PERGAMON

Accident Analysis and Prevention 35 (2003) 37–46

ACCIDENT ANALYSIS & PREVENTION

www.elsevier.com/locate/aap

Health–health analysis—an alternative method for economic appraisal of health policy and safety regulation Some empirical Swedish estimates

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Received 10 October 2000; received in revised form 15 June 2001; accepted 2 July 2001

Abstract

Health–health analysis (HHA) focuses on statistical lives themselves as a numeraire. The underlying principle is that the expected gains in health and safety of reduced risks in one area may result in increasing risks somewhere else in society. By reducing one risk other risks may increase due to changed individual behaviour.

In addition to this direct effect, another indirect effect will also be present. Expenditure on a particular health policy or safety regulation must be financed in one way or another, which will result in an opportunity cost or income effect leaving less resources for other health and safety promoting activities in society. Thus, we will have an effect that reduces safety and health benefits induced by that income loss. Whether the total net health effect from a specific safety regulation or health policy is positive or negative must be empirically analysed. One way of estimating the income loss that induces one death, which we call the value of an induced death (VOID), is to estimate it as a multiple of the traditional value to avert a statistical death, also named the value of a statistical life (VOSL).

A contingent valuation (CV) study eliciting the willingness-to-pay (WTP) for reducing the overall risk of dying was performed as a postal questionnaire in Sweden in 1998. By use of data from this study, it was possible to estimate the VOID and the VOSL in Sweden amounting to SEK116 and SEK20.8 million respectively, indicating that the net health result confined to mortality effects, will be negative (more lives will be lost than saved) if a health policy or safety regulation will cost more than SEK116 million per life saved.
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Keywords: Risk reduction; Value of statistical life; Economic evaluation; Safety regulation; Induced death cost

1. Introduction

Economists usually argue for economic efficiency, resulting from maximising the difference between benefits and costs, to be a fundamental criterion for evaluating public policies for health, safety and environmental regulations. The golden standard for such assessments is the cost–benefit analysis (CBA) by which all costs and benefits originating from the proposed policy are supposed to be valued in a commensurable unit—money. Decisions based on a CBA-test, advocating recommendation when benefits exceed costs, rely in principle on an ex ante trade-off between, e.g. lives saved and other benefits.

Substantial scepticism and opposition, mostly from non-economists, have focused on both ethical and practical limitations regarding the usefulness of adopting such economic efficiency criteria for social welfare recommendations especially in life saving activities. For instance, one of five ethical principles to justify the Swedish Vision Zero for traffic accident fatalities states that "One must always do everything in one's power to prevent death or serious injury" (Tingvall, 1997). Saving lives can never be regarded too economically expensive when setting road safety policy in line with Vision Zero. Elvik (1999), in opposition to Tingvall (1997), makes an interpretation of this by pointing out that the justification for that principle is that human lives cannot be exchanged for some gain and rules out the trading off of lives for other commodities.

Reluctance to make explicit trade-offs between costs and health benefits have increased the attention given to analytical devices such as cost-effectiveness and cost-utility analyses. These methods avoid monetary valuation of health outcomes and typically compare costs for achieving units

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0001-4575/02/$ – see front matter © 2002 Elsevier Science Ltd. All rights reserved.
PII: S0001-4575(01)00084-7

of health measures that may include both mortality and morbidity effects. Although these methods are not well-founded in welfare economics and are less capable of aiding decision-makers to efficient goals in, e.g. health, traffic and environmental policies, they have a well-documented reputation of practical usefulness in many other ways.

Dating back to Wildavsky (1980), who was one of the first to point out negative health effects due to the opportunity costs of public health spending, the idea behind health–health analysis (HHA) has evolved. Primarily this evaluation method was intended to solve the moral dilemma of valuing life and limb in public proposals and regulations without giving up economic efficiency aspects. HHA is based on the fundament that policies aimed to increase health status should reveal such effects measured in some physical rather than monetary unit, comparing health status with health status. Policies protecting human health should also provide positive health benefits in general. However, risk reducing and health promoting activities proposed in one area or by some policy may have adverse health effects on other areas or for other policies so that the net effect becomes negative. For instance, Lutter and Morrall (1994) and Portney and Stavins (1994) give an outline of an economic context for analysing policies using HHA. By defining a new criterion for evaluating regulations aimed at protecting public health, they focus on both direct and indirect health effects where the sum of these decide the desirability. The health effects should, in principle, encompass mortality as well as morbidity outcomes constituting health status, although empirical applications of the ideas of HHA all seem to confine the analyses by only assuming mortality effects as the numeraire.

