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Value of Statistical Life: A Meta-Analysis with Mixed Effects Regression Model

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VALUE OF STATISTICAL LIFE: A META-ANALYSIS WITH MIXED EFFECTS REGRESSION MODEL

Agamoni Majumder* and S Madheswaran**

Abstract

Value of Statistical Life (VSL) is a concept which was born out of political interest but later started serving as a policy instrument. Viscusi (2003) in his grand compilation of over 100 studies has broadly discussed the issues, methods and controversies related to VSL. This paper is an extension to his work in the sense that it intends to compile more literature on VSL from 2003 till 2015. After 2003, many new developments took place in VSL literature which has been reviewed and presented in this paper. This critical review of literature incorporates various econometric issues with estimation of VSL besides addressing various other issues like role of unionization and effects of worker's compensation benefits on risk premiums, heterogeneity issues of VSL and existence of segmented labour markets. VSL values estimated from different studies are not uniform and the source of this variability needs to be understood in order to guide present and future policy making. This article presents a meta-analysis based on 34 observations from 30 VSL studies which have used hedonic wage method to estimate VSL. Our meta-analysis based on mixed effects regression method suggests that the emerging areas such as the effect of worker's age, compensation benefits and long–term health-related job risk need to be explored further when VSL is estimated.

Keywords: Valuations of Life/Injury, Value of a Statistical Life, Risk, Compensating Wage Differentials, Hedonic wage method.

JEL Classification: J31, D80, J58, J17, J38.

Introduction

Any government policy needs to be evaluated before it is implemented. Policy makers popularly use cost and benefit analysis approach for this purpose whereby they evaluate the benefits of a policy against its costs. Valuing the benefits from government policies that aim at reduction of fatality risk is one of the most contentious issues in the arena of policy valuation. The benefits that a society accrues from mortality risk reduction policies is the value of reduction in probability of fatal occurrences. Regulators often use the Value of Statistical Life (VSL) as a key economic parameter to estimate such benefits. The aim of this paper is to provide a concise review of literature of VSL studies across the world besides presenting a meta-analysis of the VSL studies using Mixed Effects Regression model.

Section 1 of this paper briefly introduces and explains the concept of VSL, its origin and its application in the policy arena. Although controversies exist regarding the most appropriate methodologies that can be used to estimate VSL, Section 2 discusses how VSL can be estimated using one of the most widely used methods, which is the hedonic wage approach. This section also includes a few econometric and data issues which are frequently encountered by researchers during estimation of VSL. Section 3 reviews and summarizes a few VSL literatures based on various developed and developing countries. The summary of studies contain both labour market as well as non-labour market

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based studies. One of the recent observations in the literature of VSL studies is that the VSL estimates are not constant and they tend to vary in magnitude on several grounds. Therefore, Section 4 focuses on the heterogeneity issues associated with VSL and how the estimation of VSL is modified in order to capture certain specific heterogeneity issues. Variation of VSL estimates by age of the affected population is one of the most debatable issues. Therefore, a separate summary of a few important studies focusing on the age and VSL debate has been presented under Section 4. Researchers and policy makers often argue about the choice of a suitable discount rate for long-term health-related job risk and Section 5 sheds some light on this issue. Section 6 touches on another important issue which is the effect of income and wealth on VSL. Section 7 presents a meta-analysis of 16 hedonic wage studies using mixed effects regression model. This section begins with a precise explanation of the mixed effects regression model followed by discussion on the characteristics of sample used for analysis and results from the meta-analysis. The last Section of the paper highlights a few criticisms on VSL.

1. Value of Statistical Life

People engage in various market decisions in their daily lives which reveal their implicit trade-off between risk and money. For economists, these market choices act as a key instrument to develop the estimates of Value of Statistical Life (VSL) (Viscusi, 2003). VSL measures the risk-money trade-off for tiny amount of fatal risks (Viscusi, 2011). It is ***"the amount that people are jointly willing to pay for fatality risk reduction in the expectation of saving one life"*** (Borjas, 2013). The concept of VSL has long been debated and misunderstood. This is mainly because it is thought that economists are attempting to estimate the price of life through VSL estimation. However, economists are not valuing life because life is priceless. Therefore, what they are doing is that, they are trying to estimate the monetary value that people themselves are willing to pay for fatality risk reduction in the expectation of saving one life. Willingness to pay (WTP) is the underlying principle for valuing the benefits of fatal risk reduction policies (Kniesner, Viscusi, Ziliak, 2014).

1.1. Origin of VSL

The term "Value of Statistical Life" was coined by Thomas Schelling in 1968 in his essay, named "The Life You Save May Be Your Own". However, according to Banzhaf, the intellectual origin of VSL lies in a controversy involving US Air Force (USAF) and the RAND Corporation. In 1949, RAND Corporation was asked by USAF to design its first aerial attack on Soviets. RAND Corporation was responsible for estimating the optimal combination of atomic bombs and bombers to maximize the damage on Soviets, given the budget constraint and constraint on fissile material available with USAF. However, RAND Corporation failed to weigh the lives of bomber crew and recommended USAF to use cheap propeller aircraft which would have led to huge fatalities. This incident created a massive debate concerning valuation of lives and RAND Corporation was forced by USAF to contemplate on the role of lives in an optimization framework for military decisions. Thus, the Value of Statistical Life methodology came into limelight during this event and economists started using this approach (H Spencer Banzhaf, 2014).

