improvement in their own (and possibly other people's) safety. The respondents indicate their WTP for a risk reduction, such as a reduction of the risk of having a fatal accident from $4/10^5$ to $2/10^5$ in the coming year. The VOSL can then be assessed as WTP $\times 1/(4/10^5$ to $2/10^5)$. As mentioned above, the value of a statistical life is subsequently estimated as the arithmetic average of the individual marginal rates of substitution.

A fundamental part of the contingent valuation method (CVM) is that respondents are asked directly to express their evaluation of a risk reduction in monetary terms. A related approach is to confront respondents with two or more alternatives in terms of monetary expenditures for safety and a corresponding risk level, and subsequently ask the respondent to indicate the preferred alternative. The latter approach is known as the 'stated choice approach'.

An alternative to the approach based on stated preferences is the revealed preference approach. Consumers actually reveal their preferences when making decisions in which risk plays a role (for instance, when buying a car with or without an airbag, and when choosing to use or ignore safety belts). If sufficient information is available with respect to the choice alternatives actually considered by the consumers, the implicit trade-offs determining their behavior will be revealed.

It is, however, not merely individual consumers who reveal preferences through actual behavior, public sector agents implicitly do so as well. For example, governments implementing a safety enhancing measure amounting to x monetary units per year, and intended to lead to a reduction y in the expected number of fatal accidents, implicitly reveal the valuation of a statistical life to be $z \geq x/y$. Because governments are faced with a persistent information problem, it may well be that preferences revealed by individual consumers markedly differ from the implicit individual marginal rates of substitution implied by governmental behavior. The difference between public and private valuation is one of the potential systematic causes for variation in VOSL estimates, and we therefore include this distinction in the meta-analysis.

Both the revealed and the stated preference approach have their pros and cons (see Lanoie et al., 1995, for a discussion). The analysis of revealed preference data is often hampered by lack of data on the choice-set considered by the actor and the perception of risks of the actor. Moreover, econometric difficulties (such as multicollinearity) may severely hamper the estimation of the trade-offs between money outlays and safety increases. These problems can be circumvented by the use of stated preference data, but then a major problem is that the answers of the respondents can depend rather strongly on the way in which contextual information is being presented. A more general problem, relevant for both methods, is the small magnitude of traffic risks and the concurrent problem of many respondents having difficulties dealing with these rather abstract, small probabilities. In this respect, an advantage of the stated preference approach is that the information provided in the questionnaire can be used to guide respondents to a proper understanding of the 'good' to be valued (i.e. small risks; see de Blaeij and van Vuuren, in press).

Despite these conceptual difficulties, many VOSL estimates have been reported over the last couple of decades. Table 1 presents an annotated overview of empirical studies on the value of statistical life in road safety. For the 30 studies we consider, Fig. 2 shows the mean and, in the case of multiple sampling of estimates from the same study, the highest and the lowest VOSL estimate. The mean of all sampled estimates equals 4.4 million US dollar in 1997 prices (the median is 3.2 million). It is obvious from Table 1 and Fig. 2 that there is considerable variation of VOSL estimates within and between studies. Moreover, the studies are mainly concerned with North America (particularly the US) and various countries in Europe, and the majority uses a stated preference approach. The empirical studies will be analyzed in more detail in the meta-analysis.

In an earlier exploratory meta-analysis of a subset of the studies we consider, Elvik (1995) estimates mean and median values of statistical life related to road safety and occupational safety. The data used by Elvik are VOSL estimates derived from studies using either stated and/or revealed preference methods. Taking into account this difference, Elvik investigates differences among subgroups of studies and between high, intermediate and low validity studies by splitting up the data according to characteristics of the different groups.[6] He computes the mean VOSL within these groups and compares the means between groups, however without discussing their respective significance levels. He also shows a graph of the inverse relationship between the level of risk and the value of life. Elvik concludes that the mean VOSL for occupational safety is higher than for transport safety;

[6] The studies are grouped according to the following characteristics: types of activity (occupation versus transport), sample size (greater than 500 versus smaller than 500), median value reported, pretest of questionnaire, type of good (public versus private), inclusion of a rationality test and WTP versus WTA.

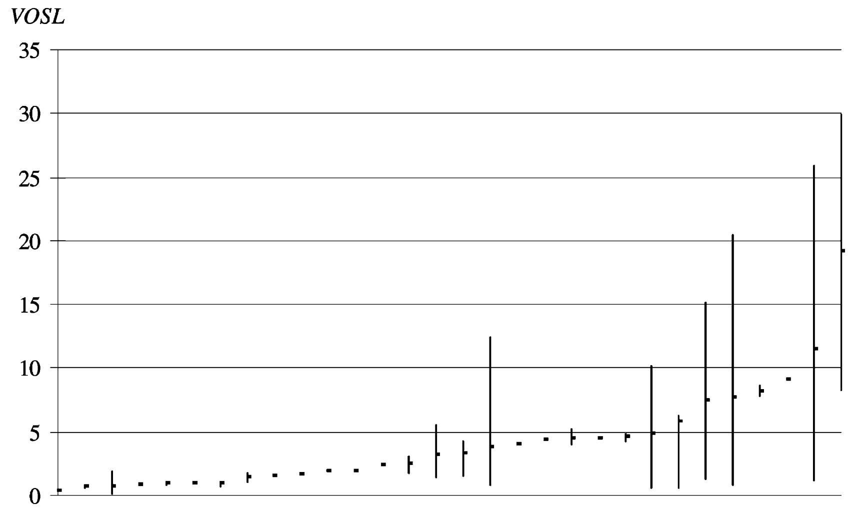

Fig. 2. Mean, highest and lowest estimate of the VOSL (×1,000,000), in 1997 US dollars, for 30 road safety studies, ordered by magnitude.

