Are all lives of equal value?
-Studies on the economics of risk regulation

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Stockholm, September 1999.

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CONTENTS

PREFACE

What could possibly motivate a thesis about the economic value of a human life? Is it, to use Paul Samuelson's [90] words, simply "mental gymnastics of a peculiarly depraved type"? I believe not. Decision making about risks is, literally, a matter of life and death. Economic analysis of those decisions may give important insights and knowledge about the processes behind risk policy, which of course is interesting in itself. If it could also help in making more informed decisions, much could be gained. Since the stakes involved in the regulation of risk are high, it is in the interest of all citizens that the resources invested to save lives are used efficiently. At the same time, it is a challenge for decision makers to properly handle important ethical and distributional issues.

The overall goal of the thesis is to deepen the understanding of collective decision making about risk, particularly government risk regulation, by studying a select set of problems, using a variety of methods. This thesis does not give a conclusive answer on how to regulate the risks we, by choice or accident, are exposed to. My hope is, though, that the reader will be stimulated to think about risk regulation in terms of the issues raised here.

Stated simply, this thesis takes the general policy problem concerning how much different risks are, or should be, reduced as a starting point. The complexity of the problem makes an interdisciplinary approach indispensable. Contributions to the exploration of decision making on risk have come from many fields, e.g. psychology, economics, decision science, statistics, political science and sociology. Although focused on economics, my work draws from all of the above mentioned fields (except perhaps sociology).

OUTLINE OF THE THESIS

The thesis, as is customary in economics, consists of a collection of articles. There is a rather extensive introductory chapter. The reason for this is that the area is so vast and that many things not covered in the articles deserve mentioning. In particular, the introductory chapter contains a discussion on the reasons why expenditure per life saved varies so much, which is an important part of the thesis. Also, the introduction includes critical discussions of utilitarian theory, attitude and preference measurement and collective decision making on risk. These are all pertinent issues in the articles where space limitations have hindered me from giving them due consideration.
An unfortunate consequence of putting together a collection of articles is that there is bound to be some repetition. To make matters worse, to make the

arguments clear, some things are also repeated in the introduction. For this, I apologize.

There are seven chapters, in the following order. The reader is also provided with abstracts of the chapters:

Chapter 1: *Introduction, summary and discussion*

Chapter 2: *The cost-effectiveness of lifesaving interventions in Sweden*

With Lennart Sjöberg.

In this article, the cost-effectiveness, together with references, are presented for 165 lifesaving interventions in Sweden. The cost-effectiveness of interventions has been found in publicly available analyses, or in some cases been calculated by us. Several of these interventions produce net savings for society, but the most expensive interventions cost several hundred million SEK, or more, per life saved. To improve the comparability of the interventions, certain criteria have been used to standardize the estimates. Still, dissimilarities in the calculation of implied life values remain and the quality of the original data is in some cases uncertain. Despite this and the fact that the interventions do not constitute a representative sample, it is nevertheless possible to conclude that implied life values vary greatly both within and between different sectors of the Swedish society, much in the same manner as in current US analyses.

Chapter 3: *The importance of cost and effectiveness for attitudes towards lifesaving interventions*

With Lennart Sjöberg.

The results from a survey of attitudes towards lifesaving interventions in Sweden are reported. We find that the median respondent accepts a variation in cost per life saved of a factor 97. In earlier studies of the public's preferences, the public has been found to support a variation in the cost-effectiveness of lifesaving interventions which is many times smaller than what we found and also many times smaller than the variation for actual interventions. Our view is that cost considerations might have been made too salient in those earlier studies, compared to the real-life situations in which preferences or attitudes are formed and expressed. When trying to explain the variation in respondent attitudes using various program attributes and background variables, we find that cost and absolute effectiveness of interventions are insignificant predictors of people's attitudes. The perceived magnitude of consequences and, to some extent, relative effectiveness are more important.

Chapter 4: *Listening to the vocal citizens: How do politically active individuals choose between lifesaving programs?*

Large disparities in the cost per life saved for different lifesaving interventions have been reported in many studies. According to some researchers, these differences reflect the public's preoccupation with selected qualitative aspects of risk. However, it is not obvious that these disparities reflect public preferences. In studies of the variation in cost per life saved that the public accepts, most respondents are willing to trade qualitative characteristics for lives saved. Yet, there is a small but significant group of respondents who will not make the tradeoff, i.e. assign infinite value to one or more of the qualitative factors. It has been suggested that this group could be particularly vocal, which might account for the large variation in cost per life saved. In the first attempt to address this issue, a survey of people living under a power line in Stockholm was undertaken. This population was chosen because the local government had decided to remove the power line after being pressured by the citizens and an interest group. Tests of how more politically active individuals differ from less active were undertaken. Most importantly, it was found that more politically active respondents were less likely to trade qualitative characteristics for lives saved, but only for the risk in which they were active and only up to a point.

Chapter 5: *Trust, risk and politically active citizens.*

Like chapter four, this chapter deals with politically active individuals. The chapter is in fact based on the same survey as chapter four, but address different questions. Given that interest groups and politically active individuals have a substantial impact on risk policy, there is a potential democracy problem. Especially if this group is not representative of the general population. The extent to which this group is representative is an important question, one that is explored in this chapter. The chapter also deals with *trust*. The inclusion of a trust variable is motivated by the recent claims that trust is a strong determinant of political activity. However, the direction of causality can be challenged; do people distrust e.g. the local government because they are active or are they active because they distrust the government? In the paper there is some support for the latter direction of causality, because it was found that political activism was correlated to distrust in the national government –a political entity that has not been involved in the issue at hand. To the best of my knowledge, this paper represents the first attempt to answer the question how trust is related to actual political activity to reduce risk. As it were, trust was somewhat important, but the strongest determinant of political activism turned out to be perceived personal risk. An implication of this is that politicians probably overestimate the public's concern about the risk. A relatively large proportion of the variation in trust in the local interest group could be explained with a model containing risk and background variables. A smaller, but still significant, proportion of the variation in political activity could also be explained.

Chapter 6: *When should expenditure per life saved vary?*

With John D. Graham.

Huge variations in expenditure per life saved have been documented in the U.S.A., Sweden, and Japan, as outlined in chapter two. Using an original-position argument, we examine normative rationales that might permit departures from equalization of marginal lifesaving investments. We conclude that adjustment for identifiability, as reflected in strict benefit-cost analysis, is not justified yet adjustments for consideration of longevity, quality of life and productivity are compelling. Less clear are whether factors such as ability to pay, voluntariness and catastrophic potential should influence lifesaving expenditures.

Appendix: *Examples of cost-effectiveness studies:*

The appendix provides brief descriptions and cost-effectiveness calculations for seven lifesaving interventions.

1. Residual Current Devices
2. Age limit on smoking
3. Soft lamp posts
4. HIB-vaccination
5. Security packages for battered women
6. Reducing childhood leukemia by moving power lines under ground.
7. Screening for prostate cancer

CHAPTER ONE.

INTRODUCTION, SUMMARY AND DISCUSSION

I would like to thank Tore Ellingssen, Arvid Nilsson, Edward Schwartz, Amatya Sen and seminar participants at Harvard University for valuable comments on various parts of this chapter. Francisca Mora-Morrison gave invaluable editorial support, and other services, in the preparation of this chapter. The responsibility for any error remains with me.

1.1 INTRODUCTION

Risk policy, in the sense that I will use the word, is concerned with societal decision making about risks to human health and safety. The aim of these policies is generally to mitigate or eliminate specific health risks to a target population. This is an important area of inquiry because of the prominence health and safety concerns always have had, and continue to have, in society. As an indicator of this, note that in the USA alone, $150 billion are spent annually on risk and environmental regulation[1] [57].

This chapter commences with a section on the variation in cost per life saved and why that variation is a problem. Next, some explanations to why cost per life saved varies so much are presented and discussed. Normative questions, like how much a particular risk should be reduced, can fruitfully be addressed in a utilitarian framework, but that approach is not unproblematic. The following sections discuss some problems with utilitarianism for collective decision making on risk.

1.2 THE VARIATION IN COST PER LIFE SAVED

The impetus for this research was the observation that the cost of saving a life in the U.S. [33], [107], [1], [76], [34], [13], [93] and the UK [104], varied tremendously between different interventions, risks and sectors of society. Later, the same variations have been found also in Japan [56]. It was postulated that the same was true also for Sweden. Two earlier works had suggested this, using only small samples [40], [101]. The research question was, then, *why* do the costs vary so much? As it were, that initial question turned out to be too general and instead a few more specific lines of inquiry within that framework have been pursued.

1.2.1 Why is the variation a problem?

First, why are large variations in cost per life saved a potential problem? A somewhat simplified answer is that the price of departure from equalization of marginal expenditure to save a life is less lifesaving. Tengs and Graham [108] explored this issue, using a database of two hundred lifesaving interventions, and found that 60,000 lives are lost (i.e. not saved) every year in the United States, due to a 'wasteful' allocation of resources. That is, if marginal expenditures to save a life were equalized across all interventions, 60,000 more

[1] Unfortunately, there are no corresponding numbers available for Sweden.

lives would be saved every year in the U.S. A corollary to this is that the same number of lives could be saved at a much smaller cost.
To talk about "lives saved" is of course somewhat of a misnomer, since, to the best of my knowledge, everyone will die sooner or later. In that sense, lives can never be saved, only prolonged, which is why it is more appropriate to talk about life-years saved. Therefore, when "lives saved" is used in the text, the reader should be aware of this qualification.

Formally, in a Pareto-optimal allocation of lifesaving resources, all consumers' marginal rate of substitution between every pair of lifesaving interventions must be equalized. If we assume that an individual's utility from a lifesaving intervention is a function only of the number of lives saved, the implication would be to require that the marginal cost of a life saved should be equal for all interventions. To see this, assume a continuous utility function for lifesaving interventions X of the form U(S, C) where S is the number of lives saved from the intervention and C is a vector of qualitative characteristics of the risk and the intervention. A social planner then solves the following maximization problem

$$\text{Max}\sum_{i=1}^{N} U(s_i, c_i)$$

$$s.t.\sum_{i=1}^{N}(p_i x_i)$$

Where $p_i >> 0$ is the marginal cost of intervention i and B is the total budget allocated to lifesaving interventions. B is a compact set and with a continuous utility function the utility maximization problem has a solution. For two arbitrary interventions i and j the solution is given by the first order conditions,

$$\lambda = p_i U'(s_i c_i)$$

$$\lambda = p_j U'(s_j c_j)$$

$$\frac{U'(s_i c_i)}{U'(s_j c_j)} = \frac{p_j}{p_i}$$

That is, in an interior optimum the social planner's marginal rate of substitution between any two interventions must be equal to their marginal cost ratio.

If the utility received from a lifesaving intervention is a function only of the number of lives saved, the first order condition is

$$\frac{U'(s_i)}{U'(s_j)}=\frac{p_j}{p_i}$$

or, in words, that the marginal cost per life saved must be equal for all interventions.

Note that continuity of the utility functions implies that the lifesaving interventions must be continuous. This is a somewhat unrealistic assumption since many programs are characterized by discontinuities; a particular program may, e.g., be administered either to everyone or not at all. In other cases, there are only so many people at risk and when everyone has been given, say, a vaccination, there is nothing to do even if the cost-effectiveness suggests that more people should be vaccinated.

An additional problem associated with spending excessively on some interventions is the effect on fatalities of the induced reduction in disposable income. Some lifesaving interventions may have a negative net effect on fatalities because reductions in disposable income lead to increased mortality risk. The computation of the net number of lives saved from regulations was called risk-risk analysis by Viscusi [120], who summarized evidence from American data where it has been found that an income loss of $2 –33 million will induce one fatality. Thus, regulations that cost more than that will be counterproductive.

A first important task was to examine to what extent the variation in expenditure per life saved found in the United States was present also in Sweden. This is the topic of the second chapter in this thesis: *The cost-effectiveness of lifesaving Interventions in Sweden.* The results reported in that paper strongly suggested that also in Sweden there is a very large variation in cost per life saved, much in accordance with the U.S. data. However, comparing cost per life saved between countries like this is somewhat complicated. An intervention with a particular cost per life saved in one country will not in general have the same cost-effectiveness in another country. There are several reasons for that. Productivity loss is often a substantial cost avoided with an intervention and productivity differs between countries. Demographics, like life expectancy, may also differ substantially among countries. Organization, costs and financing of health care varies, which affects cost estimates. This is especially true when the U.S. is compared to e.g. Western Europe. Benefits other than lives saved vary in scope and magnitude between countries and, importantly, they may also be valued differently. All this contributes to making comparisons of cost-effectiveness between countries somewhat difficult. However, it is likely that estimates obtained in one country are reasonable indicators of the cost-effectiveness in other countries as well.

Note that in chapter two, a concept called "implied life-values" is used. Later I have endorsed the common position that "implied life-value" has inappropriate connotations in that it assumes a deliberation on behalf of the decision maker that may not be present. Therefore "cost per life-year saved" is a better term.

Some of the reported cost-effectiveness estimates concern programs that are only proposed. Of course, an efficiency problem arises only to the extent that expensive programs are implemented and inexpensive programs are not. Besides, most of the programs reported in chapter two are in fact implemented.

There are methodological inconsistencies that could explain some of the discrepancies in the estimates of marginal expenditure per life saved. The sources of these methodological inconsistencies are outlined in chapter six of this thesis. In short, they concern a lack of consistency in cost-benefit and cost-effectiveness analyses both within government agencies and in the peer-reviewed literature.

However, the reported disparities in lifesaving investments are unlikely to be a complete artifact of analytical inconsistencies. The disparities often span several orders of magnitude and, in some cases, it has been shown that a movement toward analytical consistency would tend to exacerbate the reported discrepancies rather than reduce them [107], [33].

1.3 EXPLAINING THE VARIATION

Assuming the variations are real, the cost per life year saved has been suggested to vary between interventions for several reasons. First of all, the assumption that an individual's utility from a lifesaving intervention is a function only of the number of lives saved has been widely challenged [44]. Then, as we have seen, some variation is mandated. In a democratic society, decision making is supposedly an aggregation of the public's preferences (a somewhat oversimplified statement that is qualified in chapter five) and if the public feels that there should be a premium on saving some lives, government regulation naturally should reflect this. According to e.g. Starr [105] the, divergent, investments in risk reduction are roughly at a societal optimum, in which people's preoccupation with the qualitative aspects of risk is reflected.

Chapters three and four report results from surveys in which people's attitudes towards, and preferences for, variation in cost per life saved have been investigated. Earlier research into that question is discussed in those chapters. Briefly, however, it has earlier been found that the public accepts a variation of a factor two or three. This simply means that a more desired intervention could save as little as a third of the number of lives saved by the less desired intervention and still be chosen in a pair-wise comparison. Thus, the large variation that can be seen in actual costs per life saved, which varies by a factor of thousands or millions, could not be justified or explained in any of those studies.

However, the answer you get to questions about accepted variation is largely dependent on how you ask the question. The study reported in chapter three illustrates the point. By studying attitudes, rather than preferences, and incorporating some other aspects into the design of the survey, it was found that the median respondent accepted a variation of a factor 97. That is considerably more than what had been found in earlier studies. In chapter four, in contrast, a preference approach is used and the accepted variation is in the more modest .5-10 range.

So, what is the "right" answer, should attitudes or preferences be studied? That is a quite intricate problem and the next section is a digression on that subject.

After the digression on preferences, another line of explanation for variations in cost per life saved will be considered: Institutional factors.

1.3.1 Attitudes or preferences?

This section is an attempt to give an overview and critical discussion of models to study individual decision making in general and how they relate to preference measurement in particular. The starting point of the discussion is utilitarian and the first part of the section presents the so-called expected utility theory and some empirical evidence from psychology that behavior often contradicts the predictions of the theory. Subsequently, alternatives to expected utility from psychology are discussed in the framework of attitudes and an attempt to link the two concepts is made. But the expected utility theory is also normative and the normative claim is primarily based on the alleged rationality of the model. Therefore, the paper proceeds with a discussion of rationality and the concept of ecological rationality is introduced. Next, the psychometric model of risk perception is presented. The second to last part is devoted to the practical measurement of attitudes. Finally, some conclusions complete the section.

1.3.1.1 Expected utility theory

The relevant utilitarian theory in this area is the theory of individual decision making under risk as first formulated by von Neuman and Morgenstern [121]. A convenient setting in which to formulate a theory of decision making under risk is to use lotteries over outcomes. I will follow Knight's distinction between *risky* and *uncertain* outcomes [58]: Risky refers to situations in which the probabilities of the outcomes are known and uncertainty when the probabilities are not objectively known.

A *lottery* is a list of probabilities $L = (p_1,....,p_N)$ that assigns probabilities to a set of outcomes. Preferences over lotteries can be given considerable structure by a set of axioms first formulated by von Neuman and Morgenstern: The first axiom ensures that the preference relation over lotteries is complete and transitive. The second axiom, the Archemedian (or continuity) axiom, says that it is always possible to construct a lottery over the best and the worst alternatives such that the decision maker will prefer this lottery to an intermediate alternative with certainty. The third and final axiom, the independence axiom, says that if the decision maker is equally satisfied with two alternatives, then he is also willing to substitute one alternative for the other in a lottery. Or equivalently, the preference ordering of two alternatives is not affected by the particular third alternative they are mixed with in a lottery.

With these axioms it is possible to construct a utility function of the *expected utility* form:

$U(L) = u_1p_1 + ...u_Np_N$

that satisfies the property: $U(\Sigma_k p_k L_k) = \Sigma_k p_k U(L_k)$

This utility function is linear in the probabilities and expected utility is a cardinal property, i.e. utility differences have meaning. Within this framework it is possible to use the standard concept of utility maximization also for risky choices.

As mentioned earlier, the expected utility theory of von Neuman and Morgenstern is concerned with choices under risk, i.e. when the probabilities are objectively known, a condition that is frequently violated in reality. The theory was later generalized to uncertainty by Savage, with the *Savage axioms* [54]. What those axioms essentially do is to ensure that the decision maker ascribes probability distributions to every possible state of the world and von Neuman-Morgenstern utilities to those states and choices are made by maximizing expected utility. The Savage axioms lead to the *subjective expected utility theory.*

The central axiom of expected utility theory is the independence axiom, but the first two axioms are certainly not innocuous. Note for example that the first axiom says that the binary relation ▯ must be rational, i.e., it must be complete and transitive. This requirement is, if anything, stronger in this setting than it is in choice under certainty. Transitivity has been violated by subjects in numerous experiments, the most famous examining the *preference reversal phenomenon* [66]. The subjects often choose a bet with a high probability of winning a small sum over a bet with a low probability of winning a large sum, but ask a higher selling price for the bet with the larger sum.

The second axiom rules out lexicographic preferences such as “safety first”. It is more of a technical axiom and is not very restrictive.

The third axiom, the independence axiom, has, in contrast to the other two, no equivalent in choice under certainty. The independence axiom has been demonstrated to be frequently violated by subjects in for example the Allais paradox and Machina’s paradox [66].

With respect to the descriptive content of the subjective expected utility theory, very much the same anomalies as in the expected utility theory have been demonstrated to hold also in this formulation. An important additional objection to the subjective expected utility theory is that it, in a way, takes away the distinction between risk and uncertainty (as defined by Knight), by reducing all uncertainty to risk by letting beliefs be expressed as probabilities. An illustration to why this might be undesirable is given by the Ellsberg paradox (from [68]): There are two urns, denoted Left and Right (L and R), each containing 100 balls. The balls are either red or green. Urn R contains 49 red balls and 51 green balls and urn L contains an unspecified mix of balls. Without disclosing the colors, one ball has been picked from each urn and been denoted R-ball and L-ball respectively. Now, consider two choice situations. In both situations, the subject must choose one of the two balls and after the choice has been made the color of the ball will be disclosed. In the first choice situation the subject will be given $1,000 if the ball is green and in the second situation the same prize is awarded if the ball is red. With this information most people choose the R-ball in the first situation. If this choice is consistent with subjective expected utility theory, it implies that the subject assigns a probability greater than .49 that the L-ball is red. Hence, he should choose the L-ball in the second choice situation, but in experiments this is frequently violated.

The choice situation is clear enough for the decision maker to realize that he only has a 49% chance of winning in the second situation, but this probability is *known*, as opposed to the probability if he chooses the L-ball. Apparently this knowledge has a value to many subjects in experiments. Thus, the empirical evidence suggests that individuals are *ambiguity averse*, implying that the confidence with which they hold their subjective probability estimate will affect their choices. There seems to be something to the distinction between risk and uncertainty [68].

Another anomaly in individual decision making is *framing effects*, which refers to the observation that alternative means of presenting probabilistically equivalent choice problems will lead to systematic differences in choice [110]. For example, the choice people make over two health policies will regularly depend on whether you present the same outcome in terms of mortality or survival probability, as a famous experiment by Tversky and Kahneman [112] illustrated. The subjects were asked to assume the role of a public health official and assume that a disease was about to break out. They were told that if nothing is done 600 people will die and then asked to choose between two programs. The programs were presented in two different frames:

<u>Frame 1:</u>

A: 200 people will be saved. *(72 percent preferred this alternative)*

B: With a probability of one third, 600 people will be saved. With a probability of two thirds, no one will be saved. *(preferred by 28 percent)*

<u>Frame 2:</u>

C: 400 people will die. *(preferred by 22 percent)*
D: With a probability of one third, no one will die. With a probability of two thirds, 600 people will die. *(preferred by 78 percent)*

The preferred program varied greatly between the two frames, despite the fact that alternatives A and C are identical, as are alternatives B and D. This illustrates the framing effect, which is a violation of an implicit assumption of description invariance [110].

1.3.1.2 Attitudes - preferences

Most psychologists, I believe, would agree that the expected utility model is a poor description of actual behavior. Psychologists have devised alternative models that are more solidly based on empirical observations of behavior. In the following, I will try to start from the psychologists' concept of attitudes, examine what is needed to turn it into an explicit theory of choice and contrast it to utility theory. There will also be some mention of alternative models. This is not an attempt to make a comprehensive formal treatment of the relation between attitudes and preferences, but rather a conceptual discussion. An example of a formal model linking attitudes to intentions and choice, with references to the relevant literature, can be found in Warshaw and Dröge [115].

There is no single universally accepted definition of attitudes, but typically, definitions is based on the notion that an attitude is evaluative, i.e. an attitude is an evaluative response on some favorable-unfavorable scale towards objects [78]. However, individuals also need to make a mental representation of the stimulus they are going to evaluate and consequently, attitude-formation is often seen as a two-stage process; forming a belief about an object and evaluating that belief.

What this says is just that objects are assigned an attitude. The next step is to relate this to choice in order to make the comparison to utility theory clear. A weakness of this comparison is that attitudes are rarely used for studying choices. Historically they have been used mostly in non-choice settings [115], but there are no technical or logical difficulties in pursuing this line of inquiry.
It is easy to come up with some axiom relating attitudes to choice e.g.,

Attitude/preference axiom: If O is the choice set and $x, y \in O$, then $x \, R \, y$ if $A(x) > A(y)$, $\forall$ x,y.

Where R is the binary relation "is chosen over".

To do this, the attitude function would, mathematically, have to be a mapping from some finite subset (i.e. the choice set) of the set of objects to the set of real numbers, i.e. $A: O \rightarrow R$.

The connection is most apparent when there is a dominant alternative. If there is an alternative A which is evaluated as at least as good as alternative B on all attributes and as better on at least one attribute, alternative A will be chosen. This, I believe, is uncontroversial. However, many choice situations involve conflicting values where alternatives are better on different attributes. How these conflicts are resolved is not uncontroversial. As a side note, there are in fact models where the conflict is not even resolved [80].

In e.g. Fishbein's and Ajzen's [29] classic model the resulting attitude from the evaluation of attributes is a linear function

$$A = \sum_{i=1}^{T} b_i e_i$$

where *b* is the belief about an aspect of the object and *e* is the importance weight of the aspect. This model assumes that individuals trade off more of one valued attribute for less of another valued attribute. The specific functional form, furthermore, assumes additive independence of attributes, i.e. a fixed level of an attribute will make the same contribution to attitude regardless of the levels of other attributes. The functional form of attitude functions has been debated [24], but is not a primary concern here.

To sum up, specific attitude values are a function of a belief and an importance weight. Furthermore, if the attitude value is higher for object x than for object y, we assume that x is chosen over y.

Arguably, the restrictions put on the binary relation R is the source of divergence between economics and psychology. Utility theory is really a theory about consumer choice, i.e. it is a theory of behavior. Utility theory puts a set of restrictions on preferences; the binary relation R is a preference if and only if it is complete and negatively transitive. But by the axioms of revealed preference theory, actual choice can be linked directly to utility, making preferences (which are mental phenomena, impossible to study directly) redundant (See e.g. [68]. The revealed preference approach might seem practically tautological [71]. If an individual makes a particular choice, it must be because he thought that choice was the "best", according to *some* criterion. But since the revealed preference and the preference-based theories give the same utility functions, the rationality constraints are placed on the choices instead of the preferences. And they are no less stringent in that setting.

In any case, psychologists are generally reluctant to place firm restrictions on the choice-relation. A primary reason for this is the constructive nature of preferences that has been the focus of much research in psychology [80]. The attitude/preference axiom requires not that each object has a unique attitude value --many objects can give rise to the same attitude value-- but it does require that each object gives rise to only one attitude value. A large literature in psychology focuses on the context dependency of attitudes (see e.g. Schwarz [92] for a good introduction). According to this view, preference or attitude measurement does not amount to record a value from an index present in peoples' minds, because attitudes and preferences are formed in the evaluation process and will be greatly influenced by the context of evaluation. But even more important, there is not even a fixed algorithm (such as expected utility) for these evaluations and formations of preferences [80]. Thus, on the ground that empirical evidence seems to contradict them, the assumptions of transitivity and completeness are refuted in psychology.

People do not seem to have one attitude, but rather any number of attitudes towards an object, depending on what cognitive schema is used [92]. As was stated earlier, individuals need to make a mental representation of the stimulus they are going to evaluate, and subsequently also a mental representation of the standard against which the stimulus is evaluated. The standard of comparison can be e.g. values, which are defined as more deeply held and stable constructs than attitudes [24]. The mental representations of both the object and the standard of evaluation are considered to be formed on the spot, based on only a subset of the relevant information [92]. The problem is that the subset used changes continuously, to a smaller or greater extent. To be more specific, it is e.g. often assumed that it is the information that most easily comes to mind that is used; the so-called availability heuristic [51], [92].

1.3.1.3 Alternative utility formulations

The preference relation in economic theory is given by a total preorder on a consumption set, which amounts to being able to rank all alternatives in a finite sub-set of the consumption set, allowing also for ties. Even constructed preferences could give at least a partial ordering of sets, which is one way of dealing with the ambiguity created if people resolve (or do not resolve) the problem of conflicting values differently depending on the choice situation. An example of this approach is fuzzy utility [89].

It is certainly possible to construct utility functions based on constructive preferences. There have been many attempts at accommodating empirical findings, including the apparent anomalies, from psychology into a utility maximization framework. Examples of this are various non-expected utility models [66].

The Allais paradox can e.g. be accommodated by a theory called *regret theory* in which the subject values not only what he actually receives, but also what he receives in comparison with what he might have received [7]. In the case of Machina's paradox it is actually more *disappointment* than regret that affects the valuation [68]. Regret theory explains some behavior that cannot be explained by expected utility theory and thus has a clear descriptive appeal.

A widely accepted normative postulate is *consequence monotonicity*, which simply states that utility is monotonically increasing in outcomes [65]. If a certain lottery, A, has as one outcome a profit of 10, another lottery, B, which is exactly the same as A expect that the profit is instead 20, will be seen as better than A. Monotonicity is sometimes confused with description invariance, but they are altogether different concepts [65].

One line of modeling, rank-dependent utility, keeps monotonicity, but replaces description invariance with a principle of decomposition of gambles into loss and gain subgambles, which is more appealing as a description of actual behavior. Cumulative prospect theory (a generalization of the original prospect theory [111]) is also essentially a rank-dependent utility theory [65]. In these theories, the utility of a gamble is the weighted utility of its subgambles, but the weights do not sum to 1, as they would in subjective expected utility theory. Rank-dependent utility and cumulative prospect theory has had considerable descriptive success [80].

In a different tack on the problem, choice is seen as probabilistic. In e.g. random utility models, a stochastic element enters individuals' choices, but it enters as a statistical add-on; only choices, not utilities, can be observed so an error term is added to the utility function in statistical models to explain individual choice. However, there have been many attempts to construct models where probability is an inherent aspect [71]. Alternatives x and y are not ranked according to preferences, instead a probability P(x,y) that x will be chosen over y is postulated. This is an appealing approach in that it potentially could be used to model the apparent randomness of choices, but according to Luce [65] severe difficulties have been encountered in the attempts to impose structure on these models.

1.3.1.4 Rationality

The violations of the axioms of expected utility theory raise serious doubts about the descriptive power of the theory. The problems are widely recognized also among economists, as is evident from the attempts to formulate more realistic models. I can see at least two important reasons why the standard model still prevails. One reason is economists' reluctance to sacrifice parsimony for realism [63]. In my view this is a justified reluctance. However, expected utility theory is also a normative theory of choice. The normative claim is based on the reasonableness or rationality of the axioms of expected utility theory. Whether this is justified or not depends on what rationality is.

In Mirriam-Websters, rationality is defined as "the quality or state of being rational" with rational in turn being "relating to, based on, or agreeable to reason". It hints at a definition of rational as similar to logical and consistent; if you have, or are given, information about some relationship in the world then your acts should be guided by this information where relevant. A rational being has to deduce the relevant implications of what it knows and apply these implications to its acts. In general, it is hard to think of rationality without also specifying a goal for a certain act, but the particular goal does not have to be included in the definition of rationality. Thus, a workable definition of rationality for a choice setting would have to include a notion of appropriateness or functionality in addition to being consistent with reason. I would argue that it also needs some justification in terms of operative success.

Formal science uses mathematics, logic, probability theory and methods of inference that certainly are rational, both in the sense of obeying the axioms of utilitarianism and in operational success. However, if people use an intuitive science that does not always adhere to the requirements of formal science, it does not follow that people are irrational. Or, as Pinker ([81], p. 302) puts it: "Natural selection, however, did not shape us to earn good grades in science class or publish in refereed journals. It shaped us to master the local environment...". Pinker lists three reasons why the intuitive science of people differs from the modern institutionalized version of it. First, scientific methods of inference are literally without content, they are meant to be applicable to any situation. But living organisms do not need universal algorithms, void of content; they need to solve *specific* problems. This view of rationality has also been called *ecological rationality* by Tooby and Cosmides [109]. Natural selection have led not to a brain with a general information processing device but instead to a collection of computational specializations, or modules, many of which are domain-specific, all of them well designed to exploit the ecological structure of a recurrent problem. Tooby and Cosmides suggest that these evolved mechanisms are indeed ecologically rational: they solve adaptive problems[2] more effectively than standard normative methods drawn from mathematics and logic [17].

Pinker's second reason is that knowledge is costly. It does not pay off for the individual to be a good scientist, it is not worthwhile to go through the trouble. This argument connects to the decision theoretic problem of valuing information and is an optimality argument [75] More will be said about "deciding how to decide" later.

The third and final reason is that evolution has rewarded fitness, not truth. Sometimes, truth is conductive to fitness, sometimes it is not. For example, in social interaction we want our version of the truth rather than truth in itself to prevail [81].

The ecological rationality of the mind and its restricted cognitive capacity has made it optimal for the human mind to use certain "tricks" to process information effectively. This is particularly clear when it comes to probabilistic thinking; it is hard for people to handle probabilistic information. People feel that if a roulette wheel has stopped on red ten times in a row, it is due to stop on black [81]. Furthermore, people most often cannot use Bayes' theorem even in simple calculations, they tend to "forget" the base rate [113]. This was illustrated in one study where researchers and students at Harvard Medical School were asked the following question:

"A test do detect a disease which is present in 1/1000 people has a false positive rate of five percent. What is the probability that a person that has tested positive actually has the disease?"

The median response was 56 percent, but the correct answer is two percent [11].

The psychological literature on the processing of probabilistic information is much too large to summarize here. However, an important result is that people seem to use a set of heuristics, or rules of thumb, in dealing with probabilities and this leads to some systematic errors [50]. The most important of these biases are the following: *Availability bias.* How easy it is to recall an event affects the probability judgement. But availability is affected by factors other than actual frequency. *Representativeness bias.* If A is similar to B, then it is

[2] Adaptive problems are problems that may have an effect on the evolutionary success of the organism. Arguably, those are the only problems that can affect the design of the mind.

perceived as likely that A is caused by B. Consider which is the more likely outcome of tossing a coin six times:

A: Head-tail-head-tail-head-tail B: Head-head-head-tail-tail-tail

A is seen as more representative of a random process, but the two sequences are in fact equally likely. The coin has no memory. *Optimist-bias* [117]. Risks are greater to other people, than to oneself. *Over-confidence in small samples.* Many people report the same probability regardless of the size of the sample. *Conjunctive and disjunctive events.* Most people overestimate the probability of conjunctive events and underestimate the probability of disjunctive events.

The adaptive usage of probabilities is to turn patterns in observations into predictions, and for this reason people are better at handling frequencies than probabilities of single events [81], [16]. Gambling devices, and many experimental choice situations, can be expected to generate anomalies, because the previous history of events does not count. They are in fact in a way designed to generate them, and it would be a bit backward to say that we are irrational for that reason. Consequently, also small probabilities and infrequent events, which characterize many environmental hazards, are expected to be hard for people to deal with.

Formal, logical reasoning does not come easily for most people either. Wason [116] showed his subjects four cards and told them that each card had a number on one side and a letter on the other. He then asked them which cards they would have to turn over to test the rule that "if a card has a D on one side, it has a 3 on the other." The cards could e.g. be:

D	F	3	7

The correct answer is D and 7, but less than 10 percent of the test subjects selected the right cards. (Most people picked D or D and 3). It would be easy to draw the conclusion that most people are incapable of logical thinking, but that is not necessarily true. Cosmides [15] later found that people behave like logicians when the logical rule in question is a *contract* and showing that the rule is false is the same as detecting a cheater. People are good at detecting cheaters because that has been adaptive behavior. Again, we see that context-free rationality is not rewarded in evolution.

The limits of the cognitive capacity are not taken seriously in the definitions of rationality used in utilitarianism. And the more complex the choice situation, the more apparent this becomes. The completeness axiom, for example, is usually seen as quite innocent, but it can hardly be assumed that people have well defined preferences over very large sets of random variables. It would in fact be irrational to go through the work of making your mind up about a practically endless number of outcomes. Given a limited cognitive capacity, a better solution is often to use simple choice heuristics even though they may contain numerous biases.

To sum up, there are many instances in which the expected utility theory has been refuted as a descriptive, psychological theory and I have discussed some of them, but the list is certainly not exhausted. Normatively, the Savage axioms are sometimes taken to be the *definition* of individual rationality. Any deviation from this just shows how unsophisticated the violator is. What I have tried to argue is that the human mind can be rational in an ecological sense without, and sometimes in direct conflict with, the axioms of expected utility theory. However, it does not follow from this that we can completely refute expected utility either as a normative or a descriptive theory. From a normative point of view, just because individual decision making is unavoidably behavioral does not mean that there is no room for improvements in particular choice situations. Importantly, as was noted by Tversky [110], the possible normative appeal of these theories is ultimately an empirical question just as the descriptive claims are; what axioms do people *want* to obey? Tversky's answer is that the most compelling axioms, in order of desirability are, stochastic dominance[3], transitivity and independence.
Regarding the descriptive content of the theory, it has been noted in experimental work that stability of preferences (and thus attitudes) is increasing with incentives and practice [21]. Plott [82] has put forward a "discovered preferences hypothesis" which postulates that behavior go through stages of rationality that begin with a type of myopia when faced with unfamiliar tasks, as manifested in the labile attitudes identified by psychologists. With incentives and practice, the myopia gives way to more stable attitudes or preferences. Finally, social institutions play a role in the attainment of a third stage of rationality in which individual decisions incorporate the rationality of others, or the lack of it, in their own decision.

Thus, it seems that people have access to several different ways of making decisions. Loosely speaking they can be called the "rational" and the "intuitive"

[3] Stochastic dominance gives meaning to two important ideas. First, that a distribution F(□) is preferred over another distribution G(□) if it gives unambiguously higher returns, which is called first order stochastic dominance: For every non-decreasing function u: R→ R, we have $\int u(x)dF(x) \geq \int u(x)dG(x)$. Second, if a risk-averse individual prefers F(□) over G(□) when the two distributions have the same mean, then F(□) is said to second-order stochastically dominate G(□). Formally, for every non-decreasing concave function u: R_+→ R, we have $\int u(x)dF(x) \geq \int u(x)dG(x)$.

models [96]. An observation is that it might be possible to reconcile the two in a model that allows people to sometimes go with intuition and heuristics, depending on the payoff. The motivation for this could then be evolutionary. It does not always pay to stop using your heuristics because it is the magnitude of the payoff and not the alleged "rationality" of the process by which it was reached, that affects evolutionary success [10]. This, however, can not be the end of the story. The individual would still need a rule to determine exactly when to switch from one model to another, but this leads to an infinite regress problem: "What is the optimal rule to determine the optimal rule to...determine the optimal action". A cost-benefit approach would provide an answer but would, as far as I can understand, be rather closely related to the expected utility set up. Intuitively, it seems the solution is to pick the best alternative, in terms of expected value or utility, already from the beginning.

1.3.1.5 Attitude or preference measurement?

Often, whether attitudes or preferences should be measured is of course given by the task, but sometimes there is a choice. The advantages of studying attitudes rather than preferences are that the task is usually easier for the respondent and the assumption of rationality the investigator does not have to make. However, to the extent that it is at all possible, measurement of preferences gives qualitatively better information, better suited to aid decision making. Specifically, when using a utilitarian model for decision making it is essential that willingness to pay can be measured, as will be discussed later.

However, the policy implications of the problems with attitude and preference measurement are not entirely clear. In the light of available evidence it is not unreasonable to assume that people are stating attitudes rather than making well considered choices in the political arena. From a descriptive point of view, then, it might be just as well to study not-so-well considered attitudes. However, there might not be any normative implications of this. We do not need to measure values just to have a way of making decisions; there are already other ways of making decisions, such as courts, elected officials or experts. As Baron [6] argues; value elicitation should be a way of making *better* decisions. Specifically, decisions based on people's fundamental values.

An important point to be made is that regardless of whether attitudes or preferences are measured, the variation in actual expenditures per life saved documented in chapter two can not be accounted for. This raises serious concerns about to what extent decision making in those areas is a proper reflection of the public's preferences.

Some alternative explanations of why the cost per life saved varies so much will be offered, but first there will a brief discussion on the subjects of measuring attitudes and perceived risk.

1.3.1.6 Measuring attitudes

Technically, at least at first sight, it is not very difficult to measure attitudes. The respondent is simply presented with an object and asked to evaluate it on some positive-negative scale. This can be done in a postal survey, an in-home interview, a telephone interview, etc. Of course, just like other empirical methods, attitude measurement is sensitive to details in the design of the study. Steps must be taken to avoid problems like interviewer bias and low response rates.

The constructive nature of values and attitudes that has been discussed previously has consequences not only for preference elicitation studies, but, naturally, just as much for attitude measurement. Potential biases include framing effects, anchoring and a host of other biases relating e.g. to the subject's willingness to satisfy and aid the researcher [92]. Awareness of these problems is key to proper survey design and there are procedures available that reduces them. Generally the procedures make the task easier, help the respondent focus on relevant information and remove irrelevant information [6].

However, there are also substantial conceptual problems with studying attitudes. I will focus the discussion on attitudes towards risk and risk policy, but the problems are quite general in nature.

Presumably, risk perception data are collected in part because it is thought to be of importance to policy makers [100]. From the assumption that perceived risk is partly an expression of concern or an attitude towards a risk, a hypothesis that perceived risk should be closely related to demand for risk reduction also follows. In practice, however, the correlation is not that strong [99]. A possible explanation is that people probably care less about changes in small probabilities than about e.g. procedural issues and fairness in their demand for risk reduction [12]. Demand for risk reduction has been found to correlate most strongly with the perceived consequences of the risk, not the probability or some notion of expected value [97].

This relates to the general problem that attitudes are only weakly related to behavior. There is in fact empirical evidence that at least reported attitudes and actual behavior is far from perfectly correlated [92]. However, attitude and behavior are certainly not unrelated and e.g. attitudes toward political parties are of course good predictors of voting behavior.