1.2. Application of VSL to Public Policy Decisions

The advent of VSL literature dates back to the 1970s and 1980s. However, it faced strong criticisms since its inception mainly because the concept of VSL is misinterpreted. Therefore, policymakers used the Human Capital Approach which valued improvements in life expectancy using foregone income. The introduction of VSL in public policy decision making occurred during 1982, when a debate arose within the US government regarding analysis of a proposed hazard communication regulation. Occupational Health and Safety Administration (OSHA) recommended for using human capital approach whereby the costs exceeded the benefit of the regulation and hence it was rejected. This issue was finally resolved by using VSL estimates which showed that the regulation should be accepted since the benefits of that regulation exceeded its cost (Shanmugam, 2013). This had been a historical event in the context of application of VSL in policy purpose by the US government. Later on, the governments of other countries started recognizing and applying VSL estimates for evaluation of the risk regulations.

2. Value of Statistical Life Estimation from Labour Market

An everlasting debate among the policy makers and researchers is about the use of appropriate methodology to estimate the risk-money tradeoff which is used to estimate VSL. However, as observed from the VSL literature, the dominant approach used in this context is the wage-risk trade-offs from the labour market (Viscusi, 2011). Thus, analysts commonly transfer the risk-money trade-off estimates from labour market context to health and environmental policy context. One might think whether it is appropriate to transfer such estimates from one scenario to another. Since, the magnitude of risk reduction is similar under these two circumstances and people have similar preferences towards risk, this transfer of estimates is considered appropriate and justified (Viscusi, 2007).

For valuing fatality risks, US commonly uses compensating wage differential (CWD) which arises in labour market (Nathalie *et al*, 1999). In 1776, Adam Smith, the father of economics, introduced the concept of compensating wage differential. He proposed that job characteristics influence the nature of labour market equilibrium. CWD measures the amount of money that a worker has to be paid so that he accepts a small increase in his death risk or in other words, it is the amount of money that the worker needs to pay to attain a small reduction in his risk of death. These values can be estimated from observed labour market data and can be converted to VSL which are then used to value various risk reduction policies (Nathalie *et al*, 1999). **"The theory of compensating wage differentials essentially tells a story of how workers and firms 'match and mate' in the labour market"** (Borjas, 2013). According to this theory, a job is viewed as a package that includes wage and non-wage job characteristics. CWD therefore arises to compensate workers for the non-wage job characteristics. Hedonic wage approach is frequently used to estimate CWD in this context. The next sub-section (Section 2.1) presents a brief discussion on this approach.

2.1. The Hedonic Wage Methodology

In 1976, Richard Thaler and Sherwin Rosen developed the modern theory of compensating wage differential in which they adopted Hedonic wage function approach. Hedonic wage treats job as a bundle of characteristics such as characteristics of workers, conditions of work and level of risk of

accidental injury. Other things remaining equal, risky jobs require wage premiums to attract workers. In this approach, wage acts as a key source of information on work-related health and fatality risk. Hence, it reveals the underlying implicit wage-risk trade-off which is used for estimation of VSL. The next sub-section (Section 2.2) briefly explains how the hedonic wage function is derived under the framework of compensating wage differential.

2.2. Equilibrium in Hedonic Labour Market

Demand for labour decreases with rise in total cost of hiring workers because providing safer working conditions for workers is a costly affair for firms. In figure 1 (in appendix), wage offer curves OC_1 and OC_2 exhibit a positive relationship between risk level and wage. Given any particular level of risk, workers will choose those wage-risk combinations on the market offer curve which offer them the highest wage. The outer envelope of these curves is called the market opportunity locus w (p). Thus, the supply of labour is partially dictated by their choice over wages and risk. Imposing various minor restrictions on preferences of workers, the labour supply can be well characterized. Let us consider Von-Neumann Morgenstern expected utility approach with two state-dependent utility functions. Let good health state represent utility "u (w)" and ill health (due to injury) represent utility "v (w)". Good health is preferred to ill health. So,

$$u(w) > v(w)$$

It is assumed that workers prefer higher wage given the risk level, therefore, the marginal utility of income is positive, i.e.

$$u'(w) > 0 \text{ and } v'(w) > 0,$$

Workers aim is to maximize their expected utility by choosing from possible wage-risk combinations along some market opportunity locus w (p). Therefore, the optimal choice of wage and job risk for a worker is obtained at the point of tangency of the expected utility curve of the worker and wage offer curve of the firm. Worker 1 maximizes his expected utility at the point of tangency between OC_1 and EU_1 while worker 2 maximizes his expected utility at the point of tangency between OC_2 and EU_2. Thus, all the optimal wage-risk choices associated with a given worker's expected utility locus must satisfy

$$Z = (1-p) \times u(w) + p \times v(w)$$

The optimal wage-risk choice is given by

$$\frac{dw}{dp} = -\frac{Zp}{Zw} = \frac{u(w)-v(w)}{(1-p)u'(w)+p\,v'(w)} > 0$$

Here, (dw/dp) is the slope of hedonic wage function which shows that wage-risk tradeoff equals the difference in utility levels in the two states divided by the expected marginal utility of income. This estimated slope not only resembles a worker's marginal willingness to accept risk but also his marginal willingness to pay for more safety. It also resembles a firm's marginal cost of more safety as well as reduction in its marginal cost for an incremental increase in risk.

However, it should be kept in mind that the estimated wage-risk trade-off locus w (p) does not indicate how a worker must be compensated for non-marginal or large variation in risk. In such a case, worker's wage-risk trade-off will alter since the appropriate wage-risk tradeoff must be made along the worker's expected utility locus and not the estimated market wage-risk tradeoff (Viscusi, 2003).

2.3. Econometric and Data Issues

The econometric specification for the hedonic wage function is obtained from the Human Capital theory whereby Mincer's earnings function is modified by incorporating risk into the wage equation. It has been observed that the wage equation is commonly used by researchers to estimate wage-risk relationship in labour market (Viscusi, 2003). Equation (1) shows that worker's wage is a function of fatal risk denoted as "p_i", non-fatal risk denoted as "q_i", a vector of worker and firm characteristics denoted as "X_{ki}" and a random error term ϵ_i.

$$W_i = \alpha + \beta_1 p_i + \beta_2 q_i + \Sigma_k \gamma_k X_{ki} + \epsilon_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

β_1, β_2 and γ_k are the parameters that are required to be estimated using regression analysis.