As an illustration of the direct effects component in HHA, the intended number of deaths prevented from a risk reducing regulation could be affected by offsetting behaviour by individuals. An example of this is found in the classic study by Peltzman (1975). Driving habits and the effect of using seatbelts were analysed for US car drivers indicating that when using seatbelt they tended to drive faster and less cautious than otherwise. If this change in driver behaviour resulted in an increased number of fatalities among pedestrians, cyclists and other unprotected road users a mandatory seatbelt regulation could in fact reduce or even eliminate the expected safety benefits. This, and similar examples (see, e.g. Blomquist, 1988; Portney and Stavins, 1994; Viscusi, 1994a; Dickie and Gerking, 1997) focus rather on traditional risk–risk trade-off situations leaving out the more controversial indirect health effects associated with the core of HHA to which we will devote most of this paper.

Since the health benefits from a risk reducing programme to some extent are dependent on the compliance costs to that programme, the reduction of disposable income for individuals and households (to finance or comply with the programme) could indirectly result in less resources for other risk reducing activities. Therefore, the reduced resources available for expenditures related to health may indirectly lead to increases in mortality and morbidity. By assuming a positive relationship between income and health, it is possible to estimate the marginal income loss that induces a marginal loss of health. If this unit loss in health is only represented by increases in mortality rates, the loss of one statistical life (the value of one avoided statistical death) induced by the expenditure on safety could be calculated.

A thorough analysis of mortality effects of regulatory cost and policy evaluation criteria is found in a seminal article by Viscusi (1994b), where a risk reduction test is formally stated (see Appendix A). The mortality risk effect could be separated into three components, one indicating the direct effect of a safety regulation on mortality (the intended one), another related to the decrease in an individuals' own investment in health because of the increase in safety (a substitution effect). Finally, there is an effect on mortality through the decrease in health investment because of the decrease in wealth or income due to the increase in regulatory costs (an income effect). In order for a safety regulation to enhance safety or health (an overall increase in survival rates), the sum of these three counteracting components must be positive. By rearranging these terms, Viscusi (1994a,b) formulates a condition for a regulation to be desirable so that the average cost per life saved must be below some critical threshold, the cut-off mortality risk value. This is represented by "the inverse of the marginal effect of health expenditures on mortality multiplied by the marginal effect of assets (income) on health" (p. 102).

The purpose of this paper is to apply the ideas of HHA in the context of traffic risk reduction (e.g. the Vision Zero) as well as in some other areas where safety risks are found. In these areas HHA would be appropriate and could provide a contribution to the decision making process. Confining our health measures only to mortality effects, we can use data from a contingent valuation (CV) study on the value of fatal risk reductions in Sweden in 1998. This makes it possible to provide an estimate of individuals' losses of income that would induce one statistical death—the cut-off value, we will call the value of an induced death (VOID).[1] Health policies or safety regulations, which will cost more than this value per life saved will be counterproductive. By applying that VOID estimate, the net health effects measured by the number of lives saved (or lost) can be calculated for some well-defined regulations and policies. However, it must be stressed that HHA is not an exact science and many of the input values used are surrounded by uncertainty, e.g. regarding estimation methods. Therefore, one should focus more on general aspects than on detailed information of desirability for single safety regulations, here given just as illustrations of the technique.

Empirically, VOID can be calculated either directly from an income–mortality relationship or indirectly using implicit

[1] This concept is also known by the name willingness-to-spend (WTS) (see, e.g. Lutter and Morrall, 1994).

value-of-life figures, estimates that are further discussed in Section 2. In Section 3, a Swedish estimate of VOID by use of implicit value-of-life figures is given. Section 4 presents applications of this value on some safety regulations in Sweden. Finally, Section 5 holds a discussion.

2. Estimations of the VOID

2.1. The income–mortality relationship

One way to calculate the VOID (the induced death cost) is to rely on studies that have directly estimated the influence of individual income on mortality rates. These estimates are controversial for many reasons. Studies of the income–health relationship and especially the income–mortality relationship raises questions like direction of causality. Normally you assume that the level of income or wealth will influence the health status of individuals so that an increase (decrease) in current income will be related to a better (worse) health in some way. This is also the underlying principle for the HHA meaning that changes in induced income will be reflected in the health status. However, the opposite relation could also be true. A good health may increase the possibilities for individuals to earn income. Controlling for initial health status in empirical studies of the income–mortality relationship could eliminate much of the problem of this reversed causality (Chapman and Hariharan, 1994). In addition to traditional problems of confounding factors not controlled for in empirical estimations of the income–mortality relationship, one is faced with the fact that the income observed often is one of the household, whereas the mortality is individually observed. You may say that there exists a public good aspect of family income on all family members at the same time as there are individual differences in risk behaviour (Viscusi, 1994b), which complicates interpretation of the results.

Viscusi (1994a) reports results from some studies relying on direct estimates of the income–mortality relationship. These studies, including works not only by economists but also from demographers and others, reveal an *implicit* value for VOID ranging from US$ 1.9 to 33.2 million (1992 prices). Great differences in aggregation level, estimation techniques, time period analysed, samples being addressed and other factors make comparisons difficult.

