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# Estimated hedonic wage function and value of life in an African country

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## Abstract

This paper reports the first study of compensating wage differentials for work-related fatalities in an African country. Using original data from the Tunisian Caisse nationale de la sécurité sociale, statistically significant compensating wage differentials are found. The implied value of statistical life is found between $553 320 and $682 080 (US $ 2000, or between $783 264 and $965 533, US $ 2013), smaller than the value estimated from developed countries. Policy makers interested to decrease occupational risk fatalities could use this outcome as a benchmark.

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## 1. Introduction

Many public projects for better road or workplace safety impose costs on society in exchange for reducing the risk of death and injuries. To determine whether a project is socially desirable, one has to compare the value of reducing risks to the costs of such reductions. The value of reducing risks can be estimated by the *revealed preference* approach, which has been used extensively to deduce a value of a statistical life (VOSL).

The majority of the studies conducted to date have been of the wage-risk type. *Wage-risk studies* or *hedonic wage function* estimate the wage premium associated with greater risks of death on the job. This premium is deduced by regressing the wage on the risk of death, accounting for factors, like traditional human capital variables, that may also influence the wage. The premium indicates that there is a trade-off between wealth and physical risk, and may be used to compute the VOSL[1].

Over the past three decades, there have been extensive discussions on this topic with a variety of data sets used in the empirical literature, mainly in developed countries. Generally, this literature shows that occupational or industry fatality rates enter the wage function with a positive and statistically significant coefficient. However, the VOSL estimates vary dramatically across studies, perhaps because of differences in the definitions of job risk (industry risk or occupational risk) and in risk preferences among samples of workers. For instance, Dionne and Lanoie (2004) review 42 studies in industrialized countries and find a range of VOSL between 0.4 to 25.7 million with a mean of $ 8 million (CND $ 2000). Bellavance et al. (2009) review 39 studies in developed countries and find a range between 0.5 and 53.6 million with a mean of $ 8.4 million (US $ 2000).

The purpose of this paper is to test the existence of a wage-risk premium in Tunisia using original labor market administrative data from the *Caisse nationale de la sécurité sociale*. To our knowledge, this is the first study which investigates the wage–risk relationship in an African country. This paper also provides estimates of the value of life and compares them with estimates for developed countries. Section 2 and section 3 present the theoretical and the empirical hedonic wage model, respectively. Section 4 describes the data source, while section 5 provides estimates of the VOSL and section 6 concludes.

## 2. The theoretical model[2]

The standard model for evaluating the VOSL is based on the *willingness-to-pay* (WTP) concept. The model stipulates that each worker is endowed with an initial wealth w, and with only two possible states of nature in relation to his existence, either to be alive ($a$) or to be dead ($d$). The probabilities associated with these states are respectively $(1-p)$ and $p$. The worker's well-being is represented by his expected utility:

$$EU(w) = (1 - p)U_a(w) + pU_d(w), \quad (1)$$

[1] See Dionne and Lanoie (2004) for a more complete discussion.
[2] This section is inspired by Bellavance et al. (2009).

where $U_a(w)$ and $U_d(w)$ represent, respectively, the worker state-dependent von Neumann–Morgenstern utility functions. Furthermore, one may suppose that, ceteris paribus, the worker will prefer life to death. Thus, we have the following inequality:

$$U_a(w) > U_d(w) \quad \forall w, \tag{2}$$

and that the marginal utility of income is positive,

$$U_a'(w) > 0, U_d'(w) > 0 \quad \forall w \tag{3}$$

The literature often assumes that the worker has aversion to risk in both states of nature. This means that his marginal utility is strictly decreasing in both states:

$$U_a''(w) < 0, \; U_d''(w) < 0 \; \forall w \tag{4}$$

The worker chooses from potential wage-risk combinations along some market opportunities to maximize his expected utility (equation 1).

The willingness-to-pay element used in evaluating the value of life boils down to asking how much one is willing to reduce w in order to lower p and keep the same level of welfare. In mathematical form, this question is a matter of calculating:

$$\frac{dw}{dp} = \frac{U_a'(w) - U_d'(w)}{(1 - p)U_a'(w) + pU_d'(w)} > 0 \tag{5}$$

Using this marginal amount that the individual is willing to pay to avoid a small variation in risk (d$p$), we can determine the corresponding VOSL using the formula (dw/dp)/dp.

