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VALUE OF A STATISTICAL LIFE

An Alternative Ending

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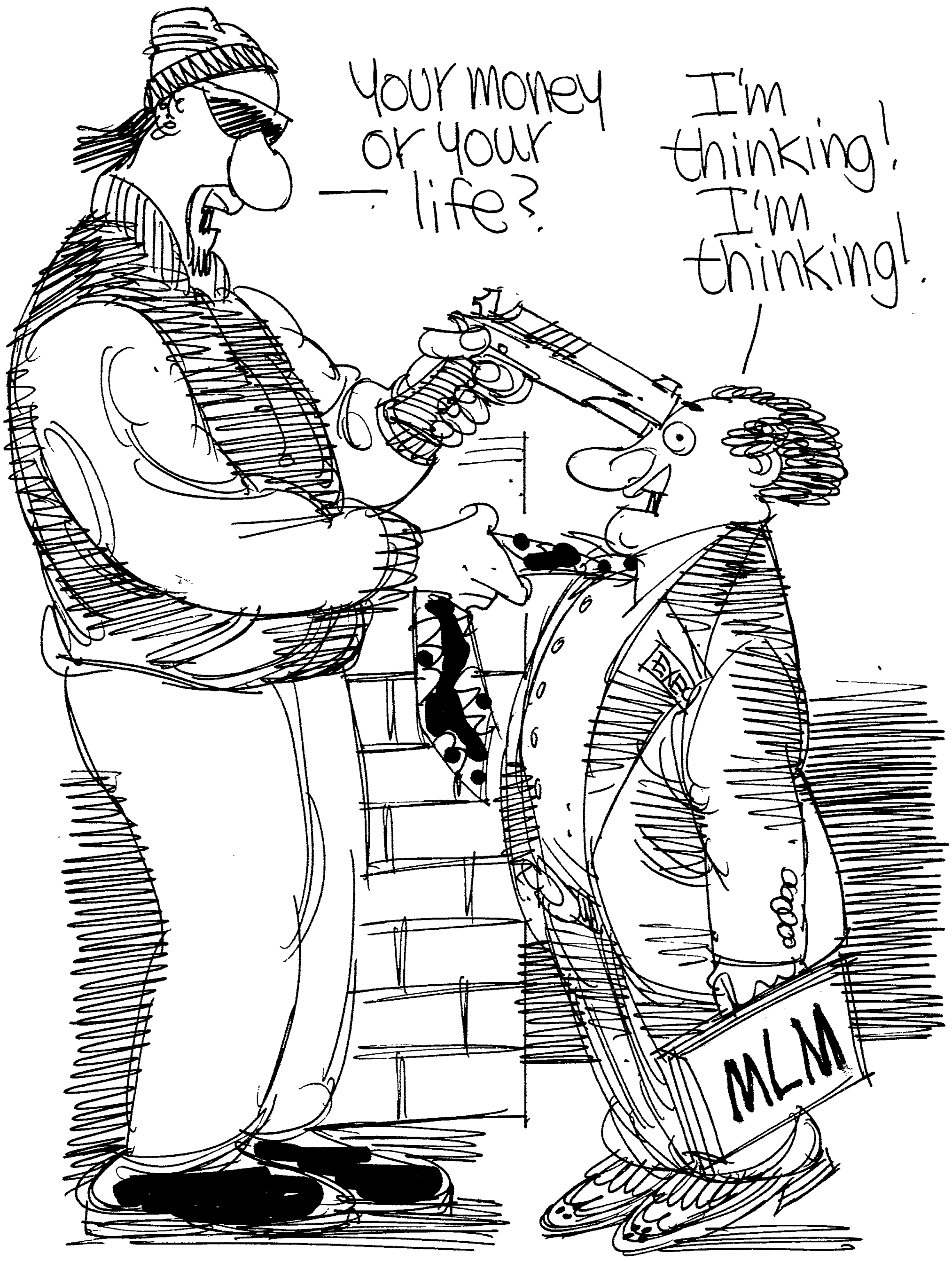

Robber: “This is a Stick-up. Your money or your life.”

(Pause)

Robber: “Look, bud. I said your money or your life!”

Jack Benny: “I’m thinking it over.”

ACKNOWLEDGEMENTS

To my parents,

For the love and support they've given me throughout these years. Thank you for giving me a chance to prove and improve myself through all my walks of life.

To my brother,

With you by my side there will always be a smile on my face and mischief to be done. I love you.

To my supervisor and professor Andrea Renda,

For the interest and patience shown in me and my work. A busy man I admit, but nevertheless a great coordinator and supervisor.

To my friends,

For all the laughs enjoyed and the tears shed together. May there be many more of both.

To my work colleagues,

For the many achievements and the few disappointments. The road to success is long, but together I know we will make it anywhere.

I THANK YOU ALL

Table of Contents

Preface

The calculation of the value of a human life is surely a controversial topic. When I first heard this phrase: the value of a statistical life, said out-loud during a long and interesting lesson in Antitrust and Regulation my curiosity was immediately aroused. At first I was a little shocked to realize that there were researchers who actually attempted to place a price tag on lives, this shock soon turned into active interest on the subject as the professor went on to explain the necessity of having value of statistical life estimates to be applied in cost-benefit analyses. This term, cost-benefit analysis, was one I did understand well, after all I had been studying economics and business for three years; benefits and costs are an economist's bread and water. The professor's lecture however soon ended, leaving me with an active wanting to understand further, and delve deeper, into this topic. Thus I decided to write my bachelor thesis on the value of statistical life, with the aim to give the reader a deeper sense of what the topic entails, and why it is necessary to have such valuations in a modern world. This thesis thus comprehends both a theoretical and practical part on how value of statistical life literature has evolved, through both its theoretical application and model development and the way in which agencies, and policy makers worldwide, have applied these estimates to cost-benefit analyses. The aim of this research is firstly to understand the causes of the high variations in life estimates studies, thus a meta-analysis section to understand which variables have the greatest effect on value of statistical life estimates under different specifications and, secondly, to find and present possible methods to correct for these variations, trying to achieve convergence of life estimates in future studies. The importance of achieving this convergence and some sort of standard model to be applied in this sector is fundamental for semi-industrialized countries, which are entering phase in their development where such value of statistical life policies must be adopted to curtail the environmental and non-environmental negative aspects of their growth through new reforms and new regulations.

The need for VSL in a modern society

Economics is the science of using scarce resources efficiently. This concept, however crude it may seam, must also be applied when analyzing the cost-benefit tradeoffs of saving a human life. The concept of assigning a monetary value to life may in itself seem paradoxical, and has, without doubt raised many social criticisms since it's earliest applications. This practice, however, is necessary in a modern democratic society where choices must be made on investment policies such as reforms to the health care system, pollution abatement strategies, road safety measures and the likes. As policy makers can never hope to save every single life through their actions, governments and institutions throughout the world must posses the correct tools to evaluate the benefits life saving programs and compare them to the costs of bringing forth the activity and so be able to achieve some sort of 'Order of Priority' to determine the potential social benefits and economic costs that these policies would infer and arrive at a conclusion to which is best to implement. Much of the controversy of assigning a value to human life stems from a misunderstanding of what is meant by the terminology; researchers in this field do not attempt to monetize the value of a single and "*tangible*" human life, rather their VSL models attempt to calculate the benefits of saving an extra *statistical life* through reducing the overall probability of death. An example: nearly all of the worlds population would agree that they would give up all of their wealth to avoid the *certain* loss of their life, or that of close family members, meaning that under this definition there is no upper boundary on the value of life. These same individuals however take everyday risks that could result in death, such as smoking or driving without a seatbelt or not installing smoke detectors, risks that could be avoided by the expense of either time or money. Whenever we take these risks we are implicitly defining a trade-off between wealth and probability of death, and thus, defining our ideologies on the value of our *statistical* life.

Past, Modern and Future uses

The concept of assigning a monetary value to life has been around for some time, early applications were mainly court hearings regarding wrongful deaths. During these hearings the judge had to calculate a compensation benefit for society and for the family of the deceased. Since the early 1960's in the US tort law had to inevitably come up with a method to monetize value of the life of the deceased so plaintiffs who prevail in a wrongful death lawsuit could recover things such as medical and funeral expenses in addition to the amount of economic support they could have received if the decedent had lived and, in some instances, a sum of money to compensate for grief or loss of services or companionship. The size of these compensations then, were inevitably very variable, with many factors such as the financial status of the deceased's family, and that of the accused, the person's earning capacity, their potential contributions to society, or how much they were loved and needed by their friends and family. This is clearly seen in one of the most media-covered trial of the last century where O.J. Simpson, accused of murder was condemned to pay damages to his own children and family for a value of around $35 million US dollars.

Modern applications of assigning a value to life involve the choice of public policies which are ever more dependent on a cost-benefit analysis designed to put various possible options in order of priority, whereas the cost of implementing a certain policy can be easily estimated, the benefits are rather harder to calculate. Benefits of a health reform for example can be measured in the state of health measured by a number of health indicators such as quality of life and certain symptoms or pathologies, but also in the number of deaths avoided through the implementation of the planned reform. In the US, the Environmental Protection Agency and the Department of Transportation have established estimates for the VSL which are used frequently by the government for the evaluation of such life saving policies. These established values however are subject to much criticism and are thought to be incorrect by many scholars. Only in the last century the EPA become a target of two very public controversies; the 2003 Clean Air Act's use of a senior discount for the value of statistical life for people over age 65, and the 2008 downward reassessment of the value of statistical life by the EPA Air Office.

Truth be told the studies which attempt to calculate the value of a statistical life are numerous and the ones which actually provide "acceptable" values few. Being a rather recent need the literature has not yet established a *standard* for the estimation of the value of life, and past studies have revealed a possible range of values. The American system, for example, uses values ranging from as low as $1.5 million to as high as $35 million. As one can easily imagine these huge variations do not help policy makers reach a decision of whether or not to approve a proposed reform, and result in wide differences in the adopted rates not only throughout America but also around the world. These differences result in valuations of "*similar deaths*" to be inconsistent, which, in my opinion, impose a serious barrier to the adoption of these cost-benefit practices in ever more policy decision-making areas, thus limiting the potential future uses of VSL.

In the majority of present day cases the value of a statistical life has been mainly used for diffusely statistically distributed death prevention cases such as traffic accidents or reducing overall possibility of medical negligence. Estimating the cost of a natural disaster or terrorist attack is however a completely different matter. A very recent study by W. Kip Viscusi[1] on valuing risks of deaths from terrorism and natural disasters clearly shows an abyss of literature in the valuation of so called "cluster deaths". In his paper Viscusi arrives at a conclusion that deaths resulting from terrorism should be valued twice as high to those resulting from natural disasters. Moreover that death resulting from different disaster of the same nature should also be valued differently. These conclusions, at least from the writer's point of view, leave ample space for the development of new and better-suited methods of VSL calculation.

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[1] Valuing the risks of death from terrorism and natural disasters. W.Kip Viscusi 2009

Methods and Models for the calculation of VSL

The Human Capital Method

VSL literature began to be established in the late 1970's and early 80's, however during these years policy makers still thought that placing a value to a human life was immoral, so instead, to value possible reforms and regulations they used the human capital method based on forgone earnings after death. This model was the first to be used in America and the EU, and it paved the way for the more modern models still in use today. The Human capital method bases itself on the lost earnings of an individual resulting from his death, firsts texts referring to this approach date back as far as the 19th century (Farr 1878), however, it was not until the late sixties, that it became a standard for the valuation of public policies (Rice 1967 and Weisbrod 1971). Under this model an individual's social value is measured using his potential future productivity, based on the present value of the forgone income. It is important to note that the forgone earnings include only the income produced in the person's working life and, earnings made on investments or capital gains, are not to be included in the calculations due to the fact that they are not tied to the person's continued existence. Some studies[2] have also included in the calculations under the human capital method forgone consumption opportunities of the individual as further alterations to be made to social value. The VSL is thus derived on the present value of the expected working income, i.e. the individual's social worth. Since, as already mentioned, it is the individual's social contribution which is to be put in monetary terms the expected labor income is to be evaluated before income taxes, as is done when evaluating the person's contribution to GNP. This approach, used through the years for it's easiness to apply, has however received a myriad of criticism and has indisputably many drawbacks. For one it does not take into consideration non-market activities such as forgone leisure time, pain and suffering of third parties and aversion to risk which may be in themselves more valuable than the economic loss *per se*. A second

[2] The Valuation of Human Capital, by Burton A. Weisbrod. 1961

problem regards the discount rate to be applied when deriving the net present value of the lost income; this social discount rate is based on what society forgoes when investing in life saving programs[3] and may present some problems in calculation. The third, and hardly the easiest to pass over, is the fact that individuals with no labor income such as pensioners and invalids have a VSL equal to zero when using this approach. The HC method however is recently finding some useful applications in evaluating the VSL in conjoint analyses with other methods of estimation.

The Human capital method came into disuse under the Reagan administration, in a debate over the proposed Occupational Safety and Health Administration (OSHA) hazard communication regulation, which proposed a rather expensive regulation that required introducing hazard-warning labels for dangerous chemicals in the workplace. The US Office of Management and Budget required all major reforms be subject to an extensive cost benefit analysis, and that, under order Executive Order 12291, dating from the Clinton administration, only regulations, which had benefits that far exceeded the costs, could be approved and put into action. OSHA at the time claimed that life was to sacred to value and resorted to the human capital method based on lost earnings and medical expenses for that calculation of the reform's benefits. As turns out, the value deriving from this model was far to low with costs far outweighing the benefits[4] and the proposed regulation was rejected. OSHA's appeal to the then vice-president Bush concluded that the problem was a technical issue on the method of calculation of the VSL. Only after the intervention of W. Kip Viscusi, which, using his VSL estimations, increased the benefits of the regulation by as much as ten times was the policy adopted[5]. Other agencies soon adopted Viscusi's 3 million dollar estimates for the value of life and the HC method fell into disuse.

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[3] The Economic Value of Life: Linking Theory to Practive. S.Lanefeld and Eugene P. Seskin
[4] What is a life worth? How the Reagan administration decides for you. W.Kip Viscusy and Pete Early. 1985
[5] How to Value a Life. W.Kip Viscusy. Vanderbilt University. Working Paper Num. 08-16

The Willingness to Pay Model

In order to arrive at his 3 million dollar value Viscusi applied an altogether different model for VSL calculation. The willingness to pay model, as explained by Mishan in one of the early theoretical discussions on calculating the value of a human life, bases itself on the same criterion used by welfare economics and in other areas of cost-benefits analysis; the Pareto improvement principle. *A Pareto improvement is said to exist when the gain from a social change are able to compensate those who stand to loose from the change and still leave a net benefit*[6]. Thus the model basis itself on what the population is *willing to pay* to reduce the overall probability of death, as Michan explained the issue is not the value of an individual's life, but rather it is the value in the reduction of the probability of death for a given population. This theory has a logical backing in the fact that nearly all regulations and policies have the objective to save lives as many lives as possible in general, rather than a defined set of lives. The question to put to the population therefore is not how much are you willing to pay to avoid a certain loss of life? but rather, how much are you willing to pay ex-ante to buy a small reduction in the probability of your death?