In many instances, a majority of the respondents to attitude questions has been found to be largely ignorant of the issues they have expressed an attitude about [123]. Some researchers have interpreted this to mean that many people do not have any meaningful political opinions (This is discussed in e.g. Zaller [123], even though he does not subscribe to that view). What is an attitude towards e.g. NATO's policy in Afghanistan worth, if the respondent does not know what that policy is, what or where Afghanistan is, or even what NATO is? It has been argued that this is an effect of the survey construction and with better surveys people do indeed have measurable and meaningful opinions [123]. The fact that you can get people to express an attitude towards even non-existing entities is just an indication of how willing the respondents are to accommodate the researcher. Respondents usually do not want to disappoint the researcher and if asked about an object they assume that it exists [92]. It is possible that this phenomena goes some way in explaining perceived risk as it is measured in psychometric surveys. People answer the questions, but it might well be the first time they ever think about the issue.

1.3.1.7 Risk perception

Much work on the psychology of decision making under risk has been in the paradigm of psychometrics (see e.g. Slovic [102] for an overview and introduction). In addition, the claims that people want society to spend more to reduce some risks than others is usually founded in psychometrics, see e.g. [106], [44], [122]. In the survey reported in chapter four in this thesis, the qualitative attributes that the respondents are asked to trade for lives saved are taken from psychometrics, as they are in earlier studies of the same tradeoffs [18], [91], [70].

In expected utility models, risk attitude is determined by the shape of the utility function. A concave utility function implies risk aversion. What this means is that an aversive attitude towards risk is caused by decreasing marginal utility of money (when we talk about monetary outcomes). This is because compared to a safe gain equal to the expected value of a lottery, the possibility of the larger gain cannot offset the utility loss should the outcome with the smaller gain prevail. "Risk" in this setting refers simply to the probability distribution over outcomes and an increase in risk is equivalent to a mean-preserving spread in the distribution [88].

It is important to comprehend how this differs from how risk is understood in the psychometric paradigm, where attitude to risk is not related to the curvature of a utility function. In psychometric research, risks are conceived as essentially constructed by the subjects and risk aversion would correspond to perceiving a risk as high or to have a strong demand for risk reduction. In fact, in most work on perceived risk, subjects are not even asked to rate probabilities and consequences of risky activities separately. Instead, they are usually asked about "the risk" of a certain event or activity [102]. This makes perceived risk closer to a "concern" for a particular risk or an attitude towards the risk. The concern or attitude should be correlated to physical risk but not identical to it. So, when asked to rate the risk of a certain activity or event, the respondent also evaluates it. This evaluation is context dependent which is potentially problematic because the perceived attributes of risks might be highly unstable.

In one study, reported in chapter three in this thesis, we asked respondents to rate the probability that people in general would suffer from 19 negative events. They were also asked to rate the consequences to people in general should the negative event actually occur and finally also about the expected number of annual fatalities in Sweden from the risks. The ratings and the number of annual fatalities cannot be directly compared, but there should be a high correlation between the ranking of events in terms of fatalities and probability times consequences. A simple Pearson correlation test did indeed show a high and significant correlation (0.83) between annual fatalities and probability times consequences. However, there was an even stronger correlation (0.86) between rankings based on fatalities and consequences alone. Thus, perceived risk is correlated to, but not identical to, expected number of fatalities and this seems to be an effect of the tendency to disregard the probability of a risky event.

The agenda of the psychometric risk research program has mainly been to explain what determines the level of perceived risk, as opposed to factual risk. Using surveys and experiments, Fischhof et al, [28] in the 1970's identified two factors --dread and unknown-- that was said to explain a large part of the variation in perceived risk. Risks that are dreaded and unknown are rated as more risky than other risks. There has been some controversy surrounding how much variation that is actually explained by the dread and unknown factors. In the psychometric tradition, mean values of perceived risk for the whole sample has been used as dependent variable in regressions with mean values of attributes of the hazards as independent variables. The critics claim that it is more relevant to use individual ratings and when that is done the explanatory power of the model drops considerably [98].

The two factors dread and unknown really consist of a number of risk attributes, including if the risk is voluntary, new, affects children, affects future generations and so on. New attributes have been added to the list over the years. There is a danger in this procedure, in that if a large enough sample is used, practically any new variable will be significant without necessarily add any meaningful explanatory power [67]. Also, the direction of causality in these analyses can be challenged. It is assumed that risks are perceived as high because they are e.g. involuntary or new. But it could also be that hazards are rated as involuntary or new because they are perceived as "risky". This seems to be true of e.g. the dread factor. Logically, it is just as likely that a hazard is dreaded because the risk is high as it is perceived as risky because it is dreaded [100].

1.3.2 Institutional explanations

Starr's conclusion that the current allocation of lifesaving resources reflects people's preferences has been the subject of much debate. Some authors focus instead on institutional factors, like the way the program is funded. Who is paying has, according to Cropper and Subramanian [18], a direct effect on the probability that an intervention will be implemented.

There is also a more subtle point to be made regarding how a project is funded. If life-years are adjusted for differences in resulting quality of life so that quality adjusted life-years (QALY) can be used, the willingness to pay for an additional QALY is found simply by dividing the change in utility by the marginal utility of income [45]. If funding comes from different sources (e.g. income tax vs. fees) it is likely that the marginal utility of income is different and so the WTP for a QALY will be different. Then, if allocations reflect public preferences cost per QALY should vary for that reason alone.

Brooks [9] suggests that whether the budget is affordable has a great influence. Projects with a small total cost are more likely to receive funding than more expensive projects even if the more expensive project has a better cost-effectiveness. From an efficiency point of view this is of course deleterious. A preliminary test of this hypothesis was conducted on the data reported in chapter two, but no significant effect was identified. This may be an effect of the relatively small sample used (total costs were not even available for all interventions).

Additional factors that enhance a project's chances of being implemented are if it is politically visible, have influential advocates or an organized target population [9], [32]. Chapter four explores one aspect of this line of reasoning. In explicit tradeoff questions, most respondents are willing to trade qualitative characteristics for lives saved, yet there is a small but significant group of respondents who will not make the tradeoff, i.e. assign infinite value to one or more of the qualitative factors. Cropper and Subramanian [18] suggest that this group may be particularly vocal, which might account for the large variations in cost per life saved for different lifesaving interventions. This hypothesis ensues naturally from the simple observation that politicians and other decision makers are more affected by preferences that are loudly stated. The effect of this would be that risk would be excessively regulated in some areas, in particular areas in which there is a vocal target population. Other risks would be neglected and this could explain the tendency for society to spend profligately to regulate some risks while leaving others under-regulated.

In the study reported in chapter four, which, to the best of my knowledge, was the first attempt to address this issue, it was found that more politically active respondents were less likely to trade qualitative characteristics for lives saved. But this was only for the risk in which they were active and only up to a point. When the less preferred program saved a sufficiently larger number of lives, also the politically active respondents choose that program. There does, however, seem to be one group of respondents who are unwilling to make the tradeoff. If this group has an inordinate influence on policy, it could be part of the explanation why the cost per life saved varies so much between actual interventions, but the results indicate that they are not particularly vocal, at least not in the ways that were measured here.

Given that interest groups and politically active individuals have a substantial impact on risk policy, there is a potential democracy problem. Especially if this group is not representative of the general population. The extent to which this group is representative is an important question, one that is explored in chapter five. That chapter also deals with trust. The inclusion of a trust variable is motivated by the recent claims that trust is a strong determinant of political activity. However, the direction of causality can be challenged; do people distrust, e.g., the local government because they are active or are they active because they distrust the government? In the paper there is some support for the latter direction of causality, because it was found that political activism was correlated to distrust in the national government –a political entity that has not been involved in the issue at hand. As it were, trust was somewhat important, but the strongest determinant of political activism turned out to be perceived personal risk. An implication of this is that politicians probably overestimate the public's concern about the risk.

1.3.2.1 Asymmetric information

A striking finding in the study reported in Chapter two was that only few proposals of lifesaving interventions were accompanied by a cost-effectiveness study, a crucial piece of information for the decision maker. If a rational decision maker with single-peaked preferences over lifesaving interventions is assumed, i.e., it is only the number of lives saved that matters, it is in fact the only piece of information she needs. The normative claim that the marginal cost of lifesaving interventions should be equal implicitly assumes that the decision maker actually knows the cost-effectiveness of the interventions that are being proposed. If she does not, it is indeed hard to make rational decisions. In addition, also when the decision maker cannot be assumed to have single-peaked preferences, cost-effectiveness data would seem useful.

It appears, then, as if the decision maker simply should require each proposal of a lifesaving intervention to be accompanied by a cost-effectiveness study. To require that, however, turns out to not necessarily be the best response in all circumstances.

The lack of cost-effectiveness information is related to an important institutional factor, namely that the agencies responsible for managing risk could have different goals than the legislature. The legislature is presumably a representation of the general public (even though also that assumption can be challenged). The agency on the other hand has expertise, which makes it potentially more efficient to delegate authority to the agency. However, as first modeled by Niskanen [77], the agency can normally be assumed to have different goals than the legislature, often to maximize its budget. A particularly interesting situation arises if there is also asymmetric information regarding the actual cost of projects. In that case, the agency can use its information monopoly to extract gains from the exchange with the legislature.

An obvious extension of Niskanen's model is to include auditing of the agency and the possibility of a counter proposal by the legislature, to get around the problem of asymmetric information. This was studied by Banks [4], who revealed that there is an interesting conflict between efficiency and equity in this case. Two procedures are compared, a closed procedure where the legislature is not allowed to make a counter proposal and an open procedure where it is allowed. The tradeoff between the procedures, when audit costs are high, is one of equity versus efficiency. The outcome under the closed rule is efficient, but the agency extracts all the surplus. Under the open rule, the agency and the legislature share the surplus, but the equilibrium outcome is not efficient (sometimes there is no exchange). Thus, it is not obvious that the legislature should audit the agency, and if they do, the outcome will be inefficient.

However, the problem with the lack of cost-effectiveness data is more closely related to the literature on *disclosure*. Most of the work in that area has been concerned with firms' decisions to disclose or not to disclose unfavorable information [72], [43], [118], [114]. In e.g. the presence of both potential entrants to the firm's market and a financial market, the firm wants to give an impression of bad times to potential competitors but an impression of good times to investors. The literature is then concerned with the prevailing equilibrium information revealing strategies. There is also a smaller, related, literature where disclosure of evidence to courts are discussed (e.g. [61]).

All of these models deal with asymmetric information, i.e., one party has private information. I want to argue that this is applicable also to the relation between an agency and the legislature, because the agency presumably has a better idea of the cost-effectiveness of its proposed interventions. Some of the work on disclosure use so-called noisy signals, where the signal contains an error. This too is in fact applicable to the use of cost-effectiveness studies because the studies are subject to errors, inconsistencies and manipulation, as has previously been discussed.

In a recent article, Lewis and Poitevin [61] discuss the disclosure of evidence in regulatory hearings. By making an application and extension of the Lewis and Poitevin model, some additional insights can be gained. The application is of course to cost-effectiveness data, which affects the pay-off structure. They use only two types of applicants and I use the more realistic assumption of a continuum of types. Furthermore, Lewis and Poitevin only consider ordinary noise, whereas I study also manipulation.

When it is assumed that cost-effectiveness studies always reveal the true cost-effectiveness of the proposed interventions, there exists a separating equilibrium such that an agency with a "good" project will always report cost-effectiveness and an agency with a "bad" project will never report. When noise or manipulation is introduced, this changes. But, importantly, requiring all agencies to report is in general not an optimal mechanism, as was shown already by Lewis and Poitevin. When the report sends a perfect signal it is Pareto-inferior because the same information could be obtained without burdening the high-cost agency with the cost of reporting. In the event that the report sends a noisy signal, requiring all agencies to report will make no difference if the cost of reporting is sufficiently high or low. However, there are cases when the legislature will be worse off with mandatory reports because a fraction of the high-cost agencies that would not have reported will now report, making the updated probability that a low-cost signal in fact comes from a low-cost proposal lower, and thus making the expected value of accepting a low-cost signal lower. Requiring all agencies to report simply means giving up a source of valuable information. The model and all proofs are presented in Appendix 1, Results 1-5.

1.3.2.2 Uncertainty

Uncertainty in the outcome of interventions can possibly explain variations in cost per life saved, even without assuming different goals for the implementing agency and the legislature. It is often the case that the exact effect of an intervention is not known when the decision is made. Decisions are made ex-ante, before the actual cost per life saved is known, but evaluated ex-post when the cost per life saved is known. This means that in an uncertain world there could be variations even with a fully rational decision maker.

To see this, assume uncertainty in the outcome for some interventions, i.e., the number of lives saved for an intervention j is $x_j + \varepsilon$ where ε is, e.g., $\varepsilon \sim N(0, \sigma^2)$

This means that ex post there will be a distribution of costs per lives saved. However, decisions are made ex ante and the optimality condition still holds in expectations: Consider two arbitrary interventions i and j where i is certain and j is uncertain. Assume for simplicity that the cost is the same for both interventions, $p_i = p_j$. Then, assuming separable utility, the utility maximization problem is to

$$\text{Max } U(x_i) + EU(x_j)$$

$$\text{s.t. } p_i x_i + p_j x_j \leq B$$

Taking first order conditions give

$$U'(x_i) = EU(x_j)$$

In expectations, the cost per util is the same, but when the effectiveness is realized with $\varepsilon \sim N(0, \sigma^2)$, there will be some interventions with a better cost-effectiveness ratio and some with a worse ratio. To what extent this can explain the empirically observed variations is not known.

As a society gets more expected life-years it is reasonable to assume that it accepts more risk in the effectiveness of lifesaving interventions, which would translate into larger variation in cost per life saved. This follows if we assume decreasing absolute risk aversion (DARA) of the social planner's utility function (see e.g. Keeney and Raiffa [54] for a treatment of DARA utility functions). With a DARA utility function, accepted variation is anticipated to increase over time. A comparison with an earlier study on cost-effectiveness of lifesaving interventions in Sweden [40] reveals exactly this pattern; not only has the average cost per life saved gone up, but also the variation has increased.

1.4 COLLECTIVE DECISION MAKING ABOUT RISK

Decision making about risk often has to take place on a societal level. Market failures are almost guaranteed because of poorly defined property rights, high transaction costs and high costs of information. Potentially, there is large room for government intervention in this area.

Yet, the available evidence suggests that current allocation of resources is not optimal in the sense that it is not an aggregation of the public's preferences. Some explanations of why the investments vary so much have been offered. But how *should* a government decide what risks to regulate and how much? In chapter six, a Rawlsian veil of ignorance is used to address that question. However, the issues involved are far too complex to be solvable in a single paper and the following sections of this introductory chapter point out a few problematic areas. In these sections I will look at collective decision making about risk and important issues include willingness to pay (WTP) as a policy guideline and how that is affected by the distribution of risk in a society. Furthermore, voluntary risk-taking, altruistic concerns and concerns for future generations raise interesting questions. In the absence of functioning markets, measuring benefits becomes a significant problem and that will also be discussed.

1.4.1 A brief introduction to social choice

The current allocation of lifesaving resources was claimed not to be Pareto-efficient. The problem with Pareto-efficiency as decision criteria is that there are an infinite number of Pareto-efficient allocations and these cannot be ranked with a Pareto-criteria. What is needed is a preference ordering of allocations, analogously to the individual's preference ordering of consumption bundles. This would make it possible to construct a complete and transitive ranking of allocations and find an optimal allocation. An optimal allocation has the property that no other allocation is ranked higher by the preference ordering that is used. If this preference ordering can be described by a continuous function, that function is called a Bergsonian social welfare function (bwf), W(A). An optimal allocation is, then, one that maximizes W(A) over the set of admissible allocations. A Pareto-bwf is a bwf that use the value judgments of the Pareto-criteria and a Pareto-optimal allocation is one where the Pareto-bwf is maximized, given technology constraints.

Each individual presumably has preferences over different states and it is not obvious whose preferences should be used to rank states. Many people feel that society should try to aggregate everyone's preferences when making decisions. Democratic elections and majority voting are examples of mechanisms in that spirit. This is an instrumental view of democracy, to which few people subscribe. The democratic process has a value in itself and is an arena where citizens, in addition to express preferences, also form preferences [26].

A well-known problem with majority voting is that it can lead to voting cycles, i.e., intransitivity. But the problem is in fact much more general than that, which is expressed in Arrow's impossibility theorem [3]. The bwf that was discussed earlier is a special case of a more general class of functions, the *Arrowian social welfare functions* (awf). An awf is a procedure that generates a social preference ordering from a set of individual preference orderings. An awf applied to a particular set of individual preferences leads to a bwf, which would be different if the individual preferences changed, but the awf would be the same. Arrow's remarkable achievement was to show that there is no awf that produces a transitive and reflexive preference ordering while also satisfying some appealing conditions of social choice:

1) Non-dictorial
2) Weak Pareto-effeciency
3) Unrestricted domain
4) Independence of irrelevant alternatives

There is a large literature in positive political theory devoted to describing how political institutions have developed so that one or more of Arrow's conditions can be violated in a controlled way (see e.g. [5]). The conditions that are most appealing to violate are Unrestricted domain and Independence of irrelevant alternatives. The germaneness rule of many parliaments is, e.g., a violation of the Unrestricted domain.

In the practical application of a utilitarian calculus to decisions regarding risk and health policy, two types of utilitarian analysis seem to be especially important: Cost-effectiveness (CE) analysis and cost-benefit (CB) analysis. In a CE analysis the cost per unit of (beneficial) output is calculated. For risk policies this is typically in the form of cost per life saved or cost per quality-adjusted life year (QALY) saved. In a CB analysis, the difference between total benefits and total costs is calculated and willingness to pay is used to measure benefits.

1.4.2 The general problem

To facilitate the exposition, I will use a fairly general formulation of the problem at hand and in this I follow the set-up by Pratt and Zeckhauser [83].

Assume a simple world with N individuals. There is a given level of risk, P, which is the expected number of deaths. Not necessarily all N individuals face the risk; instead there are n individuals at risk. This makes the individual risk p = P/n. In this world there is an option of reducing the aggregate risk P by the absolute amount R, which of course gives the individual risk reduction r = R/n. The question is how much the risk should be reduced.

1.4.3 Willingness to pay as a policy guideline

The starting point of the economists' analysis of risk policy is usually that willingness to pay is the relevant metric of benefits [83]. An integral part of the utilitarian calculus is the sum-ranking of outcomes; the goodness of a set of utilities of individuals is judged by their sum-total. Direct interpersonal comparisons of utilities are not possible and willingness to pay is a way to approximately measure utilities on a common scale. Given that only the individuals' preferences for their personal outcomes enter the analysis, aggregate willingness to pay is found simply as the sum of the individual beneficiary's willingness-to-pay. The guideline for policy most frequently used is that a project to reduce a risk should be undertaken if it is a potential Pareto improvement, i.e., with transfers, a Pareto improvement could be achieved.

Assume here that the individual is rational in the particular sense of adhering to the axioms of von Neuman-Morgenstern utility theory, and has a state-dependent[4] utility function, *U(s,w)*, where *s* takes the value 1 if the individual is dead and 2 if he is alive, and *w* is wealth. It is usually assumed that $U'(1,w) < U'(2,w)$, i.e. the individual values dollars more highly in life than in death. Note that all individuals are assumed to have identical utility functions. The individuals initial expected utility, U_0, is

$$U_0 = pU(1,w) + (1-p)U(2,w)$$

The maximum amount *m* he is willing to pay for a reduction *r* in death probability is determined by:

[4] Whenever health is one of the outcomes it is necessary to take into account the way a certain outcome is achieved, the underlying cause of the outcome. The underlying causes are called states of nature. Compare the two situations in which a poor person is either winning a very large sum of money on a lottery or is offered to sell his heart for a transplantation to a complete stranger. Presumably the utility of his suddenly acquired wealth is different in the two states of nature because in one state he is dead when he receives the money. The economic theory developed to handle this situation is *state-dependent utility theory*.

$$(p-r)U(1,w-m) + (1-p + r)U(2,w-m) = U_0$$

Pratt and Zeckhauser set out to answer the important question of how aggregate willingness to pay varies with how the risk and the risk reduction are spread in the population. To do that one need only to look at a typical individual. With the terminology from the model, we are interested in what happens to willingness to pay as n changes when P is held constant. There are two effects working to push the amount paid for a risk reduction in opposite directions [83]. The "dead-anyway effect", makes us pay more to reduce risks on identified lives because the amount an individual spends is more likely to come from the low-valued state, dead[5]. The "high-payment effect" goes in the other direction and arises because the whole cost of reduction is imposed on one, or a few, persons. With risk aversion, this means that the more the risk is concentrated, the more the affected individuals will pay, which increases their marginal utility of income. For a given utility gain, this implies that concentrating the risk will lower the amount individuals are willing to pay for this reduction. Both of these effects can outweigh the other, depending on the particular parameter values. With functioning markets, no externalities of valuation and individuals who pay for their own risk reduction, the marginal willingness to pay will be equal to the cost of further risk reduction for each individual. But as we already noted, there will in general not be functioning markets for risk reduction so we will want to examine the situation in which society pays for the risk reduction. Assume, then, that government agencies choose on the population's behalf which risks to ameliorate and how much and that the reduction is paid for with money collected from everyone.

Pratt and Zeckhauser note that if society, rather than individuals pay for risk reductions, then aggregate willingness to pay may not be an appropriate guideline because the dead-anyway effect causes individuals at high risk to wanting to spend excessively. If exactly the same expected number of deaths had been spread out over a larger risk population, the aggregate willingness to pay to save those lives had been lower. This can explain the observation that in

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[5] On a side-note, the dead-anyway effect is the explanation to the Russian roulette paradox; why you should be willing to pay more to reduce the number of bullets from two to one, than from one to zero [111]. The marginal utility of money is lower in death and when there are two bullets there is a higher probability that the money you pay comes from the dead-state. In (hypothetical!) experiments people have been found to be willing to pay more to remove the single bullet and this has been called the *certainty effect*, a concept related to ambiguity aversion.

health care, society devotes more resources to treatment after the fact than to prevention, and that biomedical research is excessively directed towards efforts that will bring big benefits to small groups of identified individuals rather than smaller benefits to much larger groups. Society, Pratt and Zeckhauser argue, is spending money raised from everyone and should not base decisions on willingness to pay of individuals at high risk whose dollars are severely depreciated because of a high risk of death. Instead the authors propose that an original-position argument can be used to establish the correct willingness to pay, i.e., what people would agree on before they know their wealth and the risk they are facing. The guideline would then be willingness to pay adjusted for the expected marginal utility of money, because this is what maximizes utility behind the veil of ignorance. The specific way of doing this correction is to use willingness to pay multiplied by the ex-post expected marginal utility of money.

1.4.4 Referendum

The foregoing discussion concerned a situation in which willingness to pay was a direct guideline to policy. A slightly different situation arises if the level of risk reduction, R, is determined in a referendum. Assume that the cost of R is T, which is divided equally among all N individuals. The cost to each individual is then $t = T/N$. For R to be instituted it needs to pass a majority voting, which it does by receiving (N+1)/2 votes in a referendum. When will R pass a referendum? An individual will vote "yes" if his expected utility with R, when he is paying t, is greater than his expected utility under status quo. He will vote "yes" if

$$pU(1, w) + (1-p)U(2,w) < (p-r)U(1,w-t) + (1-p+r)U(2,w-t)$$

Assume strictly quasi-concave utility functions (i.e. single-peaked preferences) on a single dimension, so that level of risk reduction is the only relevant dimension in a referenda (or election). Then politicians will propose a level of risk reduction, R*, with the corresponding cost T*, such that the median voter will be just indifferent between voting "yes" and "no". This result follows from the median voter theorem which says that with single peaked preferences on a single dimension, the median ideal preference is a Condorcet winner [79] and thus R* will receive a majority. Unless the median preference is equal to the mean WTP, there is always room for a Pareto improvement, because a movement from the median to the mean would be a potential Pareto improvement.

There is an ongoing debate about whether cost-benefit or cost-effectiveness analysis is the "right" way to informed decision making. In fact, the methods have turned out to be theoretically quite similar if all costs are included in the CE analysis [69]. The difference is that in CE studies (when a societal perspective is applied) a fixed WTP per QALY should be used [45]. A strong argument in favor of using a fixed WTP is that differences in WTP merely reflect differences in marginal utility of income. Interestingly, the present analysis implies that a cost-effectiveness approach using the median WTP would usually win over a cost-benefit approach using aggregate WTP, if the choice of method were to be determined in a referendum. First, note that WTP (at least for qalys) is a strictly increasing function of income and the mean income will always be at least as high as the median income. In the aggregate WTP approach, the citizens will pay mean WTP (aggregate WTP/N) when everyone pays. Since median WTP will be lower than or equal to mean WTP the intuition behind the result is then that the median voter will feel that the cost is too high in the CB-approach.

If the level of risk reduction is exogenous, i.e., determined outside of the model, there will be a range in which R will win over the status quo. This is applicable to all situations (e.g. discontinuous interventions) when the *level* of risk reduction cannot be determined in the referendum; the referendum is only determines whether a certain intervention with an associated cost should be accepted. The particular range, or win set, depends on the distribution of voters and the status quo. If the status quo is zero risk reduction and the median voter's preferred level of risk reduction is r_m, the win set is $S = [0, 2r_m]$. Thus, a cost per life year well above or below the median ideal preference could prevail.

Also in this setting, as risk is concentrated, the dead-anyway effect increases mean WTP in the part of the population at risk, n, but this might not offset the effect on the mean of the fact that more people will want to pay zero. It is reasonable to assume that the mean WTP will decrease, but the decrease will be moderated by the dead-anyway effect. Concentrating the risk will diminish the likelihood that the policy proposal will pass the referendum because a self-regarding individual who is not in the population at risk, n, will always vote "no" as,

$$U(2,w-t) < U(2,w)$$

In some situations there can be uncertainty about who is in n and in that case the expectations will change. With equal probability of being in the risk population, each person has a probability of n/N of being at risk. Thus, the relevant probability is instead $[(P/n)n]/N = P/N$. An individual will now vote "yes" if

$$(P/N)\ U(1, w) + (1 - P/N)U(2,w) < (P/N - r)U(1,w-t) + (1 - P/N + r)U(2,w-t)$$

There are no dead-anyway or high-payment effects here, because people do not know if they are in the population at risk or not. Concentrating the risk has no effect on the probability of voting "yes". Under these circumstances, the mean and median WTP are the same.

1.4.5 Discussion of willingness to pay as a policy guideline

The concept of willingness to pay rests on the axioms of utility theory. If the axioms are violated by the individual decision makers, as discussed in an earlier section, willingness to pay is not likely to be a valid measure of benefits. The axioms are needed to translate preferences into utility functions, and if the axioms are violated it is impossible to give a stated or observed willingness to pay a utility theoretic interpretation.

Also, the very use of willingness to pay and cost-benefit analysis as means of societal decision making needs to be justified. This involves accepting a utilitarian calculus as the mechanism for decisions regarding risk levels. It also involves accepting that property, which in this case include imposing bodily harm, can be taken without compensation [60].

1.4.5.1 Measuring benefits

A more worldly issue concerns the practical assessment of willingness-to-pay. For non-market goods, this has turned out to be a highly significant problem. In the absence of functioning markets there are *indirect* and *direct* methods to put a value on the good in question. Indirect methods include hedonic pricing, travel-cost and wage differential methods. They are, however, rather limited in scope and used much less frequently than direct methods. The most popular direct method is contingent valuation, but there is controversy surrounding also that method. I used a contingent valuation question in an attempt to see if more politically active individuals were less likely to accept a compensation for a risk reduction that would not take place. The results from that survey are presented in the Appendix to the thesis, under the section *Reducing childhood leukemia by moving power lines under ground.*

Another, related, direct method is conjoint analysis, which was used in the study presented in chapter four. That method is also briefly mentioned below.

1.4.5.1.1 Contingent valuation

The most frequently employed technique to measure benefits in the absence of markets is the contingent valuation method (CV), in which a hypothetical market is created and presented to the respondents. The respondents are asked for either their willingness to pay for an improvement in a public good (or to avoid a deterioration), or for their willingness to accept (WTA) a compensation for a deterioration (or for an improvement that does not take place). The individual's utility is assumed to be a function of income, y and the public good, q; U = U(y, q; s), where s is a vector of personal characteristics of the individual. A proposed increase from q_0 to q_1 is assumed to impose a cost t for the individual whose utility is changed from $U(y, q_0; s)$ to $U(y\text{-}t, q_1; s)$. The individual will agree to pay for the change if

$$U(y\text{-}t, q_1; s) \geq U(y, q_0; s)$$

The t in the expression above is either WTP or WTA and is equal to compensating or equivalent variation, depending on how the question is formulated. To get compensating variation, the question is asked as maximum WTP for an improvement or as minimum WTA a compensation for a deterioration. To measure equivalent variation, the questions are instead posed as maximum WTP to avoid a deterioration or as minimum WTA for an improvement that does not take place. Unfortunately, the compensating variation formulations, which are more appealing, are also a bit problematic, because compensating variation, as opposed to equivalent variation, does not always rank the alternatives the same way the consumer does [74]. To construct a monetary index from compensating variation one needs to assume that the marginal utility of money is constant, which is a strong assumption.

In addition, it is often claimed that CV frequently violates economic theory in that measured WTP and WTA generally differs considerably, whereas theory suggests that they should differ only by an income effect, which typically should be very small. But, it has been argued by Hanemann [36] that this is to some extent a misconception. Also a substitution effect is present, and when the private goods offered in the choice set are seen as poor substitutes of the public good, WTA and WTP can theoretically differ substantially [36].

Both proponents and opponents of contingent valuation agree that contingent valuation, just like other empirical methods, is sensitive to details in the design of the study. There is, however, widespread consensus on some aspects of the design of a CV study, such as: It should be a closed format valuation question, the payment vehicle and the scenario should be believable and particular rather than general, no convenience samples, and the questionnaire should be administered by a trained interviewer [73].

The opposition still claims that empirical evidence support that stated willingness to pay amounts in contingent valuation surveys are not measures of true economic preferences. This is not to say that the responses are random numbers, there are possible alternative hypotheses of how people answer willingness to pay questions, none of which renders willingness to pay a measure of true economic preferences:

- People can be *expressing an attitude* towards an environmental project on a dollar scale, because they are asked to do it on that scale [49]. The hypothesis that CV questions is just another way of expressing an attitude has strong merits, especially in light of the earlier discussion of the unstable nature of preferences. Even proponents of CV seem to support this if the survey is poorly done [37].

- People feel the *"warm glow of giving"* when they contribute to a good cause without actually having any preferences as to the particular project they are asked about [48].

- People perform *a casual cost-benefit analysis* where they do not even attempt to express their own preferences [22]. Then, no other costs or benefits should be added to that analysis. And in that case it would perhaps be better to leave the analysis to knowledgeable experts in the first place.

- People might be *expressing a reaction to actions that have been taken*, rather than expressing their own preferences over different states [6].

According to Diamond and Hausman [22], the main problem is that contingent valuation responses are not consistent with economic theory. The main anomaly found is the embedding effect. The term refers to the tendency of responses to be similar across surveys where economic theory suggests they differ. The typical example of this is that saving one lake in Ontario from pollution is valued just as high as saving 10 lakes, or indeed, *all* lakes in Ontario [48]. However, Hanemann [37] argues convincingly that it is really three different effects, two of which are in fact consistent with economic theory and can be explained in terms of substitution effects and diminishing marginal substitution.

It is sometimes argued that a CV study is a good predictor of how people would vote in a binding referendum but this argument is not very compelling. It is not clear why an actual referendum would be a good way of obtaining an economic value since it is doubtful whether voting in a referendum represents informed decision making [22].

Proponents of CV usually hold that the problems are mostly technical and that it is appropriate to assume that people have well defined preferences for many non-market goods [103], [73]. Note that the subject need not have held these preferences before the survey was conducted. As Haneman [37] argues, it would be unnecessarily strict to require people to have well defined preferences for perhaps previously unknown public goods. In fact, Haneman claims, the interesting question is not to what extent preferences are constructs, but whether they are *stable* constructs and he believes they are. That was discussed earlier in this thesis, with the conclusion that they might not be so stable.

Another common line of defense is that contingent valuation systematically predicts how consumers behave in markets (cf. [19]). But, as Baron [6] observed, satisfaction with any method that correctly predicts consumer choice could be foregone. Baron makes a distinction between fundamental values –the values that express our most important and fundamental opinions-- and proxy, or instrumental, values. To reduce pollution is e.g. a proxy value, connected to fundamental values about perhaps the purity of nature or the right to breathe clean air. When people are asked to value goods which they have little experience from and little knowledge about, they must use rules of thumb and heuristics. Sometimes that leads the respondents wrong and the fundamental values will not be accessed. But, frequently, also consumer choices in functioning markets are based on false beliefs, especially in the area of health risks, where people overestimate many small risks. So what is so desirable about measuring those values?

1.4.5.1.2 Conjoint analysis

The preference elicitation method in chapter four is based on the conjoint analysis method. This method is rather general and the contingent valuation method can be seen as a special case of conjoint analysis [46]. Conjoint analysis (CJA) uses the idea that individuals derive utility from a variety of attributes of the good in question. In CJA all attributes can be varied, whereas in CV only the attribute price is varied and the other ones remain constant. The theoretical framework for CJA is the random utility model, which is discussed in chapter four.

Theoretically, CJA is as sound as CV and it is more flexible, in the sense that tradeoffs can be assessed for a wide array of attributes. Widespread practical application has so far been hindered by the complexity of the survey instrument.

A practical problem is that in actual applications one usually assumes additive separability in the attributes, i.e. a change in the level of one attribute does not affect the marginal utility of another attribute. This is a rather strong assumption.

1.4.6 The veil of ignorance

In chapter six of this thesis, a Rawlsian [85] veil of ignorance is used to discuss justifiable deviations from equal marginal expenditures to save lives. In addition, the veil of ignorance has been evoked in at least two previous articles to justify the use of willingness to pay and cost-benefit analysis. As we have seen, it is used to determine how willingness to pay should be measured and used in Pratt and Zeckhauser [83]. Furthermore, the veil of ignorance is used to show that cost benefit analysis is the appropriate mechanism to make social decisions in Leonard and Zeckhauser [60]. This motivates a brief discussion of potential problems with using the veil of ignorance as a normative starting point.

In the articles mentioned above, an expected utility argument is used to justify the use of a utilitarian method for decision making. One possible objection is that it does not really answer the question: one reason for rejecting cost-benefit analysis as *the* decision making mechanism could be that you do not accept utilitarianism. A person who is opposed to utilitarianism in the first place is not likely to be persuaded into accepting it by a utilitarian argument. Rawls himself, for example, claims to have lexicographic preferences over liberty, and that is not easily compatible with utilitarianism.

Another, obvious, objection is the utterly hypothetical character of the original position and the problem of enforcing any contracts made in it. It simply cannot exist and even if it did and people behind it decided to use a certain procedure, how could you enforce that decision? When an individual finds out that he turned out to be the unlucky one to face a high risk, he will still want to pay excessively because of the dead-anyway effect and he will try to influence policy in this direction.

The individuals in Pratt and Zeckhauser maximize their expected utility behind the veil of ignorance, but Rawls rejected the idea of utilitarianism in the original position, at least as it had earlier been put forward by Harsanyi [38]. In particular, Rawls argues, behind the veil of ignorance, there is *no* ground for making *any* probabilistic assumptions about your eventual position in society, i.e., people in the original position will not even think it equally likely that they are any particular member of society. To assume they do that, Rawls argues, the principle of insufficient reason must be used, and it is inherently flawed. Such probability assessments are not based on evidence, but on guesswork. Furthermore, the individual behind the veil of ignorance has no basis for a decision, since he is supposed not to have any particular conception of his own utilities. Whose preferences does he use, then, to make the decision? In short, "expected utility" has no meaning in this setting.

The problem with insufficient reason is, however, not devastating. There are no compelling arguments why you could not *assume*, like Harsanyi does, that people will think it equally likely to be any one person in society. Furthermore, in Pratt and Zeckhauser, like in many other economic analyses, it is assumed that all individuals have identical utility functions, and that solves this problem. In this restricted setting it is tantamount to letting everyone be the "same" person, so it does not matter whose utility you maximize.

The veil-based approach is intuitively appealing as a normative guiding principle because it operationalizes impartiality. An expected utility analysis behind a veil gives important insights. However, as is incidentally shown in the veil-based paper in this thesis, the results depend on what goes into the utility functions. An interesting question that emanates from this observation concerns what kind of preferences people would have behind a veil if preferences were *formed* behind a veil, rather than just being brought from the "real world". It has been argued by e.g. Dasgupta [20] that preferences are always formed in a social context; we have the preferences we do partly because the world looks like it does. The veil is of course a completely different social context than the ordinary world and preferences can be expected to be different. Rawls' original analysis concerned exactly this, what preferences people would form.

When decisions are made in a political context, it is to be expected that issues of fairness and equity will play prominent roles. The problem Pratt and Zeckhauser set out to solve is that a life will be valued differently depending on how the risk is spread in the population. When society is paying, they argue, one expected fatality should not be valued more highly just because there are fewer persons at risk. They, however, explicitly leave out concerns for equity in their analysis. Chapter six in this thesis address exactly that question.

The next section will deal with some technical and conceptual problems encountered in the analysis of equity. However, concerns for equity are related to altruistic concerns and so the section on equity is preceded by a discussion of altruism.

1.4.7 Altruism

A critical assumption in the studies on willingness to pay discussed is that people are completely self-regarding. It has been argued that in the case willingness to pay contains an altruistic component, it would lead to double counting of utility, which has no support in theory or common sense, in addition to requiring a more complicated welfare analysis [22]. But the problem is not really that altruism cannot be incorporated in the analysis. It does however have consequences for the aggregate willingness to pay in the following way. First, there are different forms of altruism. It can be pure, in which case the *utility* of other individuals enters the utility function,

$U_i(x_{ii}, w_i, U_j(x_{ji})), i \neq j$

where x_{ii}, is individual i's consumption and w_i, is individual i's wealth.

Altruism can also be paternalistic in which case the utility is a function of other people's consumption or wealth.

$U_i(x_{ii}, w_i, x_{ij}, w_j), \ i \neq j$

Paternalistic altruism appears to be particularly important when it comes to health and safety. Most western societies seem to care more about the health care consumption and risk exposure of the poor, than other aspects of their well being [83]. Jones-Lee [47] studied the value of a statistical life in the presence of paternalistic altruism towards other members of your household. He showed that when there is a degree of altruism, the willingness to pay for a statistical life needs to be adjusted upwards by some amount, depending on the degree of concern. However, with universal *pure* altruism the willingness to pay for a statistical life is the same as if no altruism is present [47]. This makes intuitive sense because with universal altruism other people can be regarded as extensions of the own person. With respect to the value of safety, a society of N such altruists would be the same as a society of N purely self-interested individuals. When safety is set at levels that are higher than what is implied by people's valuation of their own safety it is to disregard other determinants of their utility. But this is exactly what paternalistic altruism does. Interestingly, though, with universal *pure* paternalism, i.e., individual i's marginal rate of substitution of j's wealth for j's survival probability is the same as i's marginal rate of substitution of own wealth for own survival proability, the willingness to pay for a statistical life is again the same as if no altruism is present [47]. The intuition behind this surprising result is that the paternalistic concerns within a household exactly "cancel" since individual j feels the same way about individual i.

How common these altruistic concerns are is an empirical question. In surveys of risk attitudes, respondents frequently express altruistic concerns. For example, perceived consequences for people in general (as opposed to consequences for the respondent personally) of a certain risk is an important explanatory variable for demand for risk reduction [84]. Furthermore, altruism has been found to be displayed in voting behavior [42], [41].

Altruism can also be defended as rational behavior. One compelling argument for altruism comes from evolutionary biology where we learn that altruistic genes can survive if they are altruistic towards close kin (such as siblings and children), because the same gene will, with high probability, be present also in the kin. Your offspring carries 50 percent of your own genes, so to increase the fitness of your offspring may be beneficial even if it reduces your own fitness (which in fact is the definition of altruism in biology). This makes altruism towards your family rational.

In addition, altruism in the form of reciprocity[6], can be used to sustain cooperative Nash equilibria in prisoner's dilemma games, which are not Nash choices for the individual. This altruism is, by the way, the reason why people are so good at detecting cheaters. Fitting in well with the group has always been a key survival factor. A disposition towards cooperation and effective communication would be adaptive behavior, as would spotting and punishing violators of the implicit social contract. This may sometimes produce the non-Nash choices referred to above. In problems that have conflicts between the collectively and individually rational choice, the trading off will sometimes lead to the choice of a dominated option on the individual's behalf. Simon [95] provided a potential mechanism for this in his model of docility.