## 3. The hedonic wage model[3]

The basic framework for hedonic wage model requires data on workers' wages, job risks and other characteristics. The wage that the worker is willing to accept reflects the utility expected from the job characteristics. A worker's indifference curve shows his tradeoffs between the wage rate and the risk of death in the workplace, as described above. Since workplace safety influences firm productivity and costs, the isoprofit curve measures the tradeoffs between job risk and wages. The hedonic wage function is the envelope of mutual tangencies between firm isoprofit curves and worker indifference curves.

Thus, the reduced form of the hedonic wage function can be specified as follows:

$$\mathrm{Ln}(W_i) = g(X_{Ii}, X_{Ji}) + \mu_i, \tag{6}$$

where ln $W_i$ = the natural logarithm of the $i$th individual worker's wage rate, $X_{Ii}$ = $i$th individual worker's characteristics[4], $X_{Ji}$ = $i$th individual worker's job characteristics[5] including RISK (mortality rate measured at the firm level), and $u_i$ = random error term.

[3] This section is inspired by Liu et al. (1997).
[4] These include EDUCATION, EDUCATION$^2$, EXPERIENCE, EXPERIENCE$^2$, GENDER, AGE, PERMANENCE STATUS, MARITAL STATUS, and UNION STATUS.

Furthermore, as first suggested by Garen (1988), we consider RISK as an endogenous variable. Indeed, it is arguable that, in the individual's choice of job riskiness, safety should be considered as a normal good. Consistent with this notion is that individuals with greater human capital and earning potential will experience an income effect and select jobs with less risk. If disturbances reflect unobserved heterogeneity among individuals, then those with unobserved characteristics which enable them to earn higher wages will also lead them to find safer jobs. Therefore, the endogeneity of job risk implies that ordinary least squares estimates of the wage equation may be biased and this should be corrected. Accordingly, we use the delayed RISK variable. Furthermore, Hausman tests performed with our dataset also rejected the exogeneity of the RISK variable (see below).

## 4. Data source

**Table I:** Descriptive statistics of the sample

| | Definition | Mean | Standard deviation |
|---|---|---|---|
| **Dependent Variable** | | | |
| Log (wage) | Logarithm of the monthly average wage rate | 5.93 | 0.38 |
| **Independent variables** | | | |
| RISK | The fatal injuries per 1000 workers | 21.93 | 0.158 |
| Shore | Dummy for Shore location | 0.604 | 0.488 |
| Interior | Dummy for Interior location | 0.07 | 0.259 |
| South-west | Dummy for South-west location | 0.011 | 0.106 |
| Manufacturing | Dummy for Manufacturing industry | 0.54 | 0.36 |
| Extractives | Dummy for Extractives industry | 0.014 | 0.119 |
| Agriculture | Dummy for Agriculture industry | 0.034 | 0.181 |
| Construction | Dummy for Construction industry | 0.154 | 0.36 |
| Marital status | Dummy for married worker | 0.64 | 0.47 |
| Education | The number of educated years | 7.23 | 2.3 |
| Permanence status | Dummy for a permanent status worker | 0.418 | 0.493 |
| Experience | Number of years of experience | 5.77 | 7.67 |
| Gender | Dummy for men | 0.91 | 0.27 |
| Union status | Dummy for unionized worker | 0.864 | 0.342 |

[5] These also include INDUSTRIES (manufacturing, extractives, agriculture, construction, service and trade is default) and LOCATION (shore, interior, South-West, Tunis area is default).

The data in this study are taken from one main source, the *Caisse nationale de la sécurité sociale*. This organization is in charge of workplace accidents in Tunisia. It compensates the victims of accidents, administers an experience rating scheme to finance the system, and is responsible for accident prevention (monitoring and enforcement of safety regulations, training, subsidies for protective equipment, etc.).

The year 2002 is chosen because it is the last year that was made available to us. We have data on all the 48371 employees working in the private sector and covered by the Caisse. Definitions and descriptive statistics of the variables are presented in Table I.

## 5. Empirical results

Four variants of equation (6) have been estimated (the complete model, one without industry dummies, one without location dummies, one without industry and location dummies), and results are reported in Table II. The explanatory power of the regressions is fairly good. Because of space limitations[6], we report only the instrumental variables regression estimates for the RISK variable. The coefficients are stable, positive and significant, and the control variables are mostly significant with the expected sign.

