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The Economic Value of Risks to Life: Evidence from the Swiss Labour Market

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1. INTRODUCTION

Many public policies aim to reduce mortality risks and to decrease injuries or illnesses, ranging from driver regulations, food production standards and occupational safety rules, to environmental legislation. From an economic point of view, an analysis of those policies requires both an estimate of the magnitude of the risks involved and a monetary valuation of the costs and benefits resulting from the additional safety that might be provided by a given policy. The costs are easily determined by accounting for all the policy measures outlays aimed at improving safety. On the benefits side, the issue is more delicate, because its main component is usually represented by the monetary valuation of changes in mortality and/or morbidity risks resulting from the policy.[1] Since individuals cannot explicitly buy risk premiums on the market, such information is however not readily available and thus must be indirectly estimated.

In the literature, four main approaches are used to derive a monetary valuation of health and life. The first group of studies applies contingent valuation techniques and infers from questionnaires to individuals the willingness-to-pay for (or willingness-to-accept) measures reducing (increasing) the risk of mortality/morbidity (e.g., GERKING et al., 1988). The second group infers monetary values from consumer market studies, by examining actual expenditures on items that reduce health risks (e.g. smoke detectors as in GARBACZ, 1989). A third approach, sometimes called the human capital approach, is based on the evaluation of the revenue or productivity losses associated with mortality or illnesses (e.g. MISHAN, 1971). Finally, the most widespread methodology is the hedonic technique, which infers compensating wage differentials that are paid in the labour market for additional risks taken by individuals on the workplace.

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1. For instance, the value of health impacts represents between 70 and 90 percent of the external costs of fossil fuel energy cycles as calculated by European Commission (1995) and around 75 percent of the monetary benefits of the Clean Air Act in the US (cf. EPA, 1997).

In this study, we make use of this latter technique to estimate the economic value of a statistical life from Swiss labour market data. To our knowledge, no such study has ever been undertaken with Swiss data. The great majority of existing studies are from the United States, and there are relatively few studies in Europe.[2] The study on the external costs of energy cycles by the European Commission (1995), summarises the existing studies using the hedonic approach, and reports a mean estimate for the value of a statistical life of US$ 3.2 million (1990 dollars) for the European studies and US$ 4.5 million for the US studies. These values are of the same order of magnitude as those surveyed by Viscusi (1993), where a majority of US estimates fall between US$ 3 million and US$ 7 million (1990 dollars). It should be noted that estimates vary widely, from 500'000 US$ (1988 dollars) in Thaler and Rosen (1975), to US$ 16 million (1990 dollars) in Moore and Viscusi (1990).

Existing studies explicitly valuing the risks to life and health in Switzerland are generally found in the environmental domain. Values of life and health are usually integrated in the valuation of external costs, generally by using the human capital approach (or by transferring values from other studies). The valuation of the economic value of morbidity or mortality which results from those studies is however not theoretically correct, for at least two main reasons (for a discussion, see e.g. Viscusi, 1986). First, as with other benefit categories, it is the willingness to pay (or the willingness to accept a compensation) which is the correct measure for valuing reductions in morbidity or mortality risks. Second, policies and projects do not usually give rise to the prospect of certain death or illness for specific individuals. Rather, they generally modify mortality or morbidity *rates* for whole populations, and thus change the probability of death or illness for unidentified individual members of that population. Therefore, the correct approach should refer to *ex ante* measures of *risks* for fatal or non-fatal accidents, and not to *ex post* measures of certain identified deaths or injuries. Approaches which are based on the financial costs of fatal or non fatal accidents (e.g. on medical costs, settlements in courts or lost earnings values) all refer to *ex post* compensation measures for an identified individual's death or injury, which is thus not necessarily a reliable surrogate for the benefits of risk reductions.

In a recent study by Sommer et al. (1999), the valuation of air pollution mortality risks in Switzerland is assessed in two ways. The first is based on the transfer of results from hedonic and contingent valuation studies realised in different countries and contexts. The resulting base value for a statistical life is € 1.4 million (US$ 1.5 million). This value is then adapted to account for different factors supposed to influence willingness to pay, the main one considered being the structure of the age distribution of the victims (resulting in an alternative value of € 0.9 million). The second way is based on the human capital

2. One of the main reasons why economic valuation of risks to life and health is more widespread in the US is that Presidents since the 1970s have issued executive orders calling for analysis of the benefits and costs of major regulations, in particular environmental regulations (cf. Farrow and Toman, 1999).

approach.[3] By using the average labour income, accounting for life expectancy and using a discount rate of 2 %, the authors value a fatality at € 649'000 (US$ 696'691). An adjustment to this value is operated by accounting for pain and suffering, based on reparations legally determined for fatal accidents. The final value amounts to € 1.095 million (US$ 1.18 million).

At the policy level, to evaluate the social cost of road accidents, the Swiss Federal Office of Statistics (1999) uses a mean value of CHF 1.8 million (US$ 1.2 Mio) for a fatal accident and of CHF 0.8 million (US$ 0.52 Mio) for a non fatal accident. These values are again mainly calculated using productivity losses associated with mortality or illnesses, and on the amount of monetary damages as determined in courts.

In our paper, we use two Swiss labour market datasets to provide some new and more theoretically sound estimates of the value of risks to life based on the hedonic approach. We extend the simple hedonic wage regression by following MOORE and VISCUSI (1988) to account for the expected duration of remaining lifetime. With one dataset, we are also able to distinguish workers covered from collective agreements from those who are not. Our results are mainly consistent with those found in the previous literature in this field. In particular, the value of a statistical life is not unique, but varies with age, union coverage, risk level and model assumptions. However, our results are consistently an order of magnitude higher than those of existing studies in Switzerland, none of which rely on the hedonic approach. Interestingly enough, our estimations show that the workers' discount rate is not significantly different from zero with the SFLS sample, and even negative with the SWSS database. Although this result could add some elements in the discussion over the choice of the appropriate discount rate in applied studies, it is not really surprising, knowing that in Switzerland real interest rates have been relatively low in recent years.