An interesting study by Keeney (1997) is based on the relationship between mortality risk and income determined from longitudinal data from a US mortality study including half a million individuals. He estimated a decreasing exponential function implying declining mortality rates when income is increasing, most dominant at low income levels. At high income levels, the mortality limits to a constant (low) rate, which combined with the fact that mortality risk is largest at zero income defines a range of mortality rates possible to be influenced by income. The results suggested a regulatory expenditure leading to one fatality between US$ 5 and 14 million (1991 prices) depending on which income groups and way of financing are assumed to be met with. It is important to note that the functional relationship assumed would not necessarily apply to an identified individual but rather represent statistical risks and is accordingly used to calculate statistical deaths.

A recent Norwegian study by Elvik (1999) based on time series as well as on cross section data shows a negative relationship between income per capita and mortality. The estimated loss of income that induces an additional statistical death varies substantially and ranges from NOK25 to NOK317 million (US$ 3.8–47.5 million) in 1995 prices.

Lutter and Morrall (1994) also report findings from a study based on World Bank data from over 100 low- and high-income countries. Information on longevity and GDP for the years 1965 and 1986 was used to estimate an elasticity of gross mortality with respect to income for the whole data set. Applying this elasticity (−0.27 for an OLS regression model) on the countries' different mortality and gross income data, country specific VOIDs were calculated. For Sweden, a value of US$ 3 million (1980 prices) was reported.

2.2. The value of statistical life linkage

The expenditure generating the loss of one statistical life, VOID, is directly related to the value of a statistical life (VOSL) and the marginal propensity to spend on life saving health care (MPS). VOSL is traditionally defined as the inverse of the marginal effect of health expenditures on mortality. The following equality simplified from Viscusi (1994b) states:

$$\frac{\text{VOSL}}{\text{MPS}} = \text{VOID} \tag{1}$$

indicating that if all of the marginal propensity to spend, out of income, for the reduction of risks to health and safety (affecting mortality) is equal to 1.0, the two value-of-life figures VOID and VOSL will coincide. Normally, individuals would not spend all of an income increase on risk reducing goods and services and consequently the VOID will exceed the VOSL. If information on both the numerator and the denominator of the left-hand side of the above equation are available, it is also possible to calculate a VOID without explicitly estimating the income–mortality relationship. By this indirect method, you avoid some of the technical estimation problems connected with the isolation of the effect of income levels on mortality. On the other hand, you are faced with considerable problems estimating the appropriate value-of-life and the sensitivity of "relevant" health-related expenditures to income. Which expenditure to be included as influencing mortality rates and to what extent is ambiguous. Estimates of VOSL are controversial for many reasons and ranges considerable depending on context, question format, estimation method, etc. (Beattie et al., 1998).

3. A Swedish estimate of VOID

A recent Swedish study (Persson et al., 2000) on the value of risk reduction for fatal accidents provides information on both VOSL and MPS based on *individual* CV data: to our knowledge, the only one existing. In this study, the respondents were faced both with questions about their maximum willingness-to-pay (WTP) for a specified risk reduction of dying of any cause, which makes it possible to estimate VOSL and with questions about their allocation of an additional net income on different items including health and safety promoting ones. This latter information is used to calculate their MPS. The study was performed in Sweden in 1998. The data were collected from a postal questionnaire sent to 5650 individuals aged 18–74 years. It was a split sample study where the magnitude of risk reduction was one of the factors that differed between samples, another was the cause of death, either from any cause or specifically from a traffic accident. The VOSL was estimated from the responses valuing a reduced risk of dying from any cause, information sought as a basis for VOID estimation.

The respondents, valuing a risk reduction of being killed from any cause, were informed of the average annual mortality risk for an individual in his/her fifties, which is 300/100,000. The risk was visualised in a pictorial presentation consisting of 100,000 squares, each illustrating one individual. Three hundred of these squares had been blacked out to represent the number of killed individuals every year. The respondents were then asked to estimate his/her own baseline risk.

> An average year the overall death risk for an individual in his/her fifties is 300 in 100,000. What do you think of your own annual overall risk of dying in the following year? Your risk may be higher or lower than average. Consider your present age and health status.
>
> I think that the risk is ... in 100,000.

The individuals were thereafter asked to state how much he/she was willing to pay for a certain reduction in the perceived risk of dying. Preceding the question, the respondents were asked to consider the following issues when valuing the risk reduction.

> The safety device and the preventive health care will not result in any sacrifices or inconvenience.
>
> It is only you personally who can benefit from it.
>
> The risk reduction has a duration of just 1 year and will only affect your death risk.
>
> Other people's risk is not affected and an accident will not have any impact on your financial situation as we assume that all expenditures and financial losses will be covered by the insurance system.
>
> The amount of money that you pay for the risk reduction will leave less money to consume on other goods and services.