1.4.8 Risk equity

A question related to the one posed by Pratt and Zeckhauser was raised by Keeney [53]. In many projects some members of the public will incur a risk and

[6] Some, like Dasgupta [20], argues that reciprocity is not proper altruism.

other members will receive the benefits. A major issue will then concern fairness and equity. Keeney defined risk equity as the degree to which the risk is balanced in the population. If the risk is disproportionally borne by a small group, that will be a less equitable situation than if the risk is spread in the population. In our model, a small n is less equitable than a larger n, for a given P.

Consider the following hypothetical situation, adopted from Keller and Sarin [55]: A small island has 100 inhabitants who all have suddenly contracted a fatal disease. If nothing is done, all islanders will die. Scientists on the mainland have with short notice produced three different serums against the disease; serums A, B and C. They are all on some people. The serum has to be distributed immediately, and to everyone. In addition, you cannot give more than one serum, because that would kill the person. You know for sure that one of the islanders carries a hereditary trait that makes serum A useless on that person. The problem is that there is no way of knowing beforehand who he or she is. So, if serum A is used, one person would die with certainty and 99 would live with certainty, but there is no way of knowing beforehand who will live and who will die. Serum B simply has a 99 percent chance of being one hundred percent effective on everyone and a one percent chance to not work at all, in which case all the islanders die. Serum C, finally, has a one percent probability of not being effective for each individual and the outcomes are probabilistically independent.

For a self-regarding expected utility maximizer, the scenarios are equal and he is indifferent between the three serums. In all cases the individual probability of dying is one percent. Individual willingness to pay for a reduction in risk is the same for the situations and so is aggregated willingness-to-pay. But intuitively the situations are clearly different. With serum B, the whole population could be wiped out, but there is also a high probability that no one will die. With serum A, on the other hand, it is known for sure that one person will die. The third serum, C, is a sort of intermediate between A and B

This differs from the situation encountered in the previous section in that here, it is not known who will die with certainty even when n = 1. Or to put it another way, membership in n is not known, except for the special case of n = N.

People can have preferences over risk profiles, which can be used to derive so-called equity functions, and that is what is needed to solve this question. A willingness to pay approach based on self-regarding expected utility is incapable of choosing a policy here.

To make the connection to the Pratt and Zeckhauser argument clear we can change the first case (where a single individual faces the whole risk) so that the identity of that individual is known. It is likely that that individual would be willing to pay his entire wealth for any offered reduction in risk and aggregate willingness to pay would be larger than for the other two cases. The point of Pratt and Zeckhauser's veil of ignorance is to take people from that situation and put them in the original situation where the identity was not known when society, rather than individuals, pays for the risk reduction.

1.4.8.1 Equity functions

In chapter six, equity functions are used to study concerns for the distribution of risk. A problematic feature of that analysis is that different equity functions are used to investigate different types of equity. Furthermore, equity is studied without consideration of the disutility of lives lost. Here, the relation between the different types of equity and the relation of equity to disutility of lives lost will be discussed. No claims on the final word in this discussion are made. The ambition is only to point to some technical problems in the analysis of risk equity.

As a preliminary, it is useful to derive the equity functions with an axiomatic approach. See Fishburn and Sarin [30] for details on this procedure. But, in short, let R_e be a binary relation denoting "more equitable than", so when A R_e B we say that A is more equitable than B. We assume that R_e is asymmetric and negatively transitive (from this it follows that the weak binary relation "at least as equitable as" is complete and transitive; the assumptions in Fishburn and Sarin). With these assumptions, there exists a real-valued function u_e such that
$p \, R_e \, q \Leftrightarrow u_e(p) > u_e(q)$

An equity function will look different depending on the type of equity being considered [30]. The two types considered in this thesis are individual risk equity and social outcome equity.

Individual risk equity is defined over the individual fatality profile $p_i = (p_1, ..., p_n)$. A natural measure of how balanced the risk is in the population is then some measure of the deviations from the mean risk level in the population n, $p_m = \Sigma_i \, p_i/n$.

For social outcome equity, the domain is a set of probability distributions P_s on the total number of fatalities in the population (0, 1,..., N). Consider e.g. two policies A and B where A has ½(1, 1, 0, 0) + ½(0, 0, 1, 1) and B has ½(1, 1, 1, 1) + ½(0, 0, 0, 0). Both have the same expected number of fatalities, 2, but B has the same outcome for all individuals. When B is seen as more equitable it has been called a *common-fate preference* [30]. If A is more equitable it is a *catastrophe avoidance preference* [30] since it avoids the catastrophic outcome where all die.

1.4.8.2 Total equity

The relations between different types of equity are not yet fully worked out and there is no obvious amalgamation of these into a total equity function. Fisburn and Sarin [30] claim that because individual and social risk equity measures are not highly correlated, it could be reasonable to assume an additive total risk equity function of the form $d_T = c_1 d_S + c_2 d_I$, where c_1 and c_2 are positive scaling constants reflecting the importance of individual and social outcome equity. This might be possible, although not without problems. For total inequity to be represented by an additive function some rather restrictive assumptions would have to be met. Specifically, social outcome and individual risk equity will have to be mutually "utility" independent. That is, a fixed level of d_I will make the same contribution to total inequity, d_T, regardless of the level of d_S. For this to hold, it must be possible for d_I to take any value at a fixed level of d_S, and vice versa. One can argue, rather loosely, as follows that this condition probably can not be met: Individual risk equity is essentially a measure of variation in individual risk. Variation is at a maximum whenever $n = E(k)$, i.e. when the population at risk equals the expected number of fatalities. Thus, the maximum of this function depends on the expected number of fatalities. As the expected number of fatalities goes up, the maximum variation goes down (individual risk equity increases). Social outcome risk equity puts a value on probability distributions over total number of fatalities in the population and achieves either a maximum or a minimum at the point where everyone dies, depending on whether catastrophe avoidance or common fate preferences prevail. So, where social outcome equity has an extreme, individual risk equity can *only* have a maximum. In short, individual and social outcome risk equity are not independent.

Problems arise because some changes in the probability distributions may simultaneously affect individual and social outcome equity in different directions. Those changes can have ambiguous effects on total equity, which could create zones of indeterminacy. The ordering of states would only be weak.

Note that this is not to say that people are incapable of picking the most equitable distribution of risk, it just says that it might not be possible to describe their preferences with an additive utility function.

1.4.8.3 Total utility of lives saved and equity

Obviously, the equity measures discussed are made without consideration of the disutility of lives lost. In fact, a reduction in total risk could have the effect of reducing equity. Look e.g. at the two risk distributions p = (1, 1, 1) and q = (1,1, 0) where q has a lower total risk but is more inequitable.

Generally, it is probably safe to assume $U_d'(S, w, d) < 0$, i.e. utility is increasing with decreasing inequity. However, we would like to say something about the functional form of the total utility of lives saved and equity. Is it reasonable to assume that additive utility independence holds, so that an additive function can be used? Probably not, as can be illustrated in the following way:

Let lives lost = L and risk equity = E.

Now, consider two lotteries,

Q_1: 0.5(L, E), 0.5(L', E')

Q_2: 0.5(L', E); 0,5(L, E')

Additive utility independence of lives lost and risk equity holds iff there is indifference between Q_1 and Q_2, for all amounts of L and E given a specific L', E' [54].

Select E' s.t. $d_I = 0$, i.e. an individual risk profile $(a_1, a_2, ...a_n)$ where $a_1 = a_2 = a_n \neq 0$. Then $L' \neq 0$. Now, let L = max L(k), which is where k =0. But then the pair (E', L) will not exist.

1.4.9 Distribution of a dependent risk

A situation where equity considerations are particularly important is the distribution of a dependent risk, i.e. if risk is reduced for one individual it must be increased for some other individual. This problem is encountered in e.g. the siting of hazardous facilities. Generally, the distribution of benefits is an important factor [55], but this will presently be left aside. It can e.g. be assumed that there are no benefits from this risk.

1.4.9.1 The general case

This problem will be analyzed in a simple majority-voting game model of political choice. In this setting, more precise conditions under which an equitable distribution of risk will arise can be found. In the absence of benefits or other factors that may influence deservedness, the most equitable distribution of risk will be taken to be simply the egalitarian distribution, i.e., equal treatment of all individuals. Now, under certain assumptions, the equal treatment distribution will always be in the core of a non-cooperative game[7] and we may have some hopes that an equal distribution of risk will also be in the core, even if it will not necessarily be a Condorcet-winner.

To facilitate the exposition there are only three individuals, i.e. N=3. The basic restriction is that there is a risk **X** that will have to be distributed among the three individuals such that $x_1 + x_2 + x_3 = 1$, which is a convex, closed and bounded set.

Assume that all three individuals have utility functions of the form

$$U_i = -(a_{i1}x_1 + a_{i2}x_2 + a_{i3}x_3)$$

where x_j is individual j's risk and $a_{ij} \in [0,1]$ is a constant giving individual i's degree of concern for individual j. When $\mathbf{a_i} = (1, 0, 0)$, individual 1 is completely self-regarding.

These utility functions are continuous, strictly increasing in the risk and single-peaked (or "single-dipped", since it is really a *least* preferred point).

A simple majority-voting model can be used to analyze the prevailing distribution of risk under different assumptions about preferences. Assume that there are two candidates in an election and each candidate's strategy is a distribution of risk satisfying the constraint. Furthermore, assume that a voter will vote for his most preferred distribution of risk.

Initially, assume completely self-regarding individuals so that the utility functions are;

$$U_1 = -(x_1)$$
$$U_2 = -(x_2)$$
$$U_3 = -(x_3)$$

---

[7] See e.g [68], chapter 18.

Result 6: There is no unique equilibrium with these preferences. See Appendix 2 for a proof.

This is the "base-line alternative". Individuals are commonly assumed to be completely self-regarding. Since there is *no* unique equilibrium with these preferences, the egalitarian distribution will of course not be an equilibrium either.

This result is in fact quite general and extends also to cooperative games. To show this, allow for coalitions -- which makes this a cooperative game. Since there are no negotiation costs, it has a superadditive characteristic function and then we can make use of the following theorem (theorem 8.3, page 350 in Ordeshook [79])

All superadditive constant sum-games in characteristic-function form have empty cores.

Thus, in general, the core will be empty (and thus not contain the egalitarian distribution) in this type of constant-sum voting games. It was in fact noted already by Kramer, in a different context that "…such redistributional questions are the most divisive ones a society must face, and it is not surprising that voting is unable to resolve them." (Kramer [59], p.330)

1.4.9.2 Altruistic individuals

More demanding assumptions are needed to find an equilibrium with an equal distribution of the risk. Other-regarding, or altruistic, preferences will under certain circumstances give rise to this distribution. The extreme case of altruism is when all individuals put the same weight on all other members of society as on them selves. Assume completely altruistic individuals so that $a_i = (1, 1, 1)$, with utility functions;

$U_1 = -(x_1 + x_2 + x_3)$
$U_2 = -(x_1 + x_2 + x_3)$
$U_3 = -(x_1 + x_2 + x_3)$

But, again, there is no Condorcet winner. In fact, here *any* distribution of the risk will give the same utility to all individuals which means that all points on the surface of the triangle resulting from connecting all individuals' worst points can be supported as an equilibrium. To show this it suffices to note that $U_1 = U_2 = U_3$, so that utility for any individual is maximized when $x_1 + x_2 + x_3$ is minimized. But the restriction gives this to be equal to one and the particular distribution of the risk is not an issue for any of the individuals. Nevertheless, the equal distribution is in the core.

1.4.9.3 Fairness

People can have other forms of other-regarding preferences. They can for example be concerned with fairness. One way to model fairness is to use utility functions for social outcomes of the form

$U_1 = U_2 = U_3 = - \sum_i \|x_i - x\| \qquad i = (1, 2, 3)$

i.e., utility is maximized by minimizing the sum of the Euclidean distance from the individual maximum points, which gives the maximization problem

$$\max U = ((x_1-x)^2)^{1/2} + ((x_2-x)^2)^{1/2} + ((x_3-x)^2)^{1/2}$$

$$\text{s.t. } x_1 + x_2 + x_3 = 1$$

In this example, the individual maximum points are all at zero, which gives

$$3x = 1 \Rightarrow x = 1/3$$

Thus, the unique equilibrium is the point $\mathbf{x} = (1/3, 1/3, 1/3)$.

This particular utility function identifies an egalitarian fair point. How common or likely these preferences are, is an empirical question. In an overview by Eckel and Grossman [25] it is stated that in ultimatum - dictator games, altruistic or fairness considerations are often exposed by the subjects. To what extent the fifty-fifty share (there are only two players in these games) is realized is not clear from the Eckel and Grossman article. The fair point is likely to be an interesting focal point in a situation with multiple equilibrium.

1.4.9.4 Concern only for one individual

Assume that all three individuals agree that one person is more important so that we have the following utility functions

$U_1 = -(x_3)$
$U_2 = -(x_3)$
$U_3 = -(x_3)$

In this case, utility is maximized when $x_3 = 0$, so that $x_1 + x_2 = 1$. Thus, there is no Condorcet winner but all equilibrium will lie on the line connecting individual 1's and individual 2's worst points. Preferences with this flavor are sometimes expressed in surveys when people state that children should be protected at any cost.

If instead the individuals would put a positive weight on two persons, there would be a unique equilibrium where the entire risk is put on the third person. That could describe a strange situation when everybody in society, including that individual, agree that one member of the society is disposable. It could also depict a more reasonable situation if bearing the whole risk did not imply certain death, just a positive probability of death. Then this could be a situation where someone volunteers to take the whole risk.

1.4.9.5 Probabilistic voting outcome

As a final example, consider probabilistic voting, which is not cooperative. There is an election between two candidates, A and B, whose election platforms are their positions in the risk-distribution space. The three voters are all assumed to be completely self-regarding and vote probabilistically, i.e., the candidates know the voters' maximum points with respect to distribution of risk, but they are uncertain about whether this is the only dimension the voters care about. As noted earlier, the utility functions are continuous and strictly increasing in the risk and quasi-concave. The restriction is still $x_1 + x_2 + x_3 = 1$, which is a convex, closed and bounded set. Then, by the saddle point theorem, this zero-sum game has an equilibrium in pure strategies.

Result 7: With probabilistic voting and two candidates, both candidates will propose to divide the risk equally among all the voters $x_A^* = x_B^* = (1/3, 1/3, 1/3)$. See Appendix 2 for a proof.

To summarize, in a situation with a dependent risk, an equitable, or egalitarian, distribution of risk is generally not in the core, but may arise in several ways; with probabilistic voting and completely self-regarding preferences, with "fairness" preferences and also with *completely* altruistic preferences.

Note how these results relate to Jones-Lee's analysis of the value of safety in the presence of altruism that was discussed earlier. There, completely altruistic and completely self-regarding preferences gave rise to the same value of safety. Here, the two types of preferences may cause opposite outcomes but the underlying intuition is the same as in Jones-Lee's analysis; altruists see other people as extensions of themselves.

1.4.10 Voluntariness

I will now come back to the case were the individual bearing the risk is also the one who receives the benefits. These are risks that are seen as voluntary. In particular, life-style risks as dietary habits, smoking, dangerous sports and drinking are often seen as cases of people who without coercion or externalities impose risks on themselves. It has been argued that in societal decision making, there should be a premium on saving lives from involuntary risks [8], [122].

The utilitarian analysis of voluntary risks is straightforward. The benefits of doing the activity and participate in the death-lottery it comes with gives a higher utility than not doing the activity. There are some problems with this approach, however. It is debated to what extent any risks really are voluntary [67], and if people perhaps do not understand the risks after all. From a utilitarian perspective it is more comfortable to see this as an informational problem, which is rather uncomplicated to handle, than doubting that the risks are voluntary. However, if you doubt that, e.g., smokers (at least literary smokers in the developed world) are unaware of the risks, you have to have serious doubts about their competency to process any information at all. Lack of information could be the problem in some instances, but it seems unlikely to be the general case. In fact, Viscusi [119] shows that smokers may even overestimate the probability of smoking related lung-cancer.

In contrast to the standard utilitarian analysis, it has been claimed that people often act against their own self-interest in full knowledge that they are doing so [62].

Of course, some voluntary risks are addictions, which could possible serve as an explanation of why people fail to act in their own best interest. But voluntary risks that are not addictions would not be accounted for. There is also a conceptual challenge with that approach to voluntary risks because addicts seem to want to have their addiction. Yet sometimes there is another person "in there" who does not. This, however, raises serious concerns about consumer sovereignty; who is sovereign, the self who takes the drug or the self who wants to stop? The choice based approach to utility theory becomes hard to interpret [64]. This is interrelated with the general problem of preferences over preferences [31], [35].

Connected to this is self-binding behavior. People often support regulations of behavior without complying with the regulation themselves. As an example, in Sweden a recent poll showed that a majority of voters supports mandatory use of bicycle helmets, but only about 20 percent of adult bicyclists currently use it. People keep their alarm clocks far away from the bed, because otherwise they will just turn it off in the morning, even though they set it themselves the night before [64]. Self-binding behavior is hard to accommodate in expected utility models [2], [62].

In most economic models of risk, voluntary risks are not considered. Presumably, they are seen as risks that do not need to be regulated. But in the general population there seems to be strong support for the idea that addicts need help and prevention in particular is favored. Prevention of voluntary risks is problematic in an expected utility model because it is then necessary to allow either altruistic concerns or multiple-selves; the addicts would only have a willingness to pay for prevention if they had another self that wanted to quit the addiction[8]. Altruistic concerns on the other hand would have to be paternalistic.

Voluntariness is also related to justice, through responsibility. One of the first attempts to include individual responsibility in a formal, egalitarian, analysis of justice was made by Dworkin [23]. In the liberal and conservative traditions the notion of individual responsibility has had a much longer history, but with Dworkin it becomes an important idea almost whatever the philosophical foundation for the analysis is. Some other recent contributors to the idea of individual responsibility in justice are e.g. Sen [94] and Cohen [14]. The basic idea they all put forward is that people should be rendered equal in condition, insofar as their condition is a result of circumstances beyond their responsibility. Dworkin's idea of justice is to require equal treatment of people, and this means equalizing people's opportunities for welfare with regard to circumstances beyond their control. To do this requires separating a person's ambitions from his endowments and Dworkin states that individuals are responsible for their preferences as long as they identify with them and are glad to have them. Dworkin also exclude addiction and cravings from the sphere of individual responsibility. This view has been challenged by, amongst others, Roemer [87] who remarks that Dworkin's theory demands a rather peculiar view of responsibility, in that people's preferences normally are perceived to be constructed, or at least influenced, by circumstances beyond the individual's control (influence from parents etc.). Roemer therefore tries to "relocate Dworkin's cut" and construct an algorithm that society can use in deciding an individual's degree of responsibility. A practical example, responsibility and smoking, shows the basic intuition behind Roemer's proposal: If the population is divided into groups that share some characteristics, such as age, gender, and occupation, a "normal" smoking behavior can be determined e.g. as the mean number of years smoked within that group. A person that has smoked more than the mean has exerted a lesser degree of responsibility and should, as a consequence, pay higher insurance fees to the public health system.[9]

Judging from findings in research on risk perception, Roemer's proposal seems to have less support from the general public than Dworkin's does. People seem perfectly willing to determine the degree of responsibility in a risk based only on the type of activity, regardless of who is engaged in it. People usually rate a risk as more acceptable (or demand less risk mitigation) if they perceive that one voluntarily engage in it [97]. However, at the same time, people are inclined to treat e.g. children as not completely responsible for their actions, even if the

[8] They would still have a willingness to pay to reduce the risk of their addictive behavior.

[9] If a person do get cancer from smoking, Roemer still think that person is entitled to health care.

children themselves are happy with their preferences. This can serve as a warning not to over-interpret the results from studies of risk perception, where this issue has not been explicitly studied. It is possible that people would take the background information about individuals who "voluntarily" perform risky behavior in to account, if they were given such information. The earlier discussion on the instability of attitudes also suggests this.

An important factor is whether the individual who is exposed to the risk is also the one who benefits from the activity generating the risk. To impose a risk on others, who do not receive the benefits of the activity, is commonly seen as unjust [55].

1.4.11 Future generations

Research in psychology has demonstrated that people in general are concerned about imposing risks on future generations [102]. In our general framework 'future generations' means that the population at risk, n, is not in N at all. This connects to the discussion of altruism in the sense that if we assume that people only care about their own risks, the willingness to pay to reduce future risks is zero. When people exhibit concern for future generations it must be an altruistic concern.

The standard economic analysis of future effects uses the concept of discounting. Discounting is applied to both costs and benefits, in this case lives saved in the future. It has sometimes been argued from a normative point of view that only costs and not lives should be discounted, because all people have an equal value, regardless of when they are born. That approach, it has been argued, faces a substantial problem, namely that it will always be better to wait with every investment, leading to a complete stop in investments [52]. The argument applies to all investments in environmental projects and says that instead of doing the project now, the money could be invested in the market, grow there for a while and then the problem could be addressed some time in the future. But then the same argument would apply at all times in the future, so the problem would never be addressed. That argument should be qualified, however, with the observation that environmental investments that pay off at or above the market rate of return still would be implemented [86]. In addition, as was pointed out by Revesz [86], it is not uncommon that the costs of addressing environmental problems increase greatly over time. To fix global warming now might be much less expensive than taking care of the consequences 50 or a 100 years from now. That investment could be worthwhile even with zero discount rate.

The concept of discounting has a lot of both descriptive and normative complications. One problem is determining the correct societal discount rate [86], [39], [27]. Should investments in public goods, evaluated from a societal perspective, be subjected to the same discount rate as private investments? Another issue is an apparent lack of consistency with respect to discounting people exhibit in choices [64].

Leaving those concerns aside, it can be noted that by applying even a very small positive discount rate, all investments that benefit future generations become unprofitable. However, it could be argued that there is a difference between intergenerational and intragenerational discounting [86]. Intragenerational discounting is a reflection of psychological, subjective time preferences; consumption now is preferred to consumption later and to postpone consumption some compensation is needed. Specifically, discounting should be based on alternative uses of the resources, because an investment today that pays off in the future could instead have been invested at the market rate of return. As a side note, potentially, it is problematic to discount life-years saved at the market rate of return, because the utility of being alive cannot be transferred the way utility from consumption can.

Intergenerational discounting on the other hand must be related to normative principles about the relation between current and future generations [86]. Intergenerational transfers are conceptually different than transferring utility between the same person at different times in his life. This is illustrated in macro-models where generations with finite horizons are assumed; when a social welfare function (or the utility function of an impartial observer) is maximized, no particular generation is favored over another, but intragenerational discounting is still allowed.

However, future generations have two things going against them. The first concerns what claims future generations really can make on our benevolence. Given that a "person" is defined by genetic and environmental factors, the actual composition of persons in the future will depend on our choices now. The persons that live at any given point in time can never complain about earlier generations' choices, because without those choices, they would not exist.

The other problem arises if we assume that concerns for future generations are essentially altruistic and that "genetic distance" is the strongest determinant of altruism. Altruism towards close kin is rational even in a very strong definition of rationality and also frequently displayed. Notice that it is "close kin" as opposed to "kin" in general, because in a very direct way, all people are related to each other, and thus kin. But most people are extremely distant relatives making it unlikely that they will share genes. Therefore, one would expect altruism to decline with genetic distance. The distance extends in both a "vertical" and a "horizontal" dimension; you can talk about genetic distance to your contemporaries and also to people living in other times. You are just as likely to share a gene with your children as with your parents and with your siblings. You have an equal probability (one in eight) to find a particular gene of yours in your great-grandchildren and your cousins. Eventually as you move along this distance, you will come to a point when the expected value of helping a relative is outweighed by the cost. (However, the psychological mechanisms behind altruism –which differ from the rationales for altruism- could, and probably do, make us altruistic towards people outside of our family.)

Other factors which affect altruism towards people in our own time are the aforementioned reciprocity and the social norms that are used to sustain cooperative Nash equilibria. The situation with future generations is peculiar in that there can be no reciprocity, since we will be gone. All this adds up to potential inconsistencies between how we treat people that are distant in time and distant geographically or culturally, which has no logical basis - the genetic distance is approximately the same. If we are willing to spend large sums to protect people who will live thousands of years from now from the dangers of radioactive waste or global warming, we should be willing to spend corresponding amounts on people in need in distant countries. Whether we do or not is an empirical question, but to the best of my knowledge no data on this exist.

1.A.1 Appendix 1

I will use a theoretical model to examine the use of cost-effectiveness information in the interaction between an agency and a legislature. The general framework is that an agency proposes an intervention that is accepted or rejected by the legislature. As in most of the literature in this area, the legislature is modeled as a single actor. Likewise, the agency is modeled as a single actor. This can be thought of as looking at one representative member of the legislature or agency. The legislature wants to maximize some utility function subject to a budget constraint. The legislature determines the agencies' budgets, in this case for specific projects, transfers the money to the agencies and derives utility from the policy outcomes. I assume the legislature has single-peaked preferences over the interventions and thus has a willingness to pay for the service and this should be equal to the marginal cost of producing the service, which should be equal for all agencies producing the service.

The agency wants to implement all interventions it proposes, but the legislature only wants to accept the interventions whose cost-effectiveness fall below their valuation of the service in question.

1.A.1.1 The game

When the game starts, the agency has already decided to make a particular proposal. In the first round, nature picks a type for the agency
$\theta \in \Theta = \{\theta_1,\dots\theta_N\}$. The probability of type θ is $f(\theta)$, which is common knowledge. Only the agency observes the realized θ. The agency picks an action a from the set $A = \{S, N\}$, i.e., it decides to send or not to send a report. To send a report is costly to the agency. The cost will be modeled as either a fixed cost C, which is the same for all agencies, or as a function of the type
$C = C(\theta)$ where $C'(\theta) > 0$, i.e. the cost of reporting is increasing in type. In the third round the legislature observes a, but not θ, and picks an action s from the set $S = \{0, 1\}$, i.e. a probability between 0 and 1 to accept the proposal from the agency.

The payoffs are $V_A(a, s, \theta)$ and $V_L(a, s, \theta)$ for the agency and legislature respectively. Throughout, it is assumed that the agencies receive a uniform benefit of B of an accepted proposal. The legislature is assumed to have a publicly announced valuation θ^* of the service the agencies produce. The legislature receives a benefit of $D(\theta)$ of accepting a proposal. For $\theta < \theta^*$, this is a positive benefit, but for $\theta > \theta^*$ it is negative. The latter case is the cost of making a type II error, and is denoted E_2. The payoff from rejecting a proposal $\theta > \theta^*$ is zero, but rejecting a $\theta < \theta^*$ proposal is a type I error, the cost of which is the negative of $D(\theta)$. Thus, the legislature's payoff is inversely related to increasing θ. The costs of errors are purely in the form of foregone opportunities. There are no differing psychological costs of making one or the other error

It will sometimes be useful to denote agencies $\theta > \theta^*$ with θ_H and agencies $\theta < \theta^*$ with θ_L.

In the following, it will be assumed that both θ_H and θ_L agencies exist.

The equilibrium notion used is Perfect Bayesian Equilibrium (PBE), which consists of a profile of strategies $a(\theta)$, $s(a)$ together with a belief function $\mu(\theta|a)$ that assigns a probability to type θ of the agency conditional on the observed action a, such that

- The agency's action is optimal given the strategy of the legislature

- The belief function is derived from the agency's strategy, using Bayes' rule when possible.

1.A.1.2 No noise

In this case the signal always reveals the true type of the agency. Assume a fixed cost of reporting of C, such that $B - C > 0$.

Result 1. In this case there exists a separating equilibrium in the following strategies:
$a(\theta_H) = N$
$a(\theta_L) = S$

$s(H) = 0$
$s(N) = 0$
$s(L) = 1$

Proof of result 1.
Begin at the end of the game with the legislature's strategy. It is easy to see that the legislature will always accept if the report signals a low-cost proposal and reject if the report signals a high cost, when the signal reveals the true cost, so the case we need to consider is when no signal is sent. The expected payoff to the legislature from accepting if there is no signal is

$V_L(N, A) = \mu(\theta_L|N)D(\theta) + (1-\mu(\theta_L|N))E_2$ and $V_L(N, R) = -\mu(\theta_L|N)D(\theta)$ from rejecting. The highest payoff the legislature can get is $D(\theta)$, which it will receive if $\mu(\theta_L|N) = 1$. But $\mu(\theta_L|N)$ can be 1 only if the legislature reasonably believes that high-cost agencies always send, which they do not because
$V_A(S, s, \theta_H) = -C$ and $V_A(N, s, \theta_H) = s_N (B) + (1-s_N)0$. However, the legislature minimizes loss if $\mu(\theta_L|N)$ is equal to 0, which it is if the legislature can reasonably believe that low-cost agencies will always send and by setting s_N to 0, the legislature can ensure this. The payoff to the low-cost agencies from sending is $V_A(S, s, \theta_L) = (B-C)$ and the payoff from not sending is
$V_A(N, s, \theta_L) = s_N (B) + (1-s_N)(0)$. Because $B-C>0$, the low-cost agency will always send when $s_N = 0$. Thus, the legislature's optimal strategy is
$s_H = 0, s_N = 0, s_L = 1$

The agencies' strategies follow from this. We have already seen that the low-cost agency will always send and to complete the proof we only need to show that the high-cost agency will never send. The expected payoff to the high-cost agency is $V_A(S, s, \theta_H) = -C$ and $V_A(N, s, \theta_H) = 0$ from sending and not sending respectively and since $C > 0$, the agency will never send.

It is stated without proof that there is a separating equilibrium in pure strategies also when the cost of reporting is increasing in type, $C = C(\theta)$.

1.A.1.3 Noisy signal

Here, the report does not always reveal the true type of the agency. Specifically, assume that $a = \theta + \varepsilon$, where $\varepsilon \sim N(0, \sigma^2)$. This means that there will only be some positive probability $p(\theta)$ that a report signals $\theta < \theta^*$. For agencies $\theta > \theta^*$, this probability is $p < ½$.

First, consider a fixed cost of reporting, C.

*Result 2.*When the signal is noisy, there is a separating equilibrium in pure strategies such that
$a(\theta_H) = N$
$a(\theta_L) = S$

$s(H) = 0$
$s(N) = 0$
$s(L) = 1$
This holds iff $C < B < 2C$.

Proof of result 2.
To determine when high-cost agencies will not send it is sufficient to consider the actions of the agency closest to θ^*, a "marginal-agency analysis". Let that type be $\theta^* + \delta$. If that agency will not send, an agency with a higher cost, $\theta^* + \delta'$, where $\delta' > \delta$ will not send either.

Expected payoff to the agency is a function of the probability of sending a low-cost signal, because the legislature's strategy is determined using the updated belief about the type of the agency. Define a strictly dominated action as:

Action $a \in A$ is a strictly dominated choice for type θ if there is an action $a' \in A$ such that

$$\min_{s' \in S} V_A(a', s', \theta) > \max_{s \in S} V_A(a, s, \theta)$$

Then, if action a is a strictly dominated choice for type $\theta^* + \delta$, it is strictly dominated also for $\theta^* + \delta'$ because $V_A(a, s, \theta^* + \delta) > V_A(a, s, \theta^* + \delta')$.

This equilibrium must be such that low-cost proposals will be accepted with probability 1 and high-cost proposals will be rejected with probability 1. The agencies' strategies would have to be $a_H = 0$ and $a_L = 1$, where a_H denotes the strategy of an agency $\theta > \theta^*$ and a_L the strategy of an agency with $\theta < \theta^*$.

The expected payoff to a high-cost type agency is then $V_A^*(N) = 0$. The expected payoff to a high-cost type agency from sending is $V_A^*(S) = p(\theta^*)(B-C) - (1 - p)C$. A high cost agency will never send if $p(\theta)(B-C) - (1 - p(\theta))C < 0 \Rightarrow p(\theta)B < C$, or $B < C/p(\theta)$.

As stated earlier, we only need to consider types located at $\theta^* + \delta$, where δ is an arbitrarily small constant. Given $\varepsilon \sim N(0, \sigma^2)$, $p(\theta) < ½$, so high-cost agencies will never send if $B < 2C$. Conversely, $p(\theta) > ½$ for agencies with $\theta < \theta^*$, implying that low-cost agencies will always send contingent on $B > C$, which completes the proof.

When $C < B < 2C$ does not hold, there are several possibilities. There are two possible pooling equilibria, one where all agencies send and one where no agency sends. The latter equilibrium arise if the cost of reporting is very high, so that $C > B$. It is not particularly interesting to analyze, because the legislature's decision will be independent of the signal it receives. The former equilibrium, where all agencies send, could result if the cost of reporting is zero. That is not in itself an interesting situation, but the legislature's strategy is in this case the same as if reporting was mandatory, and is determined by the costs of making type I and type II errors.

Result 3: When all agencies send, the legislature will accept a proposal if it signals that the expected payoff from accepting is at least half as much as the expected payoff from rejecting.

Proof of result 3: Note that the legislature's updated belief about the agency, when all agencies send, is just the reported value. This is because the expected value of a, is E(a) = θ, when $\varepsilon \sim N(0, \sigma^2)$. The decision facing the legislature can be described by the expected payoffs from

accepting: $V_L(A, \theta) = \int_{\theta}^{\theta^*} f(\theta)D(\theta)d\theta - \int_{\theta^*}^{\theta} f(\theta)E_2(\theta)d\theta$

rejecting: $V_L(R, \theta) = -\int_{\theta}^{\theta^*} f(\theta)D(\theta)d\theta$

The legislature will accept if $V_L(A, \theta) > V_L(R, \theta)$, or

$$\int_{\theta}^{\theta^*} f(\theta)D(\theta)d\theta > \frac{1}{2}\int_{\theta^*}^{\theta} f(\theta)E_2(\theta)d\theta$$

This implies that the legislature may accept proposals that lie above θ*.

1.A.1.4 Manipulation

A not unlikely situation is that the agencies can manipulate the results of the reports. With manipulation, all reports will send a signal that θ < θ*. Assume the cost of reporting is C(θ), C'(θ) > 0, i.e. it is increasingly costly to manipulate as the true value gets worse.

In this case there are several possible equilibria; one, albeit trivial, separating equilibrium, one pooling equilibrium where no one sends and one partially separating equilibrium such that some high-cost agencies send.

Result 4: There is a separating equilibrium in pure strategies if the cost of reporting is higher than the benefit of an accepted proposal for high-cost agencies.

Proof of result 4: A separating equilibrium in pure strategies requires the legislature to always accept if there is a low-cost signal and reject if there is no signal (there will not be any high-cost signals) The agencies' strategies would have to be $a_H = 0$ and $a_L = 1$. The expected payoff to a high-cost type agency is then $V_A*(N, R, \theta_H) = 0$. The expected payoff to a high-cost type agency from sending is $V_A*(S, A, \theta_H) = (B-C(\theta))$. A high cost agency will never send if $B-C(\theta) < 0$, or $B < C(\theta)$.

The more realistic case is to assume that $B = C(\theta)$ for some agency $\theta > \theta*$.

Result 5: Here, there is a pooling equilibrium when no one sends and a partially separating equilibrium when all low-cost agencies send, some high-cost agencies send and the legislature accepts proposals with some positive probability < 1 if they are accompanied by a report and rejects if there is no report.

Proof of result 5: The proof will proceed by ruling out the pooling equilibrium where all agencies send and the partially separating equilibrium where all high-cost agencies send and not all low-cost agencies send. The only remaining equilibria are the pooling equilibrium when no agency sends and the partially separating when only some high-cost agencies send.

First, note that agencies with costs above $C(\theta) = B$ will never send, because that strategy is dominated (see the definition of dominance under proof of result 2 above). The highest payoff the agencies can get from sending is $B - C(\theta)$, which is lower than zero, the agency's payoff from not sending. This rules out the pooling equilibrium when all send.

The partially separating equilibrium where all high-cost agencies send and not all low-cost agencies send can be ruled out, according to lemma 1:

Lemma 1: It is at least as likely that a low-cost agency will send as a high-cost agency.

This proof is similar to proof of part (i) of Lemma 1 in lewis and Poitevin [61].

Proof of lemma 1: Suppose it was not. Then the expected value of sending must be greater for the high-cost agency: $V_A(S, \theta_L) < V_A(S, \theta_H)$

$$s_N(B - C(\theta_L)) + (1 - s_N)(-C(\theta_L)) < s_N(B - C(\theta_H)) + (1 - s_N)(-C(\theta_H))$$

Thus,

$$C(\theta_L) > C(\theta_H)$$

But that is wrong by our assumptions.

The pooling equilibrium when no one sends arise only if the cost of reporting is higher than the benefit of an accepted proposal or if the legislature rejects all proposals, which they do if

$V_L(S, R) > V_L(S, A)$

which can be written,

$$-\int_{\theta}^{\theta^*} f(\theta)D(\theta)d\theta > \int_{\theta}^{\theta^*} f(\theta)D(\theta)d\theta - \int_{\theta^*}^{\theta} f(\theta)E_2(\theta)d\theta$$

or,

$$2\int_{\theta}^{\theta^*} f(\theta)D(\theta)d\theta < \int_{\theta^*}^{\theta} f(\theta)E_2(\theta)d\theta$$

In words, the legislature rejects all proposals if the expected value of accepting proposals that should have been rejected is more than two times the value of the benefits from good proposals. This could arise either because the initial probability of a low-cost proposal is low, so that the probability mass of type II errors is great, or if the cost of making type II errors is very high.

Finally, consider the equilibrium where the legislature accepts reports with $P < 1$ and agencies $\theta < \theta^+$ send and agencies $\theta > \theta^+$ do not send. The legislature will set the probability of accepting, s_S, so that
$\mu(\theta_L|L) = E(E_2(\theta))/2E(D(\theta)) + E(E_2(\theta))$

The payoff from sending to the agencies is
$V_A(S, s, \theta) = s_S(B-C(\theta)) + (1-s_S)(-C(\theta))$. The agencies will not send when $s_S(B-C(\theta)) + (1-s_S)(-C(\theta)) < 0$, or $s_S < C(\theta)/B$. In this equilibrium, the legislature is mixing, so it must be indifferent between accepting and rejecting:
$V_L(a < \theta^*, A, \theta < \theta^+) = V_L(a < \theta^*, R, \theta < \theta^+)$

and will set s_S so that

$\mu(\theta_L|S)E(D(\theta)) + (1-\mu(\theta_L|S))E(-E_2(\theta)) = - \mu(\theta_L|S)E(D(\theta))$
or,

$2\mu(\theta_L|S)E(D(\theta)) + \mu(\theta_L|S)) E(E_2(\theta)) = E(E_2(\theta))$

and thus,

$\mu(\theta_L|S) = E(E_2(\theta))/2E(D(\theta)) + E(E_2(\theta))$

The legislature will accept with a probability such that the updated probability of a low-cost intervention given that a report is sent is equal to $E_2/2D + E_2$. This value corresponds to the standard of proof in Lewis and Poitevin [61].

1.A.2 APPENDIX 2

1.A.2.1 Proof of result 6

Define the Condorcet winner ([79] p. 76):

If O is the set of alternative outcomes, then $x \in O$ is a Condorcet winner if, $\forall$ y $\in$ O, the number of people who strictly prefer x to y exceeds the number who strictly prefer y to x.

For all three voters, utility is maximized at $x_i = 0$. Note that with a simple majority rule, two voters can upset any outcome if there is some other point they prefer. Take two arbitrary voters x_i and x_j. Their joint utility $U_{ij}(x_i,x_j) = -x_i - x_j$ is maximized when $x_i = x_j = 0$. The constraint $x_i + x_j + x_k = 1$ is satisfied, then, only when $x_k = 1$. But then all the three corner solutions (1, 0, 0,), (0, 1, 0) and (0, 0, 1) will be supported by a majority, given that an indifferent voter will vote for the status quo, because the number of people who *strictly* prefer any one distribution to another does not exceed the number who *strictly* prefer the other way around. Thus, there is no Condorcet winner.

1.A.2.2 Proof of result 7

Let the probability that voter i votes for candidate A be p_{iA}. With no abstention, $p_{iB} = 1 - p_{iA}$.