The paper proceeds as follows. Section 2 briefly presents the theoretical foundations of the hedonic approach. Section 3 describes the data. Section 4 illustrates the empirical results, and finally we conclude and present some qualifications.

2. THE TRADITIONAL HEDONIC MODEL

The hedonic approach can be traced back to a general comment in Adam Smith's *Wealth of Nations*, who observed that wage rates should reflect the characteristics of the job. In particular, other things equal, unpleasant and risky jobs should command a positive compensating wage differential. More generally, the hedonic approach is based on the fact that some goods or factors of production are not homogeneous and can differ on a number of characteristics. This valuation technique thus estimates the implicit prices of the characteristics that differentiate closely related products or factors of production.[4]

3. The human capital approach was also used by Infras, Econcept and Prognos (1996), an influential study on the external costs of energy and transport in Switzerland. However, this latter study only value morbidity and not mortality.

4. For an application to the housing market, see e.g. PALMQUIST (1991).

On the labour market, the wage is the result of the equilibrium between labour demand and supply. There are many characteristics that are demanded and supplied together with labour services, one being safety. Therefore, all other things being equal, we may expect that firms will pay a lower wage to compensate for the increasing costs of reducing job risks, while workers will demand higher wages to compensate for higher risks. At the equilibrium, the wage rate that results will incorporate these job attributes, and it should therefore be possible to infer the wage-risks tradeoffs from market observations (for a detailed discussion, see VISCUSI, 1993). Under the assumption that workers' tastes for safety differ among them, and that firms' cost to reduce the riskiness of the job are different, the compensating differential model predicts a positive relation (i.e. an equilibrium locus) between the wage rate and job risk (or a negative relation between the wage rate and safety).[5] The additional main assumptions of the hedonic approach are the following (see e.g. PEARCE and MARKANDYA, 1989): (i) workers have adequate or sufficient knowledge of the risks involved and (ii) possess different preferences vis-à-vis health risks; (iii) the model is long term equilibrium; (iv) the labour market is functioning efficiently (i.e. without unemployment and monopoly or monopsony power).

The method of hedonic wages regression is used to estimate the monetary value of a "statistical life", and not the value of a given, identified life and the pain associated with it. Indeed, policies and projects generally involve changes in mortality or morbidity *rates* for whole populations, and hence changes in the probability of death or illness for unidentified members of that population. Individuals can and do make choices that involve change in the probability of death or illness.[6] Indeed, the aforementioned valuation techniques all represent different possibilities to infer willingness-to-pay for changes in the probability of death or illness from observed behaviour. To fully understand the approach, we repeat here ROSEN'S (1986) illustrative example. Take a large group of N people who contemplate a project which reduces the probability of death by $1/N$. Let V be the individual willingness-to-pay to reduce the probability of death, and thus V/N the amount that each person would be prepared to pay for that project. The population as a whole would pay N times this amount, or V itself. However, since the project reduces mortality by $1/N$ and N people are involved, on average one statistical life is saved, whose value is therefore V.

However, in transferring the results of monetary values obtained with the hedonic approach to public policies, it is worthwhile highlighting two main limits. First, there is some evidence that individuals treat voluntary risk differently from involuntary risk, with a lower willingness to pay for voluntary risk (LITAI, 1980). Second, the probability range over which the estimation is carried out in the labour market is normally different from the probability range for which a policy is considered. For instance, probabilities of death resulting from emissions of fuels cycles are on the order of 10^{-6} and lower, whereas the studies on which the estimated value of a statistical life are based are dealing with probabilities of 10^{-5} to 10^{-3} (see EC, 1995; FISHER, CHESTNUT and VIOLETTE, 1989).

5. Note that this result does not hinge on the assumption of risk aversion, as shown by VISCUSI (1978).
6. For instance when individuals use private transports instead of public transports.

3. DATA

The data set we use in this analysis combines individual labour market data with information on hazard rates by industries from the Swiss National Accident Insurance Company (also known as SUVA), mortality tables and other information on industries from the census of enterprises. For labour market variables, we use two datasets. The first is the Swiss Labour Force Survey (SLFS) of 1995, which is a telephone survey providing detailed information on approximately 30'000 individuals and their job characteristics. Our second source of labour data is the Swiss Wages Structure Survey (SWSS) of 1994, which is a questionnaire to firms, from which we extracted a random sub-sample of about 25'000 salaried employees. These databases do not contain exactly the same variables, and are thus used to check consistency of estimates. The SWSS is known to provide more accurate information on wages and includes additional information on collective agreement work contracts (about 30 percent of the sample, see Table 1). On the other hand, the SLFS contains additional information on occupations, family size, overtime hours (about 50 percent of the sample performs frequent overtime). Otherwise, the two samples are relatively similar (see Table 1). The workers have a mean experience of 12 years and a mean hourly wage rate of about 28 CHF. Note that, as expected, the dispersion of wages is much higher in the SLFS than in the SWSS. Small differences can be found on the composition of the workforce (about 60 percent male and about 85 percent workers have Swiss nationality in the SLFS, while about 70 percent for both categories in the SWSS), and the percentage of large firms (more than 100 employees) represented in the sample (50 percent in SLFS and 75 percent in SWSS).

As in most studies, we construct job hazard rates at the industry level, since it was unfortunately not possible to obtain hazard rates by occupations.[7] These industry risks are taken from SUVA (1994), as well as from unpublished tables for the most recent years.[8] We have averaged these risks over the years 1991–1995, in order to obtain more precise estimates of the actual death and morbidity probability faced by workers (non-fatal risks include professional illnesses and accidents occurring during worktime). The SUVA is the largest accident insurance Company in Switzerland, with about 55 percent of the workers affiliated to it. However, the statistics provided by the SUVA include the data for all the other insurance companies.