In the main case, the WTP referred to a 30% risk reduction, while other sub-samples valued risk reductions either of 10 or 50%. The question on WTP had the following appearance.

> How much would you at the most be willing to pay for reducing your own annual overall risk of dying by (10, 30, 50%)?
>
> SEK ... per year.

In order to stress the importance of the budget constraint, the respondents were asked to indicate what current consumption they would reduce in order to afford the expenditures for the safety device or the preventive health care. Examples of categories were listed in the questionnaire. A more detailed description of the survey and study method is found in Persson et al. (2000, 2001).

Half of the entire sample (2800) received the overall death questions with a general return rate of 50%. Since many did not answer both the baseline and the valuation questions and after excluding outliers, 732 observations were used to estimate a non-linear function with WTP as the dependent variable and absolute risk reduction as the independent variable by use of a "least absolute deviation" (LAD)-method.[2] The absolute risk reduction is defined as the product of the subjectively perceived annual risk and the (relative) risk reduction stated in the question. Thus, observations from individuals valuing different magnitudes of risk reduction, considering their subjective risk, are used for estimating a marginal VOSL. The practical calculation of a VOSL is made by dividing the WTP-value with the corresponding absolute risk reduction. For obvious reasons, different absolute risk reductions will result in different VOSLs necessitating a choice of an "appropriate" absolute risk reduction (or a range) for point estimates. For want of something better, we have chosen the median value of the absolute risk reduction, 3.25/100,000 and the corresponding (estimated) WTP (SEK675) to calculate the VOSL to SEK20.8 million in 1999 prices.

In order to estimate MPS, respondents in the samples valuing the death risk reduction were also asked to allocate a (hypothetical) monthly net salary increase of SEK1000 into different consumption categories. The question read the following.

> Imagine that you next year will get an additional 1000 (Swedish) crowns in monthly salary after taxes. How would you allocate this income rise? Allocate the 1000 crowns among the alternatives listed. You do not have to

[2] Contrary to the ordinary least-square method, the deviations from the mean value by this method are not squared. Thus, extreme values will not have that great impact on the regression (see, e.g. Greene, 2000). In order to minimise the influence of outliers on the WTP-estimate, this LAD-method is statistically more appropriate for a dispersion of a material such as this. Besides that, the LAD algorithm allows zero-valued independent variables to be included in the analysis, something we think relevant in this study. These arguments are further discussed in Persson et al. (2001).

Table 1
Mean amount spent on each category, low- and high-income groups, all respondents[a]

Categories	Low income (SEK, 1999) $n = 301$	All respondents (SEK, 1999) $n = 1464$	High income (SEK, 1999) $n = 397$
Food	116	64	32
Leisure activities, culture, TV	111	104	103
Alcohol and tobacco	26	16	12
Savings	168	238	310
Clothes and shoes	111	82	67
Housing, utensils, furniture and furnishings	85	77	72
Safety equipment, e.g. life vest, helmet, fire extinguisher, winter tires	63	65	63
Preventive medicine, health care, dentist visits, etc.	137	114	78
Computer, cellular, etc.	26	23	26
Daily travelling and holidays	113	137	162
New car	47	80	73
Total	1000	1000	1000

[a] Source: Persson et al. (2000).

use all the alternatives. When you summarise the amounts at each alternative, it shall sum up to 1000 crowns.

Eleven categories were listed in the questionnaire of which two (safety equipment and preventive medicines) were considered related to health promoting areas affecting mortality rates (Table 1). Consequently, the mean amounts spent on the categories "safety" and "health" were used as estimates of the MPS in this context. It must be stressed that these expenditures are intended to be regarded as marginal or additional to some original situation with income allocated between different types of consumption. The choice of the expenditures related to life saving activities is of course more or less arbitrary and conditioned on the confinement of only mortality effects as a proxy for a more general health concept. The categories selected are believed as the most probable ones in this respect included in the questionnaire. This is of course a restriction of the data and this kind of analysis could be improved by further refinement of the relation between health promotion and consumption categories.

Besides this, the selected MPS might very well differ among different income groups. Paying attention to this we compared a low-income group with a high one. The groups were chosen on the basis of the lower and upper 20-percentile. The low-income group had a yearly income of up to SEK160,000 while the high-income group had an annual income of SEK400,000 or more. Furthermore, these figures are related to household income possibly giving rise to interpretation problems of the influence from income on *individual* risk behaviour (which is asked for) due to the public good aspect of the household income on all family members.