However, the basic hedonic equation suffers from endogeneity and heterogeneity problem which need to be corrected. Very few studies have corrected for this problems. Shanmugam and Madheswaran (2011) have accounted for these problems in their study based on Indian labour market.

2.3.1. Estimation of VSL:

The wage-risk trade-off is given by $\hat{\beta}_1$ which can be obtained from equation (1). The fatality risk is generally measured per 100,000 workers and it is assumed that workers work for 2000 hours annually. Given these information, the estimated VSL at mean wage level $(\overline{w})$ is estimated using the following simple formula:

$$VSL = \widehat{\beta_1} \times (\overline{w}) \times 2000 \times 100{,}000$$

2.3.2. Risk and Wage Data

There exist no single source of information from which researchers can obtain the data on risk, individual worker and firm characteristics. Hence, information on these components are mostly obtained by matching observations from several sources and by deciding on how the data (which are mostly reported at aggregate levels) can be combined in the best possible way (Chris *et al*, 2004). Aldy and Viscusi (2004), identified few serious problems that may arise due to inadequacy in job risk variable. Besides encountering measurement error researchers have to face the problem of estimation errors getting correlated since job risk measures are often unable to capture the difference in risk exposure for different workers within an industry. Risk measures may also fail to consider the effect of worker's compensation on their wage.

Table 1 summarizes a few sources of risk data that are frequently used in VSL studies by researchers in USA and India.

Table 1: Sources of Risk Data for USA and India

Country	Source of risk data	Information provided
USA	**SOA (Society of Actuaries)**	Average annual fatality risk for 1/1,000 across 37 occupations
	BLS (Bureau of Labour Statistics)	Aggregate data on fatal and non-fatal injury risk by industries using 2-3 digits ICC
	NIOSH (National Institute of Occupational Safety and Health)	All fatal job injuries based on death certificates
	CFOI (Census of Fatal Occupational Injuries)	Job fatality by 4 digit ICC from worker's compensation records, various Federal and state agencies and death certificates
India	**Administrative Report of the Chief Inspector of Factories**	Number of blue collar male workers, number of deaths and accidental injuries in a year at 2 digit NIC level
	Indian Labour Yearbook	Fatality rates and non-fatal injury rates by industry

There are two categories of risk measure: one type of risk measure captures the objective risk associated with an occupation or a specific industry while the other risk measure pertains to the subjective evaluation of mortality risk by workers themselves. It has been a standard approach to use either industry-specific or occupation-specific measures of risk that reflect average fatalities over a period of time (Viscusi, 2003). Studies like Madheswaran (2004) and Shanmugam and Madheswaran (2011) used the subjective risk preference of workers in Indian labour market.

The share of unorganized sector in developing countries is quite huge. Risk data pertaining to objective risk measures for organized sector workers is mostly compiled and reported by government or government agencies. Therefore, objective risk data is available for only organized sector in developing countries while leaving out information on a vast majority of unorganized sector workers. This is a major shortcoming of secondary risk data in developing countries.

When it comes to wage data, most studies use either weekly or annual hourly wage of workers as the dependent variable for estimation of equation (1). In this context, USA-based studies commonly use surveys like Survey of Working Conditions (SWC), Quality of Employment Survey (QES), Current Population Survey (CPS) by Bureau of Labor Statistics, Panel Study of Income Dynamics (PSID) and decennial census data. For India, Nathalie *et al* (1999) obtained the data on average daily wage of workers from Occupational Wage Survey (OWS), conducted by the Indian Labour Bureau. OWS reports average daily wage of full-time, manual workers, by occupation, for various industries on the basis of 3-digit NIC codes.

Another debatable issue with estimation of hedonic wage equation (i.e. equation 1) involves finding a suitable functional form. Initially, many researchers used linear or a semi-logarithmic specification for estimating hedonic wage regression. Since, the use of any particular specification could not be justified by theory, researchers tried to address this problem econometrically. In this context, Moore and Viscusi (1987) used Box-Cox transformation to obtain a flexible functional form for estimation of hedonic wage regression and the semi-logarithmic form was found to be appropriate.

It has been observed that non-wage job characteristics are most often missed out from wage regression model. This may influence the omitted variable to get correlated with risk and yield biased estimates of risk premium (Viscusi, 2003). Different researchers employed different ways to get rid of the omitted variable bias until Garen in 1988 came up with a novel idea of using instrumental variable technique. This method is frequently used by researchers to deal with omitted variable problem (Shanmugam and Madheswaran, 2011). Costa and Kahn (2004) could not control for injury rates in their study leading to biased estimates. Worker's unobserved personal characteristics may also cause this problem. Panel data can aid researchers to weed out unobserved personal characteristics of worker using dummies. However, this will be possible only if such characteristics remain constant throughout all periods for which the dataset is available (Viscusi, 2003).

3. Brief Review of VSL Studies

3.1. VSL Studies Based on Developed Countries

There are many VSL studies in developed countries. Especially, the number of VSL studies based on US labour market is quite high. Viscusi (2003) in his grand study compiled more than 30 studies based on US. Table 2 summarizes a few VSL studies based in USA and other developed countries.