The willingness to pay for this reduced probability can be inferred through *revealed preferences* such as consumer behavior in the market i.e. the amount that is spent on good such as safer cars, airbags, smoke detectors and the likes, where money and time are traded for overall death risk reductions. Although this method is very seldom used a few researchers have attempted to use it to place a value on life. The Blomquinist study (1979) for example calculated the VSL from observing the purchase of seatbelts, although a useful study on the revealed preferences this is rather hard to re-estimate as seatbelt usage is now mandatory in all countries. Another study in this field conducted by Dardis (1980) arrives at estimates through using data on the purchase price of smoke detectors. Despite these attempts not many authors have delved into these types of studies, imposing a serious limit to their

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[6] Mishan E.J: Cost-Benefit analysis. New York: Praeger. 1971.

ability to produce reliable and consistent estimates through repeated studies. Moreover it would appear even less possible to link mortality risk to a purchase of a single consumer item, given that buyers are generally not in the possession of accurate quantitative information on the risk reduction liable to be associated with a consumer product.

On the other hand, the WTP based on contingent valuation models or *stated preferences*, which has received much more attention by authors, is widely used by policy makers. The stated preferences approach differs to its counterpart due to the fact that individuals are asked directly to reveal their willingness to pay. Faced with a hypothetical situation the individual is asked to provide answers to questions such as: how much would you be willing to pay to eliminate a one time risk of death of 1/10,000? By multiplying the average amount each person is willing to pay by the chances of death one can obtain the VSL[7]. Based on the nature of the WTP model, in theory, it comprehends in it's questions everything that contributes to an individual's wish to avoid death, such as: non labor income, value of leisure, aversion to risk and the value of avoiding pain and suffering of friends and family members, as well as incorporating an implicit rate of time preference reflecting the weights given to future benefits of living.

The WTP model can thus be brought forward in two general ways, either through the analysis of direct survey questions, as mentioned above, or through the statistical estimation of individuals revealed preferences and consumption patterns.

The main advantage of the *stated preferences* approach to calculating VSL is that it leaves in the hand of the analyst much room to maneuver, as it is he who decides what information to give to the respondents, what risk reductions to suggest and may even specify the method of payment. Another advantage derives from the possibility to have a representative sample. The main disadvantages on the other hand derive from the hypothetical nature of

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[7] How to Value a Life, W. Kip Viscusi, Vanderbilt University, 2008.

the experiment, where the respondents are required to state their intention to pay, which may be significantly different to the actual amount they would pay in case of a real life situation. The possibility of strategic behavior is also not to underestimate; individuals can easily manipulate the results by changing the amount that they are "*willing to pay*" based on the circumstances. Sociology also gives a good hindsight to the possibility of obtaining biased values of statistical lives. Sociologists believe that individuals are unable to answer rationally and consistently to questions of a hypothetical nature. An example: an increase of 0.00002 in workers' risk of death would represent an increase in the overall work fatality rates of approximately 25 per cent, nevertheless a researcher could expect very different results depending on which of these two questions are actually asked. In synthesis the *stated preference* models suffers from a number of biases, Willinger (1996) identified the five most significant ones:

1. The researcher bias is present in any survey, regardless the discipline in question. It is explained by the fact that during a face-to-face interview, some answers may be given in order to please the researcher
2. Instrumental bias resulting from the means of payment may cause the respondent to cling to the first proposed value, this can be avoided however through the referendum method.
3. Strategic bias (free rider problem) is due to the fact that's some respondents may have predicted how their answers will be used, causing them not to reveal their true preferences.
4. Hypothetical bias is based on the fact that respondents are not brought face to face with a real market. This bias can be reduced if special care is taken to make the scenario credible in the scenario design phase.
5. Inclusion bias however is the most significant. In certain studies (Hammitt and Graham et al. 1999, Krupnic et al. 2000) it is shown that WTP estimates remain practically unchanged regardless of the

mortality risk variations. I.e.: Respondents are insensitive to changes in mortality risk variations[8].

Willinger concludes that, given a properly formulated study, many of these biases can be eliminated. The most significant one, which is intrinsic to the valuation model and so harder to avoid is the inclusion bias, and nearly always consequences in some bias in the results.

Hedonic Wage-Risk Model

There is another model however, that has also received much attention by researchers, based on the Hedonic Wage-Risk relationship. The concept that salaries are somehow related to on-the-job risk was introduced more than 200 years ago by Adam smith (1776), who found that: *theory suggest that jobs with greater risk in terms of the probability of fatal and non-fatal accidents should, other things being equal, receive higher wage compensation than less dangerous jobs*. The first to provide a general discussion on this method for VSL calculation was Rosen (1974), who then went on to test his theoretical framework through empirical studies with the help of Thaler (Rosen and Thaler 1976). Undoubtedly one can argue that many variables of jobs affect the wage received by an individual, or as A. Smith put it: *Wages of labor may vary with ease or hardship, cleanliness or dirtiness, and the honorableness of the employment*.

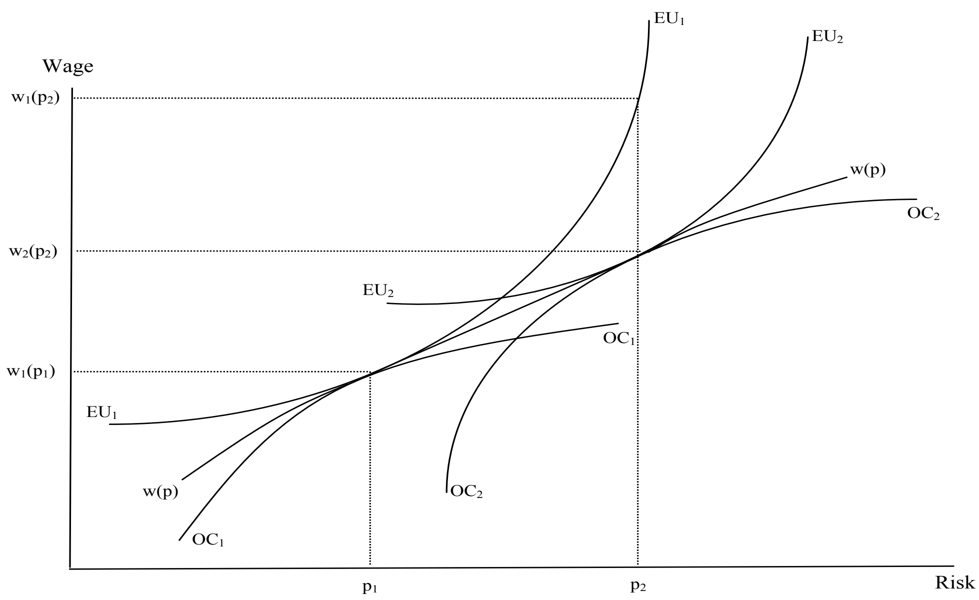
Economist through time have developed a statistical model which controls for these differences, as well as controlling differences in worker productivity and different quality components of the job. Most studies of this type are based on wage differentials that assess the premium associated with greater mortality risk incurred by a certain job type. This risk premium is found by regressing the wage over the mortality risk incurred by the job in question, and so makes it possible to factor in other elements that affect a workers salary. If this wage-risk premium is found to exist it indicates that

[8] Hammitt J.K. and J.D. Graham (1999), "Willingness to Pay for Health Protection: Inadequate Sensitivity to Probability?", Journal of Risk and Uncertainty, Vol. 18, pp. 33- 62.

arbitrage does occur in labor markets and that is can be used to arrive at a value of statistical life. Below is the theory that governs this model:

The hedonic wage-risk bases itself on the equilibrium market outcomes stemming from the joint influence of labor supply and labor demand forces. Firm's labor demand is dependent on the total cost of employing a worker, with the aggregate demand falling as total cost rise. The cost of employing a worker may include things such as: worker's wage, training, benefits of health insurance, vacation expenses, child care and, most importantly in our case, the cost of providing a safe working environment. As the total costs of employment to a firm increase with the level of safety, for any given level of profits, the firm must pay workers less as the safety level rises. Figure one[9] below offers wage-risk iso-profit curves for two firms, depicting wage as an increasing function of risk: OC_1 for firm 1 and OC_2 for firm two respectively. Obviously workers who try to maximize overall utility prefer the wage-risk combinations from the market offer curve with the highest wage level. The outer envelope of these offer curves is the market opportunities locus w(p).

Figure 1
Market Process for Determining Compensating Differentials



[9] THE VALUE OF A STATISTICAL LIFE: A CRITICAL REVIEW OF MARKET ESTIMATES THROUGHOUT THE WORLD
W. Kip Viscusi Joseph E. Aldy February 2003

A worker's supply of labor is now defined in part as a function of the worker's preferences over wages and risk level. Consider a von Nuemann-Morgensten expected utility model with state dependent utility functions. Let U(w) represent the utility of a healthy worker at wage level w and let V(w) represent the utility of an injured worker. Assuming that the worker's compensation and wage is subsumed into the functional form of V(w), that workers prefer to be healthy rather than injured [U(w) > V(w)], and that the marginal utility of income is positive [U'(w) > 0, V'(w) > 0], we can arrive at the conclusion that workers choose maximizing utility combinations along the market opportunity locus w(p). Thus choosing their level of utility maximizing wage-risk combinations. This can be seen in the graph as worker 1 maximizes utility at the tangency point between EU_1 and OC_1, the same applies to worker two who maximizes utility at point EU_2 and OC_2. All wage risk combinations associated with a given worker constant expected utility locus must satisfy:

$$Z = (1-p)U(w) + pV(w)$$

The wage risk tradeoff along this curve is then given by:

$$Z = -\frac{Z_p}{Z_w} = \frac{U(w) - V(w)}{(1-p)U'(w) + pV'(w)} > 0$$

So that the required wage rate is increasing with the risk level. The wage risk tradeoff then equals the difference in the utility levels in the two states divided by the expected marginal utility of income. In the graph above labor decisions by workers can be seen by the wage-risk combinations at the tangency of the offer curves and expected utility loci at points (p_1,w_1) and (p_2,w_2). Expanding beyond the two worker example above, through observations of a large set of workers, can show the locus of these workers' wage-risk tradeoff, depicted by the curve w(p) in figure 1. Hedonic wage analyses trace out the points along this curve that workers find acceptable, so the observed market decisions (p_1,w_1) reflect the joint influence of labor demand and supply on the market equilibrium. The estimated slope of the tradeoff between wages and risk i.e. $\partial w / \partial p$ corresponds to both the workers marginal willingness to accept risk and the worker's marginal willingness to pay for more safety and less risk, but also includes the firm's marginal cost of more safety as well as the firm's marginal cost reduction from an incremental increase in risk. Thus the (p_1,w_1) and the $\partial w / \partial p$ reflect both the worker's and firm's marginal supply and marginal demand price of risk enabling econometric models to estimate the VSL through multivariate regressions of the type:

$$w = \alpha + H'\beta + X'\beta + \gamma p + \gamma q + \gamma q\, WC + p\, H'\beta + \varepsilon$$

Where w_i is the worker i's wage rate, α is a constant term, H is a vector of personal characteristic variables for worker i, X is a vector of job characteristic variables for worker i, p_i is the fatality risk associated with worker i's job, q_i is the nonfatal injury risk associated with worker i's job, WC_i is the workers' compensation benefits payable for a job injury suffered by worker i, and ε_i is the random error reflecting unmeasured factors influencing worker i's wage rate. The terms α, β1, β2, β3, γ1, γ2, and γ3 represent parameters estimated through regression analysis. The term H in the equation considers all personal characteristics variables such as education, job experience, union status, age and weather a worker has a family. The term X on the other hand specifies job characteristics variables and often includes indicators for blue-collar jobs, white-collar jobs, management positions, the worker's industry, and measures of physical exertion associated with the job.

Although this model for calculating VSL is dynamic and leaves much room for variations it too suffers from some drawbacks, as it based on two assumptions that can easily fail: The first assumption is that all workers are fully aware of their on the job risks and make their decisions based on sure figures, this is sometimes not the case as information asymmetries can lead to a substantial difference between perceived risk and statistical risk, where the resulting risk premium for each unit of risk is does not take into account the true mortality hazard associated with the job. In this case studies must be conducted on the *perceived* risks by workers rather than the *actual* statistical risks associated with a given job. The second assumption is that the labor market is frictionless, i.e. that workers are free to move easily from one job to another, and that each worker can be satisfied with a job meeting his risk expectations. Something that in many countries is not always the possible due to unemployment and market characteristics. If job markets are not frictionless workers may be forced to accept wages that are below their actual comfort risk level and do not result in the worker's optimal choice. This could lead to the appearance of biases and result in an under-estimation of the value of a statistical life. A further problem with this model is that the VSL cannot be calculated for all jobs, or in other words, some white-collar jobs can be considered to be riskless and so the whole concept of wage-risk return collapses, making it impossible to have a representative sample based on the whole population.

Human capital model and The Revealed Willingness to Pay

The models presented above compose the backbone of VSL calculation, they do however present some problems: the willingness to pay through revealed preferences is hard to apply and calculate, while its sibling of stated preferences suffers from important and significant bias. The hedonic wage-risk seams to provide a complete and accurate picture for dangerous jobs, such as blue collar jobs, but leaves substantial gaps in jobs that can be considered to be riskless. Finally the human capital model is a good indicator to the costs to society following a death, but leaves personal factors completely out of the equation. There are however some researchers which have tried to factor out some of these inherit weaknesses of these models by combining them; economists such as Usher[10], Rappaport[11],

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[10] Usher D: An imputation to the measure of economic growth for changes in life expectancy .In: Moss M (ed): Measurement of Economic and Social Performance. New York: Columbia University Press for NBER, 1973;pp193-232.

[11] Rappaport E: Economic analysis of life-and-death decision- making. In: Hirshleifer J, Bergstrom T, Rappaport E (eds): A General Evaluation Approach to Risk Benefit for Large Techno-logical Systems and Its Application to Nuclear Power. Los Angeles: UCLA, Department of Economics and Engineering, 1974.

Conley[12] and Bailey[13] have tied to link the Human capital model to the revealed willingness to pay model by specifying a priori what rational individuals would be willing to pay to avoid the financial losses deriving from small risks to life. These models take into careful consideration the decision making process of an individual in making risk-avoiding choices. In order to successfully link these two models two assumptions must be made about individuals' behavior: first that their objective functions are based solely on the maximization of the expected value of discounted lifetime income, and secondly, that they are risk averse; treating economic losses associated to risks to life symmetrically with risks to financial and other assets. This models can be presented through a simple example: supposing a town of 100,000 inhabitants, which all receive the same income, have similar life expectancies as well as identical aversions to risk and rates of time preference and with each individual trying to maximize the expected discounted value of lifetime income. Initially this population is subject to a risk of death level and lifetime income which results in a probability equal to 1 of a lifetime income with a present value of $400,000. Now suppose that the overall risk levels increase to 10 deaths per population, so they can expect only a probability of 0.9999 of surviving to enjoy their lifetime income of $400,000. As a result of this risk increase the expected value of discounted lifetime income would now drop to $399,960, resulting from multiplying the original $400,000 with the new risk of death, bringing a loss for each individual of $40 in the expected value of lifetime income. Under the assumption of risk averse individuals, each should be willing to pay at least $40 to avoid a 0.0001 risk of a $400,000 loss, bringing the total WTP for these inhabitants to $4 million ($40 x 100,000 residents). This result is exactly equal to the present value of the forgone discounted lifetime income of the 10 unfortunate folks, resulting in a value of statistical life of $400,000 per individual.