poorly designed stated preference studies result in higher estimates than more carefully designed studies; estimates of studies with high validity lead to lower variation; and lower risk levels result in higher VOSL estimates. The latter result is particularly remarkable as it contradicts our expectation based on Fig. 1. We return to this issue in the context of the meta-analysis.

Another recent study is Miller (2000), who estimates the income elasticity of VOSL estimates across 68 studies from different fields, including transport. The studies are concerned with wage-risk, contingent valuation and consumer behavior, and show an income elasticity ranging from 0.85 to 0.96. The wage-risk studies and contingent valuation surveys yield roughly comparable VOSLs, which are significantly higher than VOSLs from consumer behavior studies. Miller (2000) uses the estimated income elasticity to present VOSLs for most countries in the world, using a procedure that is generally called ‘value’ or ‘benefit transfer’ (see Brouwer, 2000).

3. Meta-analysis

In view of the substantial differences within and between VOSL studies, we now attend to a specific type of analysis to explain the variance among observed estimates. The situation of a rather scattered pattern of estimates is not at all uncommon in applied research. For instance, in agronomy, medicine and psychology, there is usually a substantial number of studies available, often cast in a similar experimental setting, reporting effects of a specific treatment, be it fertilizer, drugs, or therapies. Over the years, a distinct trend towards synthesizing available quantitative evidence can be witnessed in these disciplines. Instead of performing an additional study, attention increasingly focuses on the statistical analysis of research results attained previously, either as a way of seeking common ground or as a means of investigating potential causes for observed differences. Glass (1976) coined the term ‘meta-analysis’ to refer to the synthesis of research findings of different studies by means of statistical techniques. Over the last 20 years, meta-analysis has become a standard tool in many experimental sciences, and it is now increasingly being used in economics, in particular in environmental and natural resource economics.[7]

The main feature distinguishing meta-analysis from other types of summarizing techniques, such as state-of-the-art literature reviews, is its statistical nature. Meta-analysis is concerned with the statistical analysis of research results of studies performed previously, and is therefore distinct from primary and secondary analysis (Glass, 1976). Hunter and Schmidt (1990) succinctly explain the term ‘meta-analysis’ stating that meta-analysis is the ‘analysis of analyses’. Traditional research synthesis by means of narrative reviews including occasional tabulations and graphs is hampered by selective sampling, lack of statistical rigor, and a misleading (although intuitively appealing) inference process.

Potential bias due to selective sampling can occur when the reviewer reports on a specific subset of the population of studies without a proper justification of the sample selection process. But even if an adequate justification for the sampling of studies is provided, bias can be present owing to editors of journals and books being more likely to accept and publish statistically *significant* research results (see Card and Krueger, 1995, for an example in economics). Olkin (1990, p. 5) denounces this practice as ‘a form of statistical Star Wars’. In a review, this impact can be partly circumvented by sampling from the fugitive literature (containing unpublished research memoranda, government reports, the-

[7] Hunt (1997, p. 13) observes that 20 years ago, five major scientific databases (ERIC, PsycINFO, Scisearch, SOCIAL SCISEARCH, and MEDLINE) contained no listing of meta-analyses, whereas some 5 years ago their number already exceeded 3000.

ses and dissertations). In the context of meta-analysis, various methodologies have been developed to assess and remedy publication bias (see Florax, 2002, for an overview).

A simple starting point of meta-analysis is the comparison of means of the effect size indicator among various classes of studies (for example, VOSL in stated preference and revealed preference studies). Statistical methods can be used to determine whether these means are different. A more complete approach is an analysis of variance (Hedges, 1994). Consider, for example, the case that the data arise from a series of k independent studies, which can be divided into p disjoint groups on the basis of an a priori defined independent grouping variable. The number of estimates in the groups are labeled m_i, where $i = 1, 2, \dots, p$, the jth population value in the ith group is denoted by θ_{ij} and its estimate by T_{ij} with variance v_{ij}. The group mean effect estimate for the ith group $\bar{T}_{i\bullet}$ is defined as:

$$\bar{T}_{i\bullet} = \frac{\sum_{j=1}^{m_i} w_{ij} T_{ij}}{\sum_{j=1}^{m_i} w_{ij}} \quad (1)$$

where the weight w_{ij} is the reciprocal of the variance of T_{ij},

$$w_{ij} = \frac{1}{v_{ij}}. \quad (2)$$

The grand mean $\bar{T}_{\bullet\bullet}$ is given by:

$$\bar{T}_{\bullet\bullet} = \frac{\sum_{i=1}^{p}\sum_{j=1}^{m_i} w_{ij} T_{ij}}{\sum_{i=1}^{p}\sum_{j=1}^{m_i} w_{ij}}. \quad (3)$$