Table 2: Summary of VSL Studies Based on USA and Other Developed Countries

Author (Year)	Country	Title of study	Summary/Findings	Value of Statistical Life (million)		
Alberini *et. al* (2001)	USA & Canada	**The Willingness To Pay for Mortality Risk Reductions: A Comparison of the United States and Canada**	With increase in size of risk reduction, WTP also increases. Found little evidence of variation of WTP with respondent's age.	930,000 - 4.8 (2000 USD)		
W Kip Viscusi and Joseph E Aldy (2003)	USA	**The Value of a Statistical Life: A critical review of market estimates throughout the world**	Reviewed 60 studies of mortality risk premium and 40 studies of injury risk premium. Critically examined various econometric issues, role of unionization in risk premiums and effects of age on the VSL. Conducted a meta-analysis of VSL studies.	16,070,278 (2000 USD)		
Jin-Tan Liu James K Hammitt Jung-Der Wang Meng-Wen Tsou (2003)	Taiwan	**Valuation of the risk of SARS in Taiwan**	WTP for risk reduction increased with degree of risk reduction. WTP for a vaccine that protected individuals from SARS was fairly high compared to WTP for other fatal risk reduction	3 - 12 (USD)		
Viscusi (2003)	USA	**Racial Differences in Labor Market Values of a Statistical Life**	Implicit VSL and annual compensation for fatal risks was lower for black workers compared to white workers.	$9.4 - $18.8 (for whites) $5.9 - $8.9 (for blacks)		
Alberini *et. al* (2003)	USA & Canada	**Does the value of a statistical life vary with age and health status? Evidence from the US and Canada.**	WTP did not decline much with age.	WTP for	5 in 1000	1 in 1000
				WTP in US	700,000 -1.54	4.8
				WTP in Canada	506,000933,000	3.7

Joseph E Aldy and W Kip Viscusi (2004)	USA	**Age variations in workers' Value of a Statistical Life**	VSL exhibits an inverted U-shaped relationship over an individual's life cycle.	$4.23 (general OLS Estimate) (1996$) At age of 60: $2.5-$3.0
Viscusi and Kniesner (2004)	USA	**Value of a Statistical Life: Relative Position vs. Relative Age**	Disregarding relative position of worker in wage distribution had little impact on VSL but, disregarding planned consumption of worker underestimated VSL by about 20 percent.	$4.7 – $4.8
Lucas W Davis (2004)	Nevada, USA	**The Effect of Health Risk on Housing Values: Evidence from a Cancer Cluster**	Housing values fell by 15.6 % during peak risk period, for various risk measures and size of house.	(Value of Pediatric Leukemia, VPL) 5.6$
Victor Brajer, Morteza Rahmatian, (2004)	Iran	**From Diye to Value of Statistical Life: A Case Study for the Islamic Republic of Iran**	The ancient cultural tradition "Diye" had significant impact on preferences of individuals and their WTP for avoiding premature death.	1) 45,000$ 2) 66,750$ 3) 100,000$ (2003 USD)
Louis R Eeckhoudta and James K Hammitt (2004)	USA	**Does risk aversion increase the value of mortality risk?**	Though financial risk aversion increases VSL in certain defined cases, the relationship between VSL and risk aversion is ambiguous under many reasonable assumptions.	------
Orley Ashenfelter and MichaeL Greenstone, (2004)	USA	**"Using Mandated Speed Limits to Measure the Value of a Statistical Life**	US federal government law which raised the speed limit in rural interstate roads from 55 miles per hour to 65 miles per hour which was found to cause a surge in speed limit by 4% and fatalities by 35%.	$1.03 – $1.64 (1997 USD)
Fredrik Carlsson, Olof Johansson-Stenman and Peter Martinsson (2004)	Sweden	**"Is Transport Safety More Valuable in the Air?"**	Individuals thoroughly overestimate risk of flight accidents relative to accidents in other modes of transport. 50% respondents stated higher WTP for risk reduction.	------
Chris Rohlfs (2005)	USA	**Estimates of the Willingness to-Pay to Avoid Military Service and Fatality Risk: Evidence from the Vietnam Draft**	WTP of white men were higher than black men.	1.1-4.0 (2003 USD)
Thomas J Kniesner, W Kip Viscusi and James P Ziliak (2006)	USA	**Life-Cycle Consumption and the Age-Adjusted Value of Life**	Age pattern of consumption was found to vary. Observed that implicit VSL increased and then declined over lifetime in a manner such that the value for aged workers was higher than the average value of young.	VSL without industry controls: $20.8 VSL with industry controls:$8.9

3.2. VSL Studies Based on Developing Countries

Very few VSL studies existed in developing countries. Recently, countries like Malaysia, Tunisia, Pakistan, Bangladesh and India have come up with VSL studies. Some of these studies are summarized in Table 3.

Table 3: Summary of VSL Studies in Developing Countries

Author (Year)	Country	Title of the Study	Summary/Findings	Value of Statistical Life (million)
Nathalie *et al* (1999)	INDIA	Valuing Mortality Reductions in India, A Study of Compensating Wage Differentials	Fatal and injury risk was found to have positive influence on worker's wage. Found the ratio of VSL to foregone earnings is higher for India compared to U.S.A. Transferring VSL estimate from U.S.A to India using BTM undervalues Indian VSL.	153,000-358,000 (1999 USD)
Nor Ghani MD. Nor and Mohd Faudzi Mohd Yusoff (2001)	MALAYSIA	The value of life and accident costing: a willingness to pay study amongst young motorcyclists in Malaysia	Although young riders were initially thought to have higher valuation of lives compared to senior counterparts, however, this result was not robust.	l.2 (RM)
S Madheswaran (2004)	(Mumbai & Chennai) INDIA	Measuring the Value of Life and Limb: Estimating Compensating Wage Differentials among Workers in Chennai and Mumbai	Found that job risk decreases with worker's wealth. Worker's wage increases with his education level, being in union and belonging to lower caste. Fatal, non-fatal job risk and subjective risk assessment of workers had positive influence on wage,	15 (INR)
Minhaj Mahmud (2005)	BANGLADESH	Measuring trust and the value of statistical lives: Evidence from Bangladesh	Used CVM approach and found that young people underestimated risk compared to older people	$1,783 to $2,922
Muhammad Rafiq and Mir Kalan Shah (2006)	PAKISTAN	How Much is a Life Worth? Examining the Risk-Wages Trade Off in Pakistan	Found that higher fatality risks were associated with higher wage. However, for injury risk the results were unclear.	$ 122,047 (10.4 million PKR) to $435,294 (37 million PKR)
Abdelaziz Benkhalifa (2010)	TUNISIA	The value of mortality risk reductions in the Tunisian building and manufacturing industries.	Found positive and significant fatal risk premium implying higher value of mortality risk in the building and manufacturing industries.	448663.32 Dinnars (Manufacturing) 689280.5 (Building)
K R Shanmugam and S Madheswaran (2011)	INDIA	Economics of Human Resources: An Econometric Study on the Compensating Wage Differentials for Job Risks	Fatal, non-fatal and subjective job risk were found to positively and significantly affect worker's wage. Age and VSL showed an inverted-U shaped relation. Union and backward community workers had higher wage.	3.74 (million) (1990 USD)