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[12] Conley BC: The value of human life in the demand for safety. 1976;66:45-55.
[13] BaileyMJ: Safety decisions and insurance. Am EconRev1978; 68:295-298

The table below allows us to have a clear comparison of the human capital approach, the revealed preference willingness to pay and the Adjusted willingness to pay/human capital:

Method	Expression	Comments
(1) Human Capital	$\sum_{t}^{T} \frac{L_t}{(1+i)^t}$	T = remaining lifetime L_t = labor income[a] i = social discount rate; opportunity cost of society investing in life-saving programs
(2) Revealed-Preference Willingness to Pay	$\left[\sum_{t}^{T} \frac{B_t}{(1+\rho)^t}\right]\alpha$	T = remaining lifetime B_t = benefits of living = $L_t + NL_t + NM_t + P_t$ where L_t = labor income[a] NL_t = non-labor income NM_t = nonmarket activities and leisure P_t = premium for pain and suffering ρ = individual rate of time preference α = risk-aversion factor
(3) Adjusted Willingness-to-Pay/Human Capital	$\left[\sum_{t}^{T} \frac{Y_t}{(1+r)^t}\right]\alpha$	T = remaining lifetime Y_t = after-tax income = $L_t + NL_t$ where L_t = labor income[a] NL_t = non-linear income r = individual's opportunity cost of investing in risk-reducing activities α = risk-aversion factor

[14]

As can be seen in the table the expressions to not vary much, and all depend on a stream of "benefits" through time, these benefits can either be labor or non-labor income and are all discounted at a discount rate resulting from the opportunity cost involved in each model. In the first model (1) the discount rate applied represents the social opportunity cost that society must face when investing in life-saving programs instead of some next-best alternative. The use of this discount rate may make sense in theory, but applying it in practice presents some problems, as it is difficult to determine the actual investments that society will forgo and therefore the relevant rate of discount to be applied. The discount rate (ρ) in model two (2) is implicit to the individual's determination of the present value of the future benefits and not based on social opportunity cost, but rather on the individual's time preference. Finally equation three (3) in the table presents the WTP/HC model, which embeds characteristics of both the willingness to pay in equation two and the human capital model in equation one. From the human capital approach it includes only economic losses associated with death. i.e.

[14] The Economic Value of Life: Linking Theory to Practice J.Steven Landefeld and Eugene P.Seskin.

the lower bound estimates for VSL, while as from the willingness to pay through revealed preferences, the WTP/HC model is also based on the small changes in risk of death from the perspective of the individual rather than from that of society. We can see from the equation that the future benefits are specified as the summation over time of an individual's after-tax income (Y_t), where (Y_t) includes labor income (L_t) and non labor income (NL_t), but does not include measures of nonmarket activities or leisure. The discount rate in this case is the individual's, rather than the society's, opportunity cost of investing in risk-reducing activities using the household's assets. The use of this discount rate is adopted because the Pareto improvement principle which "implies an unambiguous and straightforward resolution to the discounting equation", or, namely: the use of the individual's private rate of time preference, as noted by Jones Lee[15]. Furthermore a risk aversion factor is applied (α), as can be noted also in equation two (2), to include the fact that, as hypothesized in the assumptions, individuals are risk averse with regard to loss of life just as they are to the potential loss of other financial or economic assets.

The WTP/HC model factors out some weaknesses that can be found in the stand-alone WTP and HC models. Firstly the WTP/HC, through its links with the revealed willingness to pay model, provides the welfare basis that is missing in the stand-alone human capital model. Secondly the choice of the appropriate discount rate is made easier as the adjusted willingness to pay/ human capital adopts the discount rate chosen by the individual, which is easier to calculate that the more uncertain social rate of return. Lastly while the WTP/HC model does not include all the intangible factors that are included in the willingness to pay models, such as the value of pain and suffering, it provides policy makers a consistent estimation procedure for placing a value on the statistical life.

Below we can see the difference in values resulting from the willingness to pay/ human capital model compared to the general human

[15] Jones-Lee MW: The Value of Life: An Economic Analysis. Chicago: University of Chicago Press, 1976.

capital model. It is important to note that the study was conducted by J.Steven Landefeld and Eugene P.Seskin[16] in 1982, using data from 1977 and so expressed in 1977 dollars. The study was conducted on the present value of both expected lifetime after-tax income and housekeeping services and applied to different age groups subdivided by sex.

Age Group (years)	Adjusted Willingness-to-Pay/ Human Capital[a]		Standard Human Capital[b]	
	Male	Female	Male	Female
0 to 1	668,461	457,139	31,918	28,625
1 to 4	704,303	481,290	39,657	35,539
5 to 9	770,438	526,147	58,367	52,273
10 to 14	850,562	580,490	89,604	80,196
15 to 19	928,875	623,496	130,874	112,390
20 to 24	976,304	626,792	170,707	133,238
25 to 29	966,434	586,710	196,612	136,664
30 to 34	880,836	526,912	205,062	130,044
35 to 39	790,452	465,115	197,881	121,547
40 to 44	660,193	414,562	180,352	111,647
45 to 49	522,064	332,221	156,297	99,796
50 to 54	380,389	266,482	124,989	86,286
55 to 59	240,382	201,726	86,246	70,417
60 to 64	119,328	143,086	45,169	53,426
65 to 69	50,127	99,056	18,825	39,213
70 to 74	25,294	69,306	9,781	29,189
75 to 79	12,816	48,202	5,108	21,728
80 to 84	6,787	33,936	2,820	16,787
85+	2,039	9,966	943	5,705

We can see that the use of the WTP/HC model gives estimates for VSL that are considerably larger that the stand-alone HC model, especially for the younger age groups.

[16] Jones-Lee MW: The Value of Life: An Economic Analysis. Chicago: University of Chicago Press, 1976.

A Meta-Analysis Study on Variables affecting VSL

A rather more recent addition to the literature covering the value of a statistical life is applying econometric tools such as multivariate regressions to conduct meta-analyses on past studies and statistical data. These methods not only allow to find the sources of variance in past studies conducted but also allow for the testing of individual variables and their effect on the VSL. The first study of this type was conducted in 1997 by Liu et al.[17] who ran their regressions on 17 VSL estimates for which the average income and average probabilities of death were available. These observations where selected from the study conducted by Viscusi in 1993, for which the majority contains American data. In this meta-analysis the natural logarithm of VSL is used as the depended variable regressed, through the ordinary least squares method (OLS), with the only explanatory variables being income and risk. Strangely they obtain a positive but non-significant coefficient for the income variable, this as we will see in future meta-analysis results, is the only time a study found a non-significant income variable. The risk explanatory variable however is negative and statistically significant. Finally the income-elasticity is positive with a value of 0.53 but it is not statistically significant.

Miller (2000)[18] conducted the next study in our timeline. It contains an analysis of a sample composed of 68 studies conducted in 13 different countries. Unlike the previous analysis conducted by Liu et al. Miller includes studies conducted on the consumer market and the contingent evaluation method to measure the willingness to pay. Another major difference compared to the study mentioned above is the fact that Miller instead of including as explanatory variables of personal income, uses the gross domestic product and the gross national product per capita as his right-hand-side equation variables. Both of these variables substituting for income are

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[17] Liu, J.T., Hammitt, J.K., Liu, J.L., 1997. Estimated hedonic wage function and value of a statistical life in a developing country. Economics Letters 57 (3),
353–358.

[18] Miller, T.R., 2000. Variations between countries in values of statistical life. Journal of Transport Economics and Policy 34 (2), 169–188.

positive and statistically significant in all specifications. The income elasticity in all specifications is positive and remains quite stable, oscillating between 0.85 and 1.00. It is important to note however that these regressions do not include an explanatory risk variable.

Bowland and Beghin (2001)[19] base their meta-analysis on the studies conducted by two authors: Viscusi (1993) and Devousges et al. (1995). These two studies contain data coming only from industrialized countries, and consider both the wage-risk method and the contingent evaluations method. Since it was Bowland's and Beghin's goal to use these studies to arrive at a VSL in Chili they link each study to the demographic characteristics of the county where it was conducted. In difference to the analysis conducted above the authors in this case run their regressions of the Huber-type method of robust regressions. These types of regressions developed in 1963 allow the researcher to apply weighted coefficients to each variable based on its importance or its credibility. In their study Bowland and Beghin obtain an income-elasticity in the ranges of 1.7 and 2.3 for several specifications, with the parameters to estimate the probability of death statistically significant. Critics of these regressions argued that the results could be biased due to the weight assignments in the Huber-type regressions, however they have been proved wrong as the repetition of the same regressions using the ordinary least squares method have provided very similar results.

A year later Mrozek and Taylor (2002)[20] sample data coming from 33 studies conducted in America and other countries. Using the hedonic-wage method a total of 203 observations are used, although large samples are generally welcome in econometrics this may result in losing independence between variables, which results in the outcomes suffering from heteroskedasticity. To avoid running into such problems or giving more weight to studies with large numbers of specifications the authors assigned a

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[19] Bowland, B.J., Beghin, J.C., 2001. Robust estimates of value of a statistical life for developing economies. Journal of Policy Modeling 23, 385–396.
[20] Mrozek, J.R., Taylor, L.O., 2002. What determines the value of a statistical life? A meta-analysis. Journal of Policy Analysis and Management 21 (2), 253–270.

weight of 1/N to each observations, where N is the number of values of a statistical life drawn in question. Consequently the estimations are regressed by weighted least squares and not by OLS. All the models presented show a significant and positive relation between risk and value of a statistical life. Their complete and reduced model, which excludes three explanatory variables, finds significant income elasticity of 0.49 and 0.46 respectively.

Viscusi and Aldy (2003)[21] continue this stream of literature on meta-analysis with a study involving data from 50 studies deriving from 10 countries. As in the study mentioned above they include only methods based on the wage-risk relationship. Conducting their study both by ordinary least squares and the Hubert robust regressions they find parameters regarding the risk variable to be all negative and statistically significant for all specifications. Income elasticity is also statistically significant for all model specifications ranging from 0.49 and 0.60 for OLS and 0.46 and 0.48 using Hubert-robust regressions.

De Blaeij et al. (2003)[22] conduct an important meta-analysis based on a sample of 30 studies with about 95 values. This study comes to some very important conclusions, as it was their aim to compare the effects produced by revealed preference versus stated preference models. The authors first from several groups with common characteristics and then compare them, finding large variations between groups and within these groups as well. To strengthen the results of their findings the authors proceed to run meta-multivariate analyses, obtaining a significant and positive income elasticity of 1.67 with income expressed in the form of GDP per capita. The authors attribute this high income elasticity to the presence of multicolinearity with the time trend variable that measures time. By removing this variable income elasticity drops to 0.50. The results of this meta-analysis lead to the

[21] Viscusi, W.K., Aldy, J.E., 2003. The value of a statistical life: a critical review of market estimates throughout the world. Journal of Risk and Uncertainty 27, 5–76.
[22] De Blaeij, A., Florax, R.J.G.M., Rietveld, P., Verhoef, E., 2003. The value of statistical life in road safety: a meta-analysis. Accident Analysis and Prevention 35,973–986.

conclusion that the revealed preference approach produces significantly lower VSLs than the contingent evaluation approach.

The table below provides a summary of the results obtained by these studies:

Summary and results of meta-analyses.

	Risk		Income		Income elasticity
	Sign	Signif.	Sign	Signif.	
Liu et al. (1997)	–	YES	+	NO	0.53
Miller (2000)	n.a.	n.a.	+	YES	0.85–1.00
Bowland and Beghin (2001)	+	YES	+	YES	1.7–2.3
Mrozek and Taylor (2002)	+	YES	+	YES	0.46–0.49
Viscusi and Aldy (2003)	–	YES	+	YES	0.46–0.60
De Blaeij et al. (2003)	+	YES	+	YES	0.5

[23]

The results conducted in the meta-analyses above confirm the expected positive relation between income and the value of a statistical life. It can be also seen that except for the study conducted by Bowland and Beghin (2001) the income elasticity obtained is always lower than 1. Furthermore as predicted by theory no stable relationship is found between average risk and value of statistical life, with some studies finding positive and statistically significant relationships and others negative and statistically significant relationships.

The meta-analyses conducted in the past years and discussed above have no doubt given some very useful insights to the relationships between the estimated VSL values, the probability of death and income. So where does this leave us? In a very recent paper Francois Bellavance, Georges Dionne and Martin Lebeau (2008) have put together a group of 37 studies, which are thought to be, by the authors mentioned above, some of the most reliable and with the most complete data sets on the estimation of VSL. Investigation into these studies provides very important and reliable conclusions to how, and in

[23] The value of a statistical life: A meta-analysis with a mixed effects regression model. Francois Bellavance, Georges Dionne, Martin Lebeau. 2008

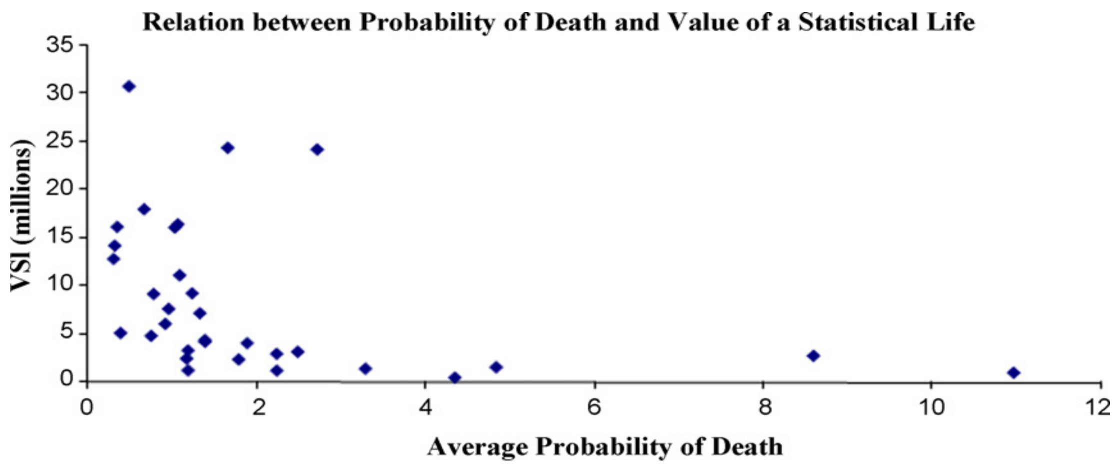
which measures, do variables affect VSL. Below is a table with the descriptive statistics[24] of the sample taken into consideration:

Descriptive statistics of the sample ($n = 32$).