A test that there is no variation among the population VOSL estimates within the groups of studies Q_{w} can then be based on:

$$Q_{\mathrm{w}} = \sum_{i=1}^{p}\sum_{j=1}^{m_i} w_{ij}(T_{ij} - \bar{T}_{i\bullet})^2. \quad (4)$$

Under the null hypothesis $\theta_{i1} = \cdots = \theta_{im_i} = \theta_{i\bullet}$, the Q_{w}-test is χ^2 distributed with $(k - p)$ degrees of freedom, where k is the total number of studies. Similarly, a between-groups variation test Q_{b} can be defined as:

$$Q_{\mathrm{b}} = \sum_{i=1}^{p} w_{i\bullet}(\bar{T}_{i\bullet} - \bar{T}_{\bullet\bullet})^2 \quad (5)$$

which, under the null hypothesis, has a χ^2 distribution with $(p-1)$ degrees of freedom. Finally, the total variation Q_{t} can be computed as the sum of the within- and between-groups Q-tests and follows a χ^2 distribution with $(k-1)$ degrees of freedom.

Many meta-analyses in the area of economics employ the so-called meta-regression technique. Concisely, a meta-regression is based on some least square estimator of the following relation (Stanley and Jarrell, 1989):

$$y = f(p, x, r, t, l) + \varepsilon, \quad (6)$$

where y is an effect measure observed in a series of studies, p the specific underlying cause, x moderator variables affecting the cause–effect relationship, and r, t, and l moderator variables representing differences in research designs, time-periods considered, and locations covered by the initial studies. In economics, the latter set of moderator variables has the distinct advantage of discriminating between, for instance, revealed preference and contingent valuation designs and temporal and spatial dynamics. In the context of the current analysis, a series of estimates for the statistical value of life is used as the dependent variable. An overview of the set of explanatory variables is presented in Section 4.

Three evident methodological pitfalls exist (see also Glass et al., 1981). First, sample selection bias due to selective sampling on the basis of, for instance, theoretical framework, date of publication, publication as such, theory, time-period, and geographical scale. Second, dependence between the observations included in the sample, owing to multiple sampling from the same study, dependencies over space and/or time, and studies with the same author. Third, heterogeneity among sample observations, which can show up in varying parameters (or heteroscedasticity in a regression context), due to factors such as differing sample sizes of the initial studies, quality differences among studies, and differences in research designs.

The issue of sample selection bias obviously constitutes an important potential problem. It is straightforward to see that there is actually no need to analyze the complete population of studies if no systematic relationship between the sampling process and the effect size exists. However, it is unclear how mis-specification testing should be carried out, and what solutions are available in the context of meta-analysis. Smith and Huang (1995) use a logit model to determine the likelihood of sample selection bias by explaining the probability of including a study in the meta-sample on the basis variables such as, year of publication, published or unpublished, and significance. As the sample selection process in the current analysis has been geared towards obtaining the full population of studies, this issue will not be treated in the meta-analysis.

The methodological caveats of dependence and heterogeneity among the observations are not easy to treat with the relatively small sample that is available for the meta-analysis (i.e. 30 studies with 95 usable VOSL estimates). Although fixed and random effect specifications are a common solution, we choose to remedy potential dependence and heterogeneity by including variables indicating the location and time-period relevant for the underlying studies. Heterogeneity in terms of heteroscedasticity is inherently present in meta-samples, because the underlying studies differ in sample size. Its disturbing influence can be straightforwardly handled by means of standard econometric techniques, such as an appropriate estimator for a heteroscedastic error structure or the use of White-adjusted variances. Heterogeneity due to quality differences and differences in research design are more difficult to handle, but we use the common approach of specifying these in terms of fixed effects.

4. Empirical assessment of VOSL

We investigate the distribution of VOSL estimates for the traffic safety studies summarized in Table 1, using the overall and trimmed means presented in the studies. The values are transformed into 1997 US dollars (see footnote b of Table 1), for reasons of comparison. The starting-point of the sample selection process is the list of reference in Elvik (1995). In addition, we searched the literature in 'EconLit' using various relevant keywords, searched recent volumes of the most relevant journals, and approached individual scholars over e-mail. This extensive search resulted in seven additional studies.

It was, however, not possible to use all studies referenced in Elvik (1995). One study was intractable (Jones-Lee, 1977); some studies did not seem to contain a usable VOSL-estimate (Graham and Vaupel, 1981; Kamerud, 1983, 1988; Muller and Reutzel, 1984; Robertson, 1977); and some studies are in a language of which we have insufficient command (Hellquist et al., 1977; Persson and Cedervall, 1992). Consequently, the meta-analysis is concerned with 30 studies, providing 95 usable estimates. Fig. 3 shows the distribution of VOSL estimates in 1997 US dollars. The estimates vary between approximately 150,000 and 30 million US dollars.