4. Heterogeneity Issues of VSL

VSL is observed to vary on various dimensions like individual risk taking behaviour and individual characteristics such as age, income, gender, race, immigrant status, etc. Thus, there is no uniform VSL and the VSL estimates have to be adjusted for these dimensions (Viscusi, 2011).

Many studies found that people who are risk lovers in their personal life decision making are likely to select riskier jobs. Risk averse individuals are observed to have high wage-risk trade-offs and therefore high VSL since they are located on steeper portion of the hedonic wage function. In contrast, risk-loving workers are observed to have low wage-risk trade-off and therefore low VSL since they are located on the flatter portion of the hedonic wage function. However, above discussion is based on a key assumption that labour market opportunities faced by one worker is independent of choices of other workers (Viscusi, 2011).

4.1. Segmented Labour Market

By segmented labour market, it is meant that, within the labour market, there are categories which further differentiate and subdivide the workers. Therefore, different worker will face different market opportunity locus and will consequently have different market equilibria (Viscusi, 2011). In 2001, Viscusi and Hersch undertook a comprehensive test to examine the presence of segmented labour market. A question that arises in this context is: do different workers face different market opportunity locus? According to Viscusi (2011), this is possible if compensating wage differential of workers vary even though they are exposed to same risk level. It is also possible when one group of workers faces lesser level of risk and earns a higher wage differential while another group of workers faces higher level of risk and earns a lower wage differential.

4.1.1. Variation in VSL on the Basis of Race, Colour, Caste and Gender of the Worker

In many studies undertaken in USA, key differences occur due to the origin of the worker, i.e., whether the worker is a US citizen by birth, Mexican, Hispanic, etc. Another factor is whether the worker is white or black. Viscusi (2003) found significant differences in the wage risk trade-off between the white and black workers in US labour market.

Prevalence of segmented labour market in terms of job opportunities for workers of different castes is quite prominent in India. Madheswaran (2004) employed a dummy variable model for caste of the worker and found that caste had a positive and significant influence on worker's wage. This result implied that the backward caste workers earned a higher wage premium compared to other caste workers in blue collar manufacturing industries. Madheswaran and Shanmugam (2011) found similar results which highlights the fact that workers belonging to the lower caste tend to earn more in risky jobs.

Discrimination in job market opportunities on the basis of gender of the worker has been one of the most controversial and debatable issues for a long time. As more and more women are becoming a part of labour force, it is very important to study and enquire about the evidence of a segmented labour market based on the gender of the worker. Dora L Costa & Matthew E Kahn (2004) found that

during 1940, male workers had an average risk exposure that was nearly 4 times larger than that of the female workers while in 1980 it doubled.

4.2. Variation in VSL by Union Status

Union can play an effective role in demanding better work environment for workers, greater job safety, higher compensation in case of injury and death of workers, higher pensions, etc. Mostly, workers are unaware of actual risks associated with a job unless they start working. Union can play an important role in informing workers about the level of risk involved in a particular job. US labour market-based VSL studies indicate that a worker's union membership and higher wage-risk tradeoff is positively correlated (Viscusi, 2003). For Indian labour market, Madheswaran (2004) found that union workers were better aware of the riskiness of their jobs compared to non-union workers. While union was observed to negatively influence fatal risk, its influence on the non-fatal injury risks was found to be positive.

4.3. VSL and Worker's Compensation Benefits

Worker's compensation comprises of ex-ante compensation and ex-post compensation. Ex-ante compensation includes the compensating wage differential for undertaking job risks. On the other hand, ex-post compensation takes the form of worker's compensation benefits. The compensation benefits not only consists of medical outlays but also a certain portion of lost wages of workers. Therefore, excluding worker's compensation benefit from estimation of wage premium for risky jobs will lead to biased outcome.

Shanmugam and Madheswaran (2011) used standard benefit rates from Employees State Insurance Scheme (ESIS) to compute worker's compensation (WC_i or R_i) in the context of Indian labour market. They modified the basic hedonic equation in the following manner to incorporate ex-post compensation of workers:

$$\mathbf{Ln\ W_i = \alpha + \beta_1 p_i + \beta_2 q_i + \Sigma_k \gamma_k X_{k\,i} + \varphi_k WC_i q_i + \epsilon_i}$$

Worker's compensation is given by $\mathbf{WC_i = R_i = [w_i/b_i]}$, where $\mathbf{(w_i)}$ is daily wage rates per worker and $\mathbf{(b_i)}$ is daily benefit rates from ESIS. They found that the interaction term $\mathbf{(WC_i \times q_i)}$ was negative and was statistically significant. On inclusion of worker's compensation, injury risk coefficient $\mathbf{(q_i)}$ was found to increase leading to a decline in the value of statistical injury.