Following the convention of most previous studies, we have restricted our sample to private sector salaried workers aged 16 to 64 (61 for women) working no less than 20 hours per week. We have also excluded managers in the SLFS, and higher level executives in the SWSS, as the determination of their remuneration most probably follows more complex schemes.

The mean industrial death rate for the whole economy is 0.64 per 10'000 insured work-

7. In fact, the ideal risk measure would be based on subjective assessment of the mortality and morbidity risks of the job by both the worker and the firm (see Viscusi, 1993).
8. The fatalities are only those occurring on the work place and need not therefore be corrected for (exogenous) age and gender related mortality risks as in Marin and Psacharopoulos (1982).

ers for the SLFS and 0.59 for the SWSS. These figures are quite close to the mean value (over 1991–1995) computed from SUVA's official tables of 0.74 death per 10'000 workers, so that no major representativity problem seems to be present. These mean death rates range from 4.86 per 10'000 insured workers in the building sector and 4.58 for the mineral and metal industry, to 0.00 in the tobacco and the clothing industry. Industrial non fatal risk is obviously much higher and ranges from 2'961 casualties per 10'000 insured workers in the building sector, to only 103 in the insurance and the banking sectors.

Table 1: Selected Sample Characteristics, SLFS 1995 and SWSS 1994

Variable	SLFS		SWSS	
	Mean	Std Dev	Mean	Std Dev
Hourly wage rate (in 1995 Swiss Francs)				
Weekly hours of work				
Education (in years)				
Experience				
Tenure				
Married				
Swiss nationality				
Large firm (more than 100 employees)				
Industrial rate of foreign workforce				
Foreign resident				
Latin canton				
Industrial death rate (per 10'000 workers)				
Industrial non-fatal risk (per 10'000 workers) (illness and accidents)				
Gender (1 for male)	0.58	0.49	0.67	0.47
Employee with subordinates	0.27	0.44	–	–
Frequent overtime	0.48	0.50	–	–
Flexible hours of work	0.32	0.47	–	–
Shiftwork	0.07	0.25	–	–
Sometimes evening work	0.30	0.46	–	
Indeterminate contract	0.95	0.22		
Collective agreement work contract	–	–	0.28	0.45
Firm agreement work contract	–	–	0.10	0.30
Public sector type contract	–	–	0.01	0.09
Middle hierarchical level	–	–	0.07	0.26
Lower hierarchical level	–	–	0.12	0.32
Supervision and control level		–	0.12	0.32
Number of observations	*8'034*		*22'888*	

Additional variables not reported here include, for the SLFS: special bonus payments and gratifications, two-digit occupational dummy variables, and days of vacation. For the SWSS, only occupational dummy variables are not shown. Education is the number of (approximate) years for the highest educational attainment. Experience is defined traditionally as age minus years of education minus 6.

4. EMPIRICAL IMPLEMENTATION AND RESULTS

4.1 The traditional hedonic model

Our basic wage equation used for empirical applications of the hedonic approach takes the following form:

$$\ln w_i = \alpha + \sum_{k=1}^{m} \beta_k x_{ik} + \gamma DR_i + u_i \tag{1}$$

Where w_i is the hourly wage rate of worker i, α is a constant term, the x_{ik} are different personal and job characteristics variables of worker i ($k = 1, \ldots, m$), DR_i is the death risk faced by the individual in his industry, and u_i is a random error term reflecting unmeasured factors that influence the wage rate.

The x_{ik} are standard human capital and demographic variables, as well as variables pertaining to the job held by the individual, like the hierarchical position in the firm or the type of labour contract.

As already mentioned, due to lack of data, we use the mortality variable (DR_i) as calculated at the industry level. However, since not all workers face the same level of risk as the average in the industry, this risk measure will mask significant variation in injury risks across occupations.[9] Therefore, to correct somehow for this factor, we introduce a set of occupational dummy variables at the two-digit level.

Non fatal accidents are also part of the job risk and should therefore influence the wage rate. However, as in a majority of studies, we have decided not to include this variable in our estimations, because of its high collinearity with the fatal risk variable.[10]

In the same vein, and contrary to some other studies (see VISCUSI and MOORE, 1988 or VISCUSI 1993), we do not include the worker's compensation benefits for accidents in equation (1), as it is irrelevant for the Swiss labour market. Indeed, the program (entirely paid by employers) covers all expenses for medical care, and at least 80 % of the income, during all the period for which medical assistance is needed (for Canada, see COUSINEAU, LACROIX and GIRARD, 1992). In addition, as discussed by LEIGH (1995), workers' compensation variables are controversial even from a theoretical point of view, especially when workers are presumed to be more careless if death benefits are high and more careful when death benefits are low.

9. See DILLINGHAM (1985) for a discussion.
10. Unreported regressions showed that the non-fatal risk variable was mostly insignificant, with a negative coefficient and of marginal amplitude. An additional issue is related to the severity of accidents. Indeed, as pointed out by COUSINEAU, LACROIX and GIRARD (1992), payments for work will depend not only on the probability, but also on the (expected) severity of accidents. In theory, the number of days of absence per injury, as well as the gravity of the injury should be used. However, data from the SUVA do not contain the number of days of absence, but only the costs of injuries. Various attempts with such a variable proved unsuccessful, but did not affect our main results concerning the death risk premium.