An important aspect of the data series concerns the homogeneity of VOSLs within and between different groups of estimates. We categorize different groups according to, for instance, private or public safety, willingness to pay or willingness to accept, stated or revealed preferences, payment vehicle, and elicitation format. A complete list is given in Table 2.

The dimension *private* versus *public* indicates whether the valuation of statistical life is based on the valuation of a risk reducing private or public good (for instance, seat belts and road improvement, respectively). Economic theory suggests a difference: VOSLs based on private good valuation are expected to be higher because of the free-rider problem inherent to public goods. A related categorization concerns the *type of safety enhancing measure*. Safety measures can be concerned with the vehicle, the road, or behavior. One may expect people to prefer safety devices that make the vehicle safer without a need to adjust behavior, above actions that imply behavioral adjustments, or policy measures where benefits have a public good character (such as road improvements).

Regarding the distinction between WTP and WTA, earlier studies (Lanoie et al., 1995; McDaniels, 1992) show that WTA estimates tend to be higher. One of the reasons is that in the case of WTP the respondent immediately faces the income constraint: an increase of expenditures in one direction implies that other expenditures have to be reduced. In the case of WTA questions the issue of how to spend the additional money is usually less prominent so that the respondent is less alert on the benefits. Similarly, it can be expected that *stated preference* methods exhibit higher VOSL estimates as compared to revealed preference methods (see, e.g. Lanoie et al., 1995).

It is less clear whether one should expect a difference among studies that have been performed for *policy purposes* or for strictly scholarly purposes. In the analysis, the former type of studies is distinguished using the criterion of the government being the client or the performer of the research.

It would be ideal to investigate whether there are significant differences in VOSL estimates within and between urban and rural areas, as it is reasonable to assume the type of accidents to differ between urban and rural areas (Wadhwa, 1998). However, for the underlying studies, no

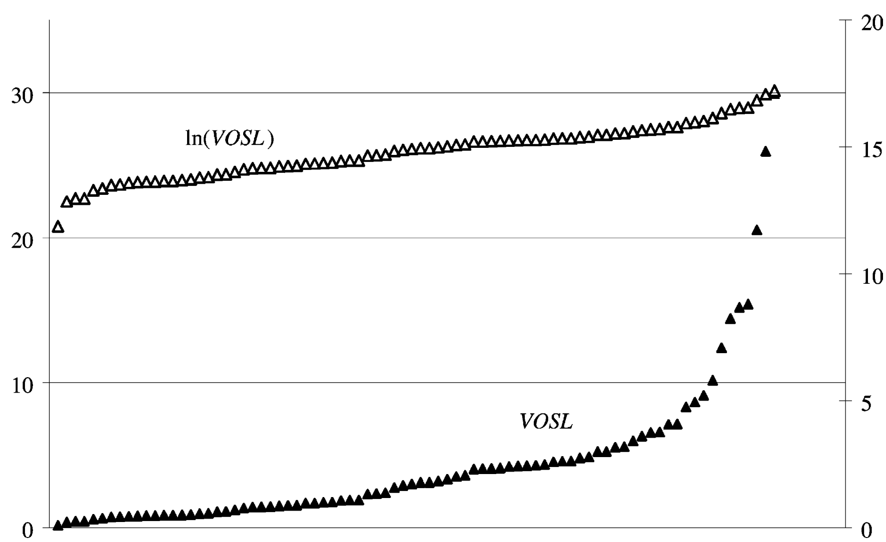

Fig. 3. The distribution of VOSL (×1,000,000) and ln(VOSL) estimates in 1997 US dollars, on the left and right hand axis, respectively.

Table 2
Conditional means of ln(VOSL) for various categories of studies[a]

Groups	All studies ($n = 96$)		Without CPLS studies ($n = 85$)		Stated preference studies ($n = 74$)	
	Group size	Mean	Group size	Mean	Group size	Mean
RP, SP, CPLS						
(1) Revealed preference	11	7.655	11	7.655		
(2) Stated preference	74	+0.473	74	+0.473*		
(3) CPLS	11	−0.995**				
Overall vs. trimmed means						
(1) Overall	83	7.880	71	8.066	61	8.140
(2) Trimmed	13	0.188	13	0.002	13	−0.072
Private vs. public safety						
(1) Public	20	7.655	19	7.609	18	7.661
(2) Private	75	0.320	66	+0.559**	56	+0.616***
Purpose of the study						
(1) Strictly scholarly	52	8.177	52	8.177	50	8.353
(2) Policy	44	−0.415*	33	−0.182	24	−0.334
Country						
(1) Rest of the world	40	7.661	29	8.041	20	8.155
(2) Europe	56	+0.417**	56	+0.038	54	+0.022
Payment vehicle						
(1) Price of private good					30	8.356
(2) Tax					14	−0.585**
(3) Donation					2	−1.320**
(4) Toll					11	−0.265
(5) Other					17	−0.188
Elicitation method						
(1) Risk level only					21	8.174
(2) Risk level + visual presentation					39	+0.023
(3) Victims in population					11	+0.141
(4) Risk level + explanation					3	−1.373**
Type safety enhancing measure						
(1) Vehicle	52	8.029	45	8.299	39	8.346
(2) Road related	18	−0.200	16	−0.503**	16	−0.550**
(3) Behavior	9	−0.655*	7	−0.682*	3	−0.228
(4) Other	17	−0.143	17	−0.412*	16	−0.421
Format of VOSL						
(1) WTP					67	8.101
(2) WTA					7	+0.281

[a] The first category of each group is used as the reference category, and the figure represents the mean of that group. For subsequent categories, the deviations from the mean of the reference group are presented, and the statistical test is concerned with the comparison of means. Significance is indicated by ***, **, and * for the 0.01, 0.05 and 0.10% level, respectively.

such information is available. Instead, we distinguish studies for *European countries* and for countries in the rest of the world (mainly the US).