4.4. VSL and Age

Initial studies had very little evidence to support the statement that VSL varies with age. As more studies focused on enquiring about the relationship between age and VSL, new results emerged. This in turn created more controversies on this issue among the researchers. Table 4 briefly summarizes the studies that examined the relationship between age and VSL.

Table 4: Summary of a Few Important Studies Examining Relationship Between Age and VSL

Author (Year)	Country	Title of study	Summary/Findings	Value of Statistical Life (million)
Aldy and Viscusi (2004)	USA	Age variations in workers' Value of a Statistical Life	• Developed a life-cycle model in which consumption levels and job fatality risks are chosen by workers. • Used age-dependent fatal and nonfatal risk variables. • Found an inverted U-shaped relationship between age and VSL	$4.23 (general OLS Estimate) (1996$) At age of 60: $2.5-$3.0
Joseph E Aldy and W Kip Viscusi (2006)	USA	Adjusting the Value of a Statistical Life for Age and Cohort Effects	• Measured the effect of year of birth on VSL. • Used age-dependent fatal risk measure to estimate age-specific hedonic wage regressions. Found an inverted-U shaped relationship between age and VSL.	Age groups (18-24): $ 3.2 (35-44): $ 9.9 (55-62): $3.8
Joseph E Aldy and W Kip Viscusi (2007)	USA	Age Differences in the Value of Statistical	• Applied estimates of VSL-age relationship to Clear Skies initiative and illustrated the policy implications of recognizing this relationship.	VSLY: $ 275,000
		Life"-A Revealed preference evidence	• Found that, including effects of age in estimating VSL has significant impact on estimated benefits of fatal risk reduction. • Estimated risk reduction benefits using VSLY approach	
Joseph E Aldy and W Kip Viscusi (2008)	USA	Adjusting the value of a statistical life for age and cohort effects	Looked at age VSL relationship from point of view of life expectancy. • Two questions were addressed in this study: How does the value of life vary with age across population? And how do differences in cohorts influence this relationship? • Fatality risk data by age and industry was used. • Used a single cross section, to confound the cohort-specific influence and age-specific effects on estimated compensating differential.	Age group: (18-24): $3.7, (35-44): $9.7, (55-62): $3.4 Peak VSL- Age 46: $7.8

While most recent studies have evidenced an inverted-U relationship between age and VSL, Alberini *et al* (2001) found little evidenced on variation of WTP with age of the respondent. Glenn C Blomquist (2004) suggested the use of multi-period model with uncertain lifetime since it is more realistic and helpful in deriving an individual's WTP for changes in fatality risks at various phases of his life cycle. Aldy and Viscusi (2004) made a significant contribution in life-cycle VSL literature and it altered the standard life-cycle models.

Older people are expected to pay less for fatality risk reduction compared to younger people because they have fewer remaining expected life years. However, theory may not consider lower VSL for older people (Alan Krupnick, 2007). In this context, many economists proposed that VSL should be rather converted to Value of Statistical Life Year (VSLY). VSLY estimates are based on how a worker values the discounted years of remaining life. If in each year, we assume a time-invariant value of statistical life year then,

$$\mathbf{VSL} = \frac{\mathbf{VSLY}}{\mathbf{r}} - \frac{\mathbf{1}}{(\mathbf{1+r})^{\mathbf{L}}}\left[\frac{\mathbf{VSLY}}{\mathbf{r}}\right] \text{.................... (I)}$$

Here, "r" is the rate of interest used to discount worker's years of life, "L" is worker's remaining life expectancy.

From equation (I), VSLY can be obtained as follows,

$$VSLY = \frac{rVSL}{[1-(1+r)^{-L}]}$$

Viscusi (2007) found that the WTP for fatality risk reduction in younger cohort will depend on lifetime income. Aldy and Viscusi (2006) on the other hand found, that VSL increase with the year of birth of worker. Researchers are putting effort to explore possibility of multiple equilibria with respect to age of the workers. The position of a worker on wage-risk curve is observed to change as he ages (Viscusi, 2007). On the other hand, employers can offer different wage-risk combinations according to the age-specific safety productivity. Thus, not only worker's expected utility curve but also firm's wage offer curves vary with worker's age (Viscusi, 2007).

5. Discount Rate for Long-Term Health-Related Job Risks

Workers themselves place certain discount rates on inter-temporal death risks. A young worker has to incur more loss from death compared to an old worker. Therefore, appropriate discount rate is required for estimation of long-term health benefits. Health is not directly traded in an inter-temporal market. In absence of perfect capital markets, risk free rate of time preference of society may not be an appropriate discount rate for all benefits. Therefore, the question that remains is: whether to use same rate or different rates of time preference for health impacts? This issue is solved empirically. Approaches that can be used to estimate appropriate discount rate are: and Discounted Expected Life Years Approach, Discounted Annuity approach and Markov Decision Model (Shanmugam and Madheswaran, 2011).

6. Income and Wealth Effects on VSL

Previous studies are found to establish theoretically as well as empirically that there exists a positive relationship between worker's income level and his VSL. Since, VSL should rise with per capita income of a country, poorer developing countries tend to have lower VSL compared to developed countries (Viscusi, 2011). In any society, finest jobs pay more to workers. However, one question still lingers: Is it possible for wage to increase as the riskiness of job increases? Hedonic wage theory had long been criticized on the basis of this contradiction. It is known that safety is a normal good which implies that, as wealth of an individual increases, his demand for safety should increase. Hence, a richer individual will demand for a safer job. This also shows that wealth of a worker affects the job risk choice of an individual (Madheswaran, 2004). In Indian context, Shanmugam and Madheswaran (2011) found wealth to have a negative and significant influence on fatal as well as non-fatal job risks.