Table 2: Results for the traditional model

Independent Variable	Parameter Estimates (standard errors)	
	SLFS	*SWSS*
Education	0.0562 (0.0026)	0.0634 (0.0009)
Experience	0.0277 (0.0014)	0.0256 (0.0006)
Experience squared ($\times 10^{-3}$)	−0.0492 (0.0031)	−0.4276 (0.0115)
Tenure	0.0038 (0.0006)	0.0046 (0.0002)
Married	−0.0293 (0.0126)	−0.0394 (0.0052)
Swiss nationality	0.1399 (0.0083)	0.0144 (0.0045)
Large firm	0.0552 (0.0083)	0.0985 (0.0035)
Industrial rate of foreign workforce	−0.4298 (0.0489)	−0.4459 (0.019)
Foreign resident	0.1081 (0.0246)	−0.0070* (0.0054)
Latin canton	−0.0395 (0.0084)	−0.0471 (0.0035)
Gender (1 = male)	0.0827 (0.0120)	0.1067 (0.0048)
Gender × married	0.1039 (0.0161)	0.1004 (0.0063)
Collective agreement work contract	–	−0.0262 (0.0035)
Firm agreement work contract	–	−0.0122 (0.0050)
Public sector type contract	–	0.0192* (0.0157)
Middle hierarchical level	–	0.2590 (0.0062)
Lower hierarchical level	–	0.1190 (0.0049)
Supervision and control level	–	0.0187 (0.0047)
Employee with subordinates	0.0811 (0.0092)	–
Frequent overtime	0.0087* (0.0087)	–
Flexible hours	0.0586 (0.0093)	–

Independent Variable	Parameter Estimates (standard errors)	
	SLFS	*SWSS*
Shiftwork		
Evening work		
Indeterminate contract		
Death risk (per 10'000 workers)	**0.0169** **(0.0047)**	**0.0215** **(0.0021)**
Adjusted R^2		
Standard error of the regression		
Observations		

* Statistically not significant at the 0.05 level.
The specification for the SLFS also includes dummies for special payments, bonuses, days of vacation and 2-digit occupational dummy variables. For the SWSS, occupational dummy variables were also included.

As can be seen from the R^2 measure, the fit of the regression is good, in particular with the SWSS sample. Most variables have the expected coefficients and the magnitudes are remarkably similar across the two datasets. The only notable exceptions are the nationality and the foreign resident variables, so there may be a representativity difference of foreigners in both samples. The coefficients on nationality and foreign resident indicate that the premium for these workers compared to foreign non-residents (mainly guest-workers and cross-border workers) are positive and significant with the SLFS, while only the Swiss nationality variable is significant (and of small amplitude) with the SWSS. As expected, the hourly wage rate rises with education, experience, tenure and the size of the firm. Being male bears a premium of 8–10 %, which can be taken as a crude measure of discrimination.[11] The marital status has opposite effects on men and women as can be seen from the crossed gender and "married" coefficients. This result would suggest that marriage is considered as a factor of stability that enhances the loyalty to the firm only for men. Another interesting result is provided by the industrial rate of foreign workforce, which indicates that wages are notably lower the higher the share of foreign workers in the industry. These results are broadly consistent with other studies that have relied on the SLFS (e.g. FERRO LUZZI, 1994). Most job specific variables included in the SLFS estimation also have coefficients that are significant and have the correct sign. These variables capture part of the compensating differentials that pertains to specific working conditions, like the type of contract and the kind of timetable.

11. We have also estimated the model with gender sub-samples, but because of the high number of occupational dummy variables, some regressions were not full-rank. We therefore added an interaction of gender and the industrial death rate variable, which was always negative but significantly so only with the SWSS sample. These results suggest that the compensating wage differential is higher for women than for men, although the possibility remains that this interaction term captures some other gender related effect.

Turning now to the risk variable, we note that its coefficient has the correct sign and is significant for both the SWSS and the SLFS samples. The risk coefficients can be interpreted as the average willingness to pay (in percent of the wage rate) for a marginal increase in safety (or a marginal decrease in injury risk). This coefficient can be used to derive a measure of the value of a statistical life on the Swiss labour market. Using the average hourly wage and weekly hours, we compute mean annual earnings. Once multiplied by the coefficient on death risk, we get the mean wage premium a worker demands to switch to an industry where the fatal risk is 1/10'000 higher. Again multiplying by 10'000 (the denominator of the death risk measure), we obtain the value of a statistical life. In our case, the resulting value of a statistical life is approximately CHF 9.42 million (6.08 Mio 1999 US$) for SLFS and CHF 12.88 million (8.31 Mio 1999 US$) for SWSS. It should be stressed that these statistical values of life are only valid for small changes in risk, i.e. of the same order of magnitude as those faced by workers in the labour market. In our context, an individual faced with an annual additional fatal risk of 0.64×10^{-4} (the mean for the SLFS sample), or 0.59×10^{-4} (the mean for SWSS), would receive a yearly wage premium of CHF 603 and CHF 760 respectively.

These values are analogous to those found in most studies surveyed by Viscusi (1993), although a great majority of these refer to US or UK data. It is difficult to find an explanation for the difference of value between the two samples. It may be that the occupational dummies included in the SLFS regression capture more of the occupation specific risks than the more broadly defined occupational dummies used for the SWSS regression.

4.2 The level of risk and the value of a statistical life

In the traditional hedonic model (1), we assumed a constant wage premium per unit of risk. However, there is no reason why all individuals should have the same preferences with respect to death risks, and thus demand the same wage risk premium per unit of risk. Indeed, we may expect that individuals working in high-risk occupations could be less averse to risks and thus willing to accept lower compensation per unit of risk. This may explain some of the differences in the value of statistical life which are found in the literature since, apart from different modelling assumptions, the samples analysed may be different with respect to the risk level. This point was emphasized by Viscusi (1978; 1992), when explaining the relative low estimates obtained by Thaler and Rosen (1975). Indeed, the sample considered by Thaler and Rosen (1975) is composed of workers in very hazardous occupations, who may be less averse to serious death risks, than the average member of the population. Those workers may thus demand a lower wage risk premium per unit of risk, resulting in a lower value for a statistical life.