Now, suppose that

$p_{iA}/p_{iB} = U_i(x_A)/U_i(x_B)$

so that

$p_{iA} = x_{iA}/(x_{iA} + x_{iB})$ and $p_{iB} = x_{iB}/(x_{iA} + x_{iB})$

Candidate A's expected plurality then, will be

$$E[plA] = \Sigma_i p_{iA} - \Sigma_i p_{iB} = \Sigma_i [x_{iA}/(x_{iA} + x_{iB}) - x_{iB}/(x_{iA} + x_{iB})]$$

To solve candidate A's maximization problem we use the Lagrangian

$$L = \Sigma_i [x_{iA}/(x_{iA} + x_{iB}) - x_{iB}/(x_{iA} + x_{iB})] - \lambda(\Sigma_i x_i - 1)$$

Candidate 2's maximization problem is set up in a corresponding way. Taking first derivatives for both candidates and solving for two arbitrary voters for each candidate gives the optimality condition,

$$x_{iA}/x_{jA} = x_{iB}/x_{jB}$$

Thus, both candidates will have the same ratio between any two candidates. Moreover, since the vote of each voter is worth the same to the candidates, they will both propose to divide the risk equally among all the voters
$x_A^* = x_B^* = (1/3, 1/3, 1/3)$.

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CHAPTER TWO.

THE COST-EFFECTIVENESS OF LIFESAVING INTERVENTIONS IN SWEDEN

With Lennart Sjöberg

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2.1 INTRODUCTION

What is the value of a human life? One way of approaching that question is to use the value of a saved statistical life. Statistical lives refer to a situation in which ex-post unidentified persons are subject to the risk of dying. A statistical life is said to be saved when the risk upon a whole population is reduced and an unidentified person is saved. Interventions from government, or other parts of the public sector, that save lives will be termed lifesaving interventions[10]. In the present article we report cost-effectiveness data for a large number of lifesaving interventions in Sweden[11].

2.2 REFERENCE CASE - OPTIMALITY

Jones-Lee [17] stated the condition for Pareto-optimality, with respect to the value of a statistical life under a willingness-to-pay approach: The value of a statistical life for a society of self-interested utility-maximizers[12] is given as the mean marginal rate of substitution between own safety and own wealth.

A similar condition for optimality can be derived in a simple general equilibrium model. This model can be found in any good textbook on microeconomic theory, e.g Varian [62] chapter 17 or Mas-Colell, Whinston and Greene [26], chapter 16 and Mathematical appendix M.K. In this model, the optimal cost per life saved and the relation between cost per life saved for different interventions can be simultaneously determined.

Consider an economy with I consumers and J "firms" that produce L lifesaving interventions. The firms in this model can be thought of as institutions that produce lifesaving on a competitive market. A peculiarity of this economy is that lifesaving is the only good produced. One unit of this good is one life saved.

Assume that the consumption set of every individual is R_+^L and that the preferences of each individual can be represented by the twice continuously

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[10] Our definition of a lifesaving intervention resembles that of Tengs et al. [57]: *A lifesaving intervention is defined as any measure directed towards changing the behavior and/or technology of individuals or organizations, where reducing the probability of premature death in a population is a primary goal or an actual effect of the intervention.*

[11] A large group of lifesaving interventions are politically decided. In this paper we will only be concerned with that type of decisions; private decisions regarding risks are not considered. The risks are health risks only, other kinds of risk such as financial risks are not considered.

[12] However, the analysis can be extended to cover various degrees and types of altruism, and for some types of altruism the value of a statistical life should be adjusted [17].

differentiable utility function $u_i(x_i)$, which satisfies $\nabla u_i(x_i) >> 0$ at all x_i (preferences are strongly monotone). Furthermore, assume that the production set of firm j is $Y_j = \{y \in R^L: F_j(y) \leq 0\}$. Assume that $F_j: R^L \rightarrow R$ is twice continuously differentiable, $F_j(0) \leq 0$, and that
$\nabla F_j(y_j) = (\delta F_j(y_j)/\delta y_{1j}, \ldots \delta F_j(y_j)/\delta y_{Lj}) >> 0, \forall y_j \in R^L$.

Then the Pareto optimal allocations of this economy are the allocations
$(x, y) = (x_1, \ldots x_I, y_1, \ldots y_J) \in R_+^{LI} \times R^{LJ}$

that solve

Max $u_1(x_{11},\ldots,x_{L1})$			(1)
	s.t. (i)	$u_i(x_{1i},\ldots,x_{Li}) \geq \bar{u}$	$i = 2,\ldots, I$
	(ii)	$\Sigma_i x_{li} \leq \varpi_l + \Sigma_j y_{lj}$	$l = 1,\ldots, L$
	(iii)	$F_j(y_{1j},\ldots, y_{Lj}) \leq 0$	$j = 1,\ldots, J$.

What this does is to maximize individual 1's utility constrained by a given required level of utility, $\hat{u}$ for all other individuals and the resource and technological constraints of what is feasible, given an initial endowment, ϖ. Under the assumptions of the model, all the constraints will be binding at the solution.

Result 1. Any allocation (x, y) that solves (1) is Pareto optimal.

Proof of result 1. The proof is by contradiction. So, suppose it is not true that any allocation (x, y) that solves (1) is Pareto optimal. Then there exists a feasible allocation (x',y') such that $x'_i \succsim x_i$, $\forall$i and $x'_i \succ x_i$ for some i, implying that $u_i(x'_i) > u_i(x_i)$ for some i. Strong monotonicity of preferences (which implies that if x' is larger than x for some good and is no less for any other, then x' is strictly preferred to x) together with the fact that constraint (i) will hold with equality in optimum means that we cannot have $u_i(x'_i) > u_i(x_i)$ for $i \neq 1$ (because $u_i(x_i) = \hat{u}$, and $u_i(x'_i) > \hat{u}$ is not a solution even though strong monotonicity would require $u_i(x'_i) > u_i(x_i)$) Thus, $u_1(x'_1) > u_1(x_1)$. Next, consider the set of all allocations $(x, y) \in R_+^{LI} \times R^{LJ}$ satisfying the constraints of the utility maximization problem and denote this C, the constrained set. The solution to (1) must belong to the constrained set (see appendix M.K. in [26]), or equivalently, the allocation (x,y) is a global constrained maximizer if it solves (1), i.e. if $u_1(x_1) > u_1(x_1')$ for all $x' \in$ C. But if $u_i(x'_i) > u_i(x_i)$., then x cannot be an optimum. Thus, an allocation can only be a solution if it is Pareto optimal.

Denote the multipliers associated with constraints 1, 2 and 3 by λ, μ and γ. First order conditions are then

$$\lambda_i \frac{\partial u_i}{\partial x_{\lambda i}} - \mu_\lambda = 0 \qquad (2)$$

$$\mu_i - \gamma_j \frac{\partial F_j}{\partial y_{\lambda j}} = 0 \qquad (3)$$

This leads to that in any Pareto optimal allocation the following ratio condition must hold:

$$\frac{\partial u_i / \partial x_{\lambda i}}{\partial u_i / \partial x_{\lambda' i}} = \frac{\partial u_{i'} / \partial x_{\lambda i'}}{\partial u_{i'} / \partial x_{\lambda' i'}} \text{ for all i, i', 1, 1'} \qquad (4)$$

which says that in any Pareto optimal allocation, each consumer's marginal rate of substitution between every pair of goods must be equalized.

Furthermore,

$$\frac{\partial u_i / \partial x_{\lambda i}}{\partial u_i / \partial x_{\lambda' i}} = \frac{\partial F_j / \partial y_{\lambda j}}{\partial F_j / \partial y_{\lambda' j}} \text{ for all i, j, 1, 1'} \qquad (5)$$

must also hold.

This ratio condition says that every consumer's marginal rate of substitution must equal every firm's marginal rate of transformation for all pairs of interventions.

The multiplier μ_1 in the first order conditions is interpreted as the marginal value, or shadow price, of good 1; in this case the marginal value of lifesaving intervention 1. In optimum, by the second fundamental welfare theorem[13], the Pareto optimal allocation (x,y) is a Walrasian equilibrium with $p_1 = \mu_1$ and we can combine (3) and (5) and state that

$$\frac{\partial u_i / \partial x_{\lambda i}}{\partial u_i / \partial x_{\lambda' i}} = \frac{p_\lambda}{p_{\lambda'}} \text{ for all i, 1, 1'} \qquad (6)$$

[13] Technically, this also requires convexity of preferences, which is not a strong assumption.

i.e., in optimum, the ratio of marginal cost per life saved between two interventions would equal the ratio of marginal utilities from the interventions. The same result was stated, but not derived, in Cropper and Subramanian [4], Furthermore, we want to determine p, the price of a life saved in equilibrium. Start with the ordinary consumer utility maximization problem and the associated Lagrangean

$$L = u(x) - \lambda(px - m)$$

with first order condition

$$\partial u(x)/\partial x_i - \lambda p_i = 0 \text{ for } i = 1,\dots k$$

where λ is the consumer's marginal utility of income.

In a market equilibrium, all consumers have maximized their utility so if (x,p) is a market equilibrium, then there exists a set of numbers $(\lambda_1,\dots \lambda_n)$ such that (see e.g. Varian [62] chapter 16, for a complete derivation of this result)

$$Du_i(x) = \lambda_i p \qquad i = 1,\dots n$$

$$\text{or } p = (1/\lambda_i)Du_i(x)$$

Here, this represents the familiar result that in optimum, the price of a life saved is equal to the marginal change in utility from saving a life times the reciprocal of the marginal utility of income. This can be stated in different ways; the cost-effectiveness ratio of lifesaving interventions should be equal to the reciprocal of marginal utility of income [28], or that the willingness to pay for a utility change from a life saved is found from dividing the utility change by the marginal utility of income [16].

To summarize, in a Pareto optimal allocation, all consumer's marginal rate of substitution between every pair of lifesaving interventions must be equalized and the optimal cost per life saved is the marginal change in utility from saving a life times the reciprocal of the marginal utility of income.

Following Cropper and Subramanian [4], we have assumed that an individual's utility from a lifesaving intervention is a function of the number of lives saved, X, *and* a vector of qualitative characteristics of the intervention and the risk, C.

$$U = f(X,C)$$

If we instead would assume that utility is a function only of the number of lives saved by the intervention, the result would be to require that the marginal cost of a life saved should be equal for all interventions. If they were, the number of lives saved would be maximized for a given total investment, or conversely, the same number of lives could be saved at a smaller cost. Tengs and Graham [58] explored this issue, using a database of more than five hundred lifesaving intervention, and found that 60,000 lives are lost (i.e. not saved) every year in the United States, due to a 'wasteful' allocation of resources!

However, in the literature there is strong support for the idea that risks are perceived differently depending on a number of qualitative dimensions [50]. It is by no means inconceivable that the cost per life saved *should* vary, because some risks are seen as more important than others. Also, it could very well be the case that an intervention from society can only be tolerated up to a certain point, even if this is well below the 'efficient' level. This qualification seems most appropriate for lifestyle risks, such as alcohol use, smoking and dietary habits. Some areas can even be expected to be regarded as completely private and off the turf of government[14]. In reality, it is of course often the case that there are only a limited number of lives to save, i.e. an intervention can only be implemented to one hundred percent of the target population. If more resources are allocated at that point, the marginal cost of the intervention would immediately rise to infinity.

2.3 IMPLIED LIFE-VALUES

The above discussion of conditions for optimality is normative, in the sense that it aims at deriving an explicit value of a statistical life, or explicit value*s* if we recognize that valuation should differ between risks with different characteristics.

A different, descriptive, angle is to look at *implied* life-values, i.e. the value on a statistical life that a certain intervention implies. An implied life-value is thus simply the cost-effectiveness of a lifesaving intervention, measured as cost per life saved. Below, we refer to a number of studies that present collected or computed data on the cost-effectiveness of lifesaving interventions. However, note the important distinction that although an implied life-value is the cost-effectiveness of a lifesaving intervention, the cost-effectiveness of a lifesaving intervention is an implied life-value only under certain conditions:

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[14] Interestingly enough however, in a recent survey in Sweden, hardly *any* risks were seen as inappropriate for government regulation by a vast majority of the respondents [47].

1) The intervention is implemented.
2) The sole purpose of the intervention is to save lives.
3) The intervention can be continuously implemented up to infinity.

2.4 Earlier studies

The most ambitious effort to date to collect data on cost per life-year saved is reported by Tengs et al. [57], where the cost-effectiveness of more than five-hundred lifesaving interventions is presented.

To the best of our knowledge, only two studies have been previously published concerning the cost-effectiveness of life saving interventions in several sectors of the Swedish society.[15] Hellqvist et al. compared implicit and explicit life-values as early as 1977. Implicit and explicit life-values were calculated for 10 sectors of society. Both the implicit and explicit values were found to vary between a few hundred dollars up to $2.4 million[16] [11]. Sjöberg and Ogander [49] later presented eight cases and found that the cost per life saved varied from $77 for a campaign against smoking to $35.7 million for a system for reducing gasoline gas pollution. In the USA, several studies regarding the cost-effectiveness of life saving interventions have reported variation in the same order of magnitude as Sjöberg and Ogander, or more [3], [29], [1]. In a British study, Soby, Ball and Ives [51] also reported a very large variation.

Implied life-values, if they can be obtained, would give a description of society's implicit valuation of a statistical life in the sectors for which values have been obtained. The three conditions stated above are not fulfilled in any of the studies referred to above. This severely restricts the possibility to draw conclusions about life-values from the empirical data.

In spite of its important policy implications the issue has not been thoroughly investigated except in the USA. A comparison with Swedish data is interesting because Sweden, although a wealthy country, has considerably lower

[15] We use "sector of society" somewhat loosely here, meaning a part of society that can be distinguished either in administrative or functional terms. The "health care" sector can e.g. be defined both in administrative and functional terms whereas e.g. "crime" basically is a functional sector (which sometimes also overlaps "health care"). We are aware that this is not stringent, but stringency is neither crucial, nor common, in this case.
[16] Throughout, Swedish *kronor* has been converted to dollars using an exchange rate of $1 = SEK 7.

GNP/capita[17] than the U.S., and is yet much oriented towards safety and security.[18] Furthermore, Swedish taxes are much higher than American. Another factor which differs between the American and Swedish societies is the level of damages awarded by courts; Swedish levels are two or three magnitudes less than the US ones. The net outcome of these factors for investment in lifesaving interventions could not be deduced; it had to be investigated empirically.

Having established that the issue is, indeed, an important one, we go on to present our findings.

2.5 Method

Our intention was to use published economic analyses of lifesaving interventions in Sweden. These could be from the scientific literature, government reports or reports from non-government organizations. The criteria for including an analysis were that it should concern lifesaving interventions in Sweden and report cost per life saved, cost per life-year saved or sufficient information to calculate one of these measures. However, the result of this search was somewhat disappointing in that very few articles reported cost per life saved. Many government reports and proposals did not even contain any quantified information on the costs or effects of a proposed intervention. This is remarkable since Swedish law requires government agencies to present costs and expected effects of proposed regulations and interventions. However, by combining information from different sources it was in many cases possible to calculate the cost per life saved.
In order to be able to compare the cost-effectiveness of different interventions, they should ideally be in the same form with respect to a number of factors [45]. Here, we have followed Tengs et al. [57] in many respects and the factors are:

- Interventions have both direct and indirect costs and when the analyses are carried out on a societal level all net opportunity costs should be included. However, in practice it is often difficult to obtain estimates of all indirect costs. An additional problem in the present study was that different standards are used by different authors. There are also some unresolved theoretical issues involved; e.g. regarding how to handle future costs induced by people that are saved by an intervention [46]. Tengs *et al.* [57] chose to include only

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[17] It has to be recognized, however, that the total GNP of Sweden is *much* smaller than that of the U.S. and this could mean less resources to spend on very expensive lifesaving interventions (such as a "star wars" program).
[18] In a recent study, Ramsberg found that the general public in Sweden perceives Sweden as more safe than at least the other European countries, but yet thinks that too little resources are spent on safety.

direct costs and exclude indirect costs such as foregone earnings. The Panel on cost effectiveness in health and medicine [46] recommends including all indirect costs, but acknowledges the conceptual and practical problems involved. We decided to include indirect costs related to foregone earnings in the present time period, but exclude future health care and future non-health care costs.

- Costs and benefits should be calculated on a societal level.

- Some interventions have costs and benefits distributed over time. Regarding costs, it is common practice to discount the costs to a present value in these cases. Concerning lives saved in the future, there has been a debate whether or not they should be discounted as well. The main argument against discounting lives saved is that all lives have the same value, including future lives. However, if it is accepted that costs should be discounted, but not lives, the conclusion will be that it is *always* better to wait with an investment that saves lives in the future [21]. Both costs and lives should therefore be discounted. We have chosen a discount rate of five percent, which is the recommended standard for societal cost-benefit analyses in Sweden. All the analyses that had already used discounting, used a discount rate of five percent.

- Costs and effects should be incremental [46].

- Cost-effectiveness should be expressed in 1994 SEK using the general consumer price index. However, in this article we decided to present the data in 1993 dollars in order to facilitate a comparison with the data from Tengs et al.
- An additional factor concerning comparability is that some interventions are only proposed and some of the proposed interventions will be implemented in the future and others will not. To make matters worse, it is not always clear whether an intervention has been implemented or not and to what degree. Paltiel *et al.* has addressed this issue in one article [33] by letting an expert panel assess the level of implementation in the database of 500 lifesaving interventions, but that information was not included in Tengs et al [57]. Due to limited resources, we have not done this. Anyway, we believe that in the current setting it is sufficient to state that the intervention has not been implemented or that we do not have the information in the relevant cases.

2.6 Result

The number of interventions we describe is 167. However, many of these are data points for the same intervention and the number of distinct interventions is approximately 80. The mean cost per life saved is $34.7 million and the median is $0.6 million. The mean cost per *life-year* saved is $863,000 and the median cost per life-year saved is $19,500. However, in the data there is one extreme outlier of $4,893 million per life saved and if that observation is dropped, the mean cost per life saved is $5.1 million and the mean cost per life-year saved is $122,000.

Cost per life saved and cost per life-year saved have been collected or calculated for nine different categories of lifesaving: medical care, radiation protection, road safety, life style risks, electrical safety, accidents, pollutants in the environment, fire protection and crime. These categories are admittedly somewhat *ad hoc*. Medical care includes by far the largest number of observations, whereas crime and accidents contain only one observation each. The number of observations and mean and median cost per life saved for the different categories are presented in Table I.

Table I: *Number of observations and mean and median cost per life-year saved for nine categories of lifesaving interventions. All costs in 1993 dollars.*

Category	n	Mean	Median
Medicine	101	1,244,874	14,000
Radiation	13	30,008	1,400
Road safety	32	242,209	66,500
Life style risks	3	470	340
Fire protection	7	211,214	15000
Electrical safety	2	1,245,000	1,245,000
Accidents	1	280,000	280,000
Pollutants in the environment	5	235,000	67,000
Crime	1	15,000	15,000

The cost per life saved for the interventions are presented in Table II.

Table II. *Cost per life-year saved in 1993 dollars for 165 lifesaving interventions in Sweden*[19]*. Interventions that are only proposed are marked* (P) *and interventions for which we do not know the level of implementation are marked* (U).

INTERVENTION	Cost/life-year in 1993 dollars	Primary Source
Medical care		
Screening		
(P)AAA-screening, all men > 60 (assumed mean age: 65)	9,800	[2]
(P)AAA-screening, risk groups only	8,400	[2]
(P)APCR-screening of all women prior to prescribing medical contraceptives	130,000	[5], [31]
Screening of donated blood: HIV	2,800	[13]
Screening of donated blood: HTLV-I	120,000,000	[13]
(P)Virus elimination of blood plasma	180,000	[13]
(P)Quarantine of blood plasma	350,000	[13]
Lung cancer screening program	28,000	[65]
(P)Prostate cancer screening	4,500	[43]

[19] In a report by Ramsberg and Sjöberg [38], most of the interventions and how the cost-effectiveness was calculated are more extensively presented.

Mammography	9,800	[18], [56]
Two-picture mammography, compared to one-picture mammography	15,000	[25], [56]
Suicide prevention program	≤ 0	[41]
— *Asthma*		
(P)Upgrading ventilation in the whole stock of buildings in Sweden	1,000,000	[34]
Vaccination		
Pertussis vaccination	≤ 0	[30]
HIB vaccination	≤ 0	[61]
General influenza-vaccination: H2N2 virus, age groups:	≤ 0	
0-4	8,400	[40]
5-19	20,000	[40]
20-34	28,000	[40]
35-44	28,000	[40]
45-54	28,000	[40]
55-64	14,000	[40]
65-74	7,000	[40]
75-84	2,800	[40]
85-	1,400	[40]
All	14,000	[40]
Excluding 0-19	14,000	[40]
Only people > 65	24,000	[40]
General influenza-vaccination: H3N2 virus, age groups:		
0-4	98,000	[40]
5-19	98,000	[40]
20-34	98,000	[40]
35-44	70,000	[40]
45-54	28,000	[40]
55-64	28,000	[40]
65-74	14,000	[40]
75-84	7,000	[40]
85-	2,800	[40]
All	28,000	[40]

Excluding 0-19	28,000	[40]
Only people > 65	34,000	[40]
Ambulance service		
(U) Physician Presence on Ambulance and Helicopter Emergency Medical Service in the County of Västernorrland	2,800	[55]
Helicopter Emergency Medical Service:		
Sparsely populated areas, with physcian	14,000	[36]
Sparsely populated areas without physcian	12,000	[36]
Urban areas	71,000	[36]
Västerbotten	20,000	[36]
Hypertension treatment		
Hypertension treatment with diuretics or beta-blockers, men < 45 years: diastolic blood pressure:		[42], [14]
90-94 mmHg	98,000	
95-99	84,000	
100-104	70,000	
>105	42,000	
men 45-69 years: diastolic blood pressure:		[42], [14]
90-94 mmHg	4,200	
95-99	≤0	
100-104	≤0	
>105	≤0	
men > 70 years: diastolic blood pressure:		[42], [14]
90-94 mmHg	1,400	
95-99	420	
100-104	≤0	
>105	≤0	
Hypertension treatment with diuretics or beta-blockers,		[42], [14]

women < 45 years: diastolic blood pressure:		
90-94 mmHg	260,000	
95-99	200,000	
100-104	140,000	
>105	56,000	
women 45-69 years: diastolic blood pressure:		[42], [14]
90-94 mmHg	14,000	
95-99	8,400	
100-104	≤0	
>105	≤0	
women > 70 years: diastolic blood pressure:		[42], [14]
90-94 mmHg	1,200	
95-99	≤0	
100-104	≤0	
>105	≤0	
Hypertension treatment with ACE-inhibitor or kalcium antagonist, men < 45 years: diastolic blood pressure:		[42], [14]
90-94 mmHg	180,000	
95-99	150,000	
100-104	120,000	
>105	98,000	
men 45-69 years: diastolic blood pressure:		[42], [14]
90-94 mmHg	14,000	
95-99	11,000	
100-104	5,600	
>105	≤0	
men > 70 years: diastolic blood pressure:		[42], [14]
90-94 mmHg	5,600	
95-99	4,200	
100-104	1,400	
>105	≤0	
Hypertension treatment with ACE-inhibitor or kalcium		[42], [14]

antagonist, women < 45 years: diastolic blood pressure:		
90-94 mmHg	490,000	
95-99	380,000	
100-104	280,000	
>105	170,000	
women 45-69 years: diastolic blood pressure:		[42], [14]
90-94 mmHg	42,000	
95-99	28,000	
100-104	14,000	
>105	560	
women > 70 years: diastolic blood pressure:		[42], [14]
90-94 mmHg	5,600	
95-99	2,800	
100-104	560	
>105	≤0	
Lipid lowering, in men (mean age: 49):		
normal advice+ pharmacological treatment	56,000	[15]
intensive advice only	21,000	[15]
Treatment		
Surgical treatment of aortic stenosis	4,200	[65]
Heart transplantation	14,000	[65]
Lung-cancer treatment program in Uppsala	56,000	[65]
Surgical treatment of oesophagus cancer	7,000	[65]
Surgical treatment of cardiovascular transposition in infants	700	[65]
Bone-marrow transplantation	8900	[49]
Radiation		
Measures to remove indoor radon:		

1979-1992, existing houses	4900	[54]
1979-1992, new houses	350	[54]
(P)Proposed measures 1992-2002, existing houses	1400	[54]
(P)Proposed measures 1992-2002, new houses	350	[54]
Sealing up leakes + radon suction in private homes with > 400 Bq/m3	250	[54]
Sealing up leakes + radon suction in private homes with 200-400 Bq/m3	700	[54]
Sealing up leakes + improved vemtilation in private homes with > 400 Bq/m3	2100	[54]
Measures to detect and remove radon in drinking water	20,000	[23]
Guideline for reconstruction in nuclear power plants (explicit value)	220,000	[53]
The Nordic Council: Guideline for all types of radiation protection measures (explicit value)	45,000	[53]
Information campaign to increase public awarness regarding the risk of malign melanoma:	700	[53]
(U) Reduced risk for cancer from radiotherapy by an increased use of coal-fibre cassettes:	350	[53]
The Radiation Protection Institute's policy (explicit value)	94,000	[53]
Road Safety		
Motor vehicle inspection	640,000	[12]
Break-away Lamp-posts	6,500	[22]
Various road safety measures:		[35], [64], [60], [10], [27]

(P)New speed limit system, present control and tolerance	57,000	
(P)New speed limits, +5 times present control and +10% tolerance	59,000	
(P)+5 times present speed control +10% tolerance	67,000	
Overpass at 4-road intersection, rural areas.	17,000	
Intersections, rural areas; 4-road intersections, shifted 3-road intersections	7,700	
Concrete barrier between directions on highways	12,000	
Intersections, rural areas, traffic circles	17,000	
(U) Local speed limit in 4- road intersections with left-turn pockets, rural areas	22,000	
Intersection urban areas, traffic circles	28,000	
(P) 70 km/h ADT 4 000-8 000	41,000	
(P) 70 km/h ADT > 8 000	2,800,000	
(P) 90 km/h ADT 4 000-8 000	310,000	
(P) 90 km/h ADT > 8 000	270,000	
(P) 110 km/h ADT 4 000-8 000	29,000	
(P) 110 km/h ADT > 8 000	43,000	
Speed bumps, urban areas	48,000	
Speed bumps on residential streets ADT>10 000	66,000	
Mini-traffic circle	78,000	
(P)Reconstruction to motorway 110 km/h: all trunk roads 110 km/h, ADT 8 000-9 999	70,000	
(P)Reconstruction to motorway 110 km/h, all trunk roads 110 km/h, ADT >10 000	73,000	
(P)Reconstruction to motorway 110 km/h, all other main roads 110 km/h, ADT>8 000	78,000	
(P)Reconstruction to motorway	130,000	

90 km/h, all other main roads 90 km/h ADT 8 000 -9 999		
(P)Reconstruction to motorway 90 km/h, all other main roads 90 km/h ADT>10 000	140,000	
(P)Reconstruction to motorway 90 km/h, all trunk roads 90 km/h, ADT>8 000	98,000	
Fences between directions on highways central reservation > 2 m.	11,000	
Intersection, urban areas, traffic circle	700,000	
Traffic lights in 4-road intersections with large traffic flows, urban areas, 50 km/h	840,000	
(P)Airbag mandatory in all new cars	110,000	
Reconstruction of all railway crossing with sound and light signals to half- level crossing gates	34,000	
Reconstruction of level crossing gates to overpass or underpass intersections	840,000	
Life-style risks		
Age limit on tobacco use	545	[8], [52]
Campaign against smoking	340	[49]
A Tobacco Quit and Win Contest	250	[59]
Fire Protection		
Rescue service at airports	760,000	[24]
Battery-operated fire detector in one-familly homes,	≤0	[19]
Battery-operated fire detector in multifamilly homes,	15,000	[19]
Mains-operated fire detector in one-familly homes,	≤0	[19]
Mains-operated fire detector in multifamilly homes,	3,500	[19]

Sprinkler system in private homes	480,000	[20]
Fire prevention in health care institutions	220.000	[49]
Electrical Safety		
(P)Residual Current Device mandatory in all private houses	600,000	[37]
Removing electromagnetic field from power lines in Bergshamra	24,620,000	[6], [7], [9]
Accidents		
Safety-lids on wells	280,000	[49]
Pollutants in the environment		
Sleeves on gasoline pumps to remove benzene	890,000	[49]
Ethyleneoxide	32,000	[63]
Vinylchloride	140,000	[63]
Arsenic	67,000	[63]
Polyaromates	46,000	[63]
Crime		
Security packages for battered women	< 0	[39], [32]

2.7 COMPARISON WITH AMERICAN DATA

We will make a simple comparison of our data to the data presented in Tengs et al. It would be pointless to make the comparison on the level of individual interventions, because we have described much fewer interventions and they are not the same as in Tengs et al. Instead the comparison is made for the overall median and the median for sectors. Our sectors were not the same as in the American study, but we reclassified our data to produce Table III, where the median cost per life-year saved and the number of observations are presented for both Tengs *et al.*, and our data.

Table III: *The median cost per life-year saved and the number of observations for the data in the present study, compared with the data from Tengs et al. [57].*

	Sweden Cost per life-year saved, in 1993 dollars	USA Cost per life-year saved, in 1993 dollars
Medicine	13,800 (n=102)	19,000 (n=310)
Toxin control	19,600 (n=19)	2,800,000 (n=144)
Fatal injury reduction	69,900 (n=43)	48,000 (n=133)
All	19,500 (n=165)	42,000 (n=587)

It is obvious from Table III and Figure I that the difference between the overall median for the Swedish data, $19,500, and the median for the American data, $42,000, can be explained entirely by the very large difference in the median for toxin control interventions. Tengs *et al.* found a median of $2,800,000 for toxin control and in the Swedish sample the median was a mere $19,600. This could be due to the small size of the Swedish sample, data for only 19 interventions were found, and the sample is probably not representative.

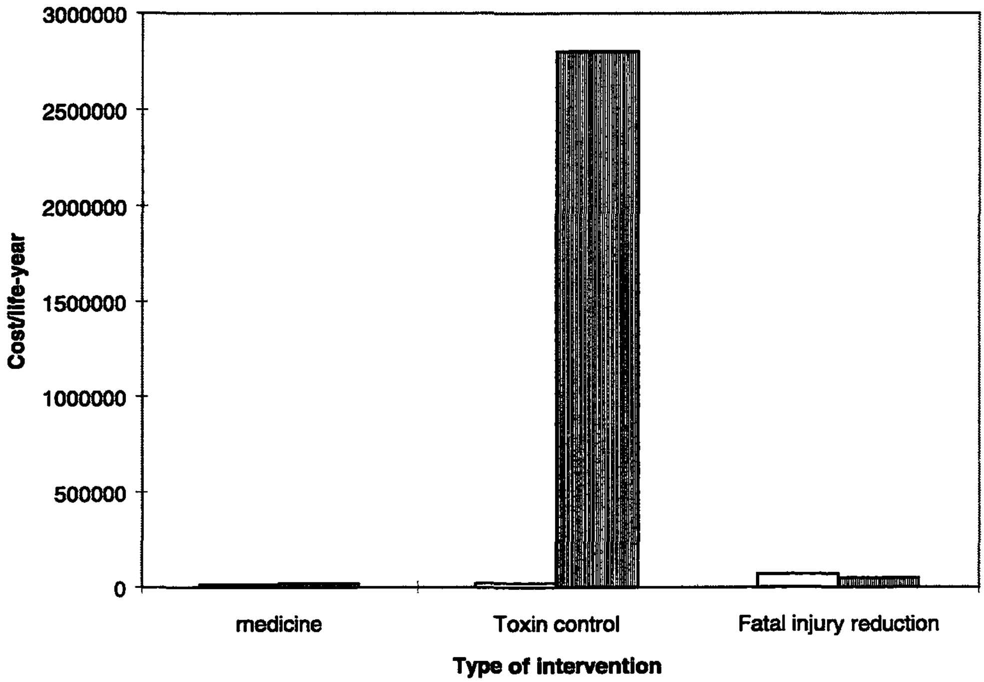

Figure I: *Cost per life-year saved in 1993 dollars for three categories of lifesaving. Swedish and American data.*

The most interesting finding is the similarity of the median cost per life-year saved in medicine between the American and the Swedish sample. Spending on the health care sector is considerably larger in the USA, also per capita, than what it is in Sweden and we had expected this to be reflected as a higher median in the American data. Note, however, that the figures presented here need not be representative of the cost per life-year saved in the health care sector, neither in Sweden nor in the USA.

2.8 COMPARISON WITH EARLIER SWEDISH DATA

In Hellqvist et al. [11], the cost per life saved for different sectors of society are presented and they make an interesting comparison to our, more recent, study. Some of these costs are presented in Table IV.

Table IV: *Cost per life saved in 1993 million dollars for some of the life saving interventions presented in Hellqvist et al. [11].*

Intervention	Cost/life saved in million 1993 dollars
Medical examinations for workers exposed to asbestos	1,8
Driver's protection on tractors	1,3
Fire fighting in Gothenburg	0,2
Improved air traffic controll	1,6
Safety measures at abandoned mining sites	1,2
Automatic door locks on railway cars	0,03
Safety-at-sea information	0,01
Swedish Lifeboat Service (sjöräddningen)	0,04
Under-driving protection on heavy trucks	0,6

One of the most striking features when comparing the cost per life saved in Hellqvist with the costs that we present is that the variation is much larger in our data. This could reflect either that the variation is indeed larger today than it was 20 years ago, or that the Hellqvist sample is not representative and rather small. Unfortunately, the material is too small to permit a statistical analysis of the two data sets. If it is the case that the variation in cost per life saved has increased over time, an explanation could perhaps be sought in organizational factors. Firstly, regulatory agencies have changed, with respect to both organization and scope. Secondly, the number, and impact, of interest groups have increased in the last decades, which might have an influence on the cost per life saved in areas where interest groups are active. This explanation is pure speculation on our behalf, but it would certainly be interesting to pursue the issue in future research. The risk-literature, especially in sociology, supports the idea that organizational factors are important in explaining society's response to risk [44].

The cost per life saved in the most expensive interventions is considerably higher in our study than what it is in that of Hellqvist. One possible explanation is that there is a decreasing marginal effect of safety measures and to gain additional safety has in some areas, such as donated blood, becomes very expensive. To further increase safety in some areas can only be done at a higher marginal cost. In the 1970's, there were, according to this hypothesis, simply more cost-effective measures to implement than in the 1980's and 1990's. Safety is most likely a normal good and as income increases, so does demand for safety. Because real income has increased substantially in Sweden since the 1970's, we would expect an increase in demand for safety, which could motivate more and more expensive interventions.

In a study of bill proposals in the Swedish parliament, increased risk concerns were related to the low rate of economic growth true of Sweden currently. In the 1960´s economic growth was more rapid and MP´s much less interested in risk issues and more in resource allocation bills [48]. High cost per life saved may be seen as a politically expedient signal about concern and need not be very costly due to the often rather small investments called for. High cost per life saved often occur due to the small probabilities of the adverse effects which are mitigated.

2.9 Limitations

Comparisons of cost effectiveness data between sectors of society, countries and over time is only interesting to the extent that the data represent implied life values. As we have seen, there is a perfect match between cost effectiveness and implied life value only under certain conditions that are not normally met.

It has been our ambition to make the figures concerning the cost-effectiveness of the interventions as comparable to one another as possible. The costs and effects of the different interventions were originally calculated by different authors, in many cases using different methods. With this compilation, we have enhanced the comparability of the interventions, but the reader should be aware that dissimilarities in the calculations still remain. For instance, the lives saved and the costs are not discounted for all the interventions.

Just as Tengs et al did [57], we note that the original data on which the original analyses were based of course put a limit on the accuracy of our results as well.

As mentioned earlier, some interventions have only been proposed or proposed and rejected. These are marked in Table II.

The somewhat uncertain quality of the data and the fact that cost-effectiveness data is not always equal to implied life-values, both restrain the possibility to draw conclusions about investment in lifesaving interventions in Sweden. Furthermore, it is unlikely that these interventions constitute a representative sample of all lifesaving interventions, yet another reason to be cautious when drawing conclusions from these results.

2.10 Discussion

We have been cautious in drawing conclusions from the data. We believe this is a sound policy given the problems encountered in this kind of studies. Nevertheless, at this point, we want to state that we consider it highly likely that implied life-values varies greatly between different risks and sectors of society. This is because most of the interventions we describe are in fact implemented and practically all of the interventions have other objectives than saving lives. The last statement means that although the nominal value of a saved life is not correctly estimated, the *difference* between values can still be a good approximation. An example illustrates the point. A life saved in one of the most expensive interventions, reducing exposure to gasoline gazes was 46,000 times as expensive as one saved in a campaign against smoking, which was one of the least expensive. Both interventions were implemented. It is our view that this variation can probably only be slightly modified by considering the effect of conditions 2); that they have other objectives than saving lives and 3); that they are not perfectly continous.

The present results also suggest that Swedish and US cost per life, or life-year, saved, are on the whole comparable, the exception being the area of toxic control, where the median cost is much higher in the USA.

Part of the explanation of the similarity could be that small countries tend, to some extent, to imitate policies of a large, dominating, power such as the USA with its high media saliency and many important contributions to research.
Could social rationality be improved if results such as the present ones were to be taken into account? It is obvious that total equality is impossible and perhaps also undesirable. However, authorities and politicians need, in our view, be more aware of the implications of their decisions with regard to cost

effectiveness. Few of the figures presented here appear to have been calculated by those making the decisions. Hence, they may find that they wish to review some of those policies, once the analyses have been made.

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CHAPTER THREE.

THE IMPORTANCE OF COST AND EFFECTIVENESS FOR ATTITUDES TOWARDS LIFESAVING INTERVENTIONS

With Lennart Sjöberg.

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3.1 INTRODUCTION

Several studies have reported large disparities in the cost per life saved for different lifesaving interventions. Such studies have been conducted in the U.S. [12], [38], [37], [1], [21], [4], the U.K., [33], in Japan [18] and in Sweden [22], [30], [16]. Typically, results indicate that some interventions have benefits that outweigh the costs, i.e., a cost per life saved at or below zero, whereas others incur a cost per life saved in the range of hundreds of thousands or even hundreds of millions of dollars.

Our definition of a lifesaving intervention resembles that of Tengs et al.[37]; A lifesaving intervention is defined as any measure directed towards changing the behavior and/or technology of individuals or organizations, where reducing the probability of premature death in a population is a primary goal or an effect of the intervention.

In a seminal article, Starr [34] concluded that the divergent investments in risk reduction are roughly at a societal optimum. According to this view, society has arrived at this optimum by a trial-and-error process, in which people's preoccupation with the qualitative aspects of risk is reflected. However, as Graham and Vaupel [13] and Cropper and Subramanian [6] note, it is in no way obvious that current disparities in cost per life saved reflect public preferences.

Starr's conclusion has been debated at great length, and the cost per life saved of interventions have been suggested to vary for several other reasons. Brooks *et al.* [3] suggest that an intervention implementation can be driven by regulatory compliance issues, influential advocates associated with the project, an affordable budget, or politically visible risk addressed by the intervention. Cropper and Subramanian [6] argue that the manner in which the programs are funded can explain many of the differences. Although Graham [11] concludes that society may be concerned with values other than economic efficiency, he concedes that there might be serious imperfections in the political decision making process, leading to perverse variations in lifesaving investments. Graham hypothesizes that the political process devotes more attention to risks where the target population is politically organized, the costs of regulation are less visible, and the regulatory agency is subject to co-optation[20] by the regulatee.

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[20] Co-optation means that a special interest has taken authority over the regulator which then makes decisions that are in the best interest of the regulatee.

A few have attempted to study public preferences with respect to acceptable variation in the cost per life saved. Savage [23] found that mean willingness to pay to reduce four different risks varied by a factor of three and that the variation was associated with the psychometric risk attributes dread and unknown[21]. Mendeloff and Kaplan [20] and Cropper and Subramanian [6] have both examined the issue of acceptable variation in cost per life saved. The results in both of the latter studies indicated that the median respondent supports a variation of a factor two or three in certain circumstances. In other words, a more preferred program could have as little as a third of the efficiency in saving lives as that of a less preferred program and still be chosen in a pair-wise comparison[22]. A majority of the respondents however, were not willing to trade lives for qualitative characteristics beyond that point. Thus, the large variation that we see in actual costs per life saved, which varies by a factor of thousands or millions, could not be justified or explained in any of the studies.

Gregory and Lichtenstein [14] sought to determine which respondents would sacrifice lives for psychometric risk attributes, without trying to determine the accepted variation in cost per life saved. The results were mixed. Most respondents were willing to make some tradeoff, but a large group refused to make any tradeoff at all.