From Table 1, a mean value of MPS for health promoting commodities can be estimated to 0.179 ((65 + 114)/1000). The low-income group would spend a fairly higher amount on preventive medicine than the high-income group. Likewise, the amounts spent on food (however, not chosen in this example as a health influencing factor) if receiving an extra SEK1000 a month is considerably higher in the low-income group.[3] Using the mean value of MPS based on all (1464) observations, the VOID can be calculated to SEK116 million (20.8/0.179). Thus, the expenditures on health promoting (risk reducing) activities that generate an additional statistical death in Sweden, i.e. the VOID would amount to SEK116 million in 1999 prices. This estimation indicates that a safety regulation which cost more than SEK116 million on average per life saved will be counterproductive by causing more deaths than it intends to prevent. This apparently exact value which follows from the underlying assumptions made should, however, not be taken too literally but chosen here only for illustration purposes of the HHA principles.

4. HHA of some safety regulations in Sweden

Table 2 summarises applications of the HHA approach for a sample of life saving interventions in Sweden. These interventions represent different areas of safety regulations. The examples of interventions are taken from published documents and are presented in more detail in Persson et al. (1991), Ramberg and Sjöberg (1996), Nilsson (1999) and Söderström (2000).

In Table 2, the direct health effects are expressed as number of lives saved. Cost per life saved is calculated by dividing the reported total cost for the intervention with the assumed number of lives directly saved by that intervention. No analysis of different cost components in the given total cost concept has, however, been made, which may imply a cautious interpretation of intervention costs. Furthermore, the assumed number of lives saved may be overestimated because usually no consideration to possible behavioural changes is taken. The indirect health effects (in terms of increased number of deaths) due to decreased income is estimated by dividing the total cost with the VOID. In this

[3] These differences were also statistically significant confirmed by Mann-Whitney U-tests ($P = 0.000$ for both food and preventive medicine).

Table 2
Cost-effectiveness, total cost, direct and indirect health effects due to some Swedish safety interventions, in 1999 SEK prices

Intervention	Costs/life saved (M SEK)	Total costs (M SEK)	Direct health effects (saved number of lives)	Indirect health effects due to decreased income (increased number of deaths)	Net health effect (number of deaths)
Termination of nuclear power station[a]					
Optimistic alternative	3400	17000	5	155 (147 + 8)	+150
Pessimistic alternative	–	17000	0	192 (147 + 45)	+192
Safety-lids on wells[b]	146	728	5	6	+1
"Residual current devices" mandatory in all private houses[b]	153	2550	17	22	+5
"Sleeves" on gasoline pumps to remove benzene[b]	255	1275	5	11	+6
Construction of over- and underpass railway intersections[c]	192	384	2	3	+1
Reconstruction of expressways to motorways[c]	18	1708	95	15	−80
Snow tires in wintertime[d]	86–112	515–673	6	4	−2 to 0

[a] Source: Nilsson (1999).
[b] Source: Ramberg and Sjöberg (1996).
[c] Source: Persson et al. (1991).
[d] Source: Söderström (2000).

analysis, we will use the estimated VOID from our CV-study data, SEK116 million. The sum of the direct and indirect health effects gives the net health effect, where a positive sign indicates an increase in the number of deaths. A necessary condition for the health effects to arise is that the interventions are assumed to be fully carried out and that the citizens' behaviour is in accordance with the restrictions and laws that are proposed. As the model and the examples chosen apply to both privately and publicly financed safety interventions enforced by public laws, one must assume here that public decision makers who allocate public money to various health and safety measures (e.g. reconstruction of railways and roads) must do that by new or raised taxes and charges. Just reallocation within a given budget would not give place for the indirect health effects due to decreased consumer income to appear. Implication for health effects (as fatality rates) of different means for public financing could, however, be substantial and is analysed in, e.g. Keeney (1997).

4.1. Termination of nuclear power stations

A plan for termination of one of the nuclear power stations in Sweden has been approved by the Swedish government and one of its two reactors has recently shut down. The termination will reduce the risks of accidents with serious consequences and thereby cause positive effects in terms of expected number of lives saved. In addition, a number of lives will be saved connected to the operating of the nuclear power station as well as to transport and storing of the nuclear waste. However, the shut down will also give rise to negative health effects, both direct and indirect ones.

The direct effects will appear because the nuclear power must partly or totally be replaced with other energy sources. Conceivable options are coal, oil, hydroelectric power, etc. An HHA points out that these replacement sources will, as well as nuclear power, bring health risks. These risks are relevant for those individuals who are involved in the production and those who are exposed to health damaging emissions that are entailed by the power sources.

The scenario presented in Table 2 refers to the governmental decided termination plan, i.e. both the reactors at the nuclear power station Barsebäck are to be phased out, one by the year 2000 and the other by the year 2001. The total cost of the presented termination plan amounts to SEK17 billion in 1999 prices and the induced number of deaths for this scenario are estimated to 150. In addition, one optimistic and one pessimistic alternative are presented and included in the net health result. The optimistic alternative refers to a maximum of five lives saved and a lowest value of eight new deaths. The pessimistic alternative refers to zero lives saved and a highest number of 45 new deaths (Nilsson, 1999).