**Table II:** Risk variable estimations in hedonic wage regressions

| VARIABLES | Mean and standard deviation | Model (1) | Model (2) | Model (3) | Model (4) |
|---|---|---|---|---|---|
| Log(RISK) | 4.17<br>(0.35) | 0.185***<br>(0.00557) | 0.159***<br>(0.00611) | 0.196***<br>(0.00633) | 0.171***<br>(0.00679) |
| Workers'characteristics | | Inluded | Included | Included | Included |
| Industry dummies | | Included | Not included | Included | Not included |
| Location dummies | | Included | Included | Not included | Not included |
| VOSL (US $ 2000) | | 643800 | 553320 | 682080 | 595080 |
| Hausman exogeneity test | | 1590*** | 963.41*** | 853*** | 853.71*** |
| Observations | | 48371 | 48371 | 48371 | 48371 |
| R-squared | | 0.702 | 0.644 | 0.61 | 0.559 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The risk coefficients can be interpreted as the average WTP for a marginal decrease in mortality risk. These results provide strong evidence of a compensating wage differential for jobs with greater fatality risk in the Tunisia labor market. The implied values of a statistical life are

[6] Complete results are available upon request.

calculated at the sample mean wage. The figures are obtained by multiplying (1) the risk coefficient, (2) 1 000 (the denominator of the risk measure) and (3) the monthly average wage rate converted on an annual basis. The estimates range from 553 320 to 682 080 (US$ 2000).

It's useful to compare our estimates with those in other countries. Table III summarizes the estimated VOSL from some past studies. Although most previous studies on the VOSL concern North America, we have sought to present two groups of countries, developed and developing countries.

Our estimates are considerably lower than those generally found for developed countries. However, the value we have for Tunisia (0.64 million; US $ 2000) is in the same range as those found in India, i.e. $ 0.34 million (US $ 2000) (Madheswaran, 2007), or in Thaïland, i.e. $ 1.45 million (US $, 2000) (Vassanadumrongdee and Matsuoka, 2005).

**Table III**: Studies on the VOSL in developed and developing countries

| **Author (Year)** | **Country** | **VOSL(millions, US$2000)** |
|---|---|---|
| Olsen (1981) | United States | 5.7 – 44.2 |
| Marin and Psacharopoulos (1982) | United Kingdom | 4.2 |
| Weiss et al. (1986) | Austria | 3.9 – 6.5 |
| Kniesner and Leeth (1991) | Japan | 9.7 |
| Kniesner and Leeth (1991) | Australia | 4.2 |
| Siebert and Wei (1994) | United Kingdom | 9.4 – 11.5 |
| Cousineau, Lacroix and Girard (1992) | Canada | 4.6 |
| Liu, Hamitt and Liu (1997) | Taiwan | 0.2 – 0.9 |
| Dorman and Hagstrom (1998) | United States | 8.7 – 32.2 |
| Baranzini and Ferro Luzzi (2001) | Switzerland | 6.3 – 8.6 |
| Sandy et al. (2001) | United Kingdom | 5.7 – 74.1 |
| Vassanadumrongdee and Matsuoka (2005) | Thailand | 1.45 |
| Madheswaran (2007) | India | 0.33 – 0.34 |
| Guo and Hammit (2009) | China | 0.045 |

To compare these values more precisely with estimates for developed countries, we used a regression presented in Bellavance et al. (2009) to explain the 29 VOSL estimates from 29 different studies in a meta-analysis. This exercise is inspired from Liu et al. (1997), who used a regression done with 17 VOSL estimates presented in Viscusi (1993). Taking specification (4) in Bellavance et al. (2009, Table 5), we find:

$$\begin{aligned} \text{VOSL} = & -9.96\times10^{8} + 475149\times\left(\text{YEAR of PUBLICATION}\right) + \\ & 5606813\times\text{Ln}\left(\text{INCOME}\right) - 1239987\times\text{RISK} + 12120680\times\text{ENDOGENEITY} \\ & - 4216413\times\text{UNION} \end{aligned} \tag{7}$$

where YEAR of PUBLICATION is the year the study was published; INCOME is annual income; RISK is annual fatality risk per 10 000 workers; ENDOGENEITY captures the fact that

the RISK variable was considered endogenous in a given study; and UNION captures the fact that the study has accounted for unionization[7].

Substituting the appropriate information from our study in this equation yields a predicted value of life for Tunisian workers, presented in the last column of Table IV, of $3.7 million, about six times[8] the estimate we found of $643 800 (from the complete model in Table II).