Variables	Average
Average income (US$ 2000)	29,559
Average probability (10,000×)	2.05
White-workers only sample	13%
Men only sample	47%
Unionized only sample	13%
Sample without white collars	41%
Injuries taken into account	56%
Compensation taken into account	16%
Endogenous risk	13%
Observed risk	94%
SOA	9%

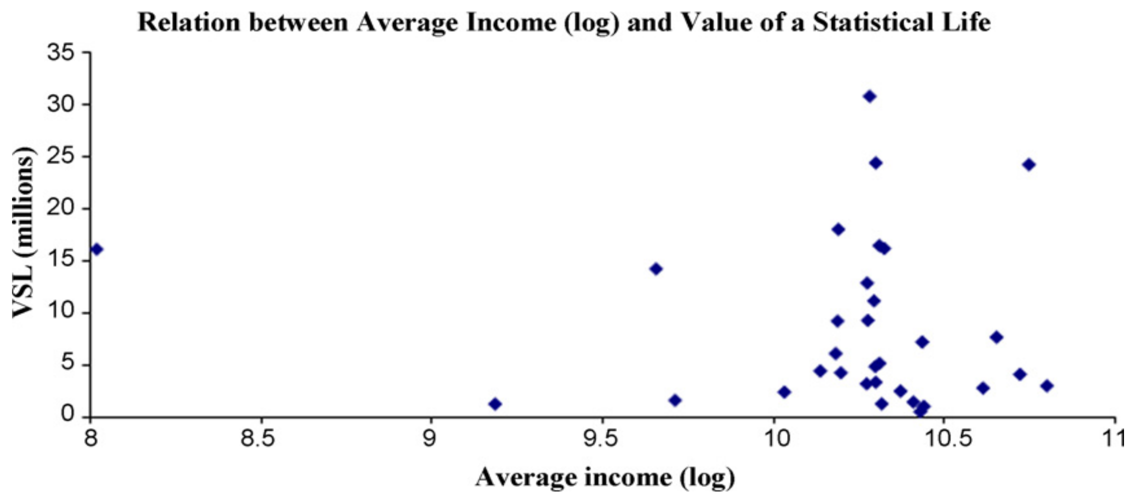
Standard deviation of income = 9576; standard deviation of probability = 2.32.

In the scatter plot below we can see the relation between probability of death and the value of a statistical life. Theory does not predict this relationship to be either positive or negative, a fact that is confirmed by analyzing the figure.



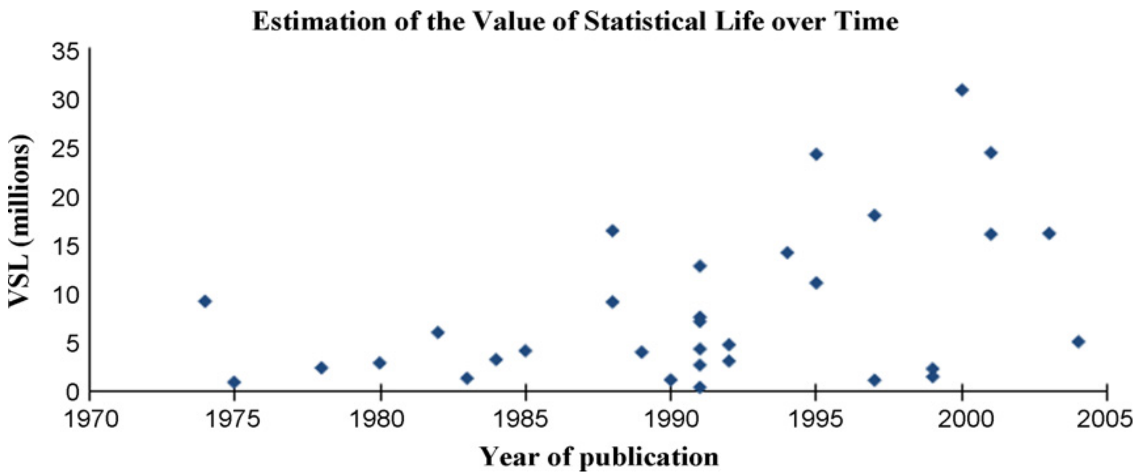
The relationship between the average income and the value of a statistical life however, as already confirmed by 5 out of the 6 studies mentioned above should result positive and statistically significant. This is clearly not the case as can be seen from the scatter below.

[24] Refer to appendix, Table 1, for complete information.



The strange conclusions that this graph leads us to make must however be investigated further by looking at the regression estimates which I will provide later on in the course of this document.

One might also expect, after 30 years of literature, stemming from numerous publications and researches, some form of convergence in the estimated values of a statistical life. Examining the figure below however one can easily realize this is not the case.



Especially the most recent studies, from 1995 onwards, show a rather worrying diverging trend, with a range of VSL values, only the quinquennial period from 2000 till 2005, from as low as 5 million to as high as 35 million. It is also interesting that there seams to exist a positive relation between the value of a statistical life estimates and the year of publication. This relation can be explained by a number of hypotheses:

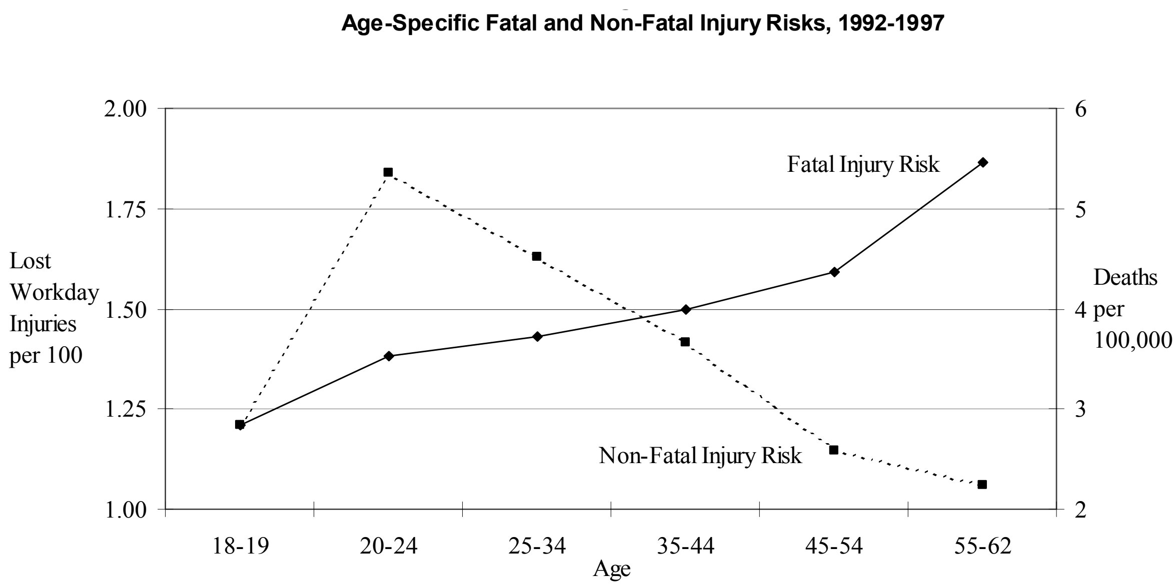
1. Using the probability as an endogenous variable usually produces higher VSL values, and this technique has only been applied after 1988.
2. Workers, due to the higher rate of information transfer of the last historical period are more informed of the inherit risks of their jobs, and are thus demanding higher compensation.
3. Workers, due to higher life expectations and higher age requirements for retirement, are assigning a higher value to their life.

The above graphs may raise more questions than the ones they were originally trying to answer, however some of these results can be explained by careful examination of the complete regression results[25] in the study conducted by Francois Bellavance, Georges Dionne and Martin Lebeau. The regression estimates do in fact find a positive relation between the logarithm of the samples' average income and the value of a statistical life, thus confirming the theory that higher income individuals have a higher willingness to pay to avoid an increase in the risk of death. The study finds that the income elasticity of the value of statistical life is in the range of 0.84 and 1.08, confirming the conclusion reached also in previous studies, e.g. see income elasticity of Miller (2000) who arrives at very similar results. Regression estimates also confirm the theory of hypothesis number one of the graph relating VSL and the year of publication. Indeed, studies, that use the risk of death as an endogenous variable, are found to arrive at significantly higher values for VSL than those who exclude this variable from the regression. These differences are in the range of $3.5 million to $5 million higher, depending on the specification of the model. The ambiguous relation between risk of death and VSL estimates observed in the graph, through regression results, appears to be negative. The economic interpretation behind this result may stem from the fact that individuals who are already

[25] Refer to appendix, table 2, for complete regression estimates.

exposed to high levels of death risk are less reluctant to further increase their risk compared to those exposed to lower probabilities of on the job fatality. There are a further two conclusions which in my opinion are worth mentioning, the first is that regression results find a lower VSL values for black workers, and these results confirm also the results found by Viscusi (2003). It must be pointed out however that this does not mean that a black person's life is worth less than that of a white person's, these results simply indicate that the willingness to pay of white workers is higher than that of black, whether this is due to racial discriminations on the job market cannot be concluded. Another interesting result tested by Francois Bellavance, Georges Dionne and Martin Lebeau is whether belonging to a worker union has an effect on the VSL, the authors seem to find negative coefficients for the union dummy variable, however only 2 out of the 3 specifications are statistically significant, and then only at the 10% significance level. This does not provide a high enough comfort level to conclude without doubts the relation between unions and VSL, however this relation was also found by other studies such as Marin and Psacharopoulos (1982), Meng (1989) as well as Sandy and Elliott (1996), pointing to a negative relation between unionization and the VSL.

Another variable, which affects the value of a statistical life, is age. Indeed in 2003 the EPA, through its Clear Skies Initiative, decided to adopt a senior discount factor for people older that 65 years old, lowering their VSL by 37% with respect to age group 18-64. The application of this senior discount however raised so much controversy throughout the American public that led the EPA to abolish this practice for benefit assessments. On a theoretical level however there are the means to legitimate an adjustment of the VSL with regards to age. Jones-Lee (1976 and 1989) and Shepard and Zeckhauster (1984) found that in markets with perfect annuity and insurance markets the value of a statistical life declines steadily with age, much like expected consumption patters under these conditions. Other models, Shepard and Zeckhauster (1984) and Johansson (1996), with imperfect insurance markets and annuity markets find that the VSL-age relationship takes the form of an inverted U shape. A recent study by Viscusi and Aldy (2006)[26] provides very useful insights to how this relationship is derived and which factors affect its shape and magnitude. By constructing a risk measure conditional on age and the worker's industry and using data from the U.S. Bureau of Labor Statistics the authors arrive at the conclusion that mortality risks are not constant across a worker's life cycle, indeed after an initial peek at age group 20-24 they find that the risk of non-fatal injuries declines steadily throughout the age groups. They also find however that the probability of fatal risks rises steadily for the same age group, reaching a peek for the oldest workers i.e. age group 55-62, meaning that older workers are much less prone to injury, but, if injured, are more likely to die.



This relationship can be observed for all age groups and throughout all industries[27]. These results undermine other proposed theories that older workers have the tendency to sort themselves into riskier jobs. Since older workers are in positions that are more dangerous than the average job, due to their greater personal vulnerability, rather than the inherent riskiness of the job. This results in VSL estimates based on a linear representation of occupational mortality risk to over-estimate older workers' VSL. Viscusi and

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[26] Labor Market Estimates of the Senior Discount for the Value of Statistical Life. W. Kip Viscusi and Joseph E. Aldy. 2006.
[27] Refer to appendix, table 3 and figure 4, for complete results.

Aldy proceed to test these results empirically through a regression study of the sort:

$$\ln(w_i) = \alpha + \sum_{j=1} \delta_j age_j + \sum_{j=1} age_j H_i' \beta + \sum_{j=1} \gamma_{1j} age_j p_i + \sum_{j=1} \gamma_{2j} age_j q_i + \sum_{j=1} \gamma_{3j} age_j q_i WC_i + \varepsilon_i$$

Where: w_i is worker i's hourly after-tax wage rate, H is a vector of personal characteristic variables for worker i, age_j are the indicator variables for the five age groups: 18-24, 25-34, 35-44, 45-54, and 55-62, p_i is the fatality risk associated with age-industry cell for worker i's job, q_i is the nonfatal injury risk for the age-industry cell for worker i's job, WC_i is the workers' compensation replacement rate payable for a job injury suffered by worker i, and ε_i is the random error reflecting unmeasured factors influencing worker i's wage rate.

Throught these regressions they find that: older workers have lower estimated value of statistical lives that the entire working population, and that this decline is not proportional to the remaining life expectancy. Thus confirming the inverted U shape relationship between age and VSL. The value of statistical life for workers in age group 55-62 is \$3.5 million, the peak VSL is reached for age group 35-44, with a value of \$9.0 million and the youngest age group has an estimated VSL of \$6.4 million.

This concludes the section regarding the models applied to calculate the value of a statistical life as well as which factors infulence it the most. Through the thorough study of the last 30 years worth of literature I have given myself, and hopefully the reader, a complete picture of what VSL encompasses, it's uses and benefits, along with its problems and drawbacks. This last point, problems and drawbacks, leads directly to the topics wich will be dicussed in the next section of this document. Unfortunately, when dealing with the reality of VSL calculation we have seen that it does present serious dilemmas. Agencies and policy makers are still sometimes at loss when choosing the correct figure for the value of a statistical life to be adopted in policy assesments, and, as we will see in this next section, the implemented values differ greatly. In the next pages of this thesis I will firstly provide an overview of how American agencies have applied VSL in the past. Next I will be discussing world wide VSL variations, both in developed and semi-developed countries. I finally conclude to how, in my point of view, these problems can be avoided in third world and developing countries, which are just recently starting to adopt VSL estimates for benefit calculations in impact assesments.