The HHA shows that the termination will lead to numerous deaths, irrespective of an optimistic or pessimistic alternative. The termination will induce a larger number of deaths because of the decrease in income than the number of lives saved associated to the decreased risk of severe accidents at the nuclear power station. Therefore, the shut down of the Swedish nuclear power station will be very costly, both in terms of money and decreased health status.

4.2. Safety-lids on wells

A proposal from the National Board of Housing, Building and Planning concerning regulations of implementation of safety-lids on wells would result in a total cost of SEK728 million. If the wells have sufficient lids, almost all accidents with wells could be avoided (Ramberg and Sjöberg,

1996). The cost per statistical life saved would amount to SEK146 million. This intervention would, according to a health-health approach, result in an increased number of deaths by one.

4.3. "Residual current devices" mandatory in all private houses

In 1991, the National Electrical Safety Board came to the conclusion that it ought to be compulsory for every private house to have a "residual current device". The safety device should prevent a number of deaths caused by electrical accidents. The costs of installation in all houses were calculated to almost SEK2.6 billion and the cost per life saved would amount to SEK153 million (Ramberg and Sjöberg, 1996). The realisation of this safety intervention would also result in an increased number of deaths.

4.4. "Sleeves" on gasoline pumps to remove benzene

The Swedish Environmental Protection Agency decided in 1990 that every petrol station, selling more than 2000 m^3 of gasoline annually for motor vehicles, should be equipped with "sleeves" on all gasoline pumps. This intervention would, in addition to saving human lives also save gasoline that otherwise would have been wasted. The total cost was estimated to nearly SEK1.3 billion according to the calculations by the Swedish Environmental Protection Agency. The costs per statistical life saved would amount to SEK250 million (Ramberg and Sjöberg, 1996). The net effect of this intervention would lead to an increase in number of deaths by six.

4.5. Construction of over- and underpass railway intersections

In 1998, a road traffic safety programme was drawn up by the Swedish National Road Safety Office (TSV) together with the National Council for Road Safety, that aimed at reducing the number of deaths with 400 until year 2000 (Hedman and Stenborg, 1991). TSV and the Swedish Transport Research Board (TFB) commissioned a group of experts to compile basic data for the 1990 road safety programme. The experts developed a method for socio-economic ranking of road safety measures and used the method in a proposal for such a ranking needed to achieve the road safety goals at least cost (Persson et al., 1991). One of the 32 safety interventions presented in this proposal was the construction of over- and underpass railway intersections. The cost per life saved of this intervention was estimated to SEK192 million. If these interventions were carried out at a total cost of SEK384 million, they would save two lives, but they would also cause a decreased purchasing power of the consumers and thereby a changed consumption pattern. This would consequently lead to three premature deaths. Therefore, a construction of over- and underpass railway intersections would indicate a net health loss of one statistical life.

4.6. Reconstruction of expressway to motorways

The reconstruction of expressways to motorways presented in Table 2 shows a net gain of lives saved. The number of lives saved outnumbers the loss of lives, despite the reduction of income, if the improvement of the road standard on highly busy roads is conducted (Persson et al., 1991). The estimated net effects on health imply that 80 lives will be saved by this intervention.

4.7. Snow tires in wintertime

Since December 1999, a new Swedish regulation implying a mandatory use of snow tires between December and March is in force for all cars. According to the National Road Administration, this regulation is supposed to save at least six lives per year. The intervention costs for this is estimated between SEK515 and SEK673 million per year depending on compliance assumptions (Söderström, 2000). The costs mainly consist of expenditures for road maintenance, new tires and costs for environmental effects, e.g. additional cleaning of the car and elevated noise levels. Estimated costs per life saved would be SEK85–SEK112 million indicating a possible net health gain of two statistical lives.

5. Discussion

In this paper, we used data from a nation-wide CV-survey in Sweden to collect information of both the VOSL and of the MPS. The VOSL was estimated to approximately SEK20 million (US$ 2.4 million) in 1999 prices based on valuation of overall death risk reductions. The adopted MPS-estimate amounts to 18% of a monthly increase in income. Thus, the expenditures or the income loss that induces an additional statistical death, which we have called VOID, was calculated to SEK116 million (US$ 13.3 million). The study reported here uses a value-of-life figure coupled with a marginal propensity to consume on health. This estimation technique for the expenditure per statistical life lost generally implies higher values than those emanating from income–mortality data (Viscusi, 1994b). An estimate procedure comparable to ours of a VOID is found in Viscusi (1994b), where a midpoint estimate of a value-of-life of US$ 5 million and a MPS of 0.1 (equal to average propensity to spend on health care) results in a cut-off value of US$ 50 million for safety-enhancing regulations.