7. Meta-analysis of Value of Statistical Life

7.1. Meta-Analysis with Mixed Effects Regression Model

Meta-analysis involves application of various statistical procedures to a set of studies for integrating and synthesizing them so as to utilize all the information they contain. It is different from simple literature review since it provides a basis for in-depth scientific analysis of result of various studies. A**s** mentioned earlier, VSL estimates are observed to vary from one study to another. In order to investigate and understand the major sources of this variability, meta-analysis of VSL studies is conducted. Different studies use different samples. Therefore, in many cases, variation in results arise due to sampling variance or estimation variance. Although methodological differences are observed to cause certain amount of variations, several unobserved and uncontrollable factors also influence the outcome. Under such a scenario, application of mixed effects regression model is found to be suitable for meta-analysis since it can account for this unobserved heterogeneity. Mixed effects regression model hypothesizes that: estimation variance is not the only source of variation (François *et al*, 2009). The mixed effects regression model is given as follows:

$$VSL_j = \beta_0 + \sum_{k=1}^{p} \beta_k X_{jk} + u_j + e_j \qquad \text{..... (i)}$$

VSL_j is the dependent variable which has to be estimated for each of the "**m"** studies in the sample. β_0 is the constant, $\mathbf{X_{jk}}$ is the vector of characteristics of study j which estimates VSL_j, β_1, β_2**....** β_k are the regression coefficients which capture the fixed effects of study characteristics on VSL. This model has a joint error term containing a random error $\mathbf{(u_j)}$ and an estimation error $\mathbf{(e_j)}$ which are independently distributed with zero mean and variance, $\mathbf{\sigma^2_u}$ and $\mathbf{\sigma^2_{VSLj}}$ respectively.

According to Raudenbush (1994), OLS is unsuitable for estimating equation **(i)** since mixed effects regression model is based on the assumption of heteroscedasticity. Thus, WLS should be used for estimation of mixed effects regression where optimal weights are given by

$$wj = \frac{1}{\sigma^2_{VSLj}*} = \frac{1}{(\sigma^2_0 + \sigma^2_{VSLj})} \qquad \text{..... (ii)}$$

If σ^2_θ is zero, then the fixed-effects model will be adequate and the optimal weight will be, $W_j = 1/\sigma^2_{VSLj}$. Value of σ^2_{VSLj} can be calculated from data contained in the studies itself. However, the value of σ^2_θ is not given in studies and it needs to be estimated.

An alternative to using (ii) as weight is to use the inverse of sample size of studies as weight for meta-analysis. In our meta-analysis, inverse of sample size of the VSL studies has been used as weights for estimating (i) using WLS.

7.2. Analysis of Sample

In this present study, a meta-analysis of 34 observations obtained from 30 hedonic wage studies has been conducted using mixed effects regression model following Francoise *et al,* (2009). The sample comprises a few studies from Francoise *et al,* (2009) and a few recent studies from developed as well as developing countries. Since estimated VSL values are used as dependent variable, those studies from which VSL could not be calculated (due to absence of information on certain variables) were removed from the meta-analysis. The explanatory variables included in the analysis are: average probability of death, average income, white worker's sample, union sample, worker's compensation for injury, year of publication, age of workers and square of age of workers.

7.3. Steps for Analysis

STEP I: Using the following formula, VSL for each study in the sample is re-estimated.

$$VSL = \frac{\tilde{\phi} * (sample\ average\ of\ annual\ income)}{Unit\ of\ probability\ of\ death}$$

Here, $\tilde{\phi}$ is the coefficient of risk of death.

STEP II: Re-estimated values are then converted into USD 2005. In this analysis, 2005 is used as the base year. For non-American studies, the purchasing power parity (from Penn World Table 7.1) has been used as the exchange factor to convert respective country's currency to USD. For American studies, consumer price index (from Council of Economic Advisors, 2013) has been used to adjust the VSL and average income values to USD 2005.

STEP III: Finally, the regression is run according to equation (i).

7.4. Results of Meta-Analysis and Discussion

Table 7: Result of Meta-Analysis

Variables	Co-efficient	t value
Constant	14.14846 *	8.82
Average income (Log)	0.2576024**	2.69
Average probability of death	-0.4437536*	4.86
Compensation to workers	-0.6617426**	1.98
White workers sample	0.8888838***	1.65
Union sample	0.3663709***	1.78
Age	-1.318973**	2.22
Age^2	1.511033**	2.18
Year of Publication	0.00713**	2.31
N	34	
REML estimate of between study variance ($\hat{\sigma}^2$)	0.89	
% residual variation due to heterogeneity (I^2_{res})	100 %	
Proportion of between study variance explained (Adjusted R^2)	65.72 %	
Joint test for all covariates	8.91	
With Knapp-Hartung modification (Prob > F)	0	

***, **, *** indicates statistical significance at 1%, 5% and 10% level respectively**

The dependent variable used in our analysis is the log of VSL which has been estimated from each study in the sample. As shown by Table 7, the log of average income has a positive and significant relation with log of VSL, which implies that people with high income has higher WTP.

While theory tells that there exists an ambiguous relationship between VSL and average probability of death, our results imply a negative and significant relation between these two variables. Francoise *et al* (2009) also observed a similar relationship in their meta-analysis for some of the specifications.

Compensation to workers has a negative and significant relationship with VSL. This result is in line with the results obtained in meta-analysis by Francoise *et al* (2009). Studies that incorporate measures for worker's compensation yield, on average, a VSL that is lesser than other studies. Thus, this result confirms that workers who derive benefit from compensation for job injury, demand lesser risk premium for a risky job.

A sample which entirely comprises of white workers is observed to have higher VSL compared to other samples, however, the estimated parameter is not statistically significant. Therefore, we cannot come to any conclusion regarding the presence of racial discrimination in job market. This result is however, contrary to the one obtained by Francoise *et al* (2009).

It has been mentioned earlier that international evidence of effect of unionization on worker's WTP has been quite mixed. In our analysis, union sample is observed to have a positive relationship with VSL. However, the estimated parameter is not significant. Francoise *et al* (2009) on the other hand, found a negative relationship between these two variables though their parameters were not significant as well.