For some studies, we can specify the *payment vehicle*, such as prices for safety devices in cars, taxes levied to finance investment in improved infrastructure, donations or tolls for a safe route. We expect free-rider aspects to play a role in case of a donation, resulting in a lower willingness to pay as compared to other payment vehicles.

The *elicitation method* is only relevant for stated preference studies. In addition to the simple information about risk levels, various alternative ways of explanation are possible, including visual presentations.

In Table 2, we investigate the extent to which the means for the studies falling in each of these categories are different. We start with a short discussion of the differences between revealed preference studies, stated preference studies and cost-per-life-saved studies (96 observations). This is followed by a more in-depth discussion of a subset of 74 observations based on the stated preference technique. VOSL values based on the cost-per-life-saved (CPLS) concept are significantly lower than values based on stated preference studies. This can be explained by CPLS essentially constituting the lower bound of VOSL. The fact that a particular policy measure associated with a certain cost-per-life-saved is implemented reveals that the public sector bases its decision on a VOSL that is at least as high as this value. Clearly, the CPLS figures have a rather different nature than estimates based on individuals' revealed and stated preferences. Not only do they provide minimum estimates, they are also formulated at a collective level and do not necessarily reflect individual preferences adequately. We therefore perform a more detailed analysis on a subset excluding CPLS studies and on a subset only comprising stated preference studies.[8]

Estimates based on the set of stated preference studies are presented in the right hand part of Table 2. We start with a comparison of ordinary mean values and trimmed means. Trimmed means are obtained by computing the mean of the middle group of a series of individual estimates, so trimming reduces the distance between the mean and the median. Trimmed means are obviously also less sensitive to outliers, on either side. This makes them an attractive alternative for ordinary means because outliers may easily occur when some respondents do not fully understand the interview questions. We find trimmed means to be slightly lower than ordinary means. This is caused by the distribution of VOSL estimates, which is skewed to the right. Estimates of studies with an immediate policy purpose appear to be lower than estimates of studies carried out for academic purposes. European VOSL estimates appear to be slightly higher than estimates for other countries.

The analysis for the type of safety enhancing measure shows that behavior-related measures tend to lead to lower estimates than vehicle-related measures. The results for different elicitation methods show that in stated preference studies with substantial additional explanation VOSLs tend to be lower. The payment vehicle results show that people's willingness to pay for individual safety through devices for their own vehicle is higher than the willingness to pay via taxes or donations. Finally, we note that the WTA tends to be higher than the WTP, but the difference is not significant in this sample of studies.

We proceed carrying out the Q-tests to detect heterogeneity for the subsample of the data for which the (estimated) variance of the VOSLs is available. This subsample consists only of part of the stated preference studies. The results are presented in Table 3, and show that the meta-sample contains substantial variation both within and between different groups of studies. So, apart from the theoretical reason to reject the existence of "the" VOSL, there is also substantial statistical evidence to suggest that VOSL estimates are heterogeneous within and between groups of studies with different characteristics (see also Section 5). The within group variance is very large in virtually all categories, except for two categories ('WTA' and 'Risk level + explanation') that have only two observations. Similarly, the between groups tests reveal that for all categories the null hypothesis of identical group means should be rejected.

The ANOVA and the Q-test results provide bivariate comparisons leading to useful insights, but a multivariate approach is required to systematically explain the variation in VOSLs. We perform a meta-regression,[9] and specify the exogenous variables in part on the basis of sample information from the underlying studies, but we also use out-of-sample information. The base specification is taken from the set-up given in Eq. (6). In addition to the variables used in the bivariate analysis, two variables gathered from out-of-sample information are included for theoretical reasons, GDP per capita (Jones-Lee et al., 1983; Kidholm, 1995; Miller, 2000) and the actual risk level. Actual risk levels differ among countries and over time, and we expect a higher initial risk level to lead to a greater VOSL (see also Section 2). Most of the contingent valuation studies provide information on the prevailing initial risk level, but this information is not available for all studies. We therefore initially choose to use the empirical fatal accident rate as a proxy for the risk variable. In order to account for temporal differences a variable indicating the year to which the data pertain is included.