3.2 Hypothesis and Research Question

Thus, lay respondents have been found to accept or support a variation in cost per life saved of a factor two or three in at least three well-conducted studies. However, the authors of this article feel that additional insight into the issue of accepted variation in cost per life saved could be gained by incorporating the following three aspects into the context for evaluation:

1) We wanted the respondents to evaluate a fairly large number of diverse programs, as this might increase the degree of accepted variation.

2) We did not want the respondents to choose between programs; this puts the focus on the tradeoffs made when choosing one program over the other. Consequently, in this setting, cost-effectiveness becomes very salient. In many

[21] See Slovic [32] for a comprehensive discussion of psychometric risk attributes.
[22] This was the Cropper and Subramanian study; Mendeloff and Kaplan did not use pairwise comparisons, but the intuition is the same.

instances people do not consciously choose between programs; more likely they are evaluated one at a time [7]. Further, when people form a preference or an attitude about a government program, they frequently have information about neither the program's cost nor its cost-effectiveness. This is not to say that cost or cost-effectiveness are unimportant attributes. However, in reality, people often evaluate programs without important information.

3) We wanted to use the respondents' own primitive beliefs (perceptions) about cost, effectiveness and various qualitative attributes of the programs rather than imposing these on the respondent.

Our motivation for these design choices flows from the fact that any kind of preference-elicitation exercise is potentially sensitive to the question framing [9], i.e. how the question is stated will affect the answer. In fact, it is even probable that preferences are *formed* by the valuation process.

Regarding preferences elicited in contingent valuation studies, one of the method's most vocal proponents, Hanemann [15], has said that the subject need not have held these preferences before the survey was conducted. It is unnecessarily strict to require people to have well-defined preferences - "utility functions engraved in their brain[23]" - for perhaps previously unknown public goods. In fact, Hanemann goes on to say that according to modern neuroscience and cognitive psychology, people do not even have well-defined preferences for most ordinary market goods. This is not necessarily a problem; most empirical research is sensitive to the design of the instrument it uses and it would be surprising if the same was not true for preference elicitation. It does, however, raise the issue of how to frame the question correctly.

We hypothesized that respondents would accept a larger variation with our format. However, if our hypothesis was correct it would still be an open question as to what format best describes underlying reality. We do believe that our framing captures some features of how preferences, or attitudes, might be formed and expressed. Yet, we recognize that normatively our format is inferior; this is not a way to elicit the public's well-considered references. In particular, a person's incorrect assumptions or beliefs about a certain phenomena might affect that person's actions. In such an instance it is relevant to take the beliefs as given in a

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[23] Hanemann [15], page 23.

descriptive study, but we are unaware of any particular reason to give those beliefs normative significance.

One problem with our approach is that it would be very hard to ground it firmly in utility theory. Instead of assuming that respondents have a utility function, we make the weaker assumption that they have an attitude function. Utility functions are constructed from preferences, which always concern relations between objects. For preferences to be represented by a utility function, a necessary (but not sufficient) condition is that preferences are rational. Rational preferences are defined as being complete and transitive. Attitudes, on the other hand, can be directed towards single objects, which means that we do not have to assume rationality of the respondents. In particular, we do not have to assume transitivity, which has been a problem in earlier studies of similar issues. The transitivity assumption can, for example, be violated by framing effects, which often are present in contingent valuation studies. For our purposes, the study of attitudes seemed to be both feasible and also sufficient to generate some interesting insights into what might be influencing (or not influencing) attitudes towards lifesaving.

Of particular interest was to examine the importance of cost and effectiveness as predictors of attitudes.

3.3 THE STUDY

A straightforward way of obtaining attitudes in a survey setting is to ask the respondents to state the importance of an intervention.

Respondents are assumed to have an attitude function towards objects of the form,

$$A = \sum_{i=1}^{T} b_i e_i$$

Where *b* is the belief about an aspect of the object and *e* is the importance weight of the aspect. A person might for example hold a belief about the content of sugar in grams in a chocolate bar and attach a certain importance to this sensation [10].

The additive attitude function lends itself easily to linear regression analysis. The regression coefficients that later will be obtained can be interpreted as the importance weights *e*, from the model.

This method is akin to the "headline-method" developed by Kahneman and Ritov [17]. An assumption behind our model was that people are able to evaluate lifesaving interventions without being given complete information about the intervention. This could be expressed as an assumption that people have attitudes based on underlying primitive beliefs about the lifesaving interventions. We presumed that the subjects had ideas about various qualitative and quantitative characteristics of the programs; we did not want to impose these on the respondent and, as discussed earlier, we did not want to make cost-effectiveness a salient feature in the study.

Kahneman and Ritov [17] justify the rudimentary amount of information (they gave even less information than we did) given to respondents by the hypothesis of process continuity. Errors and biases that affect quick and intuitive judgments are also present in more elaborate judgments.

In order to capture a large proportion of the variation in preferences for lifesaving interventions a host of qualitative and quantitative characteristics of the risks should be included in the analysis, in addition to the cost and effect of the intervention. However, since the survey would be lengthy even without inclusion of risk characteristics, we chose to include only a small number of such variables.

It is sometimes assumed that perceived level of risk is strongly correlated with demand for risk mitigation [31]. However, Sjöberg [29] found that this is not necessarily true and that perceived consequences were a better predictor. Therefore, both the probability and the consequence of the risks, both personal and general, were included in the survey. In addition, variables representing individual control and annual number of fatalities were included. Individual control is often assumed to be important; it also partly coincides with voluntariness [36]. Perceived annual number of fatalities was needed to assess the importance of effectiveness. An interesting finding by Fetherstonhaugh et al. [8] was that the respondents to a survey judged an intervention that saved the same number of lives more beneficial when fewer lives were at risk. That is, to save, e.g., 10 lives out of 100 at risk is more valuable than saving 10 lives out of 1,000 at risk. This can be interpreted to mean that respondents put a value on efficiency of the programs. This is also a question of interest in the present study. It was assumed that these variables, together with socio-economic background variables, would be sufficient to capture a large part of the variation in attitudes for lifesaving interventions.

3.4 METHOD

3.4.1 Sample and response rate

In May 1996, a questionnaire was mailed to a Swedish sample (N = 250), age 18 or older. It was randomly drawn from a probability sample of the Swedish population who had previously indicated that they were willing to participate in one more survey. The respondents received a lottery ticket worth SEK 25 (SEK 6.50 = USD 1) with the questionnaire. In July 1996, responses had been obtained from 189 respondents, which is a response rate of 75.6 percent.

3.4.2 Questionnaire

The questionnaire had been tested in advance on a small group of subjects interviewed after responding to the questionnaire. Later, a focus group was conducted, and a pilot survey was sent out to a sample of 50 people. Data from the pilot study were not included in these analyses.

The questionnaire was extensive (37 pages in A4 format) and contained 22 questions that called for a total of 251 responses or judgments.

Besides background data, respondents were asked for judgments concerning:

- personal and general probabilities and consequences of the 20 risks presented in Table I.

- the annual fatalities in Sweden caused by those risks.
- the degree of personal control over those risks.

- 24 different lifesaving interventions regarding:
    - how desirable they are
    - how many lives would be saved by them, and
    - their relative costs

Table 1. *The 20 different risks evaluated by the respondents.*

Risk
Influenza
Traffic
Drunken driving
Dietary habits
Sun bathing
Food additives
Car exhausts
Train accidents
Electromagnetic fields
Fire in health care institutions
Smoking
Radon
Lightning
Prostate cancer
Radiology
Domestic violence
Aids
Alcohol
Suicide
Narcotics

3.5 RESULTS

3.5.1 Background data

The background data show rather good agreement between the respondents and the general population in Sweden. However, compared to the national average, there were too many highly educated, too few unemployed and too many above-average income respondents. These differences call for caution when generalizing the findings from the study. However, they are not serious enough to question the whole study, especially since background data typically explain only a very small part of the variation in preferences for lifesaving interventions [26].

3.5.2 Perceived Risks

Ratings of perceived risks are not presented as these are not of central interest to the study; they are used only as explanatory variables. Moreover, the overall pattern they display, that people tend to rate personal risk as lower than general risk, is a result that has been replicated numerous times [27]. This tendency has been called optimist bias [39].

Now, risk is often understood has having two components; the probability of a negative event and the consequences of the negative event. In the present questionnaire, an attempt to separate the probability and the consequence of a negative event was made and it was found, as expected, that for most risks people rated both the probability and the severity of the consequences as larger for the general public than for themselves.

3.5.3 Annual fatalities

In an open-ended question, the respondents were asked to assess the annual number of fatalities from the different risks. The overall pattern is that the subjects' estimates of annual fatalities were reasonably realistic, apart from the tendency to overestimate small risks and underestimate large risks

3.5.4 The interventions

In the next section of the questionnaire, the 24 lifesaving interventions listed in Table II were evaluated by the respondents. In the questionnaire, the risk addressed by the intervention was also briefly described.

Table II. *The 24 different lifesaving interventions evaluated by the respondents.*

1) Vaccination against influenza for the whole population in Sweden. *Influenza vaccination*
2) A special education program on suicide prevention for general practitioners. *Suicide prevention.*
3) Medical treatment for high levels of cholesterol. *Cholesterol treatment*
4) Information campaign against malign ant melanoma. *Melanoma campaign*
5) Information campaign regarding indoor radon. *Radon information*
6) Start enough treatment centers to give all alcoholics who wish adequate care. *Alcohol treatment*
7) Concrete barriers between directions on all divided highways. *Barriers*
8) Double the resources for the police to control drunken driving. *Drunken driving*
9) An 18 years age limit on smoking combined with information campaigns against smoking among children and the young. *Age limit on smoking*
10) Preventive fire protection on all health care institutions. *Fire protection*
11) Protective measures against electromagnetic fields in the work place for groups exposed to strong electromagnetic fields. *Work-EMF*
12) Move all day-care centers that are exposed to electromagnetic fields from power lines. *Child-EMF*
13) Mandatory child-proof lids on all wells. *Lids*
14) A special "security package" to all women who are threatened by severe domestic violence. In some cases a life guard or a specially trained dog may be considered. *Security packages*
15) Use coal-fiber cassettes in radiotherapy, whenever possible. *Coal-fiber cassettes*
16) Mass detection program for prostate cancer for men aged 50 and over. *Prostate cancer screening*
17) Virus-decontamination of all donated blood to protect patients against e.g. AIDS. *Virus-decontamination*
18) Reconstruct 50 percent of all train tunnels to facilitate evacuation and

increase accessibility for the rescue forces in case of a fire. *Tunnels*
19) Start enough treatment centers to give all drug addicts who wish adequate care. *Narcotics treatment*
20) Require all new lamp posts that are erected along the roads to have a "slip-base". *Lamp posts*
21) An annual quit-and-win contest for smokers combined with a large information campaign against smoking. *Quit-and-win*
22) Reduce car exhausts by 50 percent through tighter standards. *Reduce car exhausts*
23) Double the resources for research on, and testing of, food additives to detect carcinogenic substances. *Food additives testing*
24) Information campaign about lightning and subsidize lightning conductors. *Lightning prevention*

3.5.5 Importance of the intervention

In the first question, the importance of interventions was rated on a scale from 0 (*should definitely not be implemented*) to 6 (*should definitely be implemented*). Respondents were told that these were to be implemented by local or national governments. Results are in Table III.

Table III. The rated importance of 24 interventions, evaluated on a scale from 0 (*should definitely not be implemented*) to 6 (*should definitely be implemented*).

Variable	Mean
Virus-decontamination	5.42
Fire protection	4.81
Age limit on smoking	4.75
Lids	4.60
Child-EMF	4.56
Security packages	4.54
Work-EMF	4.42
Prostate cancer screening	4.40
Coal-fiber cassettes	4.39
Radon information	4.37
Drunken driving	4.35
Melanoma campaign	4.27
Reduce car exhausts	4.13
Quit-and-win	4.05
Food additives testing	3.95
Lamp posts	3.84
Cholesterol treatment	3.65
Alcohol treatment	3.53
Narcotics treatment	3.46
Suicide prevention	3.19
Tunnels	3.03
Barriers	2.95
Lightning prevention	2.24
Influenza vaccination	1.46

3.5.6 Cost

The cost of the interventions was the single most interesting explanatory variable for our purposes. The alternatives at hand for dealing with the cost of interventions seem to be either to present a cost for each intervention or to let the respondent assess the cost of the intervention. The main problem with the first approach is that the subject's attitude towards the intervention could be influenced by his perception of the total cost, a factor that would be lost if a cost is given. Also, it is possible that the respondents would not believe any cost factor that you portray as true.

The second approach captures respondents' perception of cost. The major disadvantage is of course that it may be hard to construct a question that can be understood and answered by the subjects. In an attempt to solve this problem, a pair-wise comparison format for determining the perceived relative costs of the interventions was used.

The respondents are presented with several pairs of interventions to evaluate with respect to cost. If there is a large number of stimuli to evaluate, people are in general not capable of giving adequate reports of the perceived difference in their strength. To circumvent this problem, stimuli can be presented in pairs. This procedure was originally developed for physical stimuli, such as the intensity of light, but it has also been used to measure social phenomena.

There are several scaling methods that assume that the subject can give valid reports of ratios between subjective magnitudes [25]. The instructions usually require the subject to report one or two numbers that reflect the ratio between two subjective magnitudes. In this application, the respondent is asked, in each pair, to choose the intervention which they believe is the most expensive. That intervention is given the number one hundred. The respondent is then asked to assign the other intervention a number between zero and one hundred that reflects the relative cost of that intervention as compared to the more expensive one. This is repeated for a number of pairs. Ideally, all possible pairs should be evaluated by all respondents, but that would be too strenuous on the respondents since the number of pairs would be quite large. Fortunately, it is not necessary to evaluate all pairs in order to construct the whole matrix of magnitudes; the diagonal is sufficient.

It is assumed that the subject's response is a correct estimate of the ratio between the subjective magnitudes. This assumption was called the ratio assumption in Sjöberg [25]. Furthermore, it is assumed that each stimuli gives rise to one, and only one, subjective magnitude regardless of what other stimuli it is compared with. This assumption is called the invariance assumption [25].

The ratio assumption is mostly technical; if a subject reports that he thinks one object is, for example, twice as heavy as another, there are no compelling reasons to believe that he really thinks otherwise. It does not matter what the actual weight is, the assumption concerns the subjective magnitudes. The invariance assumption is a bit stronger. The subjective magnitude of how sweet a chocolate bar is could possibly be different if the chocolate is compared to a lemon instead of honey. However, in this setting the invariance assumption seems reasonable, because the subjects were asked to compare costs. In particular, if a subject thinks a chocolate bar costs one dollar, that should not change when it is compared to a jar of honey instead of a lemon.

Let w_{ij} be the reported ratio between two subjective magnitudes. Our model then assumes that

$$w_{ij} = R_i/R_j \tag{1}$$

where R_i and R_j are subjective magnitudes corresponding to stimuli i and j. In general, it can not be assumed that the report is error-free and thus, an error term will be needed in practical applications. This model implies that;

$$w_{ij}w_{jk} = w_{ik} \tag{2}$$

From equation (1) it can be seen that

$$\log w_{ij} = \log R_i - \log R_j \tag{3}$$

When the model is expressed in linear form, as here, it is possible to use linear regression procedures to estimate the parameters. We need to give the solution entirely in terms of the observed w'_{jk}, and to do this it is necessary to specify a unit of measurement. If $\log R_1 + \log R_2 + \ldots + \log R_n$ is set to 1, the system of equations to determine can be described as

$$\begin{aligned}
\log(R_2/R_1) &= \log R_2 - \log R_1 \\
\log(R_3/R_1) &= \log R_3 - \log R_1 \\
&\vdots \\
\log(R_i/R_j) &= \log R_i - \log R_j \\
&\vdots \\
\log(R_{n-1}/R_n) &= \log R_{n-1} - \log R_n \\
\log(0) &= \log R_1 + \log R_2 + \ldots + \log R_n
\end{aligned}$$

In matrix form the model can be expressed

$$\mathbf{AR} = \underline{w} + \underline{e} \qquad (4)$$

where the matrix **A** defines the right-hand side equations to be determined and all its entries are -1, 0 or +1. For n = 5 this identity matrix would, as an example, be:

$$\begin{bmatrix} -1 & 1 & 0 & 0 & 0 \\ -1 & 0 & 1 & 0 & 0 \\ 0 & -1 & 1 & 0 & 0 \\ 0 & -1 & 0 & 1 & 0 \\ 0 & 0 & -1 & 1 & 0 \\ 0 & 0 & -1 & 0 & 1 \\ 0 & 0 & 0 & -1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

The vector **R** has the entries ($R_1, R_2, \ldots, R_n$). The vector $\underline{w}$ contains the log ratios and $\underline{e}$ the errors. The standard least squares estimate of **R** is:

$$r = (\mathbf{A'A})^{-1}\mathbf{A'}\underline{w} \qquad (5)$$

The required inverse exists because of the prior specification of a unit. The estimated scale values (R'_i) themselves are given by the antilogarithms of $\log R'_i$. The estimated scale values do not contain any cardinal information about the actual cost of the interventions. The scale values reflect the respondent's perceived relative cost of the interventions and the means of these are presented in Table IV, where the cost of the least expensive intervention has been normalized to 1.

Quite a large number of responses were missing from the data. If more than 20 percent of the responses, i.e. more than nine pairs, were missing from a case it was deleted. If less than nine pairs were missing the values of the missing entries were calculated using the relationship in equation (2). In all, 38 cases were deleted and 36 calculated ratios were entered.

Table IV. *Mean estimated relative cost and number of lives saved for the 24 lifesaving interventions.*

Intervention	Mean cost	Mean number of lives saved
Tunnels	47.32	59
Narcotics treatment	32.76	419
Alcohol treatment	22.93	616
Barriers	19.93	136
Child-EMF	11.39	86
Influenza vaccination	8.22	733
Reduce car exhausts	7.54	237
Drunken driving	6.44	213
Prostate cancer screening	5.05	370
Lamp posts	4.41	112
Food additives testing	3.49	285
Work-EMF	2.98	76
Fire protection	2.95	54
Virus-decontamination	2.78	175
Cholesterol treatment	2.58	1,737
Security packages	2.07	91
Suicide prevention	1.93	240
Quit-and-win	1.85	508
Coal-fiber cassettes	1.83	52
Lids	1.58	22
Lightning prevention	1.56	15
Age limit on smoking	1.46	1,394
Melanoma campaign	1.15	199
Radon information	1	186

Note that the variation is about 1:50, a rather large number. The present design maximizes the chances of measuring a large range in perceived cost.

3.5.7 The number of lives saved

In an open-ended question, the respondents were asked to estimate the annual number of lives saved by the interventions. The result is presented in Table IV, together with the estimated costs.

3.6 ANALYSES

3.6.1 Accepted variation in cost per life saved

To examine the variation in cost per life saved that was implicitly accepted by the respondents, the ratio of the highest and lowest cost per life saved was calculated for all interventions that had a rating of five or six on the importance scale. This is a conservative estimate of the accepted variation in cost per life saved, because a value of three indicated that the interventions *probably should be implemented* and a six indicated that the intervention *should definitely be implemented.* The cost per life saved was computed as the relative cost of the intervention divided by the number of lives saved. Note again that the number in itself did not contain any information about the subject's beliefs about the magnitude of the real costs. The median variation factor was 97. This reveals that 50 percent of the respondents would accept that the most expensive intervention costs 97 times as much as the least expensive. The percentiles are presented in Table V.

Table V. *Factor of variation in accepted (rated five or six on a 0 - 6 scale) variation in cost per life saved for the 5, 10, 25, 50, 75, 90 and 95 percentiles of respondents.*

Percentile	5	10	25	50	75	90	95
Factor of variation	6	10	21	97	341	1,324	2,270

The distribution shows an interesting skewness (skewness: 5,58). There seems to be a group of respondents who put very little weight on the cost-effectiveness of the interventions. About 10 percent of the respondents accept what must be called an extremely large variation in cost per life saved. This observation was also made by Gregory and Lichtenstein [14] and was further confirmed by Cropper and

Subramanian [6]. It becomes even more clear in the extreme values, which are presented in Table VI.

To let the cost per life saved vary with a factor 97, like the median, may also seem like a very large variation, but compared to the actual variation in cost-effectiveness of lifesaving interventions, it is in fact not.

Table VI. *The five highest and lowest values for factor of variation in accepted (rated five or six on a 0 - 6 scale) cost per life saved.*

Five highest	Five lowest
12,311	1.62
11,806.67	1.71
5,873.50	2.34
3,840	3.79
3,832	4.31

We want to apply extreme caution in interpreting these results. A variation with a factor 97 can mean that the least expensive intervention is perceived to cost $1 million per life saved and the most expensive $97 million per life saved, a difference of $96 million. But it could also mean that the least expensive intervention is perceived to cost $1,000 per life saved and the most expensive $97,000 per life saved, a difference of only $96,000. We have no ground whatsoever to speculate on what kind of absolute values the subjects had in mind when answering the questions, because there is no baseline in the cost-question. However, the same is true for the Mendeloff and Kaplan and Cropper and Subramanian studies.

3.6.2 The importance of the attributes

A number of analyses were carried out to examine the importance of cost, effectiveness, the qualitative attributes and background variables for the rated importance of the interventions. All regressions were run with **Importance of intervention** as the dependent variable.

3.6.2.1 Linear regressions on the individual data

Data on individual choices were analyzed, first by means of linear and then of logistic regression. The highest adjusted R^2 achieved was .27, which was obtained for a regression on the importance of the intervention *Lightning prevention*, with outliers eliminated.[24] In most of the 24 regressions, the adjusted R^2 was typically in the range .05-.15. This is not satisfying because it means that one or more important explanatory variables were not included in the model and these omissions affect the power of the significance tests to an unknown extent. At the same time it is not surprising; regressions on individual data frequently generate low values of R^2.

Regarding the individual independent variables, we note several results. Background variables like **age**, **sex**, **income** and **place of residency** did not explain much of the variation, as was expected, although **age** and **sex** were significant in several regressions. For the variables **Cost**, **Severity of the consequences for people in general**, **Effectiveness of the intervention**, and **Individual control**, the number of regressions, out of the total 24, in which the variable was significant at 1, 5 and 10 percent are presented in Table VIII. Generally, we found low β-values for all the independent variables. Sometimes the coefficients had an unexpected sign. **Severity of the consequences for people in general**, as opposed to personal consequences, was the strongest explanatory variable. The variable was significant at the 5 percent level in 12 out of 24 regressions. This is in accordance with earlier findings. **Effectiveness of the intervention** had some importance and was significant at the 5% level in 6 regressions, but generally had low β-values. **Cost** was insignificant in most regressions and had low β-values, sometimes with the wrong sign. This supports our hypothesis that cost is not a strong determinant of people's attitudes towards lifesaving interventions. **Individual control** also turned out to be insignificant in most regressions.

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[24] An even higher adjusted R^2 of .42 was achieved when we ran the regression on the aggregated data, i.e. the means, instead. This was expected because some of the errors cancel each other in the means. The adjusted R^2 is better than what was reported by Mendeloff and Kaplan [20], which is the only comparable study. They got an adjusted R^2 around .30. However, we do not believe this is the best way of using the data. Instead, regressions should be run on the individual observations.

We note that different explanatory variables were significant in different regressions. The explanation for this is that our approach analyses why different people judge one and the same intervention differently and it is not surprising that one single model fails to explain individual differences in attitudes towards all 24 interventions. It is, for example, conceivable that men would think that an intervention against prostate cancer is more important than women do, but we do not expect a gender difference in attitude towards, for example, an indoor-radon intervention.

Table VII. *The number of regressions, out of the total 24, in which the variable was significant at the 1, 5 and 10 percent levels.*

Independent variable	
Cost	Significant at 5% in 1 regression Significant at 10% in 1 regression
Effectiveness	Significant at 1% in 2 regressions Significant at 5% in 4 regressions Significant at 10% in 1 regressions
Consequence for people in general	Significant at 1% in 8 regressions Significant at 5% in 4 regressions Significant at 10% in 2 regressions
Control	Significant at 1% in 1 regression Significant at 5% in 1 regression Significant at 10% in 1 regression

3.6.2.2 Logistic regression

The dependent variable, **Importance of the intervention**, was treated as a continuous variable in the linear regressions. However, the variable was not actually continuous, as it was constructed as a scale with seven steps. It has been argued that seven steps is enough to permit this assumption of continuity [5]. Even so, a minimal precaution is to test if the results change if a logistic regression is performed. To that end, **Importance of the intervention** was transformed to a binary variable, which corresponds to a referendum format, where 0 represents that the intervention should not be implemented and 1 that the intervention should be implemented. The logistic regression on this variable overall showed similar results, except that **Effectiveness** had very high odds in some regressions. Cost did not prove to be more significant or explain more of the variation in this format.

3.7 CONCLUSIONS

The median respondent implicitly accepted that the cost per life saved varied by a factor 97. This is considerably more than shown in other studies and is almost certainly an effect of the format we chose for assessing the accepted variation -- intended as a more realistic portrayal of attitude formation rather than as a normative guide.

The general conclusions of the analyses of the effect of our explanatory variables on the attitudes are that **Cost** did not have a strong influence on the rated importance of a lifesaving intervention and was most often not significant. **Effectiveness** of the intervention and **consequences for people in general** were the most significant and strongest explanatory variables.

To speculate a bit, nothing in our study rejects the explanation that cost per life saved vary because decision-makers are influenced by the attitudes of the general public. And when the general public does not place much weight on cost or cost-effectiveness, the implication is that they implicitly would accept huge variations in cost per life saved. In some earlier studies the preferences of the general public have been recognized to play a fundamental role in political decision making on risk mitigation, [24], [35] and [2]. Governments, at least in the U.S., have even been found to be predominantly *re*active rather than *pro*active with respect to risk mitigation. With the words of Shubik ([24], page 10), "Once a large enough political constituency appears to be actively upset (...) the politicians may react. Once the politicians have reacted sufficiently, the bureaucracy may respond." Sjöberg [28] found that local politicians in Sweden had attitudes to risk very similar to the general public's, and their demand for risk reduction was strongly influenced by their perception of the public's demand for risk reduction [Sjöberg, 1996 #111.

Overall, the results are somewhat disappointing. We were unable to explain a large part of the variation in preferences over lifesaving intervention. However, previous researchers have also had only limited success.
We would like to point out that our format for assessing the perceived cost of the intervention allows a large variation in the costs. This has not previously been done and is a methodological contribution that could be of some use. It would

however be more useful if a meaningful base level could be established such as expressing one of the costs in dollars, and the rest in relation to this value.

3.8 Limitations

We do not know the extent to which attitudes we obtained are actually expressed in public or private or if they are the same as the ones expressed. The relevant attitudes to study would of course be those expressed, because only those conceivably affect policy making. An expressed attitude is simply an attitude that is expressed in public or private and should be understood as opposed to attitudes or preferences revealed from actual decisions. It does not even have to be held internally (cf. Kuran [19] on preference falsification). At any rate, we do not know the connection between attitudes and decision-making, which clearly limits the ability to draw firm conclusions.

Also, our survey was already too extensive to include all relevant variables. We would probably have been able to explain a larger proportion of the variation in rated importance of the interventions if we also had included the following variables, which were found to be significant by Cropper and Subramanian [6]; fairness of the funding mechanism, appropriateness of government intervention[25], and time lag before lives are saved. More investigation of these variables is recommended.

[25] Although a recent survey in Sweden [28] hardly found any area in which the respondents did not want more government intervention.

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CHAPTER FOUR.

LISTENING TO THE VOCAL CITIZENS: HOW DO POLITICALLY ACTIVE INDIVIDUALS CHOOSE BETWEEN LIFESAVING PROGRAMS?

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4.1 INTRODUCTION

It has been argued that society's current approach to health risk policy is inefficient [13]. Several studies empirically show that the cost per life saved varies tremendously between different lifesaving interventions (see e.g. [10], [12]). Given that only lives saved enter people's utility functions for lifesaving interventions, an efficient allocation of lifesaving resources would have the same marginal cost per life saved for all interventions. The price of departure from equalization of marginal cost per life saved is fewer lives saved -more lives could be saved for the same cost. This loss of statistical lives could potentially be very large. An American study of 200 interventions indicated that 60,000 lives are lost every year in the US due to variation in cost per life saved in that relatively small group of interventions alone [13]. A reasoned approach to health risk policy takes both costs and effects into account and the enormous variation in cost per life saved for mitigating different risks that have been observed can not be justified as rational policy making [13].

The above result depends crucially on the assumption that only lives saved enter utility functions for lifesaving interventions. However, it is possible --in fact very likely-- that this assumption does not hold. Qualitative characteristics of the regulated risk and the target population are likely to affect the utility of a given intervention. Some risks have stronger semantic and moral force that makes lives 'weigh' stronger in that context.

A policy aimed at reducing a risk that, e.g., is perceived to be involuntary could be valued differently than one directed at a voluntary risk, even if they save the same number of lives. As an illustration, consider saving lives with smoking cessation programs, which cost approximately $500 per life-year saved, compared to measures to remove radon from the drinking water, which cost approximately $20,000 per life-year saved [10].[26] For this to be an efficient allocation, the utility of saving a life from a radon-caused death must be 40 times higher than saving a life from a smoking-caused death.

Some argue that the public does care a lot about qualitative characteristics of risks and that society's risk policy is in fact a reflection of the public's preferences. But,

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[26] Both examples are from Swedish data, but similar instances are easy to find for other countries. Also, it should be noted that the difference in cost per life-year saved in this example is relatively small, compared to many other interventions.

as has been pointed out before, [5], [2], it is in no way obvious that current disparities in cost per life saved reflect public preferences. This has been shown in studies of the public's acceptance of variation in cost per life saved, where it has been found that most respondents are willing to accept only a small variation in cost per life saved. Usually, the respondents accept that the intervention with the most desirable qualitative characteristics cost two or three times as much per life saved as the intervention with the least desirable characteristics. This is several orders of magnitude less than the variation among actual interventions.

However, it has also been found that a significant minority of the respondents is completely unwilling to consider cost-effectiveness of proposed lifesaving interventions, i.e. they are not willing to trade the qualitative characteristics that make some lives weigh stronger for more lives saved [2] [11]. Cropper and Subramanian [2] suggest that this could be a particularly vocal group of citizens. This could possibly explain the large differences in cost per life saved since a politically active and organized target population can drive the implementation of an intervention [1], [4] and if politically active, or 'vocal', citizens care little about cost-effectiveness, policy is likely to reflect this.

In this paper it is examined whether more politically active individuals differ from less active ones with respect to willingness to trade qualitative characteristics for lives saved.

4.2 Study context

A population in which there was a known political activism was selected; people living under a high-voltage power line in the city of Solna, located right north of Stockholm in Sweden. The city of Stockholm buys most of its electric power from power plants in the north of Sweden. The electricity is distributed in high-voltage power lines which, as it happens, pass right through the residential area of Bergshamra in Solna.

In recent years there has been a growing concern among the residents of Bergshamra about the electromagnetic fields (EMF) generated from the power lines. It has been postulated that the EMF may, among other things, cause leukemia in children, [3], [6]. There is no clear consensus, but the scientific evidence for this is considered weak [6], [14]. Nonetheless, in 1995 the cities of Solna and Stockholm decided, citing the public's concern about possible

detrimental health effects, to move the power lines under ground. There was a small but active interest group that certainly contributed to the decision.
In all, the situation seemed to lend itself nicely to study political activism and preferences. Also, this was a case where people had engaged in real political activities and the policy outcome was clear. It was not simply a hypothetical question.

4.3 Method

In June 1996, a written questionnaire was delivered to a sample of the Bergshamra population who lived under the power lines (N = 250), age 18 or older. In November 1996, responses had been obtained from 117 respondents (46.8 percent).

4.3.1 The respondents

The mean age of the respondents was 42 years. In the sample, there was an equal distribution of women and men. Over sixty percent of the respondents had children and of those who had them, close to 36 percent had one or more children in a day-care center in Bergshamra. On the average, the respondent had lived in Bergshamra 9.8 years. The respondents had higher education than the national average, with 56 percent having a college education. Their incomes were rather high and there were relatively few blue-collar workers.

4.3.2 Questionnaire

The questionnaire was extensive, 21 pages in A4 format, and contained 35 questions that called for a total of 163 responses or judgments. Note that not all the questions and the data are presented here; the rest are presented in another paper [9]. In the questionnaire, the respondents were asked for judgments of personal and general probabilities and consequences of nine different risks; for judgments of the degree of personal control over those risks; to choose between lifesaving government interventions, presented in six pairs, and also asked for judgments regarding characteristics of the interventions; questions about political activities with respect to the power lines; and finally for the usual background data.

4.4 RESULTS

4.4.1 Political activities

In the survey, there were a number of questions pertaining to, somewhat loosely defined, political activities of the respondents with respect to the power lines. They were asked to indicate *yes* versus *no*, and, where applicable, the number of times they had participated in the following activities:

- membership in organization dealing with the power lines in Bergshamra
- active in such organization
- membership in organization dealing with electromagnetic fields in some other way
- partaken in any legal or judicial measures regarding the power lines (several examples were given)
- had the electromagnetic fields in the home measured (which is done by the city)
- been to public meeting concerning the power lines
- expressed opinion at such a meeting
- talked to neighbors about the power lines and/or electromagnetic fields
- contacted a politician regarding the power lines
- signed protest list against the power lines
- helped distributing protest list against the power lines
- voted for a political party because of their stance on the issue of the power lines
- actively searched information regarding the power lines or electromagnetic fields
- donated money to an organization dealing with the power lines
- written letter to the editor in a paper concerning the power lines
- expressed opinion about the power lines on TV or radio
- participated in demonstration against the power lines
- planning on moving away from Bergshamra because of the power lines
- would like to move away from Bergshamra because of the power lines
- let the children switch day-care center or school because of the power lines
- would like to let the children switch daycare center or school because of the power lines
- been active in any other way, not mentioned above

The 'measure' of political activism employed in this paper is open to question. However, all the activities have the potential of sending a signal to the politicians, although some of them are not proper *political* activities. If, for example, many residents let their children switch day-care center or school because of the power lines, this is likely to be perceived by the politicians as a signal that their constituency is worried about the power lines. Thus, they are activities that may affect the political process and a core question of the paper is whether people who engage in any such activities differ from people who do not. The objective has not been to identify individuals who engage in political activities as such.

Nevertheless, the analyses were also carried out using a more restrictive definition of political activities, but as it were, the results did not change. The reason for this is that the individuals who engage in the proper political activities are also very likely to be the ones who engage in the other, less obviously political activities.

Another methodological issue is that the activities could to be weighted in the analyses in order to reflect differences in potential impact on the political process. However, a weighting scheme did not change the results. This is not surprising; a weighting scheme would be crucial if the aim was to predict the outcome of a political process, but here the outcome was already known and the aim was to investigate the preferences of the individuals involved. For this reason only the results using a simple summation index with weight 1 on all activities are reported here.

4.4.2 Tradeoff between cost-effectiveness and qualitative factors

The central part of the survey was designed to examine tradeoffs between cost-effectiveness and qualitative factors of risks and interventions. The theoretical framework was a random utility model, following the model formulation in e.g. Johnson and Desvouges [7]. There are two alternatives, A and B, from which the respondent chose. It is assumed that individual indirect utility can be expressed as a function of a set of measurable covariates, x, which are the program attributes for programs A and B, and personal characteristics of the respondent. The respondent derives utility $U_A = b_A x + e_A$ from choice A, and $U_B = b_B x + e_B$ from choice B, in which e_A and e_B are the components of the individual's utility that are unaccounted by the measured covariates, x. Thus, the choice of alternative A reveals that $U_A > U_B$. Now, consider two alternatives that save the same number of lives and A is chosen. If it is assumed that utility is strictly increasing in the number of lives saved, i.e. $U_L'(x) > 0$, which is a reasonable assumption, the respondent is expected to switch to program B when the number of lives saved by that program is sufficiently increased. So, by varying the number of lives saved by the same program and measuring the other program attributes, the tradeoff between lives saved and qualitative attributes can be measured.

The qualitative factors that the respondents were asked to rate were: Perceived probability and consequence of risk; controllability of the risk; how appropriate the intervention is for the government to undertake; the time lag between adoption and when the intervention starts saving lives, the degree of non-lifesaving benefits from the interventions; and the likely age of the target group. These are widely believed to be important determinants of public choices between lifesaving programs (see e.g. [2]). The interventions also differed with respect to other qualitative factors such as quality of life before death, natural vs. man-made etc., but it was not possible to control for all these factors; the questionnaire was lengthy already as it was. Therefore, part of the variation in choices was expected to remain unexplained.

To capture the tradeoffs, the subjects were asked to choose between lifesaving government interventions presented in pairs. There were six such pairs, presented in Table I. In the questionnaire there were more extensive descriptions of the risks and the interventions than what is presented here. The respondents were told that both programs in a pair would cost exactly the same to implement and that local or national government would pay.

Table I. *The respondents were asked to choose between lifesaving interventions presented in pairs. The number of lives saved by program B was randomly chosen from a vector given in the description.*

Program A	Risk	Program B
Lamp posts Measure: All new lamp posts that are put up along roads (approximately 7,500 per year) should be slip-base. Effect: It is estimated that 5 lives per year would be saved.	Traffic accidents	**MC** Measure: Mandatory, continuing education for motorcycle drivers. Effect: It is estimated that [5, 8, 10, 30, 50] lives per year would be saved.
Senile Measure: Equip senile, elderly people with an electronic tracking device that can be used if the person gets lost. Effect: It is estimated that one life per year would be saved.	Getting lost	**Mountain Rescue Service** Measure: More resources to the Mountain Rescue Service. Effect: It is estimated that [1, 2, 5, 10, 15] lives per year would be saved.
Radon Measure: Filters to remove radon from the drinking water. A large number of private wells and some municipal water works would be affected. Effect: If all wells with a radon content in excess of 100 Bq/l were attended, an estimated 30 lives would be saved per year.	Cancer	**Screening** Measure: A general screening program for people aged 60 and over to enable early detection of cancer in the large intestine. Effect: It is estimated that [30, 45, 100, 600, 3,000] lives per year would be saved.

Table I continued.		
Domestic violence Measure: Equip threatened women with a special security package, including a portable alarm with which the women rapidly can get police assistance. In some situations a woman can get a temporary bodyguard or a trained watch dog. Effect: It is estimated that 5 lives per year would be saved.	Violence	**Drug-related violence** Measure: Increase resources to the police and social services for preventive measures against violence among drug addicts and alcoholics. Effect: It is estimated that [5, 7, 10, 40, 100] lives per year would be saved.
EMF Measure: Relocate all day-care centers that are located close to power lines. Effect: It is estimated that 2 lives per year would be saved.	Harmful radiation	**UV radiation** . Measure: A national screening program to detect malignant melanoma. Effect: It is estimated that [2, 4, 20, 200, 1,000] lives per year would be saved.
Car exhausts Measure: Car exhausts are reduced by 50% by more stringent laws. Effect: It is estimated that 100 lives per year would be saved.	Coronary heart disease	**Cholesterol** Measure: Medication for high blood levels of cholesterol (>6.5 mmol/l). Effect: It is estimated that [100, 150, 400, 1,000, 4,000] lives per year would be saved.

The sample was split in five groups who received different versions of the questionnaire, where the number of lives saved by program B was varied. The vectors from which the number of lives saved by intervention B was chosen are also presented in Table I. The number of lives saved for the different interventions were chosen to be reasonably realistic to the respondents. For this reason, the factor of variation is not the same for all pairs.

4.4.3 Tradeoffs

The survey data showed that people were willing to make the tradeoff between lives saved and qualitative factors. In general, as the number of lives saved by one intervention increased, more respondents would choose that intervention. The variation accepted by the median respondent can be assessed by estimating a logistic regression equation for the percentage of respondents choosing program A when program B saved x number of lives and then solve for x, when the percentage is 50. The results are presented in Table II.

Table II. Variation in cost per life saved by the median respondent.