In order to capture the influence of the level of risk on the value of a statistical life, we simply extended the traditional model (1) by including the square of the death rate. In that case, the value of a statistical life thus depends on the level of risk. If a negative coefficient emerges, it would imply that the value of a statistical life or the wage premium associated to the death rate decreases with the level of riskiness. This would provide a simple test to check whether people choosing high-risk occupations self-select in these jobs and demand lower premiums for a given marginal increase in risk.

Our findings are summarized in Table 3, where we reported only the results with the SWSS sample, since they were not significant with SLFS. The coefficients on death risk and death risk squared are both significant and have the expected signs. Table 3 also shows the variation in the value of statistical life, when considering the risk levels pertaining to the different quartiles in the SWSS sample. It is worth noting that the value of a statistical life is relatively similar for the majority of workers in the low-risk industries, the values ranging from CHF 26 to 32 million. Indeed, between the 1st and 3d quartiles, calculated confidence intervals do not allow us to reject the hypothesis that the values of statistical life are different. On the contrary, the value of a statistical life decreases considerably in high-risk occupations represented in the fourth quartile. There, the difference is statistically significant compared to the first three quartiles. Our results seem thus to confirm that workers who have selected themselves into high-risk jobs demand especially lower risk premiums than those in more normal jobs, where the risk premium remains relatively constant. However, to fully corroborate this result, the traditional hedonic model (1) needs to be modified in order to endogenize the risk variable, as has been stressed by some authors (Garen, 1988; Siebert and Wei, 1994; Hwang, Reed and Hubbard, 1992). Unobserved workers' attributes may induce them to take the riskiness of the job into account – more able workers going for less hazardous jobs. Typically, instrumental variables estimation is called for to correct for the endogeneity bias. Our attempts to instrument the risk variable have however proven unsuccessful due notably to the poor choice of instruments available with the SWSS.

Table 3: Risk level and value of statistical life (SWSS sample)

Variable	Parameter Estimates (standard errors)
Death risk	0.053715 (0.0048)
Death risk squared	−0.008302 (0.0011)
Adjusted R^2	0.622
Observations	22'888

Quartile	Average Death Risk ($\times 10^{-4}$)	Value of life (in CHF million)
First quartile	0.058	31.59
Second quartile	0.175	30.43
Third quartile	0.649	25.72
Fourth quartile	2.040	11.88
Sample mean	0.590	26.30

See Table 2 for the other control variables.

4.3 The impact of union coverage

As mentioned, the hedonic model rests on the traditional atomicity assumption of the labour market, which is clearly violated in the reality. Many institutional arrangements, social habits and government interventions will introduce some rigidities and distortions in the labour market. Here we focus on unions as they have a major influence on the wage determination process, but also because they are greatly concerned with working conditions, especially those pertaining to safety. The effect of unions on risk compensation is ambiguous, since they can either directly require better safety measures on the workplace or demand higher wage premiums for hazardous working conditions. In the former case, the risk premiums will be lower if firms must incur costs to reduce the fatality risk. Conversely, if unions are more efficient in bargaining directly for risk compensation than unorganised workers, one should observe higher injury risk wage premiums in the covered sectors. One should also bear in mind that workers may select the occupation or industry depending on whether it is covered by collective agreements or whether they are themselves unionized.

Information on collective agreements is not available for the SLFS, so we restrict our analysis of unions to the SWSS sample. Collective and firm agreement coverage account for 38 % of the workers in our sample. A first result on the impact of union coverage is provided by the traditional hedonic model already reported in Table 2. Both collective agreement and firm agreement dummy variables have negative coefficients, which suggests that, other things equal and contrary to most studies, unions in Switzerland either do not bargain aggressively for higher wages, or that low-pay workers are over-represented in covered sectors. Introducing a union coverage-fatal risk crossed term does not alter this result as its coefficient is not significantly different from zero.

In order to have a more accurate image of the impact of union coverage on the risk premium, it is desirable to estimate separate regressions for both covered and non-covered sectors. As mentioned, workers may self-select into the collective agreement covered sector, which may result in biased coefficient estimates with ordinary least squares. Standard techniques exist that enable one to correct for this selection bias.[12] In Table 4, we report both uncorrected OLS and selectivity corrected estimates for both the covered and non-covered sectors.

12. We use the two-stage switching regression technique as described in MADDALA (1983). It basically consists in estimating a probit model for union coverage choice, and then to introduce inverse Mill's ratios into the wage equation of each sector.

Table 4: Fatal risk premiums for covered and non-covered sectors (SWSS sample)

Variable	Parameter Estimates (standard errors)	
	Covered	Non-covered
Average death risk (per 10'000 workers)		
Uncorrected model:		
coefficient on death risk (per 10'000 workers)	0.03315 (0.00295)	0.02596 (0.00325)
Adjusted R^2	0.531	0.610
Selectivity-corrected model:		
coefficient on death risk (per 10'000 workers)	0.0282 (0.0037)	0.0232 (0.0025)
coefficient on inverse Mill's ratio	0.9719 (0.0891)	0.7554 (0.0688)
Adjusted R^2	0.570	0.621
Observations	8'653	14'235

See Table 2 for the other control variables.