Estimated as the ratio of VOSL over MPS the VOID is consequently sensitive for value-of-life-estimations and for which components to include in the propensity to spend concept. The context in which the VOSL is estimated

could result in quite different values (Sunstein, 1997). In our study, we used a value based on answers from risk reduction of overall death. In the CV-study we also asked for payment for a risk reduction concerning a fatal traffic accident. Calculated by the same econometric method, a close VOSL-estimate, SEK23.9 million was found for a policy-relevant absolute risk reduction (2.4/100,000) in the Swedish road traffic sector (Persson et al., 2001). Besides the context from which data are collected, estimation techniques are important and may influence the results. There is a potential upward (downward) bias of VOID if the VOSL is overestimated (underestimated). Comprehensive tests of the validity and the relevance of the VOSL-estimate from the road traffic sector by use of open-ended WTP-questions in a CV-method have been performed (see, e.g. Persson et al., 2001; Norinder et al., 2001). The figure used for the VOSL should be regarded more as an illustration of the HHA-principle than some truthful estimate.

Another reason than an overestimated VOSL for the estimate of VOID to be biased upward would be an underestimation of the MPS on items and services that are expected to affect the death risk. If all expenditures on preventive medicine, health care, dentists, etc., refer to items directly related to health risk reduction, these expenditures would according to our data represent 11.4% of a marginal personal income increase which together with marginal expenditures on safety equipment of 6.5%, add up to the 17.9% used. Assuming no impact on health and life expectancy from other expenditures, e.g. food, clothes, housing and new car, our estimate of a MPS of about 18% would be adequate. However, if some of the extra income allocated to, e.g. food is used for purchasing health promoting food, then this should be added and the estimate of the MPS would rather be something between 18 and 24%. The 24% can be seen as an upper bound of the denominator in the equation, so that a resulting (conservative) estimate of a VOID would at least be four times as large as the marginal VOSL. This percentage figure compares well to the estimated MPS of 0.238 for Sweden based on macro data by Lutter and Morrall (1994).

On the other hand, underestimation of VOID would be the result if the estimate of MPS is too high. For example, if not all expenditures on preventive medicines, health care, dentists, etc. are devoted to health promoting activities, then the MPS overestimates the impact of health risk reduction and the VOID would accordingly be underestimated disqualifying too many safety regulations.

Besides the question of which consumption items to be included in the MPS-concept, the empirical estimation procedure may be of importance. In this study, we derived our estimates from questions of how to allocate an *increase* in monthly income to different consumption alternatives. Different allocations should probably arise from questions of an equal *decrease* in income. It is not the same thing to allocate an increase as a decrease in income. So, in this context where we are analysing the indirect health effects of a private disposable income decrease, a measure of MPS reflecting this is wanted but at present not available.

An extension of the model to include expenditures that harm one's health like smoking and excessive drinking is found in Lutter et al. (1999). This means that the corresponding MPS now will include health-enhancing as well as health-reducing expenditures. (see Appendix B). The cost per total risk reduced must accordingly be below a cut-off value for safety-affecting activities including all these expenditures. For instance, the implied value of the income loss associated with one additional fatality was calculated by Lutter et al. (1999) to US$ 15 million to be compared to US$ 50 million encompassing only risk reducing expenditures. An application of this procedure on our VOID estimate will reduce this value, thus tightening the risk reduction test.

We also found that MPS on safety equipment and health promotion varies by income. Data from our CV-study shows that individuals in the lower 20-percentiles of household income have a MPS of 20% and individuals in the upper 20-percentiles of household income have a MPS of 14%. Thus, individuals' marginal willingness-to-spend on safety equipment and preventive medicine varies with income in the same way as their marginal willingness–to–spend on food, on alcohol and tobacco and on clothes and shoes. Since the VOID is inversely related to MPS with respect to income, the estimate of VOID would be highly sensitive to income in our data. Our results indicate that the burden of payment of a regulation is important for a HHA in Sweden. This also indicates that a regulation for which the economic burden is placed on relatively poor people would result in a lower VOID compared to a situation when the cost is born by wealthier groups of people. The implication of the VOID's relationship to income is that a safety regulation paid primarily by low-income households will result in higher health risk somewhere else in society (and causes more loss of income induced deaths) than if the safety regulation would have been paid by higher income households.

One of the policy implications of the relationship between income and mortality risks is that it raises the question of which value-of-life to be used. Assessing the attractiveness of safety regulations by use of a cost–benefit test, Viscusi (1994b) suggests a slightly higher VOSL than the implicit value-of-life used in his analysis. If authorities do not want to adopt a cost–benefit approach evaluating safety regulations and health policies, the HHA introduces a new test where a policy to be beneficial in terms of only mortality risks must show no net increase in these. The condition for this is formulated so that the average cost per life saved imposed by the policy must be below some critical threshold, the VOID, which also is linked to the VOSL.