Table 4 presents the results of the meta-regression for the complete sample in column I, and confirms that studies based on the cost-per-life assessment have significantly lower VOSLs.[10] Given the conceptual difference between cost-per-life-saved and RP and SP studies as well as the limitations of the cost per life saved estimates we do not discuss the first column of Table 4 in any further detail, and continue with a discussion of studies where the cost-per-life-saved figures have been deleted (column II, $N = 85$), which appears to be very close to column III where only SP studies are considered ($N = 74$). The estimation results presented in column III are concerned with two different versions. In the first variant, presented in column IIIa, all VOSLs have equal weight. This provides an adequate basis for comparison with the results in columns I and II. The second variant, presented in column IIIb, should ideally be based on weighting VOSLs with the accuracy of their estimation (i.e. the estimated variance). Unfortunately, this is not feasible owing to lack of information. As the variance is inversely related to sample size, we use the information about the sample size of the original studies to calculate appropriate weights.

[8] An additional reason for not paying further attention to the CPLS studies is that we did not include a complete list of studies of this type. A complete survey on CPLS would require that not only policies are considered that have been actually implemented, but also those that have not been implemented. The latter would give upper bounds for the VOSL as valued by the public sector.

[9] We did not apply weights to take into account differences in quality between studies. For example, one may argue that studies where small changes in risk are applied are of lower quality because respondents find it difficult to deal with small changes. On the other hand, when they are confronted with large changes, this means that these changes are unrealistic because the base risk is already very low. Thus, it is difficult to give a convincing weighting scheme to correct for quality differences.

[10] One referee pointed out that meta-analysis concerns the analysis of different studies on the same concept. Given the conceptual differences between WTP and CPLS, the first part of Table 4 is not a meta-analysis in a strict sense, it is a regression analysis of differences between estimates of related, but not identical concepts.

Table 3
Q-test results for the variance weighted ln(VOSL)[a]

	Group size	Q_w	Q_b	Q_t
Private vs. Public safety			31.95***	598.45***
(1) Public	9	56.57***		
(2) Private	26	509.93***		
Purpose of the study			14.60***	598.45***
(1) Strictly scholarly	10	71.52***		
(2) Policy	25	512.33***		
Country			51.71***	598.45***
(1) Rest of the world	5	14.03***		
(2) Europe	30	532.71***		
Payment vehicle			34.58***	598.45***
(1) Price of private good	5	153.90***		
(2) Tax	2	29.35***		
(3) Donation	5	5.21**		
(4) Toll	11	61.06***		
(5) Other	12	314.35***		
Elicitation method			127.60***	598.45***
(1) Risk level only	0			
(2) Risk level + visual presentation	20	194.42***		
(3) Victims in population	13	276.39***		
(4) Risk level + explanation	2	0.03		
Type safety enhancing measure			97.13***	598.45***
(1) Vehicle	15	331.70***		
(2) Road related	7	39.30***		
(3) Behavior	2	43.62***		
(4) Other	11	86.70***		
Format of VOSL			335.07***	598.45***
(1) WTP	33	263.05**		
(2) WTA	2	0.33		

[a] Significance is indicated by ***, ** and * referring to significance at the 0.01, 0.05 and 0.10% level, respectively. The analysis is restricted to overall means and contains only VOSL estimates for which the variance is known. As a result, we use only part of the stated preference studies. This subset of the data does also not contain studies in which the elicitation method 'risk level only' is used.

The results show that GDP per capita has a significant impact on VOSLs. The income elasticity of VOSL is relatively high (1.67), but this is a result of high multicollinearity with the included time trend, which is significantly negative. When we delete the time trend, the income elasticity reduces to about 0.50.

Columns II, IIIa and b further show significantly higher VOSLs for purchases of private safety devices, significantly lower VOSLs for trimmed means, and extensive explanations about risk to be negatively associated with VOSL whereas providing absolute numbers of victims significantly increases the VOSL. Survey design is thus of paramount importance, because it significantly influences the magnitude of estimated VOSLs. The differences between the weighted and unweighted variants is rather small and of minor importance.

It is interesting to observe that we do not find significant differences related to the impact of *actual* (i.e. empirical) risk levels on VOSLs, whereas our theoretical analysis in Section 2 implies such an impact. This may be the result of many studies actually dealing with hypothetical risk levels rather than the level of actual risk. We therefore proceed by analyzing studies that explicitly provide initial risk levels and changes in risk levels as used in the questionnaires.

5. VOSL and initial risk level

The theoretical analysis in Section 2 hypothesizes WTP for a given reduction in risk to be an increasing function of the initial risk level. A greater risk decline, as stated in the valuation question, should hence lead to a declining WTP per statistical life. A careful analysis of the studies reveals exactly this hypothesized pattern. For example, in Jones-Lee et al. (1983) the initial risk level is 10 per 100,000, and a risk decline of 2 per 100,000 leads to a VOSL 2,210,000 British pounds. In comparison, a risk reduction of 5 per 100,000 results in a VOSL of 1,430,000 pounds. Similar results are obtained for the data provided in Desaigues and Rabl (1995). Fig. 4 shows the marginal WTP and risk levels associated with the latter study.