Both coefficients attached to the deàth risk variable are highly significant as in previous regressions with the SWSS. It is interesting to note that the death risk coefficient is higher for covered workers than for non-covered workers by about 27%. This result is in accordance with other studies that explicitly account for the role of unions (THALER and ROSEN, 1976; SIEBERT and WEI, 1994). However, confidence intervals of these coefficients do not enable us to accept the hypothesis that they are statistically different. This result also goes counter the widespread idea that unions in Switzerland bargain specifically for better safety measures, as it would theoretically imply a smaller compensating differential in the covered sector. It may be that other forces are at work here that are not controlled for. More specifically, the risk variable may be endogenous as already stressed. Another potential bias arises from the endogeneity of the choice of sector. Our selectivity-corrected estimates indicate that the bias is upwards for the coefficient attached to the death risk variable.

The estimated model can be used to infer the type of self-selection that is taking place between covered and uncovered sectors, as the coefficients attached to the inverse Mill's ratios are the covariances between the wage equation error terms and the stochastic term of the choice equation (σ_{1u} for the covered sector and σ_{2u} for the uncovered sector). Following MADDALA (1983, chap. 9, pp. 257–260), we can establish that when both these covariances are positive, those who chose the collective bargaining sector are worse than average in both sectors, but they are better in the covered sector. Those who chose the uncovered sector are above average in both sectors, but they are better in the uncovered sector than in the covered sector. The reverse would be true if both covariances were positive, with still a relative advantage for both workers' types, but an absolute advantage in both sectors for covered sector workers. If $\sigma_{1u} > 0$ and $\sigma_{2u} < 0$, both covered and uncovered sectors workers have an absolute advantage in their sector of choice, while the reverse case in not possible.

In our case, both inverse Mill's ratios have positive signs and are statistically significant. Hence, workers choosing the collective agreement sector are less efficient than the average worker, but they are relatively more efficient in this collective agreement sector. On the contrary, workers who are not covered by a collective agreement fare better than the average worker but are comparatively more efficient in the non-covered sector.

The values of statistical life from these estimates are higher than those found when aggregating both covered and uncovered sectors. The splitting of the sample raises the question as to which mean wage rate should be used to calculate the value of a statistical life. Using the same mean aggregate wage rate of the entire SWSS sample gives values of CHF 19.85 million (US$ 12.81 Mio.) for covered workers, and CHF 15.55 million (US$ 10.03 Mio.) for non-covered workers. However, when taking the selectivity corrected estimates, the resulting values of statistical life are lower with values of CHF 16.90 million (US$ 10.90 Mio.) and CHF 13.89 million (US$ 8.96 Mio.) respectively. Confidence intervals of these estimates reveal that these values are all in the same range.

This calculation does not account for the fact that wage levels are different across the two sectors.[13] Using the mean wage rate for each sector and the selectivity corrected estimates, we arrive at values of CHF 18.40 (US$ 11.87) million for covered workers and CHF 16.34 (US$ 10.54) million for non covered workers, so that the difference between sectors is actually much smaller than at first thought. Still, both of these values remain in the same range the value of CHF 12.88 million found with the aggregate sample.

4.4 Accounting for the duration of life

The traditional hedonic model (1) does not account as well for the fact that the quantity and the quality of life at risk differs. For instance, a 20 years-old worker faces a more substantial loss from a given death risk than a 60 years-old worker. Moreover, age may be an important factor in several other aspects, e.g. in explaining workers' choice in higher risk occupations. In what follows, we will however only focus on the quantity aspects of fatal risks valuation, since as already mentioned the health impacts of non-fatal accidents were not significant in our estimations.

There are several possibilities to obtain a quantity-adjusted value of statistical life (see Viscusi, 1993; or Moore and Viscusi, 1988). The simplest is to interact the death rate with the worker's age, and thus add a new variable $DR \times$ worker's age in the traditional hedonic regression (1), as in Thaler and Rosen (1975). A refinement would consist in including a variable reflecting the expected years of life lost ($DR \times$ life expectancy). Here, we complement these measures by following Moore and Viscusi (1988),

13. The mean monthly (adjusted for hours of work) wage rates for our sample are CHF 4'625.6 and CHF 5'245.6 for covered and non-covered workers, respectively.

who introduce the role of discounting by estimating the discounted loss in life expectancy. Thus, we replace the death rate variable with the following new risk variable in the traditional hedonic model:

$$\text{Expected Life Years Lost} = DR(1 - e^{-rT})/r, \tag{2}$$

where r is the discount rate and T is the remaining period of life.

This formula merely says that, with a positive discount rate, expected years of remaining life will be valued less in the distant future.[14] Note that with $r = 0$,this formula reduces to the product $DR\times$ life expectancy mentioned above. The equation to be estimated then becomes:

$$\ln w_i = \alpha \quad \sum_{k=1}^{m} \beta_k x_{ik} + \gamma DR_i(1 - e^{-rT_i})/r + u_i \tag{3}$$

Since the risk variable is a nonlinear function of the discount rate parameter, it is necessary to estimate the model with non-linear regression techniques. The results are reported in Table 5.

Table 5: Accounting for the duration of life

Variable	Parameter Estimates (standard errors)	
	SLFS	*SWSS*
Simple model with age interaction:		
DR	456.379	594.282
	(135.47)	(65.99)
$DR\times$ worker's age	−7.5739	−9.2298
	(3.3505)	(1.5239)
AdjustedR^2	0.402	0.62
Unconstrained model (non-linear least squares): Expected years of life lost = $DR(1 - e^{-rT})/r$		
γ	1.1543*	1.9808
	(1.3701)	(0.7230)
r	−0.0495*	−0.0434
	(0.0330)	(0.0107)
Adjusted R^2	0.402	0.621
Constrained model ($r = 0$, OLS): Expected years of life lost = $DR\times$ life expectancy		
γ	4.620	6.260
	(1.0975)	(0.5269)
AdjustedR^2	0.402	0.621
Observations	8'034	22'888

* Not significantly different from zero at the 0.05 level.
HereDR is the actual death rate (not multiplied by 10'000).
See Table 2 for the list of control variables.