Governing Agencies and VSL applications in the US

The need to calculate the value of statistical human life stems from the need of policy makers to apply cost-benefit analysis when drafting possible reforms or regulations to present to congress. This requirement to quantify the monetary costs and benefits of a proposed regulation became mandatory for any major regulation in the early 90's, when under the presidency of Ronald Reagan the executive order 12866 was passed, requiring agencies to submit a Regulatory Impact Analysis (RIA) to the Office of Management Budget (OMB)[28] for review. This executive order, that went to replace the 1981 order[29] which originally empowered the OMB to review regulations of cost-benefit grounds, is still in place nowadays; Agencies that wish to propose any reform which will have an annual effect on the economy of $100 million or higher, or that may otherwise result in any adverse effect to the economy, productivity, competition, jobs, the environment, public health or safety must conduct extensive cost benefit analyses before presenting the regulation to the OMB. Thus it became mandatory for agencies such as the Environmental Protection Agency (EPA), the National Highway Traffic Safety Administration (NHTSA), the Occupational Health Administration (OSHA), the Consumer Product Safety Commission (CPSC) and the Nuclear Regulatory Safety Commission (NRC) to monetize the benefits and costs of it's proposed regulations, mainly through the application of values of statistical life when regarding the calculation of the benefits. Assigning a correct value of a statistical life therefore became fundamental to these agencies and for the welfare of the American public, as the acceptance by the OMB and in congress of any major reform would indisputably depend on these values. The Environmental Protection Agency soon established itself in the forefront of VSL calculation, application and the fire of both VSL critics and media. Truth be told the EPA does not have a happy background, since the year 2000, with the guidelines for preparing economic analyses in which the EPA assigned a

[28] See Executive Order No. 12,866, 3 C.F.R. 638 (1993)
[29] See Executive Order No. 12,291, 3 C.F.R. 127 (1981)

VSL of $6.3 million (in 2000 dollars) the agency has become one of the most criticized regulatory makers of the decade. The EPA's $6.3 million estimate was derived on the basis of the mean values of 26 studies that it identified and selected during the review of the Clean Air Act of XX. Five of these 26 studies where conducted in a contingent valuation method, the rest were based on the hedonic wage risk model for VSL calculation. This $6.3 million dollar estimate was spasmodically used to calculate the value of a statistical life year or VSLY: Obtained by dividing the VSL by the life expectancy of an average subject in the wage-risk study. The agency sometimes adopted this method of assigning value to gained life years rather than a standard value of life estimate as, many times, especially in pollution or environmental reforms in general, it is easier to estimate the average life years gained by the regulation rather than the number of lives saved. In addition it has been shown by numerous studies that most of their environmental reforms affect mainly the elderly population i.e. over 65, as it is this age group that tends to have a higher probability of illness and death from as an example, high levels of pollution. This leads into some basic problems to using the life years approach to measure the value of risk reductions. The first is that the $6.3 million VSL estimate derived above was calculated from labor wage-risk studies, in which respondents have a mean age of 40 years. Thus applying this VSL estimate to the elderly population, with a mean life expectancy of only 10 to 15 years, implies that the VSLY estimates do not fully take into account of these differences, and so resulting in a value which is not effectively based on the actual WTP of these older individuals. This practice also results in VSL estimates for the older population to be lower than the ones that would be obtained by conducting studies based only on that specific age group. Given these factors, and also on the realization that, at the time, there weren't any reliable studies that could empirically support such steep age-dependent reductions, the EPA in its guidelines chose to use the VSL as the primary mean to value mortality risks for future studies.

Next the agency applied a rather fast and disconcerting backtrack to these declarations when, based on a study published by Jones-Lee, it decided to adopt a constant discount factor for the over 65 population. The study of Jones-Lee (1989) found that age-adjusted mean value of life for the over 70 age group was calculated to be approximately 37% less than the unadjusted mean VSL estimate. Consistent with this finding the EPA adopted this discounting factor, applying it, however, not as Jones-Lee had found, i.e. directly on the VSL estimate, but rather the agency decided to incorporate it directly on the VSLY. Bah…! This somewhat unusual application resulted in a political backlash, with what became known as the "senior death discount" receiving media attention and criticism from various publicized articles[30]. This media fire, coupled with US based studies that found no statistically significant age-VSL relationship, led the EPA in 2003 to abandon this senior discount policy and return to standard VSLY applications. The concept of applying a age discount however, as we have seen in the previous section on the variables that affect the value of statistical life is actually viable in theory. This procedure was not abandoned due to a conceptually wrong methodological flaw; rather the political backlash and the lack of US based empirical evidence led the EPA to abandon this policy. The Environmental Protection Agency then turned to the refined life years approach. This theory, put forward by John D. Graham in his 2003 memorandum to the president's management council, firstly advised the discontinuation of the use of the discount factor on both the life year approach and the standard VSL methods, and then went on to specify that, as also advised by the OMB since 1996, a refined life year approach could be valid to set life estimates for the senior citizens. The refined life years approach specifies that, unlike standard value of a statistical life year methodologies, saving 10 life years is not necessarily ten times more valuable than saving 1 life year. Thus senior citizens should be awarded a higher WTP and so have larger VSLY estimates than the younger population. The EPA had adopted a similar reasoning in the regulatory analysis of measures to cut exhaust emissions from off-read diesel engines; indeed the EPA's VSLY estimate for the over 65 population was

[30] EPA Drops Age-Based Cost Studies," New York Times, May 8, 2003; "EPA to Stop 'Death Discount' to Value New Regulations," Wall Street Journal, May 8, 2003; and "Under Fire, EPA Drops the 'Senior Death Discount,'" Washington Post, May 13, 2003.

$434,000 per life year saved, while only $172,00 for the under 65 population. The agency had thus dropped the discount factor, which assigned lower VSL and VSLY to seniors, and went on to use the refined VSLY which actually assigned higher VSLY to the over 65 population, only to then cut the VSL estimates across all the population; deciding to drop 21 of the original 26 studies used to derive the $6.3 million dollar VSL estimate. This despite it's past reliance on the wage-risk studies to assign value to human life. The EPA under the Bush administration actually abandoned this method; its future CBAs would be conducted on the mean value of only the 5 studies that used the contingent valuation method for VSL calculation. This change in dataset resulted in a significant drop in the value of statistical life adopted by the EPA, which passed from the original $6.3 million to $3.7 million. The only comment offered by the EPA on this regard was that; "*The smaller $3.7 million value of life estimate derived from the five CV studies is consistent with an alternative interpretation of the wage-risk literature*", based on a meta-analysis of 33 wage-risk studies published in 2002. This brief and inconclusive explanation however suffers from discrepancies which the EPA has so far failed to explain: firstly that the VSL calculation based on the stated preference approach has been shown to be very unreliable[31], in my point of view and that also of other critics[32], this passage to a single model results in more probability of obtaining biased results. Secondly the EPA fails to explain the reason behind this adoption of the single contingency valuation model through proofs that the five studies used for this purpose are reliable, rather they make the observation that the resulting VSL is somewhat inline with the results observable through the study of 33 meta-analyses based on the wage-risk method. This view that the CV method is incompatible is also shared by the federal government, in review of the contingent valuation method a group of experts gathered by the General Counsel of the National Oceanic and

[31] Please refer to the Methods and models for the calculation of VSL section.

[32] Anti-Regulation Under the Guise of Rational Regulation: The Bush Administration's Approaches to Valuing Human Lives in Environmental Cost-Benefit Analyses, Laura J. Lowenstein and Richard L. Revesz.

Atmospheric administration (NOAA) recognized that CV studies are only useful when dealing with situations where relative market transactions do not exist, and thus it is strictly necessary to adopt the *revealed preference* approach to assign value to the good in question[33].

The EPA non-caring about these criticisms continued to use this lower VSL estimates for policy reforms, applying it also to the calculation of the VSLY. However the value of a statistical life year was being applied in an altogether different method to the one discussed in the last paragraphs. The Environmental Protection Agency adopted a life years approach independent of age, this technique assumes that a set number of life years is gained for each premature mortality, thus an individual, irrespective of his age or health status is assigned a fixed amount of gained life expectancy as a result of the reform. The EPA justifies this method by stating that all individuals with pre-existing cardiovascular conditions have been shown to have an average life expectancy of 5 years[34], that a relationship exists between PM exposure and acute myocardial infarction[35] and that some studies have found that PM related deaths may be attributable to fatal heart attacks[36]. The EPA however does not limit this 5-year condition only to individuals that are already suffering from cardiovascular conditions, and proceeds to apply it to all PM exposure related deaths, even to those individuals who were not suffering from heart disease. The EPA does not provide support for these across the board applications and the assumption that all incidences regarding PM premature deaths are associated with 5 years of life. It does however cite some studies which have found relationships between PM and myocardial infarction, between PM and mortality from pneumonia and between PM and all cause mortality. Thus technically the EPA found a five year relation between PM exposure and death, only for individuals already suffering from heart disease, and applied this standard to all possible PM related deaths,

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[33] NOAA panel report.
[34] See, EPA, Non-road Diesel draft RIA.
[35] Annete Peters et al. Increased Particulate air pollution and the triggering of Myocardinal Infarction, 103 CIRCULATION 2810 (2001)
[36] EPA, Clean Skies Act, technical addendum.

justifying this decision based on the fact that some sort of relationship has been shown to exist, but without calculating the possible size and magnitude of this relation. The EPA thus condemns everyone to an average remaining life expectancy of 5 years, irrespective of baseline health and age. It is needless to say that also this practice has received criticism, with results that could easily over or under-estimate the value of these deaths. The EPA itself, through a statement, realizes that this practice is somewhat unorthodox, and that the 5-year umbrella underestimates life values for the under 65 population:

A recent meta-analysis has shown little effect of age on the relative risk from PM exposure, which suggests that the number of deaths in non- elderly populations (and thus the potential for greater loss of life years) may be significant. Indeed, this analysis estimates that 21 percent of non-COPD premature deaths avoided are in populations under 65. Thus, while the assumption of 5 years of life lost may be appropriate for a subset of total avoided premature mortalities, it may over or underestimate the degree of life shortening attributable to PM for the remaining deaths.

The EPA however continues to apply this 5-year constant to all life loss, non-caring of age. This, may, or may not be, empirically justified for PM-cardiovascular related deaths, it is beyond the scope of this thesis to prove it, what is baffling however is the continued use of the constant for all PM exposure related deaths, when even the EPA, through their own estimates, realize a potential 21 percent higher life expectancy in the under 65 population. This practice is still in use today.

Variance in EPA's Values of Statistical Life

As can be inferred from reading this last section on the (in)famous history of the Environmental Protection Agency, one of the most important agencies for reforms that affect social welfare, has throughout the years adopted various, and incompatible methods for assigning value to a human life. This has lead to a great variation in the actual values used for reforms. In this section I will summarize the practical effects that EPA's behavior resulted in. For each method adopted by the EPA the VSL estimates are given both for 40 year old and a 70 year old to highlight the difference in values. It is important to remember that the original VSL resulting from the full set of 26 studies was \$6.3 million, while the estimate derived from only 5 of these 26, based only on the contingent valuation models, is \$3.7 million. In line with the EPA guidelines all values are discounted at 3%, the life expectancy of an individual in the over 65 age group is 10 years and the life expectancy of an individual under 65 is 35 years. The results are presented in the table below:

		Hypothetical 40-Year Old	Hypothetical 70-Year Old
VSL Approach	---	\$6.3 million	\$6.3 million
Basic Life-Years Approach	Undiscounted	\$6.3 million	\$1.80 million
	3% Discount Rate	\$6.3 million	\$2.50 million
Age-Based Adjustment Factor	---	\$6.3 million	\$3.97 million
Hybrid Approach	3% Discount Rate	\$788,000	\$1.24 million
Latest Manifestation of the Life-Years Approach	3% Discount Rate	\$788,000	\$1.99 million

[37]

<u>VSL approach:</u>

As already specified the \$6.3 million value is derived from the mean outcomes of 26 studies, of which five where based on contingent valuation

[37] Anti-Regulation Under the Guise of Rational Regulation: The Bush Administration's Approaches to Valuing Human Lives in Environmental Cost-Benefit Analyses, Laura J. Lowenstein and Richard L. Revesz.

models and the remaining 21 on hedonic wage-risk models. No distinction is made for age.

Basic Life years Approach:

Under this approach the standard VSL estimate of 6.3 million dollars is rescaled based on the mean life expectancy of the population affected by the proposed reform. This is achieved by dividing the VSL value by the average life expectancy. The under 65 population, with life expectancy of 35 years, thus have a VSLY estimate of $180,000. A 40 year old individual, with 35 years of life remaining would therefore be assigned the full $6.3 million estimate. The over 65 population in the other hand, with a mean life expectancy of only 10 years would have a life year value of $1.8 million. Meaning that if a positive discount factor is applied, the VSL estimate would increase in value due to the larger per life year value and the differences in life expectancy. Note that the same does not apply for a 40 year old individual in the under 65 age group.

Age based Adjustment factor:

As already mentioned this involves applying to original VSL an estimated, and empirically derived, discount factor for the over 65 age group. The constant applied was a 0.37 reduction for the senior ages, as shown by Jones-Lee in 1989. Under this specification the under 65 age group is left unaffected, with the full $6.3 million value of life, while the over 65 age group would be subject to an adjustment of 0.67 of the original value, thus giving this group a VSL of $3,970,000.

Hybrid approach:

This specification takes into account both the age based reduction and the refined life years approach. Firstly the 5 study estimate of $3.7 million stemming from the retrospective study of the Clean Air Act is adjusted for senior individuals, and secondly both adjusted and non-adjusted values for refined value of life years are determined. These values can then be further rescaled to be applied in the 5 year remaining life expectancy assumption. This means that for the under 65 age group the 3.7 million dollar value is discounted at the 3% discount rate, and then amortized over the 35 year life expectancy, giving an estimate VSLY of $172,000. This estimate is further rescaled based on the 5 year assumption, again applying a 3% discount rate to calculate the present value of a 5 year avoided loss of life expectancy, resulting in a VSL estimate of approx. $788,000. As regards the over 65 age group the process is similar, firstly the 3.7 million dollar VSL is adjusted for the 0.67 age factor, giving a value of $2.3 million. Using the 3% discount rate and the life expectancy for this age group of 10 years this yields a VSLY of $270,000. The VSL is then calculated by applying the present value of these expected future life years, the only difference being that in this case the refined VSLY assigns an incremental value of approx. $100,000 higher than the under 65 age group for each year. The implied VSL is finally rescaled according to the 5 year assumption, giving a value of $1.24 million. Note that even though under this specification the VSL estimate for the over 65 age group is higher than the one assigned to the younger population both remain significantly lower than the original $6.3 million.

<u>VSLY without age adjustments:</u>

This last element in the table sees the suspension of the practice of assigning a "senior discount" for the over 65 age group. This means that the $3.7 million VSL estimate is applied across the board for all age groups, resulting in even greater discrepancies between the younger and older population compared to the hybrid approach specified above. This difference is further amplified with the decision by the EPA to carry on using the 5 year life expectancy assumption regardless of the age of an individual. The result is that the younger population has the same VSL estimate derived above of $788,000. The older age group however now starts with the full 3.7 million dollar value, giving through the same process specified in the hybrid approach a VSLY of $434,000, by calculating the present value of future life years and the 5 year assumption the over 65 age group is now assigned a VSL of $1.99 million, approximately 38% higher than the $1.24 million derived in the hybrid approach.

The EPA is not the only agency to have applied VSL estimates for policy reforms benefit assessment throughout the years. Other agencies such as the Federal Aviation Administration and the US Department of transportation have also established their own estimates. The graph below presents all the adopted value of life by US Regulatory agencies from 1885 till 2000.