The effect of worker's age and age squared on VSL is found to be significant. While age is found to have a negative relationship with VSL, the square of age has a positive relationship with VSL. Our results show a U-shaped relationship between age and VSL which implies that VSL rises with the age of workers. This result in in line with the results of earlier VSL studies.

The year of publication is observed to positively and significantly influence VSL estimates. This implies that VSL estimates tend to increase with the year of publication.

The aim of conducting meta-analysis of VSL studies is to investigate about the major source of variability observed in VSL estimates from different studies. The unobserved heterogeneity is the major cause of variation in VSL estimates (since I^2_{res} is 100%). 65.72% of the between-study variance is explained by the model while the remaining between-study variance (given by $\hat{\sigma}^2$) appears small at 0.89. Thus, it can be concluded that unobserved heterogeneity plays an important role in causing variations in VSL estimates across studies. A joint test is also conducted to test the null hypothesis that the coefficients of the covariates are all zero. The result indicates that we can reject the null hypotheses and say that the covariates are all non-zero.

8. Conclusion

The concept of VSL has long been misunderstood and misinterpreted. Most of the criticisms were based on the misperception that VSL attempted to assign a price tag on human life. Lisa Heinzerling viewed estimation of VSL to be a vague (Ike Brannon, 2004-05). According to *Sceptical Economist* (2014), problem arises in calculation of VSL, because economists make a bold assumption that individuals are informed about risks associated with a job. In reality, such information is hardly available. Besides money and probability of death, there are many other factors which affect an individual's daily life decisions (*Sceptical Economist*, 2014). However, keeping aside all these criticisms, regulators and researchers continue to use and apply VSL worldwide for evaluation of various risk regulations. VSL approach has facilitated meaningful risk regulation policies since a very long time. Therefore, it is considered the correct economic approach, which places a considerable value on lives that will be saved compared to previous approaches like the present value of lost earnings approach (Viscusi, 2011).

Presently, the application of VSL is not only restricted to risk regulation analysis but also various other areas of health and environmental studies. The availability of more and better data on fatal risk and other survey data has further expanded the application horizon of VSL. The policymakers and researches are focusing on heterogeneity of VSL which is an emerging issue in VSL literature. Several works have already been undertaken in this area leading to more refined VSL estimates that has aided policy making and policy evaluation. However, many dimensions are yet to be explored on this issue. Meta-analysis aids in understanding the variability in the estimates of VSL across studies and our meta-analysis result shows that unobserved heterogeneity is the main cause behind this variation. The results from our meta-analysis show that the log of average income, average probability of death, year of publication, compensation for injury, worker's age and square of worker's age is observed to significantly influence the VSL estimates. On the other hand, white worker's sample and union sample did not have significant influence on VSL estimates.

While ample studies exist in developed countries, the number of VSL studies available for developing countries is still low. One area that is yet to be explored is related to risk preferences of unorganized sector workers in developing economies. In Indian context, very few VSL studies are available. The latest study by Madheswaran and Shanmugam in 2011 has accounted for wealth effect, self-selection bias, insurance benefits and effect of age on VSL, life cycle issues and long–term, health-related job risk. However, the effect of insurance benefits were estimated using Standard Benefit Rates (SBRs) of 1999 which needs to be updated and re-estimated. It did not incorporate the effect of age on VSL with respect to various age groups using fatality risk data by age and industry as done by Viscusi (2008) (which is considered to be a better measure of effect of age on VSL). Therefore, many researchable issues are yet left to be explored. In Indian context, the research gaps and questions that arise from this review of literature are: What are the compensating wage differentials for job risk in various industries? How willingness to pay to reduce risk varies with age? What is the effect of worker's compensation on VSL? What is the appropriate risk premium (discount rate) for long–term, health-related job risks? These research questions will be of great interest to analyze and in turn provide better occupational safety, health and environmental policies.

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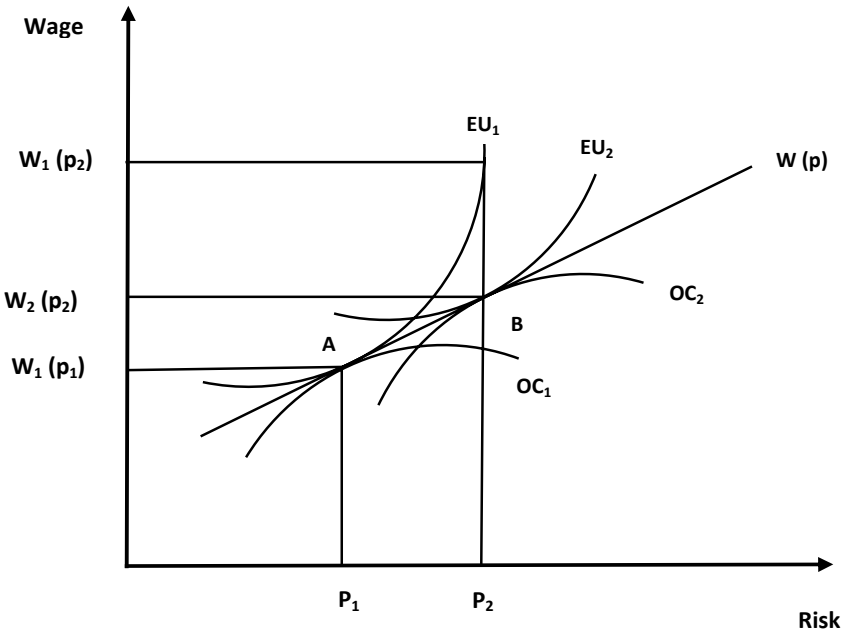
Appendix

Figure 1: Equilibrium in Hedonic Labour Market



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