One can explain the declining VOSL for higher risk declines by assuming differences in the level of risk decline are not perceived adequately by the respondents of valuation

Table 4
Estimation results for a meta-analysis of ln(VOSL) for different types of studies, weighted and unweighted[a]

Type variable[b]	Variable	All studies unweighted (I)	Excl. CPLS unweighted (II)	Excluding CPLS + RP studies		Stated preference studies (incl. risk information)		
				Unweighted (IIIa)	Weighted (IIIb)	Unweighted (IVa)	Weighted (IVb)	Weighted, stepwise (IVc)
Fixed effect	Constant	7.864*** (4.837)	2.993 (1.490)	4.063* (1.968)	0.885 (0.242)	−2.251 (−1.144)	−0.087 (−0.013)	1.621 (0.321)
Conditioning on income and risk	ln(GDP per capita)	−0.188 (−0.70)	1.670** (2.563)	1.715** (2.537)	2.453* (1.787)	3.984*** (4.685)	2.609 (1.027)	2.097 (1.077)
	Actual risk level[c]	0.013 (0.343)	−0.018 (−0.579)	−0.023 (−0.669)	0.059 (−0.754)	[–]	[–]	[–]
	Initial risk level[c]	[–]		[–]	[–]	0.017 (1.560)	0.037*** (3.102)	0.033*** (3.117)
	Risk decline	[–]		[–]	[–]	0.001 (−0.054)	−0.058** (−1.879)	−0.045** (−1.886)
Revealed vs. Stated preference	Stated preference	0.844** (2.006)	0.989** (2.570)	[–]	[–]	[–]	[–]	[–]
	Cost-per-life-saved	−0.910** (−2.336)						
Overall vs. Trimmed means	Trimmed	−0.365 (−1.462)	−0.531** (−2.295)	−0.568** (−2.454)	−0.460 (−1.627)	−0.642*** (−3.755)	−0.537* (−1.698)	−0.400 (−1.374)
Private vs. public safety	Private	0.421 (1.061)	1.004** (2.959)	0.899** (2.230)	1.526** (2.809)	1.132** (2.219)	1.670** (2.119)	1.772*** (5.989)
Purpose of the study	Policy	−0.382* (−1.805)	−0.184 (−0.895)	−0.228 (−0.717)	0.568 (0.769)	−0.415 (−0.278)	−0.583 (−0.911)	−0.024 (−0.058)
Country	Europe	0.425 (1.294)	0.286 (0.871)	0.370 (0.963)	0.219 (0.273)	0.451 (1.095)	0.569 (0.670)	0.457 (0.922)
Payment vehicle	Tax	1.05 (1.605)	0.596 (1.067)	0.746 (1.153)	0.070 (0.071)	1.030 (0.800)	0.977 (0.554)	
	Donation	−1.693** (−2.025)	−0.989 (−1.288)	−1.219 (−1.415)	−0.497 (−0.432)	−1.724 (−1.252)	0.589 (0.309)	
	Toll	−0.434 (−1.411)	−0.066 (−0.265)	−0.182 (−0.690)	0.188 (0.590)	−0.150 (0.666)	0.433 (1.067)	
	Other payment vehicle	−0.373 (−1.268)	−0.288 (−1.030)	−0.361 (−1.182)	0.297 (0.572)	−0.764** (−1.842)	−0.361 (−0.444)	
Time	Time trend	−0.013 (−0.476)	−0.079** (−2.306)	−0.080** (−2.162)	−0.092 (−1.420)	−1.813*** (−3.671)	−0.098 (−1.137)	−0.440 (−1.629)
Elicitation method	Risk level + visual	0.086 (0.380)	0.123 (0.582)	0.106 (0.479)	0.338 (0.495)	0.428 (1.212)	0.626 (1.073)	
	# Victims in population	0.483 (1.013)	1.245** (2.442)	1.170** (2.132)	2.036*** (3.501)	1.918** (2.716)	1.219* (1.832)	1.192** (2.590)
	Risk level + explanation	1.745*** (4.014)	2.564*** (5.523)	2.262*** (4.874)	1.460 (1.551)	1.935*** (2.938)	1.115 (0.972)	1.684** (2.160)
Type safety enhancing measure	Road related	0.462 (0.734)	0.355 (0.611)	0.441 (0.718)	0.182 (0.248)	0.698 (0.717)	−0.789 (−0.525)	
	Behavior	−0.220 (−0.708)	−0.295 (−1.164)	0.195 (0.661)	−0.059 (−0.099)	0.226 (0.570)	0.003 (0.003)	
	Other	0.017 (0.043)	0.362 (0.823)	0.297 (0.524)	0.216 (0.262)	0.319 (0.344)	−0.693 (0.541)	
Format of VOSL	Willingness to accept	0.083 (0.243)	0.092 (0.282)	0.048 (0.151)	0.030 (0.048)	0.200 (0.362)	1.339 (1.469)	1.228 (1.482)
R^2		0.455	0.442	0.432	0.480	0.609	0.630	0.584
R^2-adjusted		0.309	0.278	0.246	0.311	0.390	0.424	0.475
Probability value F-test		0.00018	0.00153	0.00858	0.00160	0.00454	0.00223	0.00003
Log likelihood		−135.860	−108.1941	−74.9728	−92.3314	−49.009	−56.771	−59.957
AIC		2.661	2.434	2.540	3.009	2.556	2.843	2.665
N		96	85	74	74	54	54	54

[a] Significance is indicated by ***, ** and * referring to significance at the 0.01, 0.05 and 0.10% level, respectively, with t-values in parentheses. For the weights, we use the sample size of the original studies as an approximation of the (inverse) estimated variance.
[b] The omitted category for each variable type is the first category mentioned in Table 2.
[c] Risk levels (initial risk and actual risk) are included in the analysis as number of fatal injuries per 100,000 inhabitants.