Year	Agency	Regulation	Value of a Statistical Life (millions, 2000 $)
1985	Federal Aviation Administration	Protective Breathing Equipment (50 Federal Register 41452)	$1.0**
1985	Environmental Protection Agency	Regulation of Fuels and Fuel Additives; Gasoline Lead Content (50 FR 9400)	$1.7
1988	Federal Aviation Administration	Improved Survival Equipment for Inadvertent Water Landings (53 FR 24890)	$1.5**
1988	Environmental Protection Agency	Protection of Stratospheric Ozone (53 FR 30566)	$4.8
1990	Federal Aviation Administration	Proposed Establishment of the Harlingen Airport Radar Service Area, TX (55 FR 32064)	$2.0**
1994	Food and Nutrition Service (USDA)	National School Lunch Program and School Breakfast Program (59 FR 30218)	$1.7, $3.5**
1995	Consumer Product Safety Commission	Multiple Tube Mine and Shell Fireworks Devices (60 FR 34922)	$5.6**
1996	Food Safety Inspection Service (USDA)	Pathogen Reduction; Hazard Analysis and Critical Control Point Systems (61 FR 38806)	$1.9
1996	Food and Drug Administration	Regulations Restricting the Sale and Distribution of Cigarettes and Smokeless Tobacco to Protect Children and Adolescents (61 FR 44396)	$2.7**
1996	Federal Aviation Administration	Aircraft Flight Simulator Use in Pilot Training, Testing, and Checking and at Training Centers (61 FR 34508)	$3.0**
1996	Environmental Protection Agency	Requirements for Lead-Based Paint Activities in Target Housing and Child-Occupied Facilities (61 FR 45778)	$6.3
1996	Food and Drug Administration	Medical Devices; Current Good Manufacturing Practice Final Rule; Quality System Regulation (61 FR 52602)	$5.5**
1997	Environmental Protection Agency	National Ambient Air Quality Standards for Ozone (62 FR 38856)	$6.3
1999	Environmental Protection Agency	Radon in Drinking Water Health Risk Reduction and Cost Analysis (64 FR 9560)	$6.3
1999	Environmental Protection Agency	Control of Air Pollution from New Motor Vehicles: Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements (65 FR 6698)	$3.9, $6.3
2000	Consumer Product Safety Commission	Portable Bed Rails; Advance Notice of Proposed Rulemaking (65 FR 58968)	$5.0**

[38]

[38] THE VALUE OF A STATISTICAL LIFE: A CRITICAL REVIEW OF MARKET ESTIMATES THROUGHOUT THE WORLD. W. Kip Viscusi Joseph E. Aldy

In this last few pages we have seen the inconsistency of VSL estimates adopted by a handful of agencies in a single country. Unfortunately the situation internationally is very similar, with estimates varying greatly. In the next section I will try to present an broad overall picture of how developed countries have applied VSL, and the range of values adopted, I will then proceed to explain the reasons behind these values, and finally analyze how, in my opinion, these problems could be avoided in developing countries, which still do not have such established literature on VSL calculation.

Value of a Statistical Life: World differences

While the US agencies and policy makers have benefited from innumerous studies on the Value of Statistical life the remaining developed countries have received much less attention. In the period from 1970 to 1980 in the US some 25 wage-risk studies had been conducted, in this same period however only 3 studies of the same type had been identified based on non US data. While the non-US based literature has increased after the 1990's the availability of estimates is still not at the same level as that of the American states. In this section I will analyze VSL estimates from mainly England and Canada, and how these countries apply VSL in policy reforms. Estimates will also be provided for other developed countries such as Austria, Australia and Japan as well as developing countries such as Honk Kong, India, South Korea and Taiwan.

<u>The United Kingdom:</u>

The UK was the first country aside from the United States to be subject to a hedonic wage risk study. Marin and Psacharopoulos (1982) were in fact the first to conduct such a study outside of the US. By analyzing labor market data from the 1970's they arrived at a VSL estimate of $3.5 million. Through the 1980's other studies were conducted, finding higher values for VSL than the ones calculated by Marin and Psacharopoulos. The next major study was accomplished by Arabsheibani and Marin (2000). Marin, with his new partner, sought to replicate his earlier findings through the use of more recent data. By evaluating the stability of VSL over time, Marin and Arabsheibani, reached the conclusion that VSL estimates are indeed higher than the ones calculated in the first study. The regressions which took into consideration the whole labor force resulted in VSL estimates of around $18 million, while regressions taking into consideration only subsamples of low risk class jobs resulted in VSL estimates as high as $68 million. This is in line with the US based theory, and empirical evidence, that higher risk result in lower VSL values, however the magnitude of the compensating differentials estimated seam to be questionably large. Other studies also found very high compensating differentials for the UK's labor market, a study conducted by Sandy and Elliott in 1996 implied a compensating differential for mortality risk of approximately 20%. These estimates are somewhat higher than the ones derived based on US studies, however they have been proved to be correlated with some other factor not taken into consideration by the regression, as the overall risk mortality in the UK is actually lower than in the US.

The governing agencies in the UK apply a method very similar to the one used in the United States. UK's Cabinet Office, as the OMB, has provided government regulatory agencies with guidance papers for the VSL calculation. While it does not provide a specific value of statistical life to adopt, it does recommend careful consideration as regards the application of calculated values in the economic literature to different risk and population contexts. The Department of the Environment, Transport and Regions (DETR) started using willingness to pay based VSL estimates in its policy reforms since 1988, and the original estimated value of $1.2 million is still in use by the department. The UK Health and Safety Executive (HSE) also use this derived value for the majority their policy reforms, only applying a higher VSL (nearly double) to reforms that effect cancer related fatalities.

Canada:

US aside Canada is the country that has received the most attention by VSL researchers. The Canadian based wage risk studies reveal compensating differentials much more in line with the American ones and most Canadian VSL estimates fall in the range of $3 to $6 million. The only real deviation from this value stems from a study conducted by Lanoie, Pedro and LaTour (1995), their findings show VSL estimates of $18 to $20 million, however their study eliminated a significant portion of the labor market due to their method of data collection.

In Canada the Privy Council Office has published broad guidelines for cost-benefit assessments, as in the US and UK these do not specify a set of VSL value to adopt, they rather stress the importance of taking into serious consideration the determinants of the appropriate VSL and the possible approaches to be used in order to achieve a clear representation of their information to both policy makers and the public. In the period from 1982 and 1993 Transport Canada conducted reviews on economic analyses of 145 transportation related projects, they found a range of adopted values from $400,000 to $3.2 million. A further analysis on the tobacco products information proposal found values for VSL ranging from $1.7 million to $5.7 million. In this proposal a higher value to the over 65 age group was also applied. The Proposal for Cleaner Fuels also found an upward adjustment for the elderly age group (Lang et al. 1995).

A completely different picture is painted for other industrialized and semi-industrialized countries such as South Korea, Honk Kong, Taiwan, Japan and India. Kim and Fishback (1999) analyze the South Korean labor market using data from the year 1984-1990 collected at the industry level. They find that the VSL is approximately 94 times higher than the average annual earnings, with a value of $0.8 million. A study conducted in Honk Kong by Siebert and Wei using 1991 consensus data reveals a value of statistical life for Honk Kong's population of $1.7 million. Taiwan based study conducted by Liu, Hammitt and Liu in 1997 finds a range of possible estimates: $0.2 to $0.9 million, and again Liu and Hammitt two years later establish the Taiwanese VSL at $0.7 million. Kniesner and Leeth (1991) using 1986 data sets from Japan's manufacturing industry arrive at a VSL estimate of $9.7 million. Studies in India reveal higher VSL estimates than other developing states, despite the fact that per capita income is smaller compared to these other countries. Shanmugam in three distinct studies (1996/7, 2000 and 2001) using the same data set stemming from the Madras city's manufacturing workers, arrives at three different estimates for VSL in India, respectively $1.2-$1.7 in 1997, $1.0-$1.4 in 2000 and finally a value of $4.1 in the last study. Estimates in this study range by a factor of four, even through they all stem from the same risk data, illustrating how a variety of economic specifications can produce different results[39].

Multinational organizations have also shown an interest in the methods and values deriving from international value of statistical life estimates. The Intergovernmental Panel on Climate Change (IPCC), for example, established by the United Nations Environment Programme in conjunction with the World Health Organization in 1988 provided technical assistance to participants of the global climate change talks with the economic and social dimensions of climate change papers of 1996 and 2001. Furthermore the European Commission in the year 2000 began, and established, a process to guide agencies in the calculation of cost-benefit analysis procedures within the European Union.

It is important to note that no inter-governmental procedures have been set, or discussions taken place, to try and stabilize value of statistical life estimates in the macro-areas of the globe. The result is not only that VSL estimated are wide ranging within each specific country, but also that countries which could be set on the same level, forming some sort of macro-areas, have adopted significantly different values of statistical lives. This lack of convergence and the possible ways to correct it, will be discussed in the next part of this thesis. Particular attention will be given to third world and developing countries.

[39] Refer to Appendix, Table 4, for complete non-U.S. VSL estimates.

Value of Statistical Life in Third World Countries

Many developing countries, such as India and China, have achieved significant growth levels in the past decade, bringing their respective economies to a level of high production, growing incomes, and unfortunately, growing pollution levels. In this period they are experiencing full on the environmental-growth trade off deriving from their development strategies and are in need of value of statistical life estimates to try and put into action some policy reforms with the aim of abating these growing levels pollution deriving from urbanization.

Accounting for Differences

When applying value of statistical life models in third world or developing countries one must take into account the possible differences in macro variables that could affect the final estimates. In developed countries, such as the United States, a researcher can expect some conditions, or take others as given, which may not be so straightforward in other less developed countries. For example we have seen how the hedonic wage-risk VSL model depends on the assumption than labor markets are frictionless, where each worker can freely chose his appropriate risk class and find a job that satisfies these conditions. Where this hypothesis can be made without incurring to much bias in developed countries this same condition is extremely hard take for granted in developing countries where the structure of the labor market is totally different. In countries where the unemployment rate is extremely high workers would tend to accept any job offering, without thinking to much of the risks involved, jet alone asking the employer a higher compensating differential if he believes the job to be very risky. The inherit nature of the job market itself can also present some major differences, in developing countries the overall risk of fatality is much higher than in first world countries, for example in the US labor market there where 4 deaths per 100,000 in the energy industry in 2007, while, in the same year, in less developed Zimbabwe, there were 57 per 100,000. Obviously this difference in fatality probability must be taken into account, also considering, as explained above, that the risk of death is not arbitraged by higher wage compensations. Another factor that may strongly influence the derived value of life results in third world countries is the total level of income available to an average family, in many countries with low GDP per capita this income is barely, and oftentimes not enough, to cover the daily nutritional needs of the family members. Approaching such an individual with the "How much would you be willing to pay for an 1 in 10,000 reduction in the probability of your death or that of close family members?" question would be quite useless, if not absolutely embarrassing on the part of the researcher. Note that this low-income condition rules out both the willingness to pay model based on revealed preferences and on stated preferences. The fourth and final consideration to make is that the life expectancy in many third world countries is significantly lower. As we have seen agencies such as the EPA rely heavily on the life years saved method for calculating the benefits of a proposed reform, these estimates are no-doubt linked to some considerations made on the mean age group and the life expectancy associated with that group. If by any means this same method were to be applied in other countries, with lower life expectancy, different and more accurate estimates of life years saved must be made based on a country-by-country basis.

Past Literature Models

Past literature on value of statistical life application and model development in third world countries has revealed a variety of different methods to account for the factors explained in the previous section. Some researchers such as Krupnic et al. (1995) have tried to calculate VSL estimates for third world countries by starting out with estimates, and data, of developed countries and then applying a series of scaling factors according to the difference based on income, GDP and other variables between the industrialized and developing countries. This method, although very straightforward and easy to apply, is in my point of view an extreme simplification of the problem, and does not take into account all the possible inherit cultural differences between the two countries in question and in particular, assumes that the VSL is determined largely by income and that the elasticity between countries is equal to one. Bradley, Bowland and Beghin[40] add to the information base by conducting a study in Chile. Chile had in the decade after the structural reform of the mid 1980's achieved extraordinary growth levels, however this came at a price: significant environmental pollution problems. A problem also recognized in 1994 by the World Bank in their country review. The authors in this case analyze data stemming from wage-risk relationships and then proceed to run multivariate regressions under 50 different specifications and changing explanatory variables. Below we can observe the complexity of these regressions:

Explanatory variable	MWTP	ln(MWTP)	ln(MWTP)
INTERCEPT	− 1067.38 (− 1.23)	− 20.14 * (− 4.39)	− 892.04 (− 1.37)
RISK	57.09 * (2.42)		
INC	0.05 * (3.69)		
AGE	− 9.94 (− 0.60)		
EDUC	72.18 (1.34)		
INSURANCE(= 1)		− 0.66 * (− 2.51)	
SEX		− 0.84 (− 1.37)	
ln(UNION)		− 0.55 (− 1.96)	
ln(RISK)		0.31 * (2.88)	− 37.38 * (− 2.11)
ln(INC)		2.27 * (4.71)	79.55 (1.08)
ln(AGE)		− 0.80 (− 1.07)	103.45 (1.04)
ln(EDUC)		2.58 * (2.75)	263.60 (1.52)
$^1/_2(\ln(RISK)^2)$			− 0.27 (− 0.75)
$^1/_2(\ln(INC)^2)$			− 2.59 (− 0.40)
$^1/_2(\ln(AGE)^2)$			15.71 (0.62)
$^1/_2(\ln(EDUC)^2)$			8.52 (0.48)
$^1/_2$(ln(RISK)*ln(INC))			− 3.93 * (− 2.13)
$^1/_2$(ln(RISK)*ln(AGE))			22.77 * (2.93)
$^1/_2$(ln(RISK)*ln(EDUC))			13.12 * (2.41)
$^1/_2$(ln(INC)*ln(AGE))			− 11.93 (− 0.51)
$^1/_2$(ln(INC)*ln(EDUC))			− 24.47 (− 1.35)
$^1/_2$(ln(AGE)*ln(EDUC))			− 90.35 (− 1.39)

Under these different specifications and hypothesis they arrive at two 'preferred' values of statistical life in PPP of 1992: $519,000 and $675,000. These values are in the very bottom ranges of estimated VSL values of industrialized countries. Bradley, Bowland and Beghin conclude that these values are in line with one might expect from a developing economy with

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[40] Robust Estimates of value of a statistical life for developing economies. Bradley, Bowland and Beghin.

Chile's specific characteristics of risk, income, demographics and education levels.

Another study value of statistical life study conducted on the Taiwanese labor market applies the hedonic wage-risk model to arrive at VSL estimates. Using data from the Taiwan Labor Force Survey in the period from 1982 till 1986 Liu, Hammitt and Liu[41] arrive at VSL estimates of $413,000 in 1990 dollars. It is important to note that in this study the authors included in the regression readily available information, due to the characteristics of the survey, such as variables accounting for sex, marriage status, education, job experience on top of the usual mortality risk and wage. Once again the characteristics of Taiwan's developing economy have led to average VSL values which are lower than value of statistical life estimates for developed countries.

The contingent valuation method for calculating VSL has also found space for application in third world countries. Brajer and Rahmatian[42] conducted a study using the CV method in the Islamic Republic of Iran based on data collected by the Ministry of Jihad in IRI on the willingness to pay to reduce probability of eight medical symptoms. The researchers then used these findings, converted to US dollars based on the PPP, and applied a conversion method first introduced by French and Mauskopfn (1992) and again by Johnson (1997) which through the use of a health status index links the morbidity WTP to mortality WTP numbers, i.e. the value of statistical life. The process basically consists of calculating for each health effect the number of life years lost through the use of the indexes from Johnson's study. The next step is to assign a value to these life years based on the previous step and the WTP estimates deriving from the survey. Finally the value of one life year is multiplied by the estimated remaining life years to get a value of

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[41] Estimated hedonic wage function and value of life in a developing country. Jin-Tan Liu, James K. Hammitt and Jin-Long Liu. Department of Economics, National Taiwan University.