**Table IV**: Values of a statistical life[9]

| Categories | Total sample | Experienced workers | Non-experienced workers | Permanent workers | Non permanent workers | Manufacturing industries | Other industries | Predicted VOSL |
|---|---|---|---|---|---|---|---|---|
| *Total* | 643800 | *1266008* | *518372* | *575931* | *660749* | *814830* | *614771* | 3704913 |
| Non-unionized | 547172 | 1242827 | 436929 | 411951 | 655294 | 788091 | 440051 | - |
| Unionized | 656476 | 1508061 | 529655 | 604844 | 657310 | 952206 | 643410 | - |

The comparatively small VOSL estimated from Tunisia suggests that there may be fundamental differences in the value of risk reduction between developed and developing countries, because information about occupational risks may be less accessible to workers in developing countries. Differences in labor market structures, institutional factors, cultural influences on risk preferences and magnitudes of industrial risk may also explain variations in the estimates. However, the most likely dominant cause is that developing countries are poorer, and safety is a normal good (Viscusi and Aldy, 2003).

Roughly, Table III suggests that a simple benefit-transfer equation from the existing literature is inadequate for estimating the VOSL in developing countries, and that complete estimations of a VOSL in each country is required. This result confirms that of Liu et al. (1997).

Furthermore, Table IV shows how the VOSL can vary among different groups of workers, suggesting that preferences and risk information may vary across them. Everything else being equal, it appears that unionized workers have a larger VOSL than non-unionized. In fact, if workers lack adequate information about safety at their workplace, then they may underestimate the actual risks they face. Workers underestimating their risk would demand lower wages than if they have correct perceptions of risk. Unions potentially provide workers with more information about the risks. Unions may also negotiate a higher wage for workers affected to risky job. This result is consistent with those of Siebert and Wei (1994) and Viscusi and Aldy (2003).

In the same vein, experienced workers have a higher value than non-experienced workers[10], which may also be related to their better knowledge of actual risks. Somewhat surprisingly, non-permanent workers seem to have a higher VOSL than permanent ones. This may be due to the fact that, being non-permanent, they worry more about the consequences that an accident could have on their link with their employer and ask for a higher risk premium. Finally, the workers in the manufacturing industry have a higher VOSL than in the other industries. A potential

[7] However, the union coefficient is negative and only statistically significant at 10 % of risk.
8 The results are even larger when we use specifications (2) or (3) of Bellavance et al. (2009).
9 These estimations are done by running specific regressions with each of these subsamples.
[10] Experienced workers are those with more than 10 years of work experience.

explanation is that this industry is composed primarily of foreign companies offshore[11], exporting a large share of their production, well-structured, well-organized and more productive than others. Since these firms are foreign exchange earners for the country, they are subject to permanent monitoring of the state. In addition, workers in these offshore companies, in general, benefit from better training and are more aware of occupational safety.

Overall, the difference between various groups can be fairly large[12]. For instance, the VOSL for non-experienced and non-unionized workers may be three times less than that for experienced and unionized workers.

## 6. Conclusion

This paper provides the first estimates of the value of statistical life that reflects Tunisian workers' risk preferences. We find evidence of compensating wage differentials for industrial risk in Tunisia. This outcome provides strong support for the hypothesis that Tunisian workers are compensated for the disadvantages of fatal injury risk. The implied value of statistical life is found between \$553 320 and \$682 080 (US \$ 2000, or between \$783 264 and \$965 533, US \$ 2013)[13], smaller than the value estimated from developed countries.

Therefore, the safety incentives created by market mechanisms are working. However, due to the lack of perfect information about risks, or to other market frictions limiting workers' mobility, it is likely that government intervention is useful to complement market mechanisms in order to improve health and safety in the workplace. Tunisian policy makers are thus often confronted with the need to introduce health and safety regulations[14]. These interventions impose costs on society. Since resources are scarce, it is essential to evaluate these programs and to reallocate funds to achieve maximum benefits to the society. This study could provide necessary information on the value of life in Tunisia. The estimate may be used as a benchmark for evaluating the benefits of regulations to reduce the risk of death in Tunisia.

Otherwise, African researchers have to use the VOSL from the developed country after some adjustments for valuing the health and safety impacts. However, this simple transfer does not take into account differences in willingness-to-pay values due to the fact that labor market structures, institutional factors, magnitudes of industrial risk, culture, living standards and educational attainments are very different in developed country. Therefore, it is desirable that African researchers could determine their country's own value of statistical life for adequate valuation of health and death risks in the labor market.

[11] The 1972 law established a legal framework to facilitate the migration of garment enterprises that were installed in Europe to Tunisia. These offshore companies enjoy many tax and financial benefits.
[12] All the differences across sub-groups are statistically significant.
[13] These values are updated from 2000 to 2013 year using the Tunisian deflator published by the IMF and converted to US dollar using the 2013 exchange rate.
[14] Tunisian government has implemented many regulation programs since 1995, such as public provision of the workplace accidents insurance (by the Caisse Nationale de la Sécurité Sociale) instead of a private regime.

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