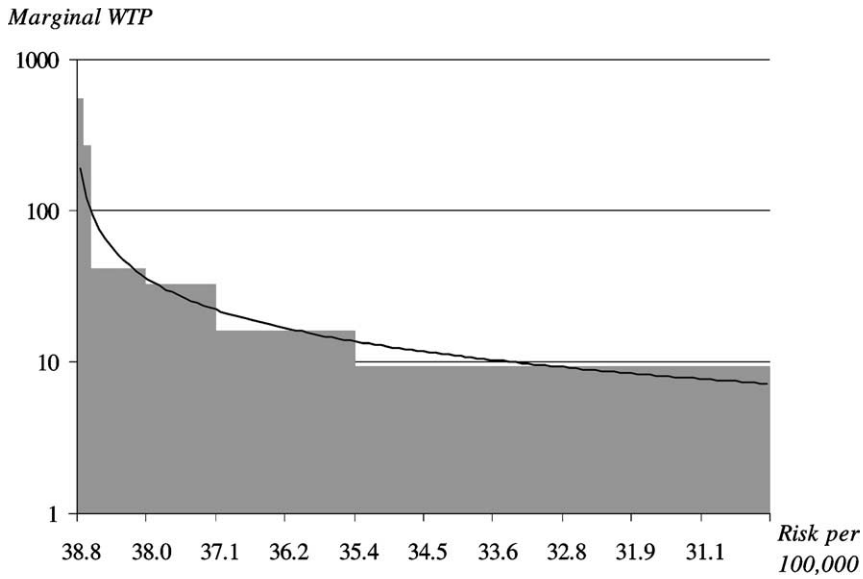

Fig. 4. Marginal WTP (in 1996 US dollars, logarithmic scale) vs. risk levels.

questions. Although this is a potential explanation for differences between studies, it is not conclusive for within-study variation. Between-study differences are likely to result from differing specifications of the initial risk level. In order to investigate whether the pattern is common to all stated preference studies we investigate a subset of studies, with 33 usable CVM estimates, for which we have sample information about the initial risk level and risk decline.[11]

The results are shown in columns IVa–c of Table 4 for unweighted regression, weighted regression, and weighted regression with stepwise backward elimination of insignificant effects related to payment vehicle, elicitation format and type of safety measure, respectively. The parameters related to initial risk and risk decline (as mentioned in the questionnaires) are significantly different from zero, and the directions are conforming expected signs. It thus appears that initial risk levels matter for the estimated VOSL. Consequently, in terms of Fig. 1, these studies seem to be in the range for which the marginal WTP is falling. This also implies that the value transfer approach proposed by Miller (2000) may have to be extended to include initial risk levels next to the level of GDP per capita.

6. Conclusions

Since the 1970s, the value of statistical life in road safety has been studied extensively, using stated and revealed preference methods. Studies have been carried out for different countries and different time-periods, in effect resulting in a wide range of estimated values. We use meta-analysis to investigate the explanatory factors that systematically affect the magnitude of VOSLs.

We show that, as expected, revealed preference studies lead to lower estimates than stated preference studies. This may be explained by revealed preference studies referring to policy measures that are actually implemented, as opposed to purely hypothetical policy measures often used in stated preference studies. For stated preference studies, we find the WTP for risk reduction to be significantly higher when comparing private to public goods, and we also show that differences in survey design (particularly regarding payment vehicle and elicitation format) are of pivotal importance.

Our results suggest that VOSLs cannot be viewed independent of the prevailing level of risk and the hypothesized changes in risk levels. The assumption that “life” can be summarized in a single numerical value (“the” VOSL), as is often suggested by scholars as well as policy makers, is neither sound from a theoretical perspective, nor warranted on the basis of empirical analysis.

Obviously, this conclusion has important implications for the validity of value transfer approaches. Prevailing methods, obtaining VOSL estimates over space and/or time, are biased if differences in risk levels and associated changes in risk levels are not taken into account. Future VOSL studies are affected by this conclusion in a similar manner. It is imperative that respondents are presented with adequate and precise information about the assumed initial risk level and subsequent changes of that risk level. Needless to say that adequacy and preciseness are in this context defined by respondents’ perceptions rather than by a neutral, objective assessment of what is being asked.

Our results also raise the interesting question whether public investment in road safety (and policies affecting private investments in road safety) should be based on ex ante or

[11] This is different and in fact more precise than the actual risk levels used in the preceding analyses, owing to lack of information.

ex post benefits. Both assessments result from a reduction in risk for the entire population affected by a specific policy measure but, with a falling marginal WTP to improve road safety, the two indicators may diverge and therefore imply different optimal levels of investment in road safety.

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