[42] From Diye to Value of Statistical Life: A Case Study for the Islamic Republic of Iran. Victor Brajer and Morteza Rahmatian.

statistical life. The VSL in using this method for Iran was estimated to be $66,750 in 2003 dollars.

An Interesting Side-Story: The Diye

The Diye is a very straightforward method of assigning compensation for wrongful deaths and injuries in the Muslim culture, due to this, this form of compensation is still used in the republic of Iran and in many other Muslim countries. According to the constitution of the IRI the Diye is a method used to bring some sort of stability in the society following unintentional mishaps and was designed to bring satisfactory resolutions to a dispute. This method of payment, conforming to the will of God, acts as a form of punishment and also provides some compensation to the victim's family. Differing from the Human Capital method of VSL calculation the Diye is not dependent on the victim, but rather is a fixed form of payment, established ex-ante for all society. The Diye has always included very specific and comprehensive rules; it specifies a compensation for the loss of every part of the body resulting from an non-fatal injury, with the highest payment being reserved for the complete loss of life. Originally this compensation was 10 camels to be paid for an unintentional deaths, this figure was later raised to 100 during the sacrifice of Abdoulmotalleb's (Prophet Mohammed's grandfather) tenth son, when his remaining 9 brothers thought of a Diye of 100 camels to save his life. After the Islamic region was established its rulers went on to specify other forms of payment of equal value which are still in use today:

-100 strong and healthy camels

-200 strong and healthy cows

-1,000 strong and healthy sheep

-200 sets of quality clothing

-1,000 dinars, where one dinar = 3.515 grams of gold

- 10,000 darham, where one darham = 2.46 grams of silver

Note that these values coincide almost perfectly with the human capital method estimate for an average worker in Iran. 1000 dinars becomes:

(3,515 grams)(0.035274 oz/g)($363.38/oz) = $45,055

Whereas:

Considering an average age worker in Tehran (37 years old), a retirement age of 62, and an average yearly salary of $1800 = $45,000.

Proposed Value of Statistical Life Model:

In reviewing the available literature on value of statistical life it becomes apparent that the lack of a standard model to apply has resulted into VSL values which vary greatly. These estimates can depend on a variety of factors such as the data used and the way this data was collected, the specification level of the regressions and the choice of dependent and independent variables. We have also seen, in the meta-analysis section of this thesis, that the relationships between a multitude of variables and value of statistical life estimates are oftentimes insignificant and inconclusive to the specification of the regression, meaning that, all in all, they tend to be irrelevant to the calculation of the VSL. Results from these regressions and past studies make me arrive at the conclusion that many of these factors, such as marriage status, job experience, union status, education and sex just to name a few, are to be dropped from future VSL estimates, also because some of this data is hard to obtain in developing countries and may not always be available, as I repeat, not a great loss. The complexity of the models adopted in past studies has also led to various VSL estimates which are often hard to replicate using different data, and also hard to understand and therefore adopt in policy making areas. Also I believe that every agency in any country should adopt a single, and standard, value of statistical life estimation model. In other words: there exists already one Environmental Protection Agency, we could really do without another. Learning from one's mistakes, and most importantly, the mistakes of others, is a fundamental step towards the achievement of self-enlightenment. With this well-known statement I strongly urge all VSL researchers to undertake this road in the future. I will try to implement this thought first hand in the remaining portion of this thesis, through a value of statistical life model which in my point of view can be applied uniformly in any country and in any field. It will, of course, be up to you, the reader, to evaluate my proposal, it may not be what some would define a science ground-breaker, it simply stems from a personal thought and personal considerations on the topic in question.

- Any intelligent fool can make things bigger and more complex. It takes a touch of genius, and a lot of courage, to move in the opposite direction -

Albert Einstein

The following model has been developed with the constant thought in mind of providing heterogeneity to VSL estimates. The objective was to provide governments with a stable and reliable method for value of statistical life calculation. The model is thus to be applied at the general population level and not at the individual level, this is due to the fact that most reforms are applied at a nationwide level; for example a road safety reform is likely to affect the whole population rather than just a single subset. The model however, due to its simplicity, can also be applied at the city or county levels (provided large observations base and the availability of data) for cost-benefits analysis such as environmental impact analysis of the opening of a new factory or electric power station in a specific area. The model proposed thus reduces the number of explanatory variables to a bear minimum, and will include only those factors that have been proved to have a constant significant effect on the VSL. I will firstly present the conceptual approach, then I will explain the choice of the independent and dependent variables of the regression, thirdly I will provide explanations on the choice of sample.

Conceptual approach

The model is based on the relationship between the log wage as a dependent variable and a series of explanatory variables which will be introduced later. The regressions take the form of:

$$\ln(w_i) = \alpha + \beta_1 X_i + \beta_2 \theta_i + \varepsilon$$

Where the ln(w) is the log from specification of the wage of the i'th individual, the α is the constant term of the regression that may be ignored, β_1 is the beta coefficient of the variable X_i which includes a vector of person specific factors, β_2 is the beta coefficient of the variable θ_i which represents the probability of on the job death, finally ε is the error term of the regression.

This regression run using the ordinary least squares will provide for coefficient estimates for each independent variable, these values will then be used to arrive at estimates of the value of statistical life through the following formula:

$$VSL = (\hat{\beta}_1 + \hat{\beta}_2 + ... + \hat{\beta}_3)\frac{SampleMeanWage}{\Pr Death}$$

The resulting value of statistical life estimate will then be based on the effect that a marginal variation of a right hand side variable, i.e. the coefficient of the independent variable, interacting with the ratio of sample's average wage and its unit probability of death. Thus, for example, taking into consideration the risk variable θ_i its coefficient would be $\hat{\beta}_2 = \partial \ln(w_i)/\partial \theta_i$.

The advantage of using this model for the calculation of VSL is that the actual coefficients, of observed in real market data, are used as multipliers to the wage-risk ratio of the sample. This implies that, given a representative sample, effects such as individual wealth are taken out of the equation, insuring a more accurate value at the population level. Also all the biases that are present in the willingness to pay method are avoided.

The model may present some problems on the base that, as previously explained, the labor market conditions in third world countries may result in non-frictionless markets, where a worker, due to lack of alternatives, may be forced to accept any wage level regardless of his risk preference. However these conditions, given time, will be reduced as the growth of developing countries brings about labor market conditions which are more in line with the present conditions of developed countries so the bias resulting from this market inefficiency will tend to disappear.

Choice of Independent and Dependent Variables

My choice of these variables is based on the review of many meta-analysis studies, conducted throughout the years, by different authors. As previously explained the model is structured to include only independent variables that have been repeatedly statistically proven to have a significant effect on the value of a statistical life. All of these variables are easily obtainable for both developed countries and developing countries, conducting basic research on the official statistics websites of each country set on the way of development, data is readily available. The regression to calculate the VSL of the model includes only three fundamental explanatory variables: on the job risk, average age and life expectancy. The regression will thus take the form:

$$\ln(w_i) = \alpha + \beta_1\theta_i + \beta_2 life\exp_i + \beta_3 age \cdot \theta_i + \varepsilon$$

Where the ln(w) is the log from specification of the wage of the i'th individual, the α is the constant term of the regression that may be ignored, β_1 is the beta coefficient of the variable θ_i which represents the probability of on the job death, β_2 is the coefficient of the life expectancy variable, i.e. the life expectancy at birth, β_3 is the coefficient of an interaction variable which takes into account the effect of age and probability of death, ε is the error term of the regression.

Probability of death

This variable takes into account the relationship between wages and risk first proposed by Adam Smith in his Wealth of Nations, we have seen how the risk variable affects the value of statistical life in the section of this thesis regarding the meta-analysis studies. Since the 1980 the majority of all meta-analysis and regression studies have included the risk as an explanatory variable. The inclusion of this variable in the regression insures that the wage-risk tradeoff is taken into account, i.e. the average wage compensation of the sample for each added unit of risk. One could expect a positive and statistically significant coefficient.

Life Expectancy

Life expectancy at birth in my opinion is another fundamental variable to be included in the regression estimates for the calculation of the value of a statistical life. This variable, regressed on the wage, gives a coefficient that takes into account a proxy for the working years available to the average population of a country, thus the model also takes into account the social side of the equation, which would otherwise be lost if one were to include only the risk variable. Following the theory this variable should have a positive and significant coefficient and therefore result in higher VSL estimates; the higher is the life expectancy of the general population the higher are the benefits resulting from the avoided loss of life. This concept is also confirmed quite easily by taking into consideration the saved life years approach.

Interaction Age-Risk

In the previous value of statistical life studies age has been treated with great caution. Many have criticized the application of a senior discount on VSL estimates, however the literature made available in the last two decades has proven that there is indeed a correlation between age and risk, and so therefore on VSL estimates. Viscusi and Aldy (2006) have demonstrated quite clearly that the on the job fatality risks increase with age, and that the VSL follows an inverted U shape function due to this condition.

Thus in my opinion the exclusion of such a variable will definitely lead to the regression suffering from omitted variable bias. However the use of the age variable must be made in conjoint with the risk variable, as the regression would otherwise give the effect of age on wages, increasing the likelihood that this effect is based on other factors such as experience. By including the interaction variable on the other hand, i.e. Probability of death * Age the regression will take into account the joint effect that age has with risk.

Choice of Sample

I have observed, in past VSL literature the importance of choosing a good data sample; many variations in the value of a statistical life stem directly from the choice of sample. For example income has been proved to have a largely significant effect on the VSL, thus the researcher when choosing the data should make sure to adopt a sample that is representative of the population targeted by the study. The choice of data used should depend on the type of reform or policy-making area that the resulting estimates will be used in, since the model proposed can be used both at the population or sub-set population level, the adopted data is fundamental. For example the calculation of VSL estimates for a road safety reform should use a data sample that is representative for the whole population in the age range 18 till 80, while a reform to the safety at construction sites should only use specific data for the age, wages and probability of death relative to only blue-collar construction workers. Very different VSL estimates could be obtained if the white-collar workers (with generally lower risks of death) are also included in the sample.

As regarding the, hopeful, convergence in value of statistical lives calculated through this model, the researcher or policy maker should use consistent and standardized data, insuring that the data sample was collected, and reported, under the same specifications throughout.

A statistical note: the data collected and used in the model may be both cross-sectional data and time-series data. For cross-sectional regressions, given correct data, the model should not present biases voiding the five basic Gauss-Markov assumptions. On the other hand, is the derived VSL estimates should be calculated using time-based data, either for lack of observations or for other reasons, the robust form of Ordinary Least Squares regressions should be adopted to avoid heteroskedacticity.

The theory behind this model, in my mind at least, is valid. The empirical testing of the model is however a completely different story. Although it would be a great wish to conduct and include in this document an extensive empirical proof of what I have stated above it is outside the scope of this bachelor thesis to do so. Hopefully a future paper or master thesis will enable me to write a more econometrics-oriented paper. Proposing a model without empirical proofs is near useless some critics might say, *I agree with you*, I am the first to criticize papers without or with insufficient testing. However it was in my heart to share also my thought on how things could be done. For this time, please forgive me this negligence.

Conclusions

Throughout the course of this thesis I have hopefully given you, the reader, a greater insight on how the application of value of statistical life affects everyday life of both the general public and the work of policy makers worldwide. I have presented the fundamental need of having these models available for applications in modern society, how the value of statistical life estimates can be calculated through the existing human capital, willingness to pay, hedonic wage-risk, and regressions models, and the inherit advantages and disadvantages of these methods. I further presented actual values derived from past studies, and the causes of the wide ranges of these estimates. The study then turned to the ways these estimated have been applied, and difficulties incurred by policy-making agencies on applying these models and estimates to policy reforms. In my opinion the road traveled by developed countries was a hard one, with many errors and setbacks along the way. Thus I was compelled to stress the point of learning from past mistakes to not repeat them in the future. A future where VSL estimates will become ever more used throughout the world as developing countries encounter the need of applying such models for their own policy assessments. The thesis is concluded by a proposed model for the value of statistical life calculation, this model was developed to try and achieve some sort of easy application and converging values to a surely controversial topic, were any mistake is immediately jumped upon by critics and the general public, many of which do not understand the need and importance of having such estimates available.

I have found, throughout the research of this thesis, a VSL author community which, in my point of view, is very divided, with each researcher applying what he thinks is best, and actively criticizing other conducted studies. It is in my belief, backed by the findings of my study, that this situation is not optimal for policy makers, who have to apply these values to reforms which affect many country related decisions. It is also sub-optimal for the general public, who sees their value of life changing continuously, and justly do not understand the causes of these variations. Thus I dedicate this last paragraph of my thesis to these researchers, these policy makers, and the general public. To the researchers: thank you, for all the literature that has made this thesis possible, but the results of my study stress the need for convergence and standards in this topic. To the policy makers: it's a tough job, be smart. To the general public: understand that the scope of value of statistical life estimates is not to place a price tag upon your head, rather it is to ensure that your safety is maximized, while your wallets remain full.