Pair	Pair 1	Pair 2	Pair 3	Pair 4	Pair 5	Pair 6
Variation accepted by median respondent	8.52	1.80	7.59	10.45	.65	182.4

Pair 1 = Lamp posts/MC; Pair 2 = Senile/Mountain rescue service; Pair 3 = Radon/Screening; Pair 4 = Domestic violence/Drug related violence; Pair 5 = EMF/UV; Pair 6 = Car exhausts/Cholesterol

In earlier studies, the respondents typically accepted that the number of lives saved varied only by a factor two or three [2], [8]. The respondents to this survey accepted larger variations, especially for program pair 6, Car exhausts/Cholesterol; the Cholesterol program would have to save 182 times more lives for the median respondent to choose it over the Car exhaust program. However, for the other programs the accepted variation ranged roughly between .5 and 10., which still is slightly more than in earlier studies. These results could reflect an actual difference in the way the residents of Bergshamra, or perhaps Sweden in general, choose compared to the American samples used in earlier research. In addition, the format used in the earlier papers could partly explain the smaller variation. Specifically, in the Cropper and Subramanian study a double-bounded format was used, which is likely to narrow the range of accepted variation for two reasons; First, it increases the saliency of the tradeoff the investigator has in mind, and second, there is most likely an anchoring effect.

Furthermore, at least some of these responses are likely to represent *random noise* rather than well considered preferences; i.e. the respondent did not carefully consider his/her choice, but answered randomly.

The predictions presented in Table II should be interpreted cautiously for several reasons: First, the assumed linear relationship between the percentage choosing a particular program and the number of lives saved by the program might not be true. Second, because of the split-sample design, it was in fact not the same respondent who was presented with the different numbers of lives saved in the preceding analyses. Each respondent did only make one choice for each program pair. Third and most importantly, in pairs 2, 5 and 6 the prediction is made outside the range of the data set.

4.4.4 Political activity and choice

The difference in mean level of EMF-related political activity between respondents choosing program A when program B saved x times as many lives is shown in Figure I. A striking finding is that the only program pair for which there was a significant[27] difference for all values of lives saved by program B was pair 5, EMF and Melanoma prevention. In that pair, more politically active individuals chose the intervention that saved fewer lives, EMF, but only up to a point. When Melanoma prevention saved 500 times as many lives, the respondents who were still choosing EMF were *less* politically active. For all the other program pairs, the results were mixed and the responses hovered around the mean level of political activity.

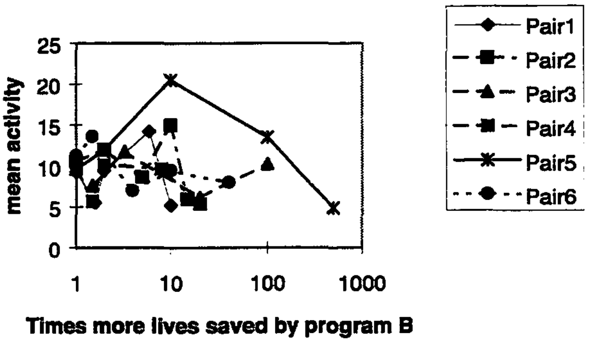

Figure I. *Mean political activity of respondents choosing program A when program B saves x times as many lives as Program A.*

[27] It was significant at the one-percent level for four out of five choices and at five percent for the fifth.

4.5 REGRESSION ANALYSES

4.5.1 Model formulation

In an effort to explain what is causing people to choose one program over the other, a *logit* model was estimated for all six program pairs. As mentioned earlier, there are two alternatives, A and B, from which the respondent chose. The set of measurable covariates, x, i.e. the program attributes, together with personal characteristics of the respondent, will be used to help explain the occurrence of one outcome or the other. The choice of alternative A reveals that $U_A > U_B$, or that $e_B - e_A \leq b_B x - b_A x$. Let $e = e_B - e_A$, and bx be an index function that represents the difference on the right hand side of the inequality. Then, the binary choice model applies to the probability that $e \leq bx$. Assume that z is this binary variable, taking values 0 and 1, and formulate *a priori* that Prob[z=1] = F(bx), where F is any function of the index that satisfies the axioms of probability. Thus, F(bx) is the conditional mean function. This function can be assumed to have any distribution, and if it is assumed to have the normal distribution, it is a *probit* model and if the binomial (or logistic) distribution is assumed it is a *logit* model. However, the normal and binomial distributions differ only in the tails, so it is really only when there is a large sample, with a substantial amount of responses in the tails, that it will make a difference what distribution is assumed. In the following, a binomial distribution is assumed and thus a logit model is constructed.
The actual model used was:

$$U_{iat} = \beta X_{st} + \alpha_{st} Z_i + \delta p_{st} + e_{ist}$$

where

U_{ist}	is individual i's utility for the program profile st, where s=A,B for pair t and t= 1,..6.
X_{st}	is a vector of attribute levels
Z_i	is a vector of personal characteristics
p_{st}	is the cost of the program pair
e_{ist}	is the disturbance term

Let the utilities to individual i for the two alternatives A and B in pair t be

$$U_{iAt} = \beta X_{At} + \alpha_{At} Z_i + \delta p_{At} + e_{iAt}$$

$$U_{iBt} = \beta X_{Bt} + \alpha_{Bt} Z_i + \delta p_{Bt} + e_{iBt}$$

In this application $p_{At} = p_{Bt}$ for all t and by assuming that the utility function parameter δ is the same for all respondents, price can be dropped entirely from the model. The probability that program A will be chosen is now
$P(A) = 1/1+ e^{-[(\alpha At - \alpha Bt)Zi + (XAt - XBt)\beta]}$

This model assumes additive separability in the attributes, i.e. a change in the level of one attribute does not affect the marginal utility of another attribute [7]. The difference in indirect utility for a commodity pair t is implicitly specified as a linear function of attributes and for program attributes it is the difference in program attribute levels that matters. The personal characteristics are the same for both the left and right side alternatives so it is the difference in the utility function parameters α that is estimated.

4.5.2 Estimation

The dependent variable was Program A, i.e. a "yes" or a "no" answer to the dichotomous choice question over program pairs. The independent variables included background, risk perception and specific program characteristics variables. The background variables were **political activity**, **age**, **sex**, **income**, **education** and **children**. The regression coefficients were expected to vary with the particular pair. For the EMF/UV pair, also how long the respondent had **lived** in Bergshamra was included and it was expected that newcomers would be less likely to choose EMF, because they have moved to Bergshamra after the debate about power lines started.

The risk perception variables were **personal probability** and **personal consequences**[28] of injury from the different hazards and individual **control** of the hazard. Specifically, the variable was constructed as perception of risk B minus perception of risk A, so the expected sign was negative, i.e. an odds-ratio below one.

Finally, some program specific variables were included; First of all, it was expected that the more lives **program B** saves, the less likely the respondent will be to choose **program A**. The difference in how **appropriate** the interventions are was expected to have an odds-ratio below one, i.e., if intervention B is perceived

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[28] General probability and consequences were also tested but they were of inferior value.

as more appropriate than intervention A, the respondent is expected to be less likely to choose A. If the **time lag** before the intervention starts saving lives is relatively shorter for A, the respondent is expected to be more likely to choose A.

Also, the respondent is expected to be more likely to choose A if the degree of **positive** effects other than lifesaving from the interventions is relatively higher for A. The difference in the **age** of the target group is expected to have an odds-ratio above one, since people can be assumed to be more willing to save younger people's lives. The results are presented in Table III.

Table III. *Results from logistic regressions of program choices. Dependent variable: Choose A.*

Independent variables:	Odds ratio (P>t) Program A: Senile	Program A: Lamp-posts	Program A: Radon
Lives saved by Program B	1.013 (0.819)	.819 (0.015)	.985 (0.036)
Pers. prob (B-A)	.958 (0.894)+	.871 (0.489)	.594 (0.021)
Pers. consequence (B-A)	2.490 (0.002)+	.846 (0.542)	1.076 (0.685)
Control (B-A)	.690 (0.109)+	.816 (0.297)	.956 (0.744)
Pol. activity	1.053 (0.103)	1.016 (0.588)	.983 (0.552)
Child	.394 (0.199)	.515 (0.313)	.907 (0.872)
Age	1.029 (0.161)	.986 (0.419)	.978 (0.225)
Sex	4.140 (0.058)	2.826 (0.064)	.445 (0.136)
Income	.587 (0.030)	1.120 (0.598)	.909 (0.613)
Education	.231 (0.036)	.842 (0.763)	.292 (0.027)
Appropriate (B-A)	.179 (0.023)	.108 (0.037)	.208 (0.012)
Other pos.eff. (B-A)	2.664 (0.171)	1.738 (0.235)	2.267 (0.141)
Timing (B-A)	3.508 (0.159)	1.637 (0.388)	1.957 (0.121)
Age target (B-A)	.924 (0.875)	.149 (0.049)	1.316 (0.226)
Number of obs	108	109	109
chi2	(14)40.12	41.10	43.08
Prob > chi2	0.0002	0.0002	0.0001
Pseudo R2	0.3246	0.3004	0.2947

Table III continued.

Independent variables	Program A: Domestic violence	Odds ratio (P>t) Program A: Emf	Program A: Car exhausts
Lives saved by Prog.B	.930 (0.054)	.999 (0.446)	.964 (0.054)
Pers. prob	1.450 (0.178)+	1.767 (0.027)+	.865 (0.321)
Pers. consequence	1.072 (0.660)+	.928 (0.758)+	.820 (0.358)
Control (B-A)	.755 (0.102)+	.928 (0.708)+	.887 (0.326)
Pol. activity	.965 (0.228)	1.028 (0.377)	1.049 (0.115)
Children	.848 (0.782)	1.145 (0.834)	.775 (0.655)
Lived		.998 (0.939)	
Age	.973 (0.158)	.973 (0.282)	.966 (0.050)
Sex	.538 (0.286)	1.254 (0.713)	.554 (0.272)
Income	1.171 (0.403)	1.349 (0.125)	1.192 (0.284)
Education	.387 (0.101)	.306 (0.058)	.511 (0.204)
Appropriate (B-A)	.192 (0.022)	.256 (0.000)	dropped due to coll.
Other pos.eff. (B-A)	2.082 (0.171)	1.274 (0.423)	2.741 (0.020)
Timing (B-A)	.827 (0.760)	.976 (0.940)	1.252 (0.705)
Age target (B-A)	dropped due to coll.	1.570 (0.139)	.376 (0.043)
Number of obs.	107	111	109
chi^2	(13) 44.63	(15) 53.31	(13) 24.42
Prob > chi^2	0.0000	0.0000	0.0275
Pseudo R^2	0.3052	0.3489	0.1805

+ Only data for program A was available. This means assuming that the utility function parameter is 0 for program B, which leads to an overestimation of the effect of the variable

Due to a mistake in the construction of the survey instrument, the risk perception variables were not assessed for all underlying risks. In these cases, only data for program A was available and in the analysis it was assumed that the utility function parameter is 0 for program B. This likely leads to an overestimation of the effect of the variable. In Table III, the affected coefficients have been marked with a "+" and caution must be exercised in interpreting these.

The overall significance of the model was good and the pseudo- R^2 was in the range .18 - .35, in four out of six regressions above .30. Regarding the independent variables, the number of lives saved by **program B** had the expected sign but only a small effect. The one variable that stands out is how **appropriate** the intervention is. It could be that the respondents answered that question more as a question about general attitude towards the intervention. The background variables **sex** and **education** had a surprisingly strong effect, even when there was no particular expectation about the effect. There is a problem with the significance of several variables. However, with the relatively low number of responses, the number of responses to each set of pairs was rather small and this will, and should, affect the significance of the findings.

4.5.3 A pooled model

The preceding analysis suffers from a small number of observations. If all the choices are combined, the number of observations is greatly increased. In that format the personal characteristics variables are hard to interpret, as noted by Cropper and Subramanian [2], so they were left out. To capture program specific characteristics that were not included in the model, a set of dummy variables, indicating program pair, was created. Logistic regressions on the pooled model confirmed that the effect of the number of **lives saved by program B** was significant but small. **Personal probability** was significant and had a rather strong effect in the expected direction. Likewise, how **appropriate** the intervention is perceived to be, and **positive** effects other than lives saved were significant and had strong effects. The dummies for pairs had significant and sometimes strong effects, indicating that characteristics not included in the model influenced choice.

4.6 CONCLUSIONS

The respondents were in general willing to make a tradeoff between lives saved and qualitative aspects of the risks and the interventions. The respondents to this survey did not make these tradeoffs to quite the same extent as respondents in some earlier research. This could in part be an effect of the double-bounded format used in the earlier work, but it could also indicate a genuinely smaller willingness to make the tradeoff in this sample. Another possible explanation is of course that there could be more random noise in the present study.

The efforts to determine exactly which aspects guide choice were only partly successful. It was firmly established that the number of lives saved by the alternative program had a significant effect in the expected direction, but the effect was rather small. Socio-economic variables were sometimes significant and sometimes not and especially education and sex tended to have a quite large effect. Appropriateness of the intervention was significant and influential. Note that this could be because the respondents answered the question as a general attitude question.

Political activism had only a small effect on the choices made. However, for the choice between an EMF related intervention (the area in which the respondents were politically active) and a screening program against melanoma, the more politically active individuals were less willing to make the tradeoff. This is an important finding, as it indicates that there is something to Cropper's and Subramanian's suggestion that people who are less willing to tradeoff lives saved for qualitative characteristics are more vocal. However, this was only up to a point after which they too switched to the program that saved more lives. When background variables, risk perception and specific program characteristics were controlled for, much of the effect of political activism disappeared. This, however, is only accounting for the fact that political activism can be explained by background variables and risk perception, a topic which has been explored in another paper [9].

For most other program pairs, i.e. for areas in which these respondents can not be assumed to be active, there was no discernible difference. Thus, the politically active individuals were not inherently opposed to making a tradeoff between lives saved and qualitative characteristics. There does, however, seem to be one group of respondents who are unwilling to do this; even when one program saved 500 times as many lives as another, at the same cost, 30 percent of the respondents would choose the less cost-effective one. If this group has an inordinate influence on policy, it could be part of the explanation why the cost per life saved varies so much between actual interventions, but this paper indicates that they are not particularly vocal, at least not in the ways that were measured here. Also, at least some of these respondents probably just reflect random noise.

4.7 References

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CHAPTER FIVE.

TRUST, RISK AND POLITICALLY ACTIVE CITIZENS

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This paper is submitted and is under review.

5.1 Introduction

5.1.1 The impact of elite groups

It has been argued that society's current approach to health risk policy is inefficient [27], [3]. The reasoning is that large investments are made to reduce small or non-existent risks at the same time as efforts to reduce some large health risks are given less than optimal resources. Many studies have empirically shown that the cost per life saved varies tremendously between different lifesaving interventions [9], [13], [21], [26].

The cost per life saved of interventions have been suggested to vary for several reasons, one of which is that a politically active and organized target population can drive the implementation of an intervention [2], [8], [23]. Efficiency may then be overshadowed in decision making by politicians' urge to satisfy a vocal minority. In addition, it is a democracy problem since political decisions are, at least to some extent, attempts to aggregate all citizens' preferences. The democracy problem arise if a small, politically active, elite has a disproportionate influence on decisions in society, especially since this group is usually found to be different from the general population in terms of socio-economic characteristics. The active elite tends to be white, well-educated, middle-aged men, even though there is some encouraging evidence that *local* activists may be drawn from more diverse backgrounds than activists in national movements [7]. However, a more serious problem is that activists, also on the local level, may have different preferences in particular questions than the general population, rendering political decisions a poor aggregation of the public's preferences.

5.2 Research Questions

5.2.1 Determinants of local political activism

This paper is an attempt to study the determinants of local political activism with respect to a particular issue; the removal of a high-voltage power line in a suburb of Stockholm.

The city of Stockholm buys most of its electric power from power plants in the North of Sweden and it is distributed in high-voltage power lines to Stockholm. As it happens, the power lines pass right through the residential area of Bergshamra in

Solna, situated right north of Stockholm. The power lines have been in place for over 70 years and are older than the residential areas. The city of Stockholm has a concession for the power lines.

In recent years there has been a growing concern among the residents of Solna about the electromagnetic fields (EMF) generated from the power lines. It has been postulated that the EMF may, among other things, cause leukemia in children [12]. Some epidemiological studies lend support to this hypothesis [4], [14], [10]. There is no clear consensus, but the scientific evidence connecting exposure to electromagnetic fields to leukemia is considered weak, partly because a biological mechanism has yet to be found [29] and partly because there are methodological problems with the epidemiological studies [12], [17]. Meta analyses suggest that there is a cause for more research, but both the quality and the quantity of the available evidence discourage from claiming anything about the nature or magnitude of the risk [30], [17], [28].

In the case of EMF, it seems clear that the public perceives the risks to be greater than the experts do. In this type of situation, Margolis [16] claims that a "better safe than sorry" attitude, where people focus on the danger of the situation and forgets about the opportunity costs of reducing the risk, often prevails.

Nevertheless, in 1995 the city of Solna reached an agreement with the city of Stockholm to move the power lines under ground. Stockholm would pay half the cost of this project. There was a small but active interest group, which contributed to this outcome. Also the general population in the area seemed concerned and informed about the issue. The official rationale for the decision was the public's concern about possible detrimental health effects.

This is a bona fide example of a grass-root environmental movement. As with most grass-root environmental movements, the focus is on a public health or risk issue rather than on environmental protection [7]. A first pertinent question to answer is to what extent the group of active individuals perceives risk differently than the general population. Note that there are two effects which can be expected to work in opposite directions at play here; politically active people tend to be men, well educated and have a high income, but the same characteristics tend to be associated with lower perceived risks [6]. In an earlier study it was found that perceived personal risk was the strongest determinant of private environmental protection behavior, like recycling, [1], but this need not be true of public political activities. There is in fact some evidence in the literature that the elite can be quite representative in terms of perceived risk. A study by Sjöberg [24] showed, e.g., that the risk perception of people serving on local environmental protection boards largely coincided with that of the general public.

5.2.2 Trust

A second focus of interest in the present study is the effect of *trust* on political activities. In recent years, trust has emerged as an important determinant of perceived risk and stated demand for risk reduction [25]. In the case of radioactive waste in particular, trust in experts has been found to be a significant and rather strong determinant of perceived risk and demand for risk reduction [5]. The direction of causality is however not entirely clear; one study claimed, and thereby reversing causality, that an increase in perceived risk of environmental hazards increase trust in interest groups but decreases trust in "traditional" institutions (government and industry) [18]. The problem is perhaps that, in contrast to most other risk perception variables, trust is of course not an attribute of the risk, but a mental state of the individual. Trust can be defined as a reliance on the integrity, strength, ability, surety, etc. of a person, institution or thing. It is not hard to see how trust could affect perceived risk. If the person or institution responsible of managing the activity that causes the risk is not trusted, the perceived risk may be higher simply because the subjective probability of a negative event occurring is higher, and the possible consequences worse, than if it was managed by a trusted party. But it is also not hard to see that a high level of perceived risk could affect trust in those responsible for managing the risk. –"Someone who lets the risk be that high, can not be trusted." The direction of causality is not theoretically obvious, nor easy to empirically determine.

At any rate, the less trust people have in those managing a risk, the stronger the demand for risk reduction tends to be. However, it is not obvious that stating demand for risk reduction in a survey implies any inclination towards political activity to bring about that reduction. When Lober [15] investigated both behavioral and attitudinal responses to a waste-recycling facility --an activity which was widely supported by the respondents-- he found that attitudes differed significantly from behavior. To the best of my knowledge, there have been no empirical studies of how trust affects actual political activity with respect to risk policy. One previous empirical study linked trust of experts to resident actions to improve neighborhood quality [11]. There it was found that neighborhood activities increased with lack of trust in experts and the same could be expected to hold also for a risk issue.

In the survey presented here, the trust variable was measured as trust in information coming from different sources. It is debatable to what extent the level of trust in information is the correct way to measure trust. It was deemed important to be explicit about the meaning of "trust" in the question. This case is largely a matter of information; the power lines are already there and the issue is not about managing the daily operation of them properly or being able to remove them in an efficient and safe way. The question is only to what extent the electromagnetic fields generated by the power lines cause detrimental health effects. But it does seem likely that if you do not trust information from, e.g., the local government, then you do not trust them to make decisions that are in your best interest either.

The levels of trust people have is likely affected by individual characteristics, such as socio-economic position. Some socio-economic groups are e.g. more alienated than others and this should affect levels of trust, because trust is connected to a sense of benevolence. To simply hold systematic expectations regarding the behavior of an actor is not necessarily trust. A better term for that is *confidence*. Also personality affects trust; some people displays more trust than others, but that factor is outside the scope of this work.

5.2.3 Hypotheses

In conclusion, the aim of this article is to investigate the impact of trust and perceived risk on local political activities to remove power lines from a residential area. In particular, the following five hypotheses will be tested:

1. Since the study is concerned with a 'grass-root movement', socio-economic variables will not be strong determinants of activism.
2. Instead, perceived risk is expected to be the strongest determinant of activism.
3. High perceived risk is hypothesized to be correlated with a high level of trust in the interest group and low levels of trust in 'traditional' institutions, like government and government agencies.
4. Trust is expected to be, at least partly, determined by socio-economic characteristics.
5. Concerning the disagreement between experts and the public, a majority of the respondents are expected to feel that they do not have enough information

about the risks from EMF, but will still want something to be done about them; a "better-safe-than-sorry" attitude.

The paper will proceed with a presentation of the survey, the survey results and analyses in which trust and then political activity are examined. In the final section, there is a discussion of the results and findings.

5.3 METHOD

In June 1996, a written questionnaire was delivered to a random sample of the Bergshamra population who lived under the power lines (N = 250), age 18 or older. The respondents received an order form for a lottery ticket worth SEK 25 (SEK 8 = USD 1, July 1998) together with the questionnaire. In August 1996, a reminder was delivered and the respondents were sent three lottery tickets upon completion of the questionnaire. In November 1996 responses had been obtained from 117 respondents, a response rate of 46.8 percent.

5.3.1 The respondents

The mean age of the respondents was 42 years. In the sample, there was an equal distribution of women and men. Over sixty percent of the respondents had children and of those who had them, close to 36 percent had one or more children in a day-care center in Bergshamra. On the average, the respondent had lived in Bergshamra 9.8 years. The respondents had higher education than the national average, with 56 percent having a college education. Their incomes were rather high and there were relatively few blue-collar workers.

5.3.2 QUESTIONNAIRE

The questionnaire was rather extensive, 21 pages in A4 format, and contained 35 questions that called for a total of 163 responses or judgments. Note that not all data are analyzed in the present paper.[29]

Apart from the usual background data, the respondents were asked for judgments concerning:

[29] In addition there were question that are analyzed in a another paper [20] and these are not reported here.

- personal and general probabilities of harm and severity of consequences from electromagnetic fields
- the degree of personal control over the risk associated with EMF
- if the power lines should be removed
- questions about their political activities with respect to the power lines
- if and where the respondents had obtained information about the power lines and electromagnetic fields
- to state their trust in information from 16 different sources

5.4 Results

5.4.1 Risks

The respondents were asked for judgments of their own personal probability of being injured, and severity of the consequences if the injury occurs, from electromagnetic fields. They were also asked to provide the same estimates for people in general. The scale was from 0 to 6 where 6 indicated larger probability and more severe consequences. The mean ratings are presented in Table I.

Table I. *Mean ratings of personal and general probability and consequences of being injured by EMF. The scale was from 0 to 6 where 6 indicated larger probability and more severe consequences. Significance levels of the difference between judgment of risk for self and people in general are also presented. N = 117.*

Risk	Personal prob.	General prob.	Signif. of diff.	Personal conseq.	General conseq.	Signif. of diff.
Electro-magnetic fields	2.46	2.42	0.356	3.38	3.40	0.440

The interesting thing to note is that there were no significant differences between the respondents' perceived personal risk and the risk for people in general from electromagnetic fields. This is an interesting result because in the general population, personal risk tends to be rated as much lower than general risk for electromagnetic fields [22]. But these respondents live right under, or in the very near vicinity of a power line and if there is a risk with electromagnetic fields, this group is certainly likely to be affected. The fact that they still did not perceive them selves to be at a significantly higher risk than the general population could serve as an illustration of just how persistent the so called *optimist bias* is [31].

5.4.2 Information

The respondents were asked whether they thought they had enough information about electromagnetic fields and power lines. 64 percent stated that they did not think they had enough information and 33 percent that they did (there were a few non-responses).

When asked if something should be done about the electromagnetic fields generated by the power lines, 82 percent of the respondents answered "yes". Together the two questions give some interesting results, which are presented in Table II.

Table II. *Percentage of respondents who thought that something should or should not be done about the power lines given that they believed they had or did not have enough information about electromagnetic fields and the power lines.*

Should something be done?	Respondent had... Not enough information (%)	Enough information (%)	Total
Yes	85.3	76.9	82.5
No	4.0	10.26	6.1
Don't know	10.7	12.8	11.4
Pearson's chi-sq.(2) = 1.9601 Pr = 0.375, Fisher's exact = 0.359			

Among the respondents who thought they had enough information, fewer wanted something to be done about the power lines. To test the significance of the difference, Fisher's exact test, which yields the probability of observing a table that give at least as much evidence of dependence as the one observed was used. For the full table this test statistic was 0.359 and we can not reject the null-hypothesis that the rows and columns in table are independent. For a table with only "Yes" and "No" responses, however, the Fisher's exact test statistic is 0.17 and, thus, there is evidence of a difference, but it is not truly convincing. What we can say for sure is that not having enough information was not seen as a compelling reason *not* to take action by these respondents. This supports the hypothesis of the "better safe than sorry" attitude.

Intuitively, it was expected that among respondents who felt they had enough information there would be fewer "don't know" answers, but instead there were more, although the difference is not statistically significant. These could be respondents who felt that they had the *available* relevant information but that this information was not sufficient to make a decision, a position that I believe would coincide with that of most experts in the area [30]. Notice that, given that this interpretation is correct, only a small group of respondents shared the view of the experts.

5.4.3 Trust

In the survey, there was a question regarding what level of trust the respondents had in information, concerning electromagnetic fields, coming from 16 different sources. In the survey, 0 represented "No trust at all", 2 represented "Some trust" and 4 " A very large amount of trust". The mean responses are presented in Table III.

Table III. *Stated level of trust in information, concerning electromagnetic fields, coming from 16 different sources.*

Source	Stated trust
Researchers at universities	2.93
Physicians	2.81
The Action Group Against the Power Lines in Bergshamra	2.64
The Swedish Environmental Protection Agency	2.51
The Swedish Environmental Protection Foundation	2.43
Family	2.34
The Swedish Occupational Health and Safety Agency	2.23
Friends	2.08
The Swedish Electrical Safety Agency	2.04
Patients advocacy groups	1.84
Neighbors	1.78
The City of Solna	1.58
The City of Stockholm	1.39
Stockholm Energy	1.38
Consulting companies	1.35
The Swedish government	1.16

The interest group had managed to build a remarkable credibility; on par with academic researchers and physicians and higher than other interest groups like patient advocacy groups and the Swedish Environmental Protection Foundation. The two cities of Stockholm and Solna, the utility company and the Swedish government were highly distrusted by the respondents. This is probably indicative of a more general distrust in politicians. The government agencies, i.e., the implementing bodies of the government, did not receive at all the same lack of trust.

To see if background variables, risk perception or specific trust variables could explain the variation in level of trust, regression analyses were carried out with two different dependent variables; first with **trust in action group** and second with **trust in Solna** (the local government). To avoid problems of multicollinearity, a separate model with background variables was tested. The results from that analysis are presented in Table IV and the variables are described in Appendix 1.

Only the results with **trust in action group** as dependent variable are presented, because with **trust in Solna** as dependent variable, the whole model was insignificant and there were no significant explanatory variables.

Table IV. *Linear regression with* ***trust in action group*** *as dependent variable.*

Independent variables	Coef. (P>|t|)
Sex	-.47 (0.066)
Education	-.612 (0.012)
Age	.001 (0.956)
Lived	-.013 (0.320)
Children	.748 (0.004)
Occupation	
Industrial	-.433 (0.390)
Health care	-.802 (0.068)
Service	-.025 (0.948)
Education	.238 (0.562)
Business owner	-.034 (0.940)
Home maker	.875 (0.306)
Retired	-.786 (0.149)
Student	.161 (0.732)
Unemployed	1.299 (0.067)
Constant	3.026 (0.000)
Number of obs	110
F(14, 95)	2.63
Prob > F	0.0029
R^2	0.28
Adj. R^2	0.17

Noteworthy is that men, university educated and people working in health care had significantly lower trust in the action group and parents and unemployed had higher trust, much in accordance with prior expectations.

Subsequently, a full model, which included the significant background variables, was tested. The results are presented in Table V. However, it was discovered that the background variables **age, sex** and **occupation** were insignificant and had only small effects on the dependent variables in the full model, presumably because other variables absorbed the effects of these. Therefore, these background variables were dropped from the analyses. The fact that all these background variables were insignificant is in itself an interesting finding. Furthermore, in the full model it was found that **personal consequences** was strongly correlated to **personal probability** and therefore dropped, as was **trust in Solna,** because of a strong correlation with **trust in utility**.

Table V. *Linear regressions with Trust in action group and Trust in Solna as dependent variables.*

Dependent variable	Trust in action group	Trust in Solna
Independent variables	**Coef. (P>|t|)**	**Coef. (P>|t|)**
personal probability	.378 (0.000)	-.094 (0.225)
control	-.169 (0.005)	.015 (0.811)
lived	-.004 (0.663)	-.010 (0.330)
children	.416 (0.028)	-.084 (0.670)
education	-.319 (0.087)	-.105 (0.589)
done	.258 (0.170)	-.058 (0.765)
trust private	.138 (0.000)	.011 (0.785)
trust utility	.025 (0.780)	.452 (0.000)
trust action group		-.002 (0.981)
constant	1.26 (0.007)	1.310 (0.009)
Number of obs	109	109
F	(8, 100)13.44	(9, 99) 4.57
Prob > F	0.0000	0.0000
R^2	0.52	0.29
Adj. R^2	0.48	0.23

Personal probability, **control**, **children**, and **trust private** are all highly significant and all have the expected sign, except **control**.

These analysis give support to hypothesis 3, that level of trust is positively correlated with level of perceived risk and hypothesis 4, that trust is at least partly determined by socio-economic characteristics.

5.4.4 Political activities

In the survey, there were a number of questions pertaining to the political activities of the respondents with respect to the power lines. They were asked to indicate whether, and where applicable, the number of times, they had participated in the following activities.

- membership in organization dealing with the power lines in Bergshamra
- active in such organization
- membership in organization dealing with electromagnetic fields in some other way
- partaken in any legal or judicial measures regarding the power lines (several examples were given)
- measured the electromagnetic fields in the home
- been to public meeting concerning the power lines
- expressed opinion at such meeting
- talked to neighbors about the power lines and/or electromagnetic fields
- contacted a politician regarding the power lines
- signed a protest list against the power lines
- helped distributing protest lists against the power lines
- voted for a political party because of their stance on the issue of the power lines
- actively searched information regarding the power lines or electromagnetic fields
- donated money to an organization dealing with the power lines
- written op-ed. concerning the power lines
- expressed opinion about the power lines on TV or radio
- participated in demonstration against the power lines
- planned to move because of the power lines
- would like to move because of the power lines
- let the children change daycare center or school because of the power lines
- would like to let the children change daycare center or school because of the power lines
- been active in any other way, not mentioned above

The 'measure' of political activism employed is certainly open to question. All the activities have the potential of sending a signal to the politicians, although some of them are not *political* activities proper. If, for example, many residents let their children switch day-care center or school because of the power lines, this is likely to be perceived by the politicians as a signal that their constituency is worried about the power lines. Thus, they are activities that could affect the political process and the core questions of the paper revolve around whether people who engage in any such activities differ, with respect to levels of trust and perceived risk, from people who do not. The objective has not been to identify individuals who engage in political activities as such.

Nevertheless, the analyses were also carried out using a more restrictive definition of political activities, but as it were, the results did not change. The reason for this is that the individuals who engage in the proper political activities are also very likely to be the ones who engage in the other, less obviously political activities.

Another methodological issue is that the activities could to be weighted in the analyses in order to reflect differences in potential impact on the political process. However, a weighting scheme did not change the results. This is not surprising; a weighting scheme would be crucial if the aim was to predict the outcome of a political process, but here the outcome was already known and the aim was to investigate the individuals involved. For this reason only the results using a simple summation index with weight 1 on all activities are reported here.

The analysis of these data had the goal of explaining political activity in terms of socio-economic factors, risk perception and trust

To this end, a regression analysis with **Activity** as dependent variable was performed. The results are presented in Table VI, while the independent variables are described in appendix 1.

Table VI. *Linear regression with* ***political activity*** *as dependent variable.*

Independent variables	Coef. (P>|t|)
personal probability EMF	1.78 (0.015)
control	-.54 (0.376)
Sex	1.37 (0.442)
Age	.021 (0.765)
lived	-.0017 (0.985)
children	6.45 (0.001)
education	4.74 (0.010)
trust action group	2.02 (0.027)
trust Solna	-.25 (0.765)
constant	-4.93 (0.314)
Number of obs	111
F(8, 102)	6.47
Prob > F	0.0000
R^2	0.34
Adj. R^2	0.28

There were two significant background variables; **Children** and **education**, both of them highly influential and with the expected positive sign. **Sex**, was relatively strong with a beta-coefficient of 1.4, meaning that men were more active than women, but not significant. **Trust in action group** was significant with a beta-coefficient of 2.0. While **trust in Solna** had the expected negative sign, its effect was much smaller and also insignificant. Of the two risk perception variables, only **personal probability** was significant and had the expected sign. **Control** had an unexpected sign and was not significant.

Overall, the model is significant and has an adjusted R^2 of 0.28, which is satisfactory for an exploratory model on individual data with a small sample.

A rather interesting result is found if we replace the variable **trust in Solna** with **trust in the national government**. This model outperforms the original model and the new variable has a rather strong effect in the expected direction, although not significant. **Trust in action group** is no longer significant in this model. A correlation test revealed that this is not due to a high correlation between trust in action group and trust in government. The model is presented in Table VII.

Table VII. *Linear regression with political activity as dependent variable.*

Independent variables	Coef. (P>|t|)
Control EMF	-.76 (0.190)
Personal probability EMF	1.90 (0.005)
Lived	-.11 (0.214)
Children	5.92 (0.001)
Education	3.08 (0.079)
Sex	1.68 (0.316)
Trust action group	1.37 (0.117)
Trust national government	-1.25 (0.114)
Constant	.28 (0.951)
Number of obs =	109
F(8, 100)	6.80
Prob > F	0.0000
R^2	0.3523
Adj R^2	0.3005

5.5 DISCUSSION

There has been no discernible public opposition to the decision to remove the power lines. It is nonetheless questionable whether this action can be justified as the outcome of rational policy making. It can be argued that if you want to spend several millions of dollars on mitigating risk, there are more urgent problems than EMF. Even if the most pessimistic estimates of the risk of leukemia from power lines are true, the cost per life-year saved is very high; $23.75 million [19]. As a comparison, the cost per life-year saved for various measures against indoor radon is between $250 and $4,500 [21]. However, it is of course possible that even a very expensive intervention passes a cost-benefit test. To help improve decision making on risk, it is important to understand the mechanisms behind this type of decisions that lead to the implementation of interventions that are very expensive in terms of cost per life-year saved.

A key issue is the "better safe than sorry attitude". The respondents to this survey, who all lived under a power line, did not perceive themselves to be at a significantly higher risk from electromagnetic fields than people in general. (However, this finding must be qualified by the observation from earlier studies that most people perceive themselves to be at a significantly *lower* risk from electromagnetic fields than people in general.) Yet, an overwhelming majority of the respondents wanted something to be done about the power lines and this was regardless of whether they thought they had enough information or not. In fact, more respondents who thought they did not have enough information wanted something to be done about the power lines. This indicates a "better safe than sorry" attitude, in which the subjects focus on the risk and forgets about the opportunity cost of reducing the risk. This attitude could be prevailing for many risks, as was indicated in a study by Ramsberg and Sjöberg [22], where cost-effectiveness was in general not an important attribute of lifesaving interventions. Potentially, this is a large obstacle to informed decision making on the regulation of risk.

A few respondents felt that they have the information but still did not know if something should be done about the power lines. My interpretation is that this (very small) group is closest in opinion to the medical experts in the area.

So, in conclusion, people were worried about the power lines although not terrified, and they wanted them removed.

For which respondents does this concern translate into political action? As was hypothesized, it was the respondents who perceived the risk to be greater that were more politically active. Note that this is likely to distort the impression decision-makers have about the level of concern among the citizens. Furthermore, people with children and university educated respondents were more politically active, which was expected. No other background variables had any significant explanatory power, lending some support to the hypothesis formulated in the introduction that in a grass-root movement background variables will not be strong determinants of activity. From a democracy point of view this is encouraging, since it indicates that the "elite" might not be so elitist after all.

Trust in information from different sources was used in an effort to explain level of political activity. Not surprisingly, political activism was associated with a high level of trust in the action group against the power lines and a lower level of trust in the local government. However, one should be careful in interpreting the trust variables as causal explanations of political activity. It could be that people who are active learn to trust the action group and distrust the local government, in which case the causality goes the other way around.

An interesting finding which might shed some light on the direction of causality is that individuals that were more politically active with respect to the power lines had a much lower trust in information from the national government than individuals that were not active. This effect is strong, much stronger than the effect of trust in the local government. It is highly unlikely that this distrust is an effect of being active since the national government has not been involved in the issue. My interpretation is that it is indicative of a general distrust in politicians and this distrust causes people to be more active.

Contrary to the hypothesis, it was found that government *agencies* was trusted also by active individuals and this was not correlated with perceived risk. This might indicate a difference between Sweden and the U.S.. In Sweden, government agencies seem to be perceived as entities not directly under political control.

I also wanted to explain trust as a function of risk perception, trust and background variables. As it were, a relatively large proportion of the variation in trust in information concerning the electromagnetic fields from the action group could be explained by the model. Trust in the local government could be explained to a lesser degree with these variables. It turned out that university educated respondents had less trust in both the action group and the local government and that respondents with children had more trust in the action group and less trust in the local government. Respondents who perceived their personal risk from EMF to be higher had more trust in the action group and less trust in the local government. The causality is hard to determine here; do they trust the action group because it confirms what they already believed, or do they perceive the risk to be greater because the action group has told them EMF are dangerous?

Is trust important? Well, the answer is yes, but perceived risk seems to be a much more important determinant of political activism. However, the policy implications of this are intricate. Even if it is recognized that it is of great importance to change perception of a risk, this can not easily be done if trust is absent. Especially in a case like EMF, when the "better safe than sorry" attitude prevails among the public, the hard question is to achieve agreement that cost is *also* an important factor.

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5.A Appendix 1

Variables used in the regression analyses.

Variable name	Variable description
Political activity	Self reported political activity index. Continuous variable.
Age	Open-ended question
Sex	Dummy variable: "1"=Man, "0"=Woman
Income	Household income stated on a 7-step scale. Treated as a continuous variable
Education	University education. Dummy variable: "Yes"=1, "No"=0
Children	Dummy variable: "Yes"=1 or "No"=0
Occupation	Dummy variable - administrative work as reference case.
Lived	How long the respondent had lived in Bergshamra. Open ended-question.
Personal probability	Perceived probability of own injury from risk. Rated on a 7 step scale. Treated as a continuous variable.
Personal consequences	Perceived severity of consequences of own injury from risk. Rated on a 7 step scale. Treated as a continuous variable.
Control	Perceived level of individual control over risk Rated on a 7-step scale. Treated as a continuous variable.
Trust Solna	Trust in the local government, rated on a 5 step scale. Treated as a continuous variable.
Trust gov.	Trust in the national government, rated on a 5 step scale. Treated as a continuous variable.
Trust aktion	Trust in The Action Group Against the Power Lines in Bergshamra, rated on a 5 step scale. Treated as a continuous variable.
Trust private	Trust in non-experts. Sum of trust in friends, family and neighbors, rated on a 5 step scale. Treated as a continuous variable.
Trust utility	Trust in the utility company, Stockholm Energi, that owns and operates the power lines, rated on a 5 step scale. Treated as a continuous variable.

Chapter six.

When Should Expenditure Per Life Saved Vary?

With John D. Graham

This paper has benefitted greatly from comments by Magnus Johannesson, seminar participants in the health economics workshop at the Stockholm School of Economics and three anonymous referees. Any errors remain the responsibility of the authors.

The paper has been submitted and is currently under review.

6.1 INTRODUCTION

A growing body of evidence indicates that the marginal expenditure to "save a life"[30] varies tremendously among lifesaving interventions. [12], [41], [46], [1], [49], [34], [19], [13], [4], [29], [38]. What is commonly found is that some interventions have benefits that outweigh the costs, resulting in a cost per life saved at or below zero, whereas other interventions have a cost per life saved in the range of hundreds of thousands or even hundreds of millions of dollars.