14. The formula is equivalent to the usual discounting factor $\int_0^T e^{-rt}dt$.

In the model with the age-death rate interaction term added, the coefficient is negative and significant, which is consistent with the idea that the wage premium demanded by younger workers should be higher. There is however no way to know if this reflects true "quantity adjustment" for years of life lost or for the fact that younger workers may be more productive at risky situations. The first row of Table 6 provides estimates for the value of a statistical life implied by this model at different ages. With the SLFS, this value ranges from CHF 17 million (US$ 10.97 Mio.) when age is 20 to CHF 4.33 million (US$ 2.8 Mio) when age is 50. The values are never significantly different though. With the SWSS, these values are CHF 24.5 and 8 million, respectively. Here, the differences are significantly different across all age groups. These figures are consistent with the "average" values obtained in the traditional hedonic model (1), and they suggest that age is an important factor to consider in valuing a statistical life.

Table 6: Duration of life and value of a statistical life

Model	*SLFS* Age			*SWSS* Age		
	20	35	50	20	35	50
DR × worker's age	17.0	10.67	4.33 ($ 2.8)	24.54 ($ 15.83)	16.24 ($ 10.48)	7.95 ($ 5.13)
Unconstrained model (with $r = -0.0434$)				34.22 ($ 22.08)	16.54 ($ 10.67)	7.32 ($ 4.72)
Constrained model (with $r = 0$)	15.46 ($ 9.97)	11.59 ($ 7.48)	7.73 ($ 4.99)	22.49 ($ 14.51)	16.87 ($ 10.88)	11.25 ($ 7.26)

NB: Expected remaining life years are approx. 60, 45, and 30 for the age levels 20, 35 and 50, respectively. Values are in CHF million. US$ values in million in parentheses.

In the second (unconstrained) model, with discounting of future years of life assumed, the results are somewhat unexpected, since they show a negative discount rate. We do not want to enter here in a detailed discussion about discount rates, a subject that has interested economists since long time. Moreover, note that the discount rate is significant and negative only with the SWSS sample. A first explanation could be that our model is mispecified. A second explanation could be related to the nature of discounting at the individual level, which is usually related to three factors (e.g. see Hanley, 1992): the "pure" time preference, the growth rate of consumption over time, and the elasticity of the marginal utility of consumption. Therefore, note that a negative discount rate could result from a relatively low individual pure time preference combined with a decreasing growth rate of consumption. This latter possibility is not to be excluded, since in the 1990s the real consumption growth rate (per head) has been very low and even negative in Switzerland. By the same token, in recent years real interest rates have been at historically low levels in Switzerland.[15] Some other studies have found that individuals

15. Nominal returns on Swiss Confederation bonds were between 4 and 5 % in 1995, while inflation was running at around 1.9 %.

may indeed possess negative discount rates. For instance, the experimental study of LOEWENSTEIN and PRELEC (1991) has shown that individuals prefer to delay the best results of their actions, so that their plans do not lead to a decreasing value over time. However, since the possibility of negative discount rates for on-the-job risks in Switzerland could have important implications, we envisage further and more detailed studies testing specifically for this surprising result.

Finally, the model with expected years of life lost interacted with the death rate corresponds to a constrained version of the previous model, with the discount rate set to nil. Again, the results are quite compatible with those obtained with the simple age interaction term, though with less variation in values of life across age levels. Note that going from the unconstrained to the constrained model could be assimilated to a rise in the discount rate, which should bring about a decrease in the value of life, all things equal.[16] This is however only observed in the 20 years age case. For the other age levels, this discount rate effect is more than compensated by the higher coefficient on the death rate variable estimated in the constrained model. As with the age interaction model, the values are statistically different across age groups only with the SWSS sample.

5. CONCLUSION

Our study is the first attempt to apply the hedonic approach to value fatal risks in Switzerland. Our results show that the value of a statistical life ranges from CHF 10 million to 15 million (6.5–9.5 million current US$). These estimates are relatively substantial, when confronted to an average annual wage of about CHF 57'000. However, it should be recalled that the value of a statistical life does not represent the amount a representative worker could and/or would pay to avoid certain death. In fact, it results from wage premiums for small incremental death risks, in our case a higher annual wage rate in the range of CHF 600 to CHF 800 for an additional fatal risk in the order of 10^{-4}. In other words, this is an *ex ante* measure of the compensating amount a representative worker would receive to accept working in an industry with a higher fatal probability of 1/10'000. Therefore, this amount does not bear the same meaning as other *ex post* monetary approaches used in Switzerland to value death losses, like lost incomes and insurance values.

In addition, our study points out that distinct groups of individuals attach different values to risks to life and thus that the value of a statistical life is heterogeneous. In particular, individuals in high-risk industries demand lower risk premiums than those in low-risk occupations. As shown by VISCUSI (1992), the risk level may thus be an important factor in explaining differences in values of statistical life. Furthermore, since unions bargain on safety conditions, being in a covered sector may also have an influence on

16. The partial derivative of the "expected years of life lost" (equation (2)) with respect to the discount rate is always negative or nil.

the value of a statistical life. Compared to uncovered workers, we show that covered workers receive significantly higher wage premiums. This result goes counter the widespread idea that unions in Switzerland bargain specifically for better safety measures. Finally, the last determinant for the value of a statistical life we considered is age. As expected, younger workers demand higher risk premiums. An intriguing result is however obtained by estimating the implicit discount rate that workers use in valuing fatal risks. Indeed, in our case the discount rate is not significantly different from zero with the SLFS sample, and even negative with the SWSS database.