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Appendix

Table 1:

#	Authors	Year of publication	Country	Sample size	Average income[a]	Average probability of death[b]	Compensation	Endogeneity of risk	White workers sample	Union sample	SOA	Coefficient ϕ	Location in the article: Page	Table	Specification	Criteria[c]	VSL[a]	Standard error (VSL)[a]
1	Smith	1974	USA	3,183	29,029	1.25	0	0	1	0	0	0.636	743	A	2	5, 6	9,231,222	3,846,343
2	Thaler and Rosen	1975	USA	907	34,195	10.98	0	0	0	0	1	0.000286	293	4	2	1, 2, 6	977,980	594,995
3	Viscusi	1978	USA	496	31,953	1.182	0	0	0	0	0	0.00153	368	2	2	2, 5	2,444,383	1,405,920
4	Brown	1980	USA	470	49,019	2.25	0	0	0	0	1	0.06	128	2	2	2, 4	2,941,140	588,228
5	*Olson*	*1981*	*USA*	*5,993*	*33,509*	*0.9508*	*0*	*0*	*0*	*0*	*0*	*0.4245*	*175*	*1*	*1*	*2*	*12,374,191*	*4,978,545*[d]
6	Marin and Psacharopoulos	1982	UK	5,509	26,415	0.93	0	0	0	0	0	0.229	836	4	3	1	6,049,041	1,338,283
7	*Arnould and Nichols*	*1983*	*USA*	*1,832*	*34,195*	*10*	*1*	*0*	*0*	*0*	*1*	*0.355*	*338*	*1*	*2*	*5*	*1,351,335*	*570,002*[d]
8	*Dorsey and Walzer*	*1983*	*USA*	*1,697*	*21,636*	*0.5756*	*1*	*0*	*0*	*1*	*0*	*0.635*	*652*	*4*	*4*	*2*	*11,768,688*	*4,971,544*[d]
9	Low and McPheters	1983	USA	72	33,172	3.3	0	0	0	0	0	129.42	277	2	1	2, 5	1,391,218	1,008,129
10	Dillingham and Smith	1984	USA	879	29,707	1.2	0	0	1	1	0	0.2218	275	1	1	3	3,294,506	1,565,559
11	*Leigh and Folsom*	*1984*	*USA*	*1,529*	*35,694*	*1.42*	*0*	*0*	*1*	*0*	*0*	*0.3629*	*60*	*3*	*3*	*2, 3*	*10,067,308*	*4,260,731*[d]
12	Dillingham	1985	USA	514	26,825	1.4	0	0	0	0	0	0.3124	285	5	2	5	4,189,995	2,323,006
13	*Weiss et al.*	*1986*	*Austria*	*4,225*	*12,841*	*1.28*	*0*	*0*	*0*	*0*	*0*	*1.2894*	*15*	*2*	*2*	*1, 5*	*8,369,952*	*3,436,763*[d]
14	Garen	1988	USA	2,863	30,013	1.08	0	1	0	0	0	0.00547	14	3	2	1, 5	16,416,982	3,538,143
15	Moore and Viscusi (a)	1988	USA	1,349	26,559	0.7918	0	0	1	0	0	0.00345	485	5	2	1, 5	9,162,972	2,390,341
16	Meng	1989	Canada	718	45,313	1.9	0	0	0	0	0	0.0892	421	2	4	1	4,041,961	2,336,394
17	Meng and Smith	1990	Canada	777	30,236	1.2	0	0	0	0	0	0.04023	141	1	1	1	1,216,395	2,252,583
18	Berger and Gabriel	1991	USA	22,837	42,316	0.97	0	0	0	0	0	0.0018	315	2	1	3	7,616,966	1,336,310
19	Gegax et al.	1991	USA	228	40,664	8.6075	0	0	0	1	1	0.0168	594	3	5	3	2,732,627	1,379,418
20	Kniesner and Leeth (1)	1991	Japan	20	28,975	0.32	0	0	0	0	0	4.422	81	2	4	2	12,812,755	6,707,897
21	Kniesner and Leeth (2)	1991	Australia	44	25,260	1.4	1	0	0	0	0	1.729	81	2	7	1, 2	4,367,434	1,753,567
22	Kniesner and Leeth (3)	1991	USA	8,868	33,843	4.36	1	0	0	0	0	0.1365	84	3	11	2, 4	461,958	310,247
23	Leigh	1991	USA	1502	34,045	1.34	0	0	0	0	0	0.0021	386	1	6	3	7,149,454	2,175,732
24	Cousineau et al.	1992	Canada	32,713	29,658	0.764	0	0	0	0	0	0.00162	168	2	5	2, 3	4,804,628	464,664
25	Martinello and Meng	1992	Canada	4,352	28,925	2.5	0	0	0	0	0	0.1087	340	2	6	1, 2	3,144,141	949,892
26	Siebert and Wei	1994	UK	1,353	15,627	0.332	0	1	0	1	0	0.9075	70	3	1	3, 5	14,181,264	6,746,558
27	Lanoie et al.	1995	Canada	63	46,535	2.73	0	0	0	1	0	0.052	248	3	1	2, 4	24,198,149	7,657,642
28	Leigh	1995	USA	1,528	29,552	1.1016	0	0	0	0	0	0.00376	91	3	2	3, 6	11,111,731	2,084,361
29	*Sandy and Elliott*	*1996*	*UK*	*440*	*30,211*	*0.452*	*0*	*1*	*0*	*1*	*0*	*3797.31*	*299*	*3*	*2*	*2*	*53,626,554*	*22,969,379*[d]
30	Liu et al.	1997	Taiwan	18,987	9,748	2.252	0	0	0	0	0	0.0123	356	2	5	2, 3	1,198,975	106,623
31	Miller et al.	1997	Australia	18,850	26,638	0.68	0	0	0	0	0	0.675	367	2	3	2	17,980,328	1,369,408
32	Kim and Fishback	1999	South Korea	321	16,516	4.85	0	0	0	0	0	0.094	238	1	1	1	1,552,525	324,796
33	Meng and Smith	1999	Canada	1,503	22,743	1.8	1	0	0	0	0	0.1035	1,106	2	10	1, 2	2,353,931	609,827
34	Arabsheibani and Marin	2000	UK	3,608	29,176	0.5	0	0	0	0	0	1.0542	258	2	5	2, 3	30,756,987	6,179,825
35	Gunderson and Hyatt	2001	Canada	2,014	29,709	1.67	0	1	0	0	0	0.082	389	3	2	2	24,361,374	3,460,422
36	Shanmugam	2001	India	522	3,038	1.04407	0	1	0	0	0	0.0529	270	2	2	1, 2, 5	16,070,278	7,183,853
37	*Leeth and Ruser*	*2003*	*USA*	*45,001*	*24,860*	*0.9757*	*1*	*0*	*0*	*0*	*0*	*0.116*	*268*	*3*	*2*	*3*	*2,723,710*	*598,605*[d]
38	Viscusi	2003	USA	83,625	30,449	0.362	1	0	1	0	0	0.0053	29	5	1	3	16,137,876	1,522,441
39	Viscusi	2004	USA	99,033	30,041	0.402	1	0	0	0	0	0.0017	39	3	1	3	5,106,991	600,822

Table 2:

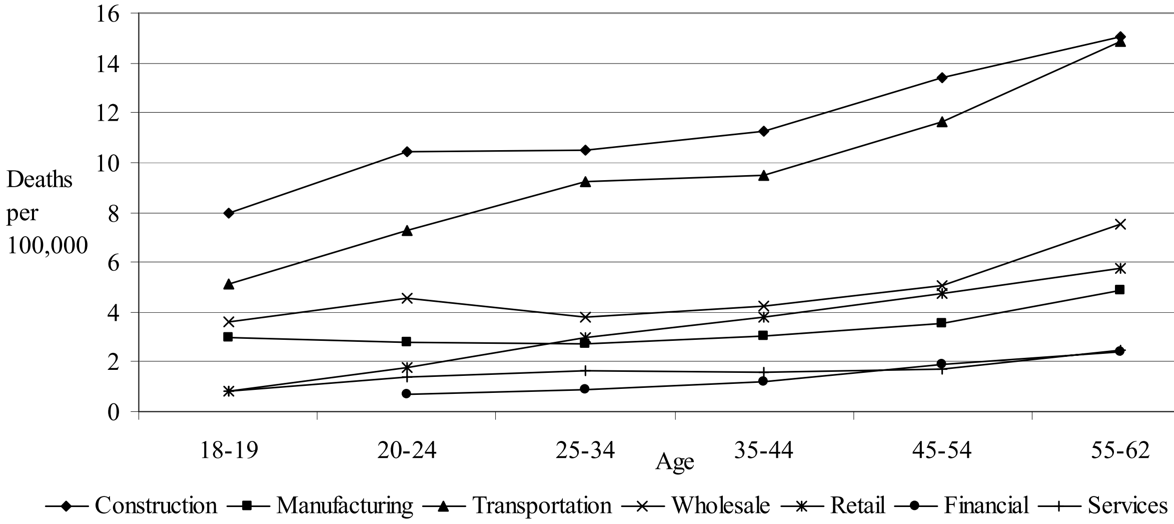
Variables	Specifications				
	0	1	2	3	4
Constant	6,519,243 (9.88)	−8.29E + 08 (3.38)	−9.02E + 08 (3.81)	−8.78E + 08 (3.82)	−9.96E + 08 (4.22)
Year of publication	–	397,154 (3.35)	432,049 (3.77)	419,944 (3.77)	475,149 (4.17)
Average income (log)	–	4,661,556 (2.23)	4,914,203 (2.47)	4,948,056 (2.56)	5,606,813 (2.88)
Average probability of death	–	−1,928,822 (3.29)	−1,590,198 (2.77)	−1,543,579 (2.79)	−1,239,987 (2.18)
Endogeneity of risk	–	11,129,173 (3.67)	11,746,697 (3.98)	12,260,997 (4.19)	12,120,680 (4.16)
Compensation	–	−3,928,681 (2.03)	−4,394,831 (2.39)	−4,567,507 (2.55)	−4,725,900 (2.66)
White-workers sample	–	–	3,901,022 (1.89)	4,979,976 (2.23)	5,996,964 (2.63)
Union sample	–	–	–	−3,445,325 (1.08)	−4,216,413 (1.32)
UK study	–	–	–	–	5,696,197 (1.99)
N	29	29	29	29	29
$\hat{\sigma}_u^2$	8.18E + 12	9.29E + 12	7.99E + 12	7.31E + 12	7.15E + 12
Prob. $\sigma_u^2 = 0$	0	0	0	0	0

Notes: (1) Dependent variable: VSL. (2) Absolute value of *t*-statistic in parentheses.

Table 3:

Industry	18-19	20-24	25-34	35-44	45-54	55-62
A. 3-Digit Industry Risk Measure						
Construction	11.43	11.43	11.43	11.43	11.43	11.43
Manufacturing	3.77	3.47	3.16	3.00	3.13	3.13
Transportation	11.19	10.23	9.96	9.04	8.34	10.04
Wholesale	4.95	4.90	4.70	4.90	5.06	5.23
Retail	2.98	2.97	3.02	3.23	3.13	3.19
Financial	*	1.18	1.23	1.23	1.32	1.37
Services	2.42	1.98	1.63	1.50	1.28	1.34
B. Age Group by 2-Digit Industry Risk Measure						
Construction	8.00	10.47	10.50	11.27	13.41	15.05
Manufacturing	3.14	3.00	2.82	3.12	3.56	4.83
Transportation	4.98	6.85	8.70	9.04	10.60	14.42
Wholesale	4.11	4.62	3.80	4.27	5.09	7.49
Retail	0.92	1.99	3.01	3.95	4.83	5.92
Financial	*	0.64	0.87	1.13	1.78	2.21
Services	1.05	1.54	1.61	1.55	1.58	2.33

Figure 4:



16
14
12
10
8
6
4
2
0
Deaths per 100,000
18-19
20-24
25-34
35-44
45-54
55-62
Age
Construction
Manufacturing
Transportation
Wholesale
Retail
Financial
Services

Table 4

Author (Year)	Country	Sample	Risk Variable	Mean Risk	Nonfatal Risk Included?	Workers' Comp Included?	Average Income Level (2000 US$)	Implicit VSL (millions, 2000 US$)
Marin and Psacharopoulos (1982)	UK	General Household Survey 1975	OPCS Occupational Mortality Decennial Survey 1970-72	0.0001	No	No	$14,472	$4.2
Weiss, Maier, and Gerking (1986)	Austria	Austrian Microcensus File of Central Bureau of Statistics 1981	Austrian Social Insurance Data on job-related accidents 1977 - 1984	NA	Yes	No	$12,011	$3.9, $6.5
Meng (1989)	Canada	National Survey of Class Structure and Labour Process 1981	Labour Canada and Quebec Occupational Health and Safety Board 1981	0.00019	No	No	$43,840	$3.9-$4.7
Meng and Smith (1990)	Canada	National Election Study 1984	Labour Canada and Quebec Occupational Health and Safety Board 1981-83	0.00012	No	No	$29,646	$6.5-$10.3
Kniesner and Leeth (1991)	Japan	Two-digit manufacturing data 1986 (Japan)	Yearbook of Labor Statistics (Japan)	0.00003	Yes	No	$44,863	$9.7
Kniesner and Leeth (1991)	Australia	Two-digit manufacturing data 1984-85 (Australia, by state)	Industrial Accidents, Australia Bureau of Statistics 1984 - 1986	0.0001	Yes	Yes	$23,307	$4.2
Cousineau, Lacroix, and Girard (1992)	Canada	Labor, Canada Survey 1979	Quebec Compensation Board	0.00001	Yes	No	$29,665	$4.6
Martinello and Meng (1992)	Canada	Labour Market Activity Survey 1986	Labour Canada and Statistics Canada 1986	0.00025	Yes	No	$25,387	$2.2-$6.8

Author (Year)	Country	Sample	Risk Variable	Mean Risk	Nonfatal Risk Included?	Workers' Comp Included?	Average Income Level (2000 US$)	Implicit VSL (millions, 2000 US$)
Kim and Fishback (1993)	South Korea	Ministry of Labor's Report on Monthly Labor Survey and Survey on Basic Statistics for the Wage Structures	Ministry of Labor's Analysis for Industrial Accidents	0.000485	Yes	Yes	$8,125	$0.8
Siebert and Wei (1994)	UK	General Household Survey 1983	Health and Safety Executive (HSE) 1986-88	0.000038	Yes	No	$12,810	$9.4-$11.5
Lanoie, Pedro, and Latour (1995)	Canada	Authors' in-person survey 1990	Quebec Workers' Compensation Board 1981-1985	0.000126	Yes	No	$40,739	$19.6-$21.7
Sandy and Elliott (1996)	UK	Social Change and Economic Life Initiative Survey (SCELI) 1986	OPCS Occupational Mortality Tables Decennial Supplement 1979/80-1982/3	0.000045	No	No	$16,143	$5.2-$69.4
Shanmugam (1996/7)	India	Author's survey of blue collar manufacturing workers, Madras, India 1990	Administrative Report of Factories Act 1987-1990	0.000104	No	No	$778	$1.2, $1.5
Liu, Hammitt, and Liu (1997)	Taiwan	Taiwan Labor Force Survey 1982-1986	Taiwan Labor Insurance Agency 1982-1986	0.000225-0.000382	No	No	$5,007 - $6,088	$0.2-$0.9
Miller, Mulvey, and Norris (1997)	Australia	Australian Census of Population and Housing 1991	Worksafe Australia, National Occupational Health and Safety Commission 1992-93	0.000068	No	No	$27,177	$11.3-$19.1
Siebert and Wei (1998)	Hong Kong	Hong Kong Census 1991	Labour Department	0.000139	No	No	$11,668	$1.7

Author (Year)	Country	Sample	Risk Variable	Mean Risk	Nonfatal Risk Included?	Workers' Comp Included?	Average Income Level (2000 US$)	Implicit VSL (millions, 2000 US$)
Liu and Hammitt (1999)	Taiwan	Authors' survey of petrochemical workers 1995	Workers' assessed fatality risk at work 1995	0.000513	Yes	No	$18,483	$0.7
Meng and Smith (1999)	Canada	Labour Market Activity Survey 1986	Ontario Workers' Compensation Board	0.00018	Yes	Yes	$19,962	$5.1-$5.3
Arabsheibani and Marin (2000)	UK	General Household Survey (1980s)	OPCS Occupational Mortality Decennial Survey 1979-83	0.00005	Yes	No	$20,163	$19.9
Shanmugam (2000)	India	Author's survey of blue collar manufacturing workers, Madras, India 1990	Administrative Report of Factories Act 1987-1990	0.000104	Yes	No	$778	$1.0, $1.4
Shanmugam (2001)	India	Author's survey of blue collar manufacturing workers, Madras, India 1990	Administrative Report of Factories Act 1987-1990	0.000104	Yes	No	$778	$4.1
Sandy, Elliott, Siebert, and Wei (2001)	UK	SCELI 1986	OPCS 79/80 - 82/3, HSE 1986 - 88	0.000038, 0.000045	No	No	$16,143	$5.7, $74.1