Focusing on the risk reduction test described here comparing lives with lives may be less demanding than a traditional cost–benefit test when it comes to practical policy for restructuring or rejecting proposed new expensive risk regulations and health policies. Accepting an upper limit, in this study estimated to SEK116 million, may be a binding

constraint for many interventions as some of the examples in Table 2 show and accordingly work as a first guide for exclusion of the most undesirable policies. On the other hand, HHA must not be regarded as a substitute for a full CBA also taking into consideration impacts on other areas besides the health and safety sector, which sometimes are important.

Further extension and refinement of HHA is, however, desirable for a wider application on safety and health enhancing policies. Typical candidates for such an improvement include an incorporation of morbidity effects and a time dimension, which is now missing in the analysis.

Acknowledgements

The research in this article was funded by the Swedish Transport and Communications Research Board. However, the opinions expressed in the article are solely the responsibility of the authors and do not necessarily reflect the views of the sponsor. We are grateful to Rune Elvik, Paul Dolan, Håkan Holm and two anonymous referees for helpful comments and suggestions.

Appendix A. An individual one-period model

The individual one-period model is based on Viscusi (1994b), "Mortality effects of regulatory costs and policy evaluation criteria", where A is the individual's income, ΔA the decrease of individual's income due to regulation, s the safety level, Δs the changes in safety level, h the individual's own investment in health and safety, q the probability of survival, $q = q[s, h(A)]$.

The risk reduction test can be formulated as $\Delta q > 0$ and is stated as follows:

$$\Delta q = \underbrace{\frac{\partial q}{\partial s}\Delta s}_{\text{(i)}} + \underbrace{\left[\frac{\partial q}{\partial h}\frac{\partial h}{\partial s}\right]\Delta s}_{\text{(ii)}} + \underbrace{\left[\frac{\partial q}{\partial h}\frac{\partial h}{\partial A}\right]\Delta A}_{\text{(iii)}} > 0 \quad \text{(A.1)}$$

where (i) is the direct effect of safety regulation on mortality > 0, (ii) the effect of the higher safety level due to changes in own investment in health and safety < 0, (iii) the effect of reduced income on health investment and mortality < 0.

Collecting the terms and rearranging the above gives the following:

$$-\frac{\Delta A}{[(\partial q/\partial s) + (\partial q/\partial h)(\partial h/\partial s)]\,\Delta s} < \frac{1}{(\partial q/\partial h)/(\partial h/\partial A)} \quad \text{(A.2)}$$

where the left-hand side in Eq. (A.2) is the cost per saved life due to the regulation. The right-hand side is the "cut-off value", i.e. the VOID, which is the marginal value-of-life, $1/(\partial q/\partial h)$ (VOSL) divided by the marginal propensity to spend on health and safety, $\partial h/\partial A$ (MPS). Thus, the VOID can be estimated by using the VOSL and MPS as given by Eq. (1).

Appendix B. An extended model with risk increasing activities

An extension of the model in Appendix A is to also include health-reducing or risk-increasing expenditures. Lutter et al. (1999) now consider the following:

$$h_i \quad (i = 1, \ldots, n)$$

where h represents the individual's different expenditures, h_1 is the health improving/risk reducing, h_i the health reducing/risk increasing ($i = 2, \ldots, n$).

The probability of survival q, can then be written as

$$q = q[s, h_i(A)]$$

and accordingly, the risk reduction test from Appendix A will now formulate as

$$-\frac{\Delta A}{\left[(\partial q/\partial s) + \sum_{i=1}^{n}(\partial q/\partial h_i)(\partial h_i/\partial s)\right]\Delta s} < \frac{1}{\sum_{i=1}^{n}[(\partial q/\partial h_i)(\partial h_i/\partial A)]} \quad \text{(B.1)}$$

where the left-hand side of Eq. (B.1) is the cost per total risk unit that is decreased. This cost per total risk reduced must be below the "cut-off" value when *all* safety or risk affecting expenditures are included, the right-hand side of the equation.

As a simplification, assume only two expenditure-groups ($i = 1, 2$), where 1: risk reducing and 2: risk increasing.

The right-hand side of Eq. (B.1), which denotes the new cut-off value, now simplifies to

$$\frac{1}{\sum_{i=1}^{2}(\partial q/\partial h_i)(\partial h_i/\partial A)} = \frac{1}{(\partial q/\partial h_1)(\partial h_1/\partial A) + (\partial q/\partial h_2)(\partial h_2/\partial A)} \quad \text{(B.2)}$$

The additional second term in the denominator of the expression in the right-hand side of the equality (B.2) consists of a product of two negatively signed partial derivatives resulting in an increase of the total value of the denominator in (B.2) in comparison to the situation where only risk reducing expenditure were considered (only the first term). Therefore, this now leads to a lower cut-off value tightening the risk reduction test for different risk affecting policies.

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