Methodological inconsistencies in these studies could explain some of the discrepancies in the estimates of marginal expenditure per life saved [8]. A recent overview of 92 regulatory decisions concludes that there is a considerable lack of consistency in cost-benefit analyses across and within federal agencies in the USA [14]. In the peer-reviewed literature, the methodology employed can vary widely across analyses, even within a specific disease category [12], [42], [44]. Different evaluations of the same intervention have sometimes produced very different results [3].

Variations in analytical practice might be explained by a variety of factors: different understandings among analysts of the appropriate conceptual model, differences in opinion among analysts about the best sources of data, different approaches by analysts to the treatment of scientific uncertainty in estimation of benefits and costs, and inconsistent application of discount rates to benefits and costs. The results of a cost-effectiveness analysis can also be manipulated by subtle analytical decisions such as the specific choice of the comparator (to the intervention of interest) and the specific choice of the target population [10].

Could the reported disparities in lifesaving investments be a complete artifact of analytical inconsistencies in how studies are conducted and reported? We suspect not. The disparities are quite large (often spanning several orders of magnitude) and, in some cases, it has been shown that a movement toward analytical consistency actually exaggerates the reported discrepancies rather than reduces them [51]. When modest efforts have been made to reanalyze various interventions with consistent analytical approaches, large disparities in expenditures per life saved continue to be reported [12].

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[30]Our definition of a lifesaving intervention resembles that of Tengs *et al [51].*: A lifesaving intervention is defined as any measure directed towards changing the behavior and/or technology of individuals or organizations, where reducing the probability of premature death in a population is a primary goal or an actual effect of the intervention.

Some of the reported interventions have not been implemented, only proposed. It is of course only interventions that actually have been implemented that are of interest in the following discussion.

Assuming they are real, what are the implications of these disparities? If instead the marginal expenditure were equal for all interventions that are implemented, the number of lives saved would be maximized for a given total investment, or conversely, the same number of lives could be saved at a smaller cost [7]. In a Pareto optimal allocation, all consumers marginal rate of substitution between every pair of lifesaving interventions must be equalized, which implies that the marginal cost of saving a life must be equal for all interventions.[31]

In this article, we investigate when it makes sense for a society to permit departures from an equalization of marginal lifesaving expenditures. Our normative position hinges to some extent on an application of the philosophical construct called the original position, where citizens designing a society make choices in the face of a veil of ignorance [39]. We argue what reasonable citizens might decide in such an original position and contrast these choices to what might be implied by strict benefit-cost analysis[32].

For simplicity, we assume that tangible non-lifesaving benefits of interventions, such as morbidity reduction, property damage savings, and ecological protection are properly handled in a formal cost-effectiveness analysis. Thus, we focus here on contextual features of lifesaving situations -- hazard characteristics, at-risk populations, and interventions -- that might motivate people to demand more (or less) expenditure on lifesaving at the margin.

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[31] Assuming continuous production functions and that the analysis is carried out at the optimum.

[32] See Johannesson and Gerdtham [22] for an empirical application of the original position.

6.1.1 The Price of Departures from Equalization

From an economic perspective, equalization of marginal lifesaving investments requires assuming that an individual's utility from a lifesaving intervention is a function only of the number of lives saved. This is a very restrictive assumption, and, not surprisingly, it is also an assumption that has been widely challenged [20]. It is commonly held that qualitative characteristics of the regulated risk and the target population are likely to affect the utility of a given intervention. How much marginal lifesaving investments *should* vary is a normative question of great interest, particularly because the stakes are so high. In the US alone, $580 billion are spent annually on risk-related regulation [11], [30]. Another trillion dollars per year are invested in the U.S. health care system, where lifesaving considerations are sometimes (though not always) an important concern.

Our position is that proposed departures from equalization of marginal lifesaving investments should be scrutinized carefully because the price of departure is less lifesaving. Using a sample of 200 lifesaving interventions in the USA, one study [52] found that 60,000 lives are lost (i.e. not saved) every year in the United States, due to a wasteful allocation of resources. But whether these resources are really all wasted depends on whether people made these investments taking into account normative considerations other than lifesaving.

6.1.2 Why Not Use the Willingness-to-Pay Standard?

The economist's take on the normative issue is usually a willingness-to-pay approach: the value of a statistical life for a society of self-interested utility-maximizers is given as the mean marginal rate of substitution between own safety and own wealth[33]. In simple terms, let people have what they want as long as they are willing to pay for it (or would be willing to pay if they were compelled to)! After all, the economist argues, why should lifesaving be treated differently than other goods and services in society such as housing, transportation, and home delivery of food?

There are some well-known problems with this approach. The rationale behind it comes from the efficiency of clearing markets; self-interested individuals acting in

[33] The analysis can be extended to cover various degrees and types of altruism and for some types of altruism the value of a statistical life should be adjusted [24].

a well-functioning market achieve a Pareto optimal outcome in which no individual can be made better off without someone else being made worse off. However, decision making about risk often has to take place on a societal level. Frequently, people do not have property rights to the levels of risk to which they are exposed; risks are imposed or removed without compensation, risks are often imposed on one individual by another, or a certain activity can impose a risk on a surrounding geographic area. In short, risks often involve externalities and public goods [32]. A further complication is that, often, there can be no compensation after the fact; No amount of money *ex post* can bring a dead person back to the *ex ante* utility level. There is also an informational problem for markets and tort systems because it may be impossible to determine the cause of an injury or death; did the person contract lung cancer from radon in his home or from smoking? Market failures are almost guaranteed in these settings.

Theoretically, if you can measure willingness to pay, you can still obtain a Pareto optimal outcome, guided by appropriate government interventions. Unfortunately, the practical assessment of willingness-to-pay for risk reduction has turned out to be a significant challenge. The cornerstone of the economic approach to health, and also the environment, is the ability to put a monetary value on damages [23]. If this cannot be done, it impairs the use of economic principles in the area. Sometimes it is a straightforward valuation of market goods, but in other cases no market exists and other methods must be used [55].

The revealed-preference method has been applied only to a limited number of lifesaving situations and the validity and precision of the reported estimates are open to some question. Perhaps the most flexible and widely used method is *contingent valuation*, a survey-based tool which is used when there are no close substitutes to the public good for which a market exist.

Both proponents and opponents of the method agree that contingent valuation, just like other empirical methods, is sensitive to details in the design of the study. The critics claim that empirical evidence shows that stated willingness-to-pay amounts in surveys are not measures of true economic preferences. This is not to say that the responses are random numbers. There are alternative hypotheses of how people answer willingness-to-pay questions, none of which renders willingness-to-pay a measure of true economic preferences. An implication, if this criticism is true, is that welfare analyses based on willingness-to-pay obtained from contingent valuation studies are not a good guide to public policy.

Proponents of contingent valuation usually hold that the problems with the method are mostly technical. Even though a demand curve cannot be observed when there is no market, there is still a latent demand curve that can be found by other means than direct observation.[34]

There are also some deeper theoretical problems, one of which is that the concept of willingness-to-pay rests on the axioms of utility theory and, if the axioms are violated by individual decision makers, willingness-to-pay is not likely to be a valid measure of benefits. The axioms are needed to translate preferences into utility functions and, if the axioms are violated, it is impossible to give a stated or observed willingness-to-pay value a utility-theoretic interpretation. There is ample empirical evidence that people frequently violate the axioms of utility theory (especially expected utility theory), though it is not always clear whether the violations have normative/prescriptive implications for how resources should be allocated [53].

Perhaps the most serious practical obstacle to use of willingness to pay in this area is that many citizens do not understand risk levels, have labile preferences, and are not easily trained to have an intuitive feel for changes in small probabilities of death and injury. A considerable body of evidence in the field of contingent valuation indicates that willingness to pay is not very sensitive to the magnitude of risk or risk reduction [2].

An additional problem is to justify the very use of willingness-to-pay and cost-benefit analysis in societal decision making. This entails accepting a utilitarian calculus as the mechanism for decisions regarding risk levels, which is a rather strong normative claim (c.f. [43]). It also requires one to accept that property, which in this case includes imposing bodily harm, can be taken without compensation [32]. The existing distribution of income/wealth also has an important influence on willingness-to-pay amounts and there is no obvious ethical justification for the current distributions of incomes in various societies.

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[34] For an overview of arguments against contingent valuation, see e.g. Diamond and Hausman [6] and for arguments in favor of contingent valuation, see e.g. Hanemann [16].

6.2 A NORMATIVE STARTING POINT

In the WTP approach, preferences and, most importantly, distribution of risk and wealth are taken as given. We want to take a slightly different normative position, one where people are forced to look beyond self-interest. Philosophers have sought to accomplish this spirit of objectivity through use of an *original position* scenario where citizens are blinded to personal circumstances by a *veil of ignorance* [39]. Still, the individuals need some basis for their decisions and we will retain the notion that citizens are (or want to be) rational utility maximizers and the utilitarian notion that resource allocation for lifesaving should reflect an aggregation of people's preferences in society [22], [37], [32], [18]. Yet the preferences that we seek to articulate are those of a deliberative form and are not a function of the particular circumstances (e.g., wealth, age, gender, race, and risk level) in which a person happens to find himself or herself.

Throughout, we assume either that the individuals behind the veil of ignorance are identical, i.e., have the same utility functions, and are facing a lottery that will determine their position in the world or that it is equally likely that an individual behind the veil is any one person outside the veil (to avoid having to use the principle of insufficient reason). We shall look at what kind of collective agreements individuals behind the veil might create with respect to departures from equalization of marginal lifesaving investments. This will be done by maximizing expected utility behind the veil. The proposed rationales for departures that we will examine are:

- Whether ability to pay should count
- Equity and fairness considerations
- Longevity versus lives saved
- A special value for children
- Special value for productive life years
- A premium for preventing involuntary risks
- Special value for catastrophe prevention
- Special value for identified lives

This is not an exhaustive list, but it covers some of the most important issues discussed in the area of risk policy.

6.3 Should Ability to Pay Count?

The first issue we address, a fundamental one, is whether variations in ability to pay across citizens should be permitted to influence lifesaving expenditures. Cost-effectiveness (CE) analysis is often advocated as ethically more attractive than cost-benefit (CB) analysis because it does not favor the wealthy over the poor [10], [35].

However, the use of CE rather than CB analysis can be justified with an original position argument only under some special and unlikely circumstances. We illustrate this by an example. Assume that there are N people in a society. Some of them are richer than others and for simplicity we assume that there are only two, equally numerous, types: those with a small wealth, σ_P, and those with a large wealth, σ_R. Following Pratt and Zeckhauser [37], we assume state dependent utility functions of the form U(S, W) where S = 1 when a person is dead and S = 2 when a person is alive. Assume

(i) $u(2,w) > u(1,w)$

(ii) $u'(2,w) > u'(1,w)$

The initial utility in the face of a risk of p is;

$$U_0 = EU(S,W) = pu(1,w) + (1-p)u(2,w) \qquad (1)$$

Now, assume that it is possible to implement a collectively financed program that will reduce individual risk by the amount r. The willingness to pay, m, for this risk reduction from p to (p-r) can be calculated from

$$(p-r)u(1,w-m) + (1-p+r)u(2,w-m) = EU(S,w)$$

If individuals are everywhere risk averse in wealth, the willingness to pay for a given reduction in risk will be greater for the wealthier individuals, as was first shown by Weinstein, Shepard and Pliskin [54]. In their analysis, they consider how the marginal rate of substitution between wealth and risk (which defines WTP for reductions in risk) depends on wealth. That is, we are interested in the sign of $\frac{\partial}{\partial w}\left[\frac{dw}{dp}\right]$.

First, from (1), obtain

$$\frac{\partial E}{\partial p} = -u(2,w) + u(1,w)$$

and

$$\frac{\partial E}{\partial w} = (1-p)u'(2,w) + pu'(1,w)$$

which gives

$$\frac{dw}{dp} = \left(\frac{\frac{-\partial E}{\partial p}}{\frac{\partial E}{\partial w}} \right) = \frac{(u(2,w) - u(1,w))}{(1-p)u'(2,w) + pu'(1,w)}$$

and, finally,

$$\frac{\partial}{\partial w}\left[\frac{dw}{dp}\right] =$$

$$\frac{[(1-p)u'(2,w) + pu'(1,w)][u'(2,w) - u'(1,w)] - [u(2,w) - u(1,w)][(1-p)u''(2,w) + pu''(1,w)]}{((1-p)u'(2,w) + pu'(1,w))^2} \quad (2)$$

The numerator in (2) is positive because the expression in the first bracket is always positive, the second is positive by assumption (ii), the third positive by assumption (i) and the fourth is negative because u'' is negative for a risk averse individual. The denominator is clearly positive, so the whole expression is positive for a risk-averse individual. Thus, the wealthier individuals are willing to pay more for a given reduction in risk.

In a CE analysis the cost per unit of (beneficial) output is calculated. For risk policies this is typically in the form of cost per life saved or cost per quality-adjusted life year (QALY) saved. To investigate the issue at hand, we need to assume that in the CE decision making process, all lives (or QALYs) have the same value. This could e.g. be the average willingness to pay for a life in the population. In a CB analysis, the difference between total benefits and total costs is calculated and willingness-to-pay is used to measure benefits. As we have seen, because of their greater wealth, the σ_R-types have a larger WTP for a life than do the σ_P-types. This implies that in a CB analysis, an intervention that saves σ_P-types must save k lives to have the same cost-benefit ratio as an intervention, with the same total cost, that saves one σ_R-type life, where k >1 is the ratio of willingness to pay for the two types.

Now look at two interventions A and b with the same total cost. Intervention A saves one σ_R-type life and intervention B saves k-1 σ_P-type lives, where k-1 > 1. A CB analysis would rank intervention A highest and a CE analysis would rank intervention B highest. It seems, then, as if CE-analysis with equal value for all lives can be justified with an original-position argument. Behind the veil, the probability of being the σ_R-type that is saved is only 2/N which is smaller than the probability of being one of the σ_P-types saved, which is 2(k-1)/N. Would not a person behind the veil prefer CE analysis? It turns out that it is not necessarily so. Formally, the expected utility behind the veil with CE analysis is

$$\frac{1}{N}u(1,w_R)+\frac{N-2}{2N}u(2,w_R)+\frac{1}{2}u(2,w_P) \qquad (3)$$

and with CB analysis,

$$\frac{1}{2}u(2,w_R)+\frac{k-1}{N}u(1,w_P)+\frac{N+2-2k}{2N}u(2,w_P) \qquad (4)$$

To find out when a CE policy is preferred, examine when $EU_{CE} > EU_{CB}$.
Comparing (3) and (4) gives, after some algebra,

$$\frac{k-1}{N}\left[u(2,w_P)-u(1,w_P)\right]>\frac{1}{N}\left[u(2,w_R)-u(1,w_R)\right]$$

or

$$(k-1)U_\Delta(w_P)>U_\Delta(w_R)$$

where $U_\Delta(W)$ denotes the absolute utility gain of being alive at different wealth positions. Thus, whether CE is preferred crucially depends on the assumption that people value being alive independently of their wealth. Something that is perhaps not intuitively obvious is that it is assumption (ii) above that must be dropped. If (ii) is replaced by (ii)': U'(2,W) = U'(1,W), CE analysis would indeed be preferred from behind the veil. Note that the expression in (2) would still be positive, i.e., WTP for risk reductions would still be increasing in wealth. Assumption (ii)' is usually not seen as viable, since it means that people would be indifferent between receiving increments to their wealth alive or dead.

If utility of being alive is dependent on wealth then this must be taken into account in an efficient allocation of lifesaving resources [37]. Thus, there is a greater value of reducing risk to wealthier lives and consequently, the individuals will prefer the WTP approach where this is recognized.

Importantly, at the core of this question is the issue of distribution of wealth and income. In our analysis we have not considered what would happen if the individuals were allowed to also decide the distribution of wealth in society. This would depend on the shape of the utility functions, i.e. the attitude to risk. Yet we have no grounds for determining the risk attitudes of people behind the veil, a concern that has plagued the efforts of philosophers to operationalize notions of justice from the original position. A further complication is that the way in which income is distributed has large effects on the incentive structure in the economy and this will also have to be taken into consideration. However, if they did decide that equal wealth is desirable, then it follows that they would also prefer marginal risk reduction to be the same for all individuals.

6.4 Risk Equity

In general, anything that enters the utility function will affect the valuation of a life also behind a veil of ignorance. Changes that only affect the *distribution* of probability of survival will not in themselves warrant special treatment of some lives. This is because the veil transforms the individual fatality profile with a known risk level into the expected fatality probability for the whole population, since people behind the veil do not know whether or not they are a member of an at-risk, identifiable group. This applies in particular to the issue of identified lives, an issue to which we will return.

A point in case is Pratt and Zeckhauser's important analysis of WTP and the distribution of risk [37]. They point out that, even with equal wealth, using aggregate WTP may cause society to spend more on the margin to reduce risk to some people than others. Then, if society, rather than individuals, pays for risk reductions, aggregate WTP may not be an appropriate guideline because the so called dead-anyway effect causes individuals at high risk to wanting to spend profligately[35]. Society is spending money raised from everyone and should not base decisions on WTP of individuals at high risk. Instead, Pratt and Zeckhauser use a behind the veil of ignorance argument to claim that the guideline should be WTP adjusted for the expected marginal utility of money. The specific way of doing this correction is to use WTP multiplied by the ex-post expected marginal utility of money. If this is done, a societal optimum is achieved with equal marginal risk reductions for every dollar spent. That is, society should *not* pay more to reduce risk to high-risk individuals. Essentially, they show that behind a veil, all lives are turned into statistical lives and thus the level of risk will not affect valuation. But to the extent that fundamental values are affected by the distribution of risk, those values can enter the utility function directly. Presently, we will show how this can be done.

6.4.1 Modeling risk equity

Risk equity is, of course, concerned with the distribution of risk in a population. The similarity to income distribution and equity is obvious. Keeney [25] defined risk equity as the degree to which the risk is balanced in the population. According to that definition, it constitutes a less equitable situation if the risk is disproportionally borne by a small group than if the risk is spread in the population. Here, we are interested in addressing the question whether society should pay more to reduce risk for individuals at high risk than for individuals at low risk.

In their paper, Pratt and Zeckhauser explicitly leave aside non-individualistic concerns for the distribution of risk, i.e. behind a veil of ignorance the individuals are assumed to be indifferent between a situation where individual A has a risk 2p and individual B a zero risk and one where both bear risk p, if he has an equal chance of being A and B. Our interest to pursue the issue further flows from empirical evidence that people *do* care about the distribution of risk [27], [15].

[35] The "dead-anyway effect", makes us pay more to reduce risks on identified lives because the amount an individual spends is more likely to come from the low-valued state, dead. The "high-payment effect" goes in the other direction and arises because the whole cost of reduction is imposed on one, or a few, persons. With risk aversion, this means that the more the risk is concentrated, the more the affected individuals will pay, which increases their marginal utility of income.

Several types of risk equity have been proposed in the literature and examples are individual, social, group and dispersive risk equity. The equity function will look different depending on the type of equity being considered. In this paper we leave aside group and dispersive (which concerns within-group equity) risk equity measures because we have assumed identical individuals and, thus, there can be no groups. Presently, we will focus on individual risk equity and return to social risk equity later.

6.4.1.1 Individual risk equity

Individual risk equity is defined over the individual fatality profile $p_i = (p_1, ..., p_n)$ which assigns a marginal probability of dying to all individuals i $\in \{1,\ldots N\}$. A natural measure of how balanced the risk is in the population is then some measure of the deviations from the mean risk level $\bar{p} = \sum_{i=1}^{N} \frac{p_i}{N}$.

A functional form that has been proposed is a measure of the variance in risk[36],

$$d_I(p) = \sum_{i=1}^{N} (p_i - \bar{p})^2$$

where d_I denotes individual risk-inequity

Now we ask the question how willingness to pay is affected by a concern for equity. We will follow the set up by Pratt and Zeckhauser as closely as possible and examine whether society should spend more to reduce risk to high-risk individuals when concern for equity enters as an argument in the utility function. A necessary deviation is that we need to consider a model with time because otherwise the expected utility formulation can not be used to study non-individualistic preferences over the distribution of risk[37]; once the risk has been realized, it is known who lived or died and there is no "distribution of risk" anymore.

To simplify, there are only two periods and no discounting. We assume that all individuals will be alive after the first period, but for the second period the expected number of fatalities is P. The P fatalities will not necessarily affect the

[36] Following Fishburn and Sarin ([9], we will for convenience use the inequity function $d_e = -u_e$ instead of the equity function.

[37] We thank Magnus Johannesson for pointing this out to us.

whole population. Instead, they will be distributed among n individuals who all will bear the risk p = P/n. We assume identical individuals with a state dependent utility function of the form U(S, w, d), where S is a state variable which takes the value 1 if the individual is dead and the value 2 if the individual is alive, w is wealth and d, finally, is a measure of inequity as described above. Assume that $U_d(S, w, d) < 0$. Finally, assumptions (i) and (ii) from the last section are invoked also here.

The initial utility for a representative individual at risk will be

$$U = u(2, w_1, d) + pu(1, w_2) + (1-p)u(2, w_2)$$

where w_1 is period 1 wealth and w_2 is period 2 wealth.

There is an opportunity to reduce total risk with the amount R which here means a reduction of individual risk, r = R/n. The risk reduction is to be paid in the first period and WTP, m, for a reduction in own risk can then be found from

$$u(2, w_1 - m, d) + (p-r)u(1, w_2) + (1-p+r)u(2, w_2) = U_0^1$$

Individuals not in n, will have an initial utility of

$$U_0^2 = u(2, w_1, d) + u(2, w_2)$$

Note that also these individuals will have a positive WTP for a reduction in risk, because the reduction affects inequity, and their WTP can be found from:

$$u(2, w_1 - m, \Delta d) + u(2, w_2) = U_0^2$$

where Δd is the change in inequity.

How does a change in n affect WTP? As n gets smaller, total inequity gets larger and the individuals both in and not in n will be willing to pay more for a given reduction in risk. When n = N inequity is zero and does not affect WTP at all. Thus, the concern for equity works in the same direction as the "dead-anyway" effect, namely to increase the aggregate WTP for risk reductions aimed at high-risk individuals.

6.4.2 What would happen behind a veil of ignorance?

In an original position, the individuals do not know their wealth or risk. Individual risk levels are distributed according to some known function $\phi(x)$. We maintain the assumption that wealth is identical for all individuals. Behind the veil they all agree to pay an amount m* , which is the mean expenditure for an aggregate expenditure on risk reduction of m. Ex-ante expected utility for a representative individual is then

$$EU(S, w-m^*, d(\Phi,m)) = u(2, w_1 - m^*, d(\Phi,m)) + p(\Phi,m)u(1,w_2) + (1-p(\Phi,m))u(2,w_2)$$

A necessary first order condition to maximize this utility can be found by first taking the derivative with respect to m:

$$u'(2, w_1 - m^*, d(\Phi,m))d_m + p_m u(1,w_2) + p(\Phi,m))u'(1,w_2) + (1-p(\Phi,m))u'(2,w_2) - p_m u(2,w_2)$$

where d_m and p_m denote partial derivatives w.r.t. m.

Set this equal to zero and solve for p_m.

$$-p_m = \frac{u'(2, w_1 - m^*, d(\Phi,m))d_m + p(\Phi,m)u'(1,w_2) + (1-p(\Phi,m))u'(2,w_2)}{u(2,w_2) - u(1,w_2)}$$

The marginal willingness to pay is found by taking the reciprocal of this. Write $p(\phi, m)U'(1, w_2) + (1-p(\phi, m))U'(2, w_2)$ as $EU'(S, w_2)$ and $U(2, w_2)$ - $U(1, w_2)$, the absolute utility gain from being alive with wealth w_2, as $U_\Delta(w_2)$. Then,

$$WTP = \frac{U_\Delta(w_2)}{EU'(S,w_2) + u'(2, w_1 - m^*, d(\Phi,m))d_m}$$

Or, in words; WTP is equal to:

$$\frac{\text{utility of life at wealth } w_2}{\text{expected marginal utility of income in period 2} + (\text{marginal utility of income in period 1} \times \text{marginal change in inequity})}$$

From this we can conclude that WTP will be higher to reduce risk to high-risk than to low-risk individuals because of the effect on marginal change in inequity. A reduction aimed at high-risk individuals will reduce individual risk inequity whereas a reduction for low risk individuals will increase it.

In conclusion, thus far marginal expenditure per life saved could be equal under some circumstances, namely if the citizens value their lives independently of their wealth or if wealth is constant in the population and willingness to pay is corrected by the ex-post expected marginal utility of money. A concern for individual risk equity could justify paying more to reduce risk to high-risk individuals.

6.5 Longevity and Quality of Life Versus Lives Saved

There has been some debate regarding the ethical justification of using QALYs instead of just lives or life-years in the analysis. We will first look at longevity versus lives saved and then consider QALYs.

To the best of our knowledge, everyone will die sooner or later. While there is some encouraging biomedical evidence that the potential human lifespan could be quite long (e.g., over 125 years), lives are never saved. They are only extended by effective lifesaving interventions (i.e., those whose lives are saved by coronary artery bypass surgery will ultimately succumb to another heart attack, cancer, or another cause).

Analysts, particularly in public health and medicine, have recognized this reality by discarding "lives saved" as a metric of effectiveness and replacing it with life years saved or other longevity-weighted measures [36], [57]. Yet some critics of cost-effectiveness analysis have rejected reliance on longevity-based measures on the grounds that they discriminate against the elderly and the sick in favor of the young and the healthy. Some ethicists in particular have questioned the morality of using resource-allocation tools that have negative effects on identifiable and vulnerable subpopulations.

From behind the veil of ignorance, citizens do not know whether they are young or old, healthy or sick. If (as seems reasonable) they will acknowledge that everyone will die sooner or later and that they may in fact emerge in society (once the veil is removed) as a young or an old person, they will give serious consideration to the argument in favor of considering longevity, because this is what maximizes utility behind the veil. The reason is simple: Behind the veil everyone will have the same expected number of life-years, say x, because they do not know who they will be. It is reasonable to assume that utility is increasing in life-years, so that $x' > x \Rightarrow U(x') > U(x)$. Now consider two interventions A and B directed at the same individual. They both "save one life", but A is expected to prolong life only one year and B is expected to prolong it two years. If longevity is disregarded, U(A) = U(B), but that violates the earlier assumption that utility was increasing in life-years.

It should be noted that age here is acting as surrogate for longevity; there will certainly be situations where a weakly effective intervention aimed at younger populations will have less impact on longevity than a strongly effective intervention aimed at the elderly.

Life years are adjusted for quality to recognize that an extension of life may be less valued if it is associated with substantial morbidity. This is also criticized as discriminating against the sick in favor of the healthy, which is said to be a double jeopardy for the sick [17], [45]. However, If QALYs measure real changes in utility it will be preferred, if you have an equal chance of being any one person outside the veil, according to the same argument as the one used for longevity.

6.6 SPECIAL VALUE FOR CHILDREN?

If longevity-weighted measures are employed, the lives of children will typically be given greater weight than the lives of adults. For example, those who die at age 10 may lose 70 years of life whereas those who die at age 50 may lose 35 years of life. Thus, strict use of life years as the metric of effectiveness will, other things equal, favor lifesaving investments aimed at young people.

Yet some advocates of children will argue that children are special for additional reasons that are not captured by the longevity calculation. There seem to be at least two other issues involved in the arguments for valuing the lives of children higher.

The first argument might be a special maternal/paternal motive reflected by parents. One can normally expect, for example, that a parent's utility function will have the welfare of their children as an argument. This type of sentiment is, however, somewhat restricted behind the veil of ignorance because it cannot be directed specifically towards your own children. Since you do not know who you are, you certainly will not know whether you have children, who your children are, or how you will feel about them. But, since you know probabilities over these states it is nevertheless possible to display parental altruism towards children in general. However, as was pointed out by an anonymous referee, one could make the parallel argument that it is entirely possible that children will feel the same way about parents and suffer if they die.

The second argument might be that children are more vulnerable than adults because they are not mature enough to protect their own interests. Yet this fact may help explain why children are at greater baseline risk and why measures aimed at children can be disproportionately effective. If this point is already reflected in estimates of lives saved, then it is not clear that any additional weight should be added because children are at stake.

6.7 Special Value for Productive Life Years?

Analysts who advocate equal weighting of life years have been criticized on the grounds that some years of life are more productive than others. From an earned-income perspective, the value of life years tends to vary over the lifespan with the shape of an inverted U. The years in the prime of life have the highest expected earned income while years in childhood and retirement tend to have little or negative earned income. Even if one takes a broader view of productivity to include uncompensated care for others in society, the (child-rearing) years of life toward the middle of the life span will tend to have more caring productivity than years of life at the endpoints of the lifespan [24], [56].

Behind the veil of ignorance, we suspect that productivity arguments aimed at distinguishing life years would be somewhat persuasive, since enhanced productivity is translated into greater expected utility for members of society. A subtle, but important, distinction that might be made here is between wealth (which might be ignored in the original position) and earned income (or related productivity measures), which might be considered relevant to weighting of life years behind the veil.

However, the current direction of CE analysis is to include the difference between productivity and consumption on the cost side [33], which implies that the weighting should instead be based on variation in consumption over the life-cycle.

6.8 Premium for Preventing Involuntary Risks?

Risks that are incurred involuntarily by an individual are typically perceived as more onerous than risks that are incurred voluntarily. But that general statement does not necessarily answer the question whether involuntary risks should carry a different expenditure per life saved than voluntary risks. The hard questions behind the veil would revolve around how informed consent is defined, including what different aspects of the situation have to be considered and evaluated.

It seems plausible that at least the following questions would have to be addressed:
- Did the risk taker have the relevant information about risk, benefit, and alternatives?
- Did the risk taker have the cognitive capacity and experience to process that information?
- Did the risk taker receive compensation or benefit for the risk that was incurred?

Unless a confident yes can be provided to each of these questions, it is not clear that a veil-based decision rule would permit a diminution of the expenditure per life saved for programs aimed at voluntary risks.

Being injured or killed is never the intended outcome of an activity (excluding suicide). Driving a car is voluntary (at least for recreational purposes) but certainly is associated with an elevated risk of death and injury. The benefits of driving are clear and indisputable. If the risks and benefits are well understood by the driver, should measures to reduce the risk be subjected to a less generous standard for expenditures per life saved?

Behind the veil of ignorance, the answer might be no, even though the risk of driving is voluntary. If a proposed expenditure (e.g., installation of a side-impact airbag) reduces the risk of driving without reducing benefits (or curtailing the freedom of the individual to drive), then a citizen behind the veil might see this lifesaving opportunity as no less worthy of investment than a measure aimed at reducing an involuntary risk. In a sense, the risk of driving without the feasible intervention is "involuntary" unless the driver is directly given the opportunity to purchase the side-impact airbag, as would occur in a theoretically perfect market.

A related difficulty, as Sunstein [50] has argued, is that there is no real sharp distinction between voluntary and involuntary risks. The risks to nearby residents from a factory's air pollution are often perceived as involuntary but the affected residents could move their families (at a cost) away from the facility. A veil-based scheme might permit more generous investments in lifesaving, through collective measures (e.g., regulation), as the cost to individuals of avoiding the risk through personal action increases.

A specific case where voluntary assumption of risk might not be trusted is where an activity offers immediate benefit yet a risk of long-term health effects. Behavioral specialists argue that this pattern of benefit and risk discourages prevention, possibly accounting for most life-style risks like smoking and excessive caloric intake. Yet distinguishing legitimate time preferences from neglect of the future is very difficult [31]. Although a veil-based scheme might permit some discounting of future (relative to current) lives saved, there might also be sensitivity to the tendency of human beings to apply excessive discount rates to future effects. A possibility is that behind a veil, discounting will be constant, or unnecessary, because it is not clear what point is "the present".

Another objection to assuming risks are incurred voluntarily is addiction. But, presumably, individuals will not have addictions behind the veil. When their actions are not guided by addictions, people are able to engage in self-binding behavior such as regulating the use of addictive drugs outside the veil.

6.9 Investing in Catastrophe Prevention

Catastrophes, incidents with a large number of casualties that cluster in space and time, may disrupt deeply held and important social values [48]. Rather than inflating the value of the lives saved, it is appropriate to identify and measure directly these ancillary benefits of catastrophe prevention.

Catastrophic potential also concerns the question of equitable risk distribution. In contrast to our earlier discussion of individual risk equity we will here make use of the notion of social outcome equity. The domain is a set of probability distributions P_s on the total number of fatalities in the population (0, 1,..., N). Consider e.g. two policies A and B where A has probability distribution ½(1, 1, 0, 0) + ½(0, 0, 1, 1) and B has ½(1, 1, 1, 1) + ½(0, 0, 0, 0). Both have the same expected number of fatalities, 2, but B has the same outcome for all individuals. When B is seen as more equitable it has been called a *common-fate preference* and if A is more equitable it is a *catastrophe avoidance preference* since it avoids the catastrophic outcome where all die [9]. In our view, catastrophe avoidance preferences are fully legitimate but it is perhaps not really an equity consideration. It might be *better* that not everyone dies, but why is it more fair or just or equitable? On the other hand, psychometric risk research has shown that catastrophe avoidance preferences are common [47].

For social outcome equity, the von Neuman - Morgenstern axioms can be evoked, and Fishburn and Sarin [9], based on Keeney and Winkler [26] have proposed the social outcome inequity function

$$d_s(p_S) = c_0 \sum_{k=0}^{N} p_S(k)k(N-k)$$

where the sign of c_0 (+,0, -) denotes catastrophe avoidance, neutrality and common-fate preferences, respectively [38] and k is the number of fatalities.

Looking at the first order conditions for an optimum, we have seen that marginal WTP is

$$WTP = \frac{U_\Delta(w_2)}{EU'(S, w_2) + u'(2, w_1 - m^*, d(\Phi, m))d_m}$$

where d_m in this case is marginal social outcome inequity instead of individual risk inequity.

Thus, WTP is affected by marginal changes in inequity. Note, however, that concern for social outcome risk equity does not imply that society will pay more to reduce risk for high-risk individuals than for low-risk individuals. For that situation, any reduction to any individual will have the same effect on the probability distribution on the total number of fatalities in the population. Thus, marginal WTP for different levels of risk behind the veil will not be affected by catastrophe avoidance preferences.

6.10 Blinded from Identifiability

When the victims of a risk can be identified (either ex ante or ex post), society may tend to spend more resources on saving lives than when the victims can not be identified. Real-world examples of identifiability include the trapped coal miner (ex ante identified), the victim of a rare form of liver cancer linked to vinyl chloride exposure (ex post identified), and the patient dying of cancer in the hospital (identifiable ex ante and ex post). Identifiability ex ante can be considered

[38] Note that also for catastrophe avoidance preferences, the function has an origin at $u_s(0) = u_s(N) = 0$. This means that equity is zero also when no one dies. Instead, the form $u_s(P_s) = c_0\Sigma P_s(k)(N-k)$, which fixes an origin at $u_s(N) = 0$ and has instead a maximum at $u_s(0)$, i.e. when no one dies, could be used.

the extreme case of an at-risk population group that faces very high baseline probabilities of death without intervention [21], [40].

Pratt and Zeckhauser [37] examined this question in an original position and, as we have already seen, found that as long as wealth is constant, marginal risk reduction should be the same for all individuals. The veil transforms identified lives into statistical lives, since people behind the veil do not know whether or not they are a member of an at-risk, identifiable group. The utilitarian lifesaver sees this outcome as attractive, since the widespread "murder of statistical lives" (in favor of small numbers of identified lives) is prevented by blinding people of identifiability.

There is still a possibility the citizens behind the veil might prefer to design a society where special efforts are made to save identified lives, in the same fashion as we have modeled concerns for equity. The motivations might include a desire to reduce regret (which might be accentuated with identified lives that are not saved) or to act as a symbol of the precious value of life (which might be difficult to express through expenditures aimed at saving unidentified lives) [28]. A preference for saving identified lives may also reflect a concern for social capital; the values and institutions that cement human relations and make human cooperation possible. The appropriate magnitude of any preference for saving identified lives remains a very difficult question.

6.11 Conclusion

A substantial body of evidence from the USA and other countries suggests that expenditures per life saved vary enormously. To the extent that the variation is real, concerns implemented programs and is haphazard or systematic without normative justification, then a heavy price is paid in the foregone opportunity to save lives and reduce costs. The potential murder of statistical lives and wasting of resources merits serious scrutiny.

Yet it is not obvious that strict equalization of marginal expenditures per life saved is normatively appealing. We have argued, using the philosophical construct of the original position, that some departures from equalization of life valuation are appropriate.

The following considerations would seem to merit some departure from equalization: longevity, quality of life, productivity, individual risk equity and informed consent in risk taking. Ability to pay and voluntariness per se have less clear justifications as determinants of investment in lifesaving. Nor is it obvious that there should be a special value for children. Catastrophic potential and identifiability raise broader questions about community and social capital that are worthy of serious consideration.

An important limitation of this analysis is that the precise constraints imposed by the original position are not entirely clear. If too many constraints are imposed, the basis for any preferences about lifesaving may be removed. If too few constraints are imposed, then prejudice as well as preference may influence decisions made behind the veil. In the context of the present analysis, the veil is tantamount to maximizing a social welfare function with identical individuals. The result of the analysis is essentially an effect of what goes into the utility function. While maximizing a social welfare function is certainly a worthwhile exercise, for the veil to be really useful, perhaps something else is needed. We would like to be able to say something about what kind of preferences people would form behind a veil. Dasgupta [5] and others have stressed that preferences are always formed in a social context. What is the social context behind the veil? This is not a question we will attempt to answer.

Like all philosophical claims, preferences articulated behind the veil are disputable. We hope this article stimulates readers to consider how their investment preferences for lifesaving might be formed in the original position and how much those preferences might differ from the views we have expressed.

An important outstanding problem is of course to determine the value at which lifesaving interventions should be equalized. It is not obvious that the current level of total investment is appropriate. A further complication is that without using a willingness-to-pay approach, it is unclear how the appropriate level can be established.

We have identified some qualitative factors that might justify departures from equalization of marginal lifesaving investments, but we have not addressed what the magnitude of these departures should be. That empirical question needs to be addressed by concerted research programs in the years ahead.

6.12 References

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APPENDIX.

EXAMPLES OF COST-EFFECTIVENESS STUDIES FOR LIFESAVING INTERVENTIONS

A.1 METHOD

The incremental cost per life saved is calculated by dividing the incremental cost by the incremental effect in the following way:

Incremental cost per life saved = $(C_i - C_b)/(E_i - E_b)$

Where,

C_i = Discounted net cost of life-saving intervention = $\sum_{t=0}^{T} \beta^t (D_{it} - S_{it})$

C_b = Discounted net cost of base-line intervention = $\sum_{t=0}^{T} \beta^t (D_{bt} - S_{bt})$

E_i = Discounted number of lives saved from life-saving intervention = $\sum_{t=0}^{T} \beta^t L_{it}$

E_b = Discounted number of lives saved from base-line intervention = $\sum_{t=0}^{T} \beta^t L_{bt}$

Where,
$\beta^t = 1/(1+r)^t$ = a discount factor, $r = 0.05$
D_{it} = Monetary (gross) cost of the life-saving intervention in year t
D_{bt} = Monetary (gross) cost of the base-line intervention in year t
S_{it}= Monetary saving from the life-saving intervention in year t
S_{bt} = Monetary saving from the base-line intervention in year t
L_{it} = Number of lives saved from the life-saving intervention in year t
L_{bt} = Number of lives saved from the base-line intervention in year t

Interventions are evaluated from t = 0, the year the intervention is implemented to t = T, the last year costs are incurred or lives saved.

Note that in the following, all costs are given in dollars, 1993 years prices.

A.2 ELECTRICAL SAFETY

A.2.1. Background

Every year, up to 10 people are killed in electrical accidents in Sweden [28].

Three to four of these fatal accidents occur on top of trains, where it is possible to come in contact with high voltage lines. Primarily, it is playing children and drunken people who have this type of accident, and they are hard to avoid with regulations. There are also other accidents involving high voltage current, e.g. in industrial work.

However, some fatalities are due to domestic accidents, involving low voltage current.

A.2.2 Intervention

It has been proposed that a Residual Current Device (RCD) should be made mandatory in all private houses. A RCD is a safety device that is primarily intended for usage in private homes, but it is also used to prevent accidents in camping sites and construction sites. It has been estimated that approximately 2-3 fatal accidents can be avoided every year if all private houses were equipped with a RCD [19].