In any case, even accounting for variations in values of life depending on union coverage, risk level and age, our results are of an order of magnitude higher than existing studies in Switzerland. Nevertheless, it should be noted that even if in some case the population at risk may be different, the level of risk in those latter studies is of the same order of magnitude as in our databases. For instance, concerning the social costs of road accidents valued by the Swiss Federal Office of Statistics (1999), the death risk is 0.82 per 10'000 individuals, while our sample mean fatal risk rate is about 0.6×10^{-4}. SOMMER et al. (1999) infer from epidemiological studies that premature death risk from air pollution in Switzerland is 4.68×10^{-4} and 2.49×10^{-4} for air pollution related to traffic, which are somehow in the higher range of the risks levels in our samples. Therefore, our results could be relevant indicators of the values of a statistical life in the context of those studies.

Our results may have additional policy relevance at two different levels. First, they may be used to assess the presence of labour market failures, if the wage premium does not adequately compensate workers for the risk they voluntarily incur. From our study, we can infer that the Swiss labour market indeed recognizes wage premiums for higher risks, which results in a substantial implicit compensation for fatal events. However, since we do not know what this compensation would be if workers were perfectly informed about their risks, we are not able to conclude on the need for additional government intervention. Second, our results could be used in the context of public policy valuation, since public policies often do not imply certain death for given individuals, but rather modify the probability of fatal events for large number of people. In this case, the value of a statistical life represents the average willingness to pay for the benefits associated with risk-reducing projects or regulations, and could thus be used in a benefit-cost context.

Finally, we would like to outline that our analysis could be extended in several directions. In particular, it would be interesting to expand the traditional model in order to endogenize the risk variable, since workers may consider this attribute when choosing their job. Moreover, our treatment of non-fatal risks is not totally satisfactory, and better results could be obtained by including the severity of accidents. Additionally, it would be interesting to assess the role of worker's wealth on the wage risk premium (see VISCUSI and EVANS, 1990). Unfortunately, the necessary data to carry out these extensions are currently lacking in Switzerland. However, such additional studies would help improving our results for the economic assessment of risk-reducing policies, by pointing out the additional factors determining the variation in the value of a statistical life.

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SUMMARY

In this paper, we use the hedonic approach to estimate the value of a statistical life based on the 1995 Swiss Labour Force Survey (SLFS) and the 1994 Swiss Wage Structure Survey (SWSS). Roughly, the value of a statistical life in Switzerland ranges from CHF 10 to 15 million (6.5–9.5 million current US$). However, more important than the absolute value, our estimates should be taken as an indicator of the value of a statistical life, which is of an order of magnitude higher than previous studies on the value of life in Switzerland, none of which is based on the hedonic approach. Our study confirms previous literature, since the value of statistical life varies with risk level, union coverage, age, and model assumptions. In particular, by separating between individuals with union coverage and those without, we find a slightly higher (but not significantly so) risk premium for the former, which runs counter the idea that in Switzerland unions bargain for safety measures. Finally, along the lines of Moore and Viscusi (1988), we take into account the discounted life years lost, and find a discount rate not significantly different from zero with SLFS and even negative with the SWSS sample.

ZUSAMMENFASSUNG

In diesem Artikel wird der hedonische Ansatz verwendet, um den Wert eines statistischen Lebens zu berechnen. Die Schätzungen beruhen auf Daten der Schweizerischen Arbeitskräfteerhebung (1995) und der Schweizerischen Lohnstrukturerhebung (1994). Gemäß unseren Schätzungen beträgt der Wert eines statistischen Lebens zwischen 10 und 15 Millionen CHF. Diese Zahl übertrifft die Ergebnisse früherer, nicht auf dem hedonischen Ansatz beruhenden Studien für die Schweiz. Im Einklang mit den Befunden früherer Studien hängt der Wert eines statistischen Lebens vom Risiko, der Gewerkschaftseinbindung sowie dem Alter ab. Die geringfügig höhere Risikoprämie von Arbeitern, welche unter Gewerkschaftsschutz stehen, lässt jedoch die Effizienz der Gewerkschaften in Bezug auf das Aushandeln von Sicherheitsmaßnahmen anzweifeln. Nicht zuletzt berücksichtigen wir auch die erwartete Restlebensdauer (vgl. Moore und Viscusi (1988)) und finden eine Diskontrate, die je nach Datensatz entweder nicht signifikant oder sogar negativ ist.

RESUME

Dans cet article, nous estimons la valeur d'une vie statistique à l'aide d'une approche hédoniste du marché du travail. Pour ce faire, nous utilisons les données de l' Enquête Suisse sur la Population Active (ESPA) de 1995, les données de l'Enquête Structurelle sur les Salaires en Suisse de 1994, ainsi que les tables d'accidents de la Caisse nationale suisse d'assurance en cas d'accidents (SUVA). Nos résultats indiquent que la valeur

d'une vie statistique en Suisse est comprise entre 10 et 15 millions de francs environ. Nous obtenons une valeur de la vie beaucoup plus élevée que celles obtenues dans d'autres études réalisées en Suisse, qui sont fondées sur des approches différentes. Les résultats de notre étude sont comparables avec ceux de la littérature existante dans l'approche hédoniste, car nous tenons compte des divers facteurs pouvant influencer la valeur d'une vie statistique, tels que le niveau de risque, la couverture par des conventions collectives et l'âge. En particulier, nous estimons le modèle de manière séparée pour les travailleurs couverts et non couverts par des contrats collectifs. Nos résultats suggèrent que les travailleurs couverts obtiennent une légère prime par rapport aux travailleurs non couverts, mais la différence n'est pas statistiquement significative. Ce résultat va quelque peu à l'encontre de la perception assez répandue que les syndicats en Suisse négocient activement pour des mesures de sécurité sur le lieu de travail. Enfin, en suivant les travaux de Moore et Viscusi (1988), nous prenons en compte la durée de vie et trouvons un taux d'actualisation nul, voire négatif selon l'échantillon utilisé.