A.2.3 Cost

The cost of installing a RCD is approximately $250-375. There are approximately 2,2 million private houses in Sweden and if all were to install a RCD, the total cost would be $550-825 million.

To calculate the cost-effectiveness of this intervention the following assumptions are made:
- -The baseline intervention is to do nothing.
- -The RCD needs to be replaced after 20 years, so the intervention will be evaluated over 20 years.

- -The number of life-years saved from preventing one fatality is 40 years. This is based on the average remaining life-expectancy of the Swedish population.

The net present value of life-years and lives saved over twenty years are:

NPV of 80 life-years annually for 20 years	1,000
NPV of 120 life-years annually for 20 years	1,500
NPV of 2 lives annually for 20 years	25
NPV of 3 lives annually for 20 years	38

The resulting costs per life-year saved and life saved are presented in Table I.

Table I. *Cost per life-year saved and life saved, in million dollars under different assumptions on total cost and effect.*

	Total cost: $550 million	Total cost: $825 million	mean
Cost per life saved			
Two lives saved annually	22	33	27.5
Three lives saved annually	14.3	21.8	18.1
Cost per life-year saved			
Two lives saved annually	0.6	0.8	0.7
Three lives saved annually	0.4	0.6	0.5

A.2.4 Discussion

In Sweden an RCD is only a complementary safety device, not intended to replace other safety measurements. In 1991, the National Board of Electrical Safety came to the conclusion that the high cost per saved life made a law requiring RCDs in all private houses indefensible [19]. Another important factor was that the Board is required to have a very strong motive, such as a large number of people being killed, for implementing a retroactive regulation. Instead, the Board put forth recommendations and later they have instituted regulations demanding RCD in bathrooms and for outdoor installations. Furthermore, there is a gradual adjustment to the European Union, where RCDs are standard in many countries. This method of slowly changing the standard is less expensive than legislating, but has not been considered here.

A.3 Age limit on smoking

A.3.1 Background

Smoking is the single largest contributor to premature death in Sweden today. It is known to cause, or contribute to, cardiovascular diseases, cancer, chronic pulmonary conditions and a large number of other diseases. These adverse effects are well documented; an astonishing 60,000 studies regarding the health effects of smoking has been published worldwide since the 1960's [6]. In Sweden, 8,000 – 10,000 people are estimated to die every year because of smoking. Over the last years there has been a decreasing trend in smoking in many western societies, including Sweden, but still 30,000 young people take up tobacco use every year in Sweden [6].

The earlier a person takes up smoking, the larger the health risks become. For example, the risk of lung cancer is four times higher when a person start smoking before the age of 15, compared to a person who starts after the age of 25. Furthermore, as many as 90 percent of all smokers start before the age of 18, and those who have not started to smoke before that age is very unlikely to ever start.

A.3.2 Intervention

The National Institute of Public Health has proposed an age limit at 18 years for buying tobacco. The rationale behind this is both that smoking is more dangerous for young people than for adults and it is also expected to make fewer people take up smoking.

An age limit is believed to make it more difficult to get hold of tobacco, but also have an effect on the social acceptability of smoking and support the parents in fostering their children. Also important, an age limit is a form of consumer information. Many countries already have age limits on smoking, at 16 or 18 years of age.

There are very few studies on the effect of an age limit, but in general an age limit seems to reduce smoking in young age groups. This conclusion is also supported by studies on other types of drugs, such as alcoholic beverages. In a report [6], the

National Institute of Public Health makes a conservative estimate of the effect of an age limit, assuming that it will reduce smoking by five percent among people under 18 years of age. In absolute numbers that corresponds to approximately 600 new smokers less annually, which, according to the institute would result in 300 lives saved every year. Now, the lives saved do not "show up" until in a rather distant future, when the adverse health effects of smoking start to take their tolls in fatalities. In the following, we will assume that the lives that are saved are saved in 40 years. Furthermore, it is assumed that each life saved corresponds to 20 life-years. The net present value of 300 lives in 40 years is approximately 42, and the net present value of 6,000 life-years is approximately 850.

A.3.3 Cost

The cost of legislating is negligible, but society will have costs for implementing the law and ensure compliance. No data on these costs exist, but in the present calculations we assume they are of the same magnitude as the costs for controlling the age limit on alcohol sale. Presently, the responsibility for controlling compliance with the age limit on alcoholic beverages is with the county boards.[39] In 1994 the total nationwide cost the county boards had for alcohol related issues was approximately $2.3 million. Out of this, about 80 percent is related to administration of permissions for the sale of alcohol and about 20 percent, or $0.46 million, to control of compliance [10], [1]. In the following, $0.46 million will be used as an approximation for the costs of ensuring compliance with the age limit on tobacco sale. Several objections can be raised against this approximation and some factors probably tend to make it an overestimation: It is not the same authorities and not the same good that is being controlled and to sell alcohol a permit is required, which is not the case for tobacco. On the other hand, a register of tobacco sale outlets will have to be put up in all municipalities and there are many more outlets for tobacco than for alcohol. These factors probably tend to make the cost higher.

Also, there will be a decrease in revenue from taxation of tobacco. In the most optimistic case, with a 50 percent reduction in smoking among young people, the reduction in revenues amounts to $one million annually and with a five percent reduction in smoking, the reduced revenues would be $100,000. However, reduced revenue from taxation is a cost for the government and not for society.

[39] As of 1996 the responsibility will be taken over by the municipalities.

The effect of reduced smoking on demand for health care has been the subject of much debate. Smoking causes many diseases, but the extra cost may be balanced, or more than balanced, by the high taxes on tobacco. Most importantly, smokers die earlier, but pay into the pension system like everybody else, which has caused some authors to argue that smoking gives net benefits to society [8]. Here, no attempt will be made to resolve this important issue. Instead, reducing smoking is assumed to not cause any reductions in health care costs.

With an annual cost of $0.46 million, given a five percent reduction in smoking resulting in approximately 42 net present annual lives and 850 life-years saved the cost per life saved is $11,000 and the cost per life-year saved is $545.

A.3.4 Discussion

At present time, it seems very likely that the proposal will be accepted and a law is expected in 1996.[40]

[40] This thesis is published 1999 and the reader can be notified that the law did indeed pass.

A.4 HAEMOPHILUS INFLUENZAE TYPE B

A.4.1 Source

Trollfors B (1994) Cost-benefit Analysis of General Vaccination against Haemophilus influenzae type b in Sweden, *Scandinavian Journal of Infect. Diseases* 26:611-614

A.4.2 Background

Haemophilus influenzae type b (HIB) is a serious infection that among other things may cause meningitis or acute epiglottitis which, at least for children, might lead to neurological damages, auditory impairment, and in severe cases the children could die. Studies have shown that during the years 1981-83 there were on the average 157 cases of HI meningitis in 0-14 year old children and 162 cases of acute epiglottitis in children, all of which in the present context are assumed to be caused by HI.

On the average, 6 children die annually from HIB diseases in Sweden.

2 children develop severe neurological sequelae, requiring chronic care at an institution.

20 children develop less severe neurological sequelae.

20 children develop auditory impairment following HIB meningitis.

A.4.3 Intervention

In 1991 and 1992 two vaccines against HIB were licensed by the Medical Products Agency in Sweden, and it was recommended that all infants should be offered a HIB vaccine, free of charge. At first, some county councils were reluctant to offer the HIB vaccine, since it is more expensive than other vaccines offered to infants. However, since 1993 all county councils offer the vaccine free of charge.

The HIB vaccine is offered simultaneously with other vaccines for infants, such as diphtheria, polio and tetanus at 3, 5 and 12 months of age. In many countries four doses of HIB are recommended instead of three. Two controlled studies have shown that HIB conjugate vaccines are more than 90% effective, but some cases will occur even after general vaccination due to the fact that some infants have not yet been vaccinated, or have only received one dose.

A.4.4 Cost

The cost of one dose of HIB vaccine is $15.6 and given that approximately 120,000 children are born in Sweden every year, the total annual cost of general vaccination with three doses is $5.6 million. With four doses the annual costs increases to $7.5 million.

However, society also have gains from vaccinating infants against HIB, in the form of costs that are avoided because of the smaller incidence of diseases caused by HIB:

1) Two children develop severe neurological sequelae, requiring chronic care at an institution and the annual cost of this care is $2.25 million, under the assumption that the children live for ten years.

2) 20 children develop less severe neurological sequelae and the annual costs for these children are estimated to be $1 million. This figure is based on a study from the USA and it should be noted that these costs are not necessarily the same as in Sweden.

3) 20 children develop auditory impairment following HIB meningitis and the estimated annual cost for these children is $1.9 million.

4) When the children are sick, a parent will in many cases have to be absent from work and the total annual cost for this loss of production is estimated at $0.4 million.

5) Hospitalization during acute disease has an annual cost of $1.25 million.

The total annual costs avoided thus amounts to a maximum of $6.8 million. If the effectiveness of the vaccination is assumed to be one hundred percent, the whole reduction is realized and society will make a net annual saving of \$1.2 million, given that three doses is sufficient. The cost per life saved will then be < 0.

It is also of interest to see how sensitive the calculations are for some of the assumptions made. Assume that the cost of treating the 20 children that develop less severe neurological sequelae in Sweden is only half of what it is in the USA, i.e. \$0.5 million. Also, assume that four doses are used with a total annual cost of \$7.5 million and that the effectiveness of the vaccine is only 95 percent. Then the total savings will amount to \$6 million annually which gives an annual net cost of \$1.5 million. The cost per life saved would in this case be \$0.26 million.

A.4.5 Discussion

One possible explanation why several county councils hesitated to offer the HIB vaccination can be seen from the analysis presented here. To society as a whole, general vaccination against HIB likely saves net resources, but for the individual county council the reduction in costs will in general not be as high as the costs of the vaccination program.

A.5 LAMP- POSTS

A.5.1 Background

Single vehicle, non-pedestrian collisions constitute a significant part of the fatalities from road accidents. Obstacles on the roadside pose a risk to vehicles that accidentally leaves the road and increase the risk of fatalities and severe injuries [3]. In Sweden, it has been estimated that about 60 fatalities and 5-10 times as many severe injuries every year are caused by collisions with obstacles near the road. Approximately 20 of the fatalities and 200 of the severe injuries are caused by impacts with lamp-posts alone.

A.5.2 Intervention

Since the 1960's there are several different types of "soft" lamp-posts that breakaway when impacted on the market. The lamp-post can either have a base that slips away when impacted with, or also be constructed to be deformed upon impact.

In all, there are approximately 500,000 lamp-posts along Swedish roads, but only a very limited number are of the soft type. Every year 7,500 new lamp-posts are erected in Sweden and the large majority of these replace old lamp-posts [11]. In 90 percent of the cases the new lamp-posts are "hard", i.e. they do not breakaway.

Most of the lamp-posts are the responsibility of local authorities and not the government. However, the National Road Administration has recommended that breakaway lamp-post should in general be used, but, apparently, this did not have the intended effect.

A private organisation for motorists in Sweden (*Motormännens riksförbund*) has suggested that only breakaway lamp-post should be erected, and the number of posts that are put up should be increased to 15 000 per year. At a rate of 15 000 per year it would take 33 years to replace all 500,000 lamp-posts currently standing along the roads of Sweden. The intervention would almost certainly have its largest effect with the first lamp-posts that are erected, and after that a decreasing marginal effect would most likely be observed. The reason for this is that as the lamp-posts that are collided with are replaced, fewer and fewer of the high-risk lamp-posts remain. Many lamp-posts are situated in a way that makes the probability of an impact with them very low.

To reflect this decreasing marginal effect of the soft lamp-posts, a function of the form $f(k, \alpha(t)) = k^{\alpha(t)}$ will be used to describe the effect of putting up a given number of lamp-posts, k, in a given year t where $\alpha(t) < 1$ is the efficiency parameter. The lamp-posts continue to save lives also after they have been put up and if we denote this life-span L, the net present value of replacing lamp-posts can be written

$$\Sigma_t(1 + r)^{-t}(Lk^{\alpha(t)})$$

Calculating the number of lives saved by this intervention requires some additional assumptions:

- A lamp-post will stand for 20 years and save the same number of lives all those years.
- The values of $\alpha(t)$ are assumed to be

  $\alpha(0\text{-}3) = 0.12$

  $\alpha(4\text{-}10) = 0$

  $\alpha(11\text{-}20) = -0.1$

  $\alpha(21\text{-}33) = -0.2$

These assumptions are intended to reflect the decreasing marginal return from the investment in soft lamp-posts, but the specific numbers can of course be disputed. Under these assumptions, putting up 15,000 lamp-posts annually the net-present number of avoided fatalities is approximately 380, using a discount rate of five percent. Assuming that each life saved corresponds to 40 life-years saved, the net present number of life-years saved is 16,185.

A.5.3 Cost

The cost of a breakaway lamp-post is today \$500-750, which can be compared to the cost an ordinary lamp-post which is around \$375. This makes the annual cost of lamp-posts today \$2.8 million and if instead 15,000 soft lamp-posts were to be erected, the cost would increase to \$9.3 million, given a cost of \$625 for a lamp-post. Thus, the incremental cost is \$6.6 million. It would take 33 years to replace all lamp-posts and the net present cost of this investment over 33 years, with a discount rate of five percent is \$105 million.

A cost of $105 million with 380 lives saved gives a cost per life saved of $0.28 million and a cost per life-year saved of $6,500.

A.5.4 Discussion

The time horizon is set to 20 years in this calculation, but it is of course possible that the lamp-posts continue to save lives even after 20 years. However, due to the discounting of future effects it would make very little difference if another 10 years or so were added. The same is true of the effect of new lamp-posts erected late in the period of analysis. Discounting diminishes those effects greatly. The biggest impact is the assumption on the effect in the first few years. Also, the situation regarding for example technology and road transport even 20 years from now is impossible to predict and it is for that reason alone pointless to have a longer time horizon in the present calculations.

A.6 SECURITY PACKAGES FOR BATTERED WOMEN

A.6.1 Introduction

Every year a large number of women are subjected to domestic violence in Sweden. Perhaps as a consequence of the private nature of the violence and feelings of guilt and shame often associated with domestic violence, the violence often goes undetected, but the extent of this violence has caused commentators to speak of a public health problem [14]. Needless to say, the extent of psychological and physical damage done to women by abusive men probably cannot be fathomed. Nevertheless, this paper represents a first attempt to assess the societal costs caused by woman battery in Sweden and the cost-effectiveness of a program to reduce it. This might seem like a cynical enterprise, because when you put a number on the damages you reduce them at the same time. However, woman battery as a public health problem competes with other public health problems for attention and resources. For that reason it is essential to have adequate estimates of the extent of the violence, the cost associated with it, and tools to determine the best way to help the victims.

The specific intervention under study here is so-called security packages. This is certainly not the only way to reduce woman battery, but it is an intervention for which exact cost data exists. Thus, the choice to study this particular intervention was guided by practical concerns.

A.6.2 Incidence of woman battery

The term *woman battery* will here be taken to mean assault and battery on a woman by a perpetrator acquainted with the victim. In 1995 a total of 49,175 cases of assault and battery were reported in Sweden, of which approximately 38 percent, or 18,956, were against women. Out of these, 14,785 were woman battery, according to the definition above. For 1993 and 1994, more detailed statistics are available and the numbers are presented in table 1, where it can be seen that the reported number of assault and battery against women in 1993 were 17,928 and in 1994 it was 18,567. This corresponded to 16,622 and 15,961 cases (i.e. reports. They differ because the same report can concern more than one incident of assault and battery) respectively. A large majority of the perpetrators (78 percent) were acquainted with their victims and most of the assaults took place indoors [29]. In all, 10,455 cases of domestic violence were reported in 1994, and 705 were reported as severe. Because the same woman can make more than one report in a year, and often that is the case with domestic violence, the number of women subjected to assault and battery is not known. A reasonable estimation of the number of reports per woman is 1.2, which means that approximately 8,700 women reported woman battery in 1994 [17].

Table I: *Assault and battery against women, number of reports and number of cases in 1993 and 1994.*

Assault and battery	1993	1994
against women, number of reports	17,928	18,567
against women, number of cases	15,961	16,622
of these severe, number of reports	1,373	1,236
of these severe, number of cases	1,178	1,057
against women, perpetrator acquainted, number of reports	14,055	14,629
against women, perpetrator acquainted, number of reports	12,217	12,803
of these severe, number of reports	1,101	1,006
of these severe, number of cases	916	841
against women, perpetrator acquainted, number of reports	11,727	12,196
against women, perpetrator acquainted, number of cases	10,019	10,455
of these severe, number of reports	918	863
of these severe, number of cases	742	705

A.6.3 Incidence of homicide

In 1991, 141 cases of homicide/manslaughter were reported to the police and 32 percent, i.e., 45, of the victims were adult women [13]. Sixty-seven percent, or 30, of the women had been killed by their husbands (or ex-husbands, boyfriends etc.). In 1994, which is the last year for which data exist, 36 women died from homicide, manslaughter or other assault, according to the "causes of death" statistics presented by Statistics Sweden [28]. Statistics Sweden does not report the type of perpetrator, other than that it in most cases was a person with whom the woman had, or had had, an intimate relationship with. It has been claimed that about 20 to 40 women die every year as a direct consequence of domestic violence [22], [18]. It should be noticed that the figure may be an underestimation. The true number could be higher if, for instance, the true cause of death is not revealed in all cases. The number of autopsies have decreased over the last years, why this might be an increasing problem [17]. In the cases were the woman commits suicide as a result of ongoing battering, this is not reported as caused by the battering. This is potentially a large source of error because violence has been claimed to be the single most common cause of suicide attempts in women [14].

However, to err on the cautious side, it will be assumed that 20 women are killed every year as a direct consequence of woman battery or domestic violence.

A.6.4 Number of unreported cases

How large the risk of being killed as a result of domestic violence really is depends primarily on the number of unreported cases. In violent crime, it is usually estimated that there are 4 unreported cases for every reported case [22]. However it is well known that woman battery is often unrecognized and unaddressed even in health care settings [2]. In fact, it has been claimed that when a woman (or a relative, a neighbor or a friend) finally calls the police, she has usually been battered more than 30 times [12]. Three circumstances regarding domestic violence makes it reasonable to assume that the number of unreported cases is higher for this type of crime than for other types:

1. The battery occurs in a close relationship.

2. The battery and assault take place in a private setting.

3. The victim's physical injuries are, *in most cases*, not extensive.

In a report from RPS, different estimations of the ratio of unreported cases (RUC) are discussed [22]. Referring to data from anonymous surveys it is estimated to be approximately 10 for crime in general and 3 for violent crimes, but much more for domestic violence, especially less severe cases. The highest available estimate is that the true number of battered woman in Sweden is 300,000, which means a RUC of about 20 [22].

In the present analysis it will be assumed that the RUC is 7 for severe assault and battery and 15 for less severe cases. These assumptions are in between the highest and lowest RUCs estimated by experts and seem reasonable, although they cannot be empirically verified at this point.

A.6.4 Societal Costs from woman battery

To the best of my knowledge there have been no studies on the consequences of woman battery on demand for health care or productivity, which are the most important sources of costs, in Sweden. The estimates provided here are uncertain and more studies are needed to determine the actual costs.

The costs of woman battery are caused by productivity loss, costs of health care and costs for the legal and law-enforcement system. In the following, three levels of severity of battery, will be assumed: Homicide/manslaughter, severe battery and less severe battery.

A.6.4.1 Homicide/manslaughter

The costs of homicide/manslaughter are the productivity loss of the victim and costs for the legal and law-enforcement system. Also the productivity loss and cost for incarcerating the perpetrator should be included in the total cost. Presently, the cost of homicide reported from a study conducted in New Zealand will be used to estimate the cost of homicide in Sweden. This is of course not the ideal, but it should give a reasonable approximation of the cost in Sweden. The estimated cost of one homicide in New Zealand was $650,000. This included costs both for the victim and the perpetrator. The GNP/capita in New Zealand $12,630, for Sweden $21,254. Thus GNP/capita in N.Z. is 59 percent of that in Sweden. This is a (crude) estimate of the difference in productivity between the two countries. Thus, it seems reasonable to adjust the cost of homicide according to the same ratio, which implies that a homicide in Sweden would cost approximately one million U.S. dollars. Incidentally, this is quite close to the human capital valuation of the loss of a life in road traffic in Sweden, which gives some validity to the estimate.

A.6.4.2 Battery

To give an estimate of the costs associated with woman battery, costs for health care and productivity loss need to be quantified.

Some preliminaries are:
One visit to an open care health care provider costs on the average $150 for general internal medicine and general surgery [26].

One day of hospital care for general internal medicine costs approximately $375 [26]. This is likely to be a conservative estimate of the cost of treating a person hospitalized for battery-induced injuries.

The productivity loss per day is assumed to be $75, which is based on a monthly salary of 13,000 and employers' social taxes of 40 percent.

No data on actual health care consumption or productivity loss caused by battery exist. However, Stark and Flitcraft [27] reported that approximately one quarter of the battered women in a study from Texas needed health care because of the battery.

"Health care" needs to be specified and more severe battery naturally should lead to more advanced health care. To give a rough estimate of the costs of health care, it will be assumed that 25 percent of the cases of severe battery cause one day of hospital care and ten percent of the cases of less severe battery cause a visit to an open care health-care provider. Regarding productivity loss, an extensive interview study in Sweden revealed that nine percent of the cases of assaults on women in the home lead to at least one day of sick-leave. To estimate the productivity loss it will be assumed that ten percent of the cases of woman battery lead to the loss of one productive day. Note that it likely leads to an underestimate of the true cost because cases that lead to less than a full day of sick leave were not included. Also, some women had longer sick leaves.

The RUC is assumed to be 7 for severe assault and battery and 15 for less severe battery. This would mean approximately 4,000 cases of severe battery and approximately 140,000 cases of less severe battery. The productivity loss would then amount to 14,400 days resulting in a total cost of $1.08 million. Severe battery would under these assumptions lead to 1,000 days of hospital care and less severe battery 14,000 visits to an open health care provider. The health care costs for battery would then amount to $2.48 million. The total costs, including productivity loss is $3.55 million.

In addition it is assumed that there are 20 cases of homicide as a direct consequence of woman battery resulting in an annual cost of $20 million. Thus, with these assumptions, the annual cost of woman battery amounts to approximately $23,5 million. The greater part of this cost comes from homicide/manslaughter. However, it is very likely that the costs of battery have been underestimated. Good data is hard to obtain and conservative estimates have been used throughout. In addition, there are most likely long-term productivity losses that have not been included here; women subjected to ongoing violence is effectively hindered from achieving there full potential. For these reasons the cost presented here should be regarded as an attempt to put a lower bound on the societal costs of woman battery.

A.6.5 Intervention

The intervention under study here is ”security packages”. This is only one of many possible measures that can be taken and it is primarily used in emergency situations, when the risk of assault is judged to be high. Other measures that can be used in acute situations include body guards or a watch dog, but those are very unusual measures [22].

Normally, the measures discussed here is part of a whole system of supporting measures that are intended to solve the battered woman's problem in a more fundamental way. Medical, economical and juridical help are examples of other types of support that can be given besides protecting the battered woman's physical and psychological integrity. Many battered women also get help and support from relatives, the social service and so-called women's aid centers.

As of July 1992, all police districts in Sweden have security packages for threatened women to use. The packages can of course also be used by threatened men, but that is not very common and is not considered here.

The packages consists of a case with the following protective equipment:

- A *protective phone*, which is a specially programmed cellular phone.
- An *answering machine/tape recorder* to record threatening calls. The recordings can subsequently be used in court.
- A *security phone*, which makes it possible for the woman to contact the police from her home, by pushing a single button.
- An *acoustic, 140 dB alarm.*

In a pilot project, 200 of these packages were administered to threatened women. In all, 7 attacks on the women were registered during the project, but all could be warded off, without anybody being injured. This does not mean that the security packages will give one-hundred percent protection in all instances. The security packages are however considered to give a high level protection [22].

A.6.6 Cost

The cost of one security package is $2,190 [22]. Since the police authorities purchased 280 packages, the total purchasing cost is approximately $625,000. Apart from the purchasing cost there is also an annual operating cost of $16,250 for 280 packages [22]. Assuming that the security packages can be used for 5 years, the net present cost of the investment is $665,000, using a discount rate of five percent.

The packages are, on the average, used for a three-month period by the woman, which means that 280 packages can be used to protect 1,120 women annually.

The number of life-years saved for a woman that is protected from being murdered by the security package is not known. However, a realistic assumption is that the average age of these women is the same as for women in general, 41. The life-expectancy for women of this age is 41 years, so in the following it is assumed that 41 life-years are saved.

A.6.7 Cost effectiveness

It can be assumed that a large number of the women that are killed in a relationship have also previously been subjected to severe assault and battery. Therefore, in the present calculations it is assumed that 10 out of the 20 women that are killed every year comes from the group that has been subjected to severe assault and battery. Earlier it was said that the number of women that reported domestic violence was 8,700 in 1994. Out of these 587 were severe and with a RUC of 7 that means 4,107 women and if 10 of these women are killed the annual risk of getting killed is 0,0024 in this group. The number of women that reported less severe assault and battery is 8,113, which would correspond to 121,700 women with a RUC of 15. The annual risk of being killed is, for this group of women, 0.000082. For the whole group, then, the risk of being killed is (0.0024 * 0.067) + (0.000082 * 0.93) = 0.00024.

Given a risk of 0.00024 of being killed and assuming that the risk is reduced to zero for the women who get the packages, 0.27 lives or 11.1 life-years will be saved annually. The net present number of lives saved over five years is then 1.17 with a discount rate of five percent. The net present number of life-years saved is 48.1

The cost per saved life is thus $569,000 and the cost per life year saved is $13,825.

However, the cost of the intervention should be reduced by the amount saved from avoided health-care costs and productivity losses. Given that 0.27 lives are saved annually, $0.27 million are saved, with a net present value of $1.17 million. This saving alone is enough to offset the cost of the intervention. In addition costs are avoided from battery that is prevented which makes the cost-effectiveness even more favorable. In all, this intervention is very likely to provide net benefits to society, and have a cost per life-year saved below zero.

A.6.8 Discussion

The risk of being killed might not be correctly estimated, which would affect the calculated cost-effectiveness. It is for example assumed that the risk of being killed is the same for the group who receives the security packages as for the group of battered woman in general. This is likely an underestimation of the risk, since the packages supposedly are given to women in a high-risk situation. On the other hand, the risk reduction is likely to be overestimated. A security package cannot give complete protection. Some possible sources of error in the estimation are presented in Table II.

Table II: *Possible sources of errors in the estimation of risk of being killed and the effect on cost/saved life*

SOURCE	Effect on cost/ life saved
The true societal costs of battery are higher	-
The packages are administered in high-risk situations (as judged by the woman and the police)	-
The RUC for severely battered women is lower than 7	-
The women who receive the packages have already ended their relationships	+
The RUC for less-severely battered women is higher than 15	+
The risk of being killed is not reduced to zero	+

More importantly, one relevant source of benefits has been omitted from the analysis. Women equipped with security packages feel safer [22]. This is of course an extremely important factor for the woman and the benefits are likely to be substantial. A willingness to pay survey could be used to put a value on the increased quality of life from feeling safer.

Another direction for future research would be to give a more precise estimate of the societal costs from woman battery using data on actual productivity loss and health-care resources used. This is an important task as those figures could be used in calculating the cost-effectiveness of other interventions aimed at reducing woman battery.

A.7 Reducing Childhood Leukemia by Moving Power Lines Under Ground

A.7.1 Introduction

It has been postulated that weak, extremely low frequency electromagnetic fields, such as the ones found around high voltage power lines, may, among other things, cause leukemia in children [9]. Epidemiological studies lend support to this hypothesis [5], [15], [7]. For example, a Swedish study found that the risk of leukemia was twice as high for children exposed to 0.2 microtesla electromagnetic fields, as compared to children exposed to 0.1 microtesla [5]. In the study, no differences in incidence could be identified for adults or for other types of cancer.

There is no clear consensus, but the scientific evidence connecting exposure to electromagnetic fields to leukemia is considered weak, partly because a biological mechanism has yet to be found [32] and partly because there are methodological problems with the epidemiological studies [9], [16]. Meta analyses suggest that there is a cause for more research, but both the quality and the quantity of the available evidence discourage from claiming anything about the nature or magnitude of the risk [34], [16], [31].

Still, it is sometimes argued that exposure to electromagnetic fields should, despite the lack of conclusive evidence, be treated as a public health risk [33]. This paper illustrates why that stand might be questionable; even if the worst case risk scenario is true, the cost per life saved is prohibitively expensive.

Specifically, this article presents an attempt to estimate the cost-effectiveness of a decision to move power lines under ground. The data are of course only valid for the specific location considered (Bergshamra in Sweden) but it is very likely that similar estimates would be obtained in other localities and even in other countries. Thus, the numbers presented here have a general interest.

The city of Stockholm buys most of its electric power from power plants in the north of Sweden and the electricity is distributed in high voltage power lines to Stockholm. As it happens, these 200 Kv. power lines pass right through the residential area of Bergshamra in Solna, north of Stockholm. Approximately 2,000 people live near the power lines and there are four child day-care centres nearby. The power lines have been in place for over 70 years and are older than the residential areas. The city of Stockholm has a concession for the power lines.

Nevertheless, the city of Solna has reached an agreement with the city of Stockholm to move the power lines under ground. Stockholm and Solna will each pay half the cost of this project.

A.7.2 Electromagnetic fields and leukemia

Leukemia used to have a mortality rate close to 100% for all groups of patients, but today the expected 5 year survival is on the average around 35% and for children as high as 75-80%. Every year there are about 1,000 new cases of leukemia in Sweden and at most 100 of these are in children. Thus, a high estimate of the annual probability of acquiring leukemia in Sweden is approximately 1/8000.

If the demographic distribution in Bergshamra is assumed to be the same as the distribution in the country as a whole one could expect a base rate of 2,000*1/8,000 = 0.25 cases of leukemia in Bergshamra every year. Of these, 1/4 * 1/10 = 0.025 will be children. (This means that there will be one case of leukemia every fourth year, and one case of childhood leukemia every 40:th year, not considering the effects of the power lines.)

Feychting and Ahlbom [4] state that slightly less than one case of childhood leukemia per year in Sweden can be attributed to exposure to electromagnetic fields from high voltage power lines. So, out of the 0.025 expected cases in Bergshamra, 1/100:th, or 0.00025 is caused by the power lines. If exposure to electromagnetic fields *in general* is used, the risk of leukemia is estimated to be twice as high for children exposed to 0.2 microtesla electromagnetic fields, as for children exposed to 0.1 microtesla [5]. However, in the present study, it is only the risk from high-voltage power lines that is relevant.

The specific risk level in Bergshamra is likely connected to circumstances in that area, such as demographics and actual exposure, but these specific circumstances are unknown. To make a worst-case estimate of the risk, it will be assumed to be twice as high as for Sweden in general, i.e. the power lines are assumed to cause 0.0005 cases of childhood leukemia per year in Bergshamra.

Again, to err on the cautious side, the survival rate for childhood leukemia is assumed to be 50 percent, rather than the more realistic 75 -80 percent. The *increase* in the expected number of deaths from childhood leukemia is then 0.00025.

A.7.3 Intervention

The cities of Solna and Stockholm have decided to move the power lines under ground, which will greatly reduce the electromagnetic field. In the following, it is assumed that this intervention will reduce the number of cases of childhood leukemia with 0.0005 every year, i.e. it will completely eliminate the assumed risk. The benefits from removing the power lines will continue into the future, presumably for as long as the power lines would have been in place, were they not to be removed. This time horizon is not known, but here it is assumed to be 40 years. This time-horizon is commonly used for projects with continuing effects. One reason is that effects that occur further away in the future are negligible because of the discounting of future effects. The discount factor used is five percent.

The net present value of 0.0005 averted cases per year for 40 years is 0.01 cases. The net present value of 0.00025 averted deaths for 40 years is 0.0043 lives.

The target group is children, age 0-16. Naturally, many adults are also worried about the effects of electromagnetic fields, but there is no evidence of detrimental health effects for that group. The life expectancy of the target group is currently, on the average, 71 years [30]. This number is needed to calculate the cost per life-year saved. The life-years must of course also be discounted and the net present value of 0.00025×71 life-years over 40 years is 0.3046 life-years.

A.7.4 Cost

The cost of moving the power lines under ground was in 1995 estimated to be SEK 60 million, according to official sources (SEK 60 million is approximately $7.5 million and in the following, all costs will be reported in dollars, using an exchange rate of SEK 8 = $1.) There is reason to believe that the estimate has gone up, but it will be assumed to still hold.

The direct medical costs of treating leukemia with bone-marrow transplantation are $ 137,500 per patient [23]. These costs are of course avoided and should be included as a benefit. Every year, 0.0005 cases are avoided, which means an avoided annual cost of $69. The net present value of this benefit is approximately $1,250. For all practical purposes, this benefit can be left out from the calculations.

As was already mentioned, the intervention was assumed to not have any positive health effects on adults. However, reducing their worry is a relevant source of benefits and should ideally be included in the analysis. In addition, there could be aesthetic reasons to remove the power lines. In a survey conducted in Bergshamra, an attempt was made to estimate the adult population's benefits from removing the power lines. The details of this survey has been reported elsewhere [20]. The median respondent was found to be willing to accept that the power lines are left as they are if they receive a compensation of approximately $1,375 per annum. If this number is taken at face value, the intervention is cost-effective in the sense that the net present value to the adult population of removing the power lines is higher than the $7.5 million cost of removing the power lines. However, there are severe problems with this estimate. First, as it were, none of the values in the bid-vector were accepted by 50 percent of the respondents. The highest compensation, $75 per month, was accepted by 27.3 percent of the respondents. This shows that the vector was poorly chosen, since the optimal vector would have included amounts high enough to cause most respondents to accept. A linear regression of the data showed that acceptance would be 50 percent at an offer of $116 per month, which is the $1,375 per year above. This is an extremely doubtful result as it extrapolates out of the range of the data. Secondly, the willingness-to-accept format is acknowledged to consistently overestimate the true willingness-to pay. Third, it is very likely that the adults included a valuation of the health benefits to children in their stated willingness-to-accept. This makes it into something else than a valid estimate of the benefits received by the adult population.

A more informative number is obtained by calculating the adults' willingness-to-pay to remove the power lines that would be needed to offset the investment of $7.5 million. Approximately 22 percent of the population in Sweden is aged 16 or under [30], so we are interested in the remaining 78 percent, or 1,500 people. To achieve a net present value of 7.5 million from annual benefits over 40 years, the aggregate willingness-to-pay will have to be approximately $0.44 million. The corresponding willingness-to-pay per capita and year is then $290.

A.7.5 Cost-effectiveness estimates

The base-line alternative against which the intervention is compared is in this case to do nothing.

Without taking the benefits from reducing anxiety in the adult population into account, the cost per averted case of childhood leukemia is ($ 7.5 million/0.01) = $ 750 million.

The cost per life saved is ($7.5 million/0.0043) = $1.75 billion.

The cost per life-year saved is ($7.5 million/0.3046) = $24.62 million.

A.7.6 Conclusions and Discussion

The extremely high cost per life-year saved with this intervention is due to the fact that the cost is quite high and that childhood leukemia is a relatively rare disease. And even with pessimistic estimates, high-voltage power lines do not increase the already low risk by much. All the risk estimates in the study have already been overestimated and the costs underestimated, so the true cost is likely to be much higher. A sensitivity analysis would not do much to change the picture of this as an extremely expensive way of avoiding childhood leukemia, i.e. the result is not an artifact of subtleties in the choice of discount rate, base-line risk and so on.

The estimated cost to save a life or a life-year by removing the power lines in Bergshamra is extremely high. The cost is much higher than what is generally accepted to avoid other kinds of risk [21] and even much higher than what is invested in treating and preventing leukemia in other settings [25]. The result is obtained despite the fact that the risks have probably been overestimated and the costs underestimated. The exception being that the benefits from reducing anxiety in the adult population and aesthetic considerations have not been included. Those kinds of benefits are notoriously hard to estimate, but they would have to be in the order of a willingness-to-pay of $290 per year and adult individual to offset the cost of the investment. In fact, the investment is probably only justifiable as a mean to reduce anxiety. The vital question one needs to ask is then whether this is really the best way to reduce anxiety?

Also, the findings put the scientific controversy over whether the health risk from electromagnetic fields is "real" in perspective, because even if it could be established that there is an elevated risk of leukemia from power lines, it is not clear what policy implications that finding should have.

A.8 PROSTATE CANCER

A.8.1 Source:

The Swedish Council on Technology Assessment in Health Care (1995), Mass screening for prostate cancer. SBU-report No. 126. The Council; Stockholm

A.8.2 Background

Prostate cancer is today the most common form of cancer among men in Sweden; approximately one-quarter of all cancer cases in Swedish men are prostate cancer. With 2,220 deaths per year (1992) it is also the most common cancer related cause of death among men in Sweden. Prostate cancer generally occurs rather late in life and the large majority (75 percent) of diagnosed cases occurs in men older than 70 years.

In most cases of cancer in the prostate, the tumor grows slowly and may not cause the patient any trouble at all, or symptoms similar to those of a benign enlargement of the prostate. However, in some instances the tumor grows more aggressively and/or have metastases, in which case the cancer ultimately may be lethal. Since many of the patients are old, the cancer might still not be the cause of death because the patient dies from some other cause before the cancer has killed them.

There are different strategies available for treating the cancer, including radical surgery of the prostate, chemical therapy, radio therapy and endocrine therapy.

A.8.3 Intervention

A screening program could be implemented to enhance the chances of early detection of the cancer. There are several different methods available for screening. Direct palpation of the prostate, transrectal ultrasonotomography, testing for prostate-specific antigen or a combination of these. A screening program would be accompanied by treatment for some of the patients that are tested positive. The major problem with a screening program is that at present time it is difficult to distinguish between a cancer that will be lethal, or cause the patient a lot of trouble, and a cancer that will not cause any, or minor, trouble for the patient. This means that the result of the screening in many cases will be, in a sense, inconclusive.

A.8.4 Target group

Only men get prostate cancer. Furthermore, the cancer is almost only found in men above 50, which is why a screening program would be directed towards men older than 50. There is also an upper age-limit where treatment of the cancer is not appropriate. In Sweden treatment is not recommended for patients with a remaining life expectancy of less than 10 years, which means that men above 70-75 years would be excluded from the screening program. The reason for this is that treatment would most likely not affect their life expectancy, and may cause the patient more trouble than the cancer does.

A.8.5 Cost

A large study from the Swedish Council on Technology Assessment in Health Care briefly describes an analysis of the costs associated with a screening program for all Swedish men in the age group 50-69 [24]. It was found that the *direct* societal costs for prostate cancer would increase with $6.4 million, including the costs for the screening program. The assumed screening method is here direct palpation (DRE), repeated every third year, and the program would result in an additional 569 men undergoing surgery for localized cancer, compared with the base-line alternative of no screening program. The costs and number of operations are presented in Table I.

Table I: *Expected average health care costs for prostate cancer and number of prostatectomy per year during 6 years, for a group of men aged 50-69.*

	Million dollars	No. of operations
Without DRE-screening	10.75	524
With DRE-screening	17.1	1093
Difference	+6.4	+569

Next, we will make an attempt to estimate the cost per saved life in this screening program. It should be noted that the authors of the report on which the calculation is based did not do this calculation and in fact emphasized that it is not possible to make a correct calculation with the current insecure knowledge of the effectiveness of different methods of treatment. Therefore, the cost per saved life should only be regarded as a very rough estimate.

The 10-year disease specific survival rate of this surgery is said to be more than 90%, and if we assume that it is 95%, we can conclude that 541 patients (out of the 569) survive their prostate cancer. However, it is not known beforehand if a given patient would have survived the cancer even without the surgery, which means that not all of these patients are "saved" by the screening program. It is thus necessary to make some assumption about the natural survival rate of prostate cancer and this is difficult, due to the fact that there are very few clinical studies on which to base the estimation. However, the result is not very sensitive to this assumption, at least not for our purposes. If an interval of 40-90% natural survival rate is used between 54 and 325 patients are saved with the screening and treatment. This results in a cost per life saved in the range $20,000-117,500, with a median of $68,750. The cost per life-year saved is $4,500.

A.8.6 Discussion

The Swedish Council on Technology Assessment in Health Care does not recommend a mass-screening program for prostate cancer in Sweden. This is based on medical reasons, it has not yet been shown that such a program would have positive effects on survival or quality of life. Cost-effectiveness of the program has not been put forward as either a support for, or an argument against a screening program.

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