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The value of a statistical life in Chile

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Abstract In this article, we estimated the value of a statistical life and the value of a statistical injury (VSI) for Chilean workers using a combination of data from the year 2006 from the Chilean National Socio-Economic Survey, which provides workers' characteristics, and annual statistics from the Chilean Safety Association, which provide labor accident risk data. We estimated a hedonic log-wage equation taking into account of selection bias and endogeneity. The estimated value of a statistical life was US$4,625,958, which increased by almost a factor three after correcting for endogeneity (US$12,826,520). On the other hand, the estimated VSI was US$30,840. The uncorrected results were lower than the values reported by other authors for various developed countries, but greater than those estimated using indirect approaches for Chile.

Keywords Value of a statistical life · Value of a statistical injury · Hedonic wages

JEL Classification J17 · J28

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1 Introduction

In this article, we estimated the value of a statistical life (VSL) and the value of a statistical injury (VSI) for Chilean workers. The VSL is defined as the willingness-to-pay (WTP) to reduce fatal risk or, alternatively, as the willingness-to-accept (WTA) compensation for a higher mortality risk (Freeman 2003). When the risk of suffering non-fatal accidents is used, it is known as the VSI. These two values are the foundation for the economic quantification of the value of life and safety.

Measuring the value of a human life is a timeless issue. We can trace attempts to place value on human life back to Hammurabi's code and it is certainly not difficult to find contemporary examples. In fact, Scheidel (2010) reports that the value of a slave in Babylonic times was 30 shekels (a piece of silver), which is close to today's US$20,000, while Viscusi and Aldy (2007) determined that the value of a 35- to 44-year-old American worker was approximately US$10.5 million in the year 2006.

While the idea of assigning a monetary value to human life could be controversial from an ethical perspective, there are many cases in our daily life in which, as a society, we implicitly or explicitly assign it a value. For instance, when the party responsible for a human loss is asked to pay a monetary compensation for that loss or when a project which involves human safety is evaluated using a cost-benefit analysis, society is implicitly assigning a monetary value to human life. The VSL method simply provides a way to quantify that value using labor market data, assuming that wages across different economic sectors have a "risk compensation" component, that is, the higher the work risk, either fatal or non-fatal, the higher the wages should be. This information is important for policy-makers, especially when designing and evaluating regulations associated with health and environmental trade-offs.

The most common approach used to calculate the VSL and VSI is the hedonic wages method (HWM) (Field and Field 2008; Viscusi 1993). This method assumes that job positions are heterogeneous in their attributes, including fatal and non-fatal risks. The risks are considered as disamenities, and workers could be willing to sacrifice a portion of their wages in order to participate in less risky jobs. This trade-off between job risk levels and wages is used to calculate the VSL or VSI using the coefficients of a hedonic wages function.

Estimations of VSL and VSI based on the HWM have focused on estimation and econometric issues, such as the functional form of the wage equation, the reliability of risk data, and the presence of endogeneity problems (Riera et al. 2007). As Siebert and Wei (1994) have suggested, a specific problem in the estimation of VSI is that the non-fatal injury data may not be as satisfactory as the fatal injury data because serious accidents are presented together with non-serious ones.

Several studies have been conducted in developed countries, but there are few in developing countries, mainly due to a lack of data. Viscusi and Aldy (2003) showed that nearly 50 studies estimating the VSL have appeared since the HWM was suggested in literature in the 1970s. Most of them have estimated the VSL for American workers, starting with Smith (1974), who obtained a VSL of US$9 million dollars[1]. However,

[1] All values throughout this paper are expressed in US dollars of 2006.

these studies differ in the samples and risk data utilized, which has resulted in a wide variation in the VSL estimates. For the United States, estimates range from US$0.7 to 20.8 million dollars. Most of the studies, however, reported a VSL between US$4.9 and US$12 million dollars for the United States (Viscusi and Aldy 2003). The remaining studies reported results for other developed countries, such as the UK (Marin and Psacharopoulos 1982; Siebert and Wei 1994), Canada (Meng and Smith 1990; Cousineau et al. 1992), Japan (Kriesner and Leeth 1991), Switzerland (Baranzini and Ferro Luzzi 2001), and Austria (Weiss et al. 1986), finding ranges between US$3.8 and US$11.3 million. Riera et al. (2007) reported a VSL between US$2.1 and US$2.9 million for Spain. Finally, for Australia, the VSL was determined to be between US$11.3 and US$19.1 million dollars (Miller et al. 1997).

Contrary to the above-mentioned countries, few studies have been conducted in developing economies. Those that have been carried out have mainly taken place in Asian countries. Kim and Fishback (1993) reported a VSL of US$0.8 million dollars for South Korea, Liu and Hammitt (1999) US$0.7 million dollars for Taiwan, Siebert and Wei (1998) US$1.7 million dollars for Hong Kong and Shanmugam (2001) US$4 million dollars for India.

Estimations for Latin American countries are almost nonexistent. Miller (2000) did make an important effort using data from North American, European, and Asian countries and the Gross Domestic Product (GDP) to predict the VSL of some developing countries. He reported a value between US$600,000 and US$900,000 for Chile. However, his estimations did not utilize the classic hedonic wages approach; he obtained the values using VSL estimates of other countries. Bowland and Beghin (2001) explored a similar approach by estimating a VSL prediction function for industrialized countries, which was then used to predict the VSL in the city of Santiago (Chile); they obtained a value of US$872,383. In spite of such efforts, there are no direct VSL estimations for Chile and the reliability of using data from developed countries to estimate values for undeveloped countries is, at the very least, questionable. In addition, these values may not be appropriate to compare with values determined by the HWM due to differences in the methodologies used in each case.

The VSI has also had a wide range of estimates. When Viscusi and Aldy (2003) analyzed 31 studies, they concluded that most of the estimates for the United States were in the range of US$20 and US$69 thousand dollars. The VSI in Canada has been estimated to be in the range of US$10.6 thousand and US$37.4 thousand dollars (Cousineau et al. 1992; Martinello and Meng 1992). Taiwan's VSI has been determined to be US$48.9 thousand dollars (Liu and Hammitt 1999), while India's was between US$150 and US$650 (Shanmugam 2001). The VSI for other developing economies, including Latin American countries, has not yet been determined.

Therefore, the aim of this paper was to determine the VSL for Chilean workers using the hedonic wage approach. We used data from 2006 provided by the Chilean National Socio-Economic Survey, which provides information on workers' characteristics, and annual statistics from the Chilean Safety Association, which provide data on labor risks.

Our contribution is twofold. First of all, most of the VSL research has been conducted for developed countries, with few studies about developing countries, most of which are focused on Asia (Viscusi and Aldy 2003). Thus, this paper represents a contribution to the scarce research on this topic for developing countries. Furthermore, the results may serve as input for political designs, such as regulation of safety standards or for financial compensation since they can be directly included in cost-benefit analyses of regulations. In addition, we corrected our estimates for endogeneity and selection bias in order to evaluate the magnitude of the possible endogeneity biases in the VSL and VSI estimations. Policy-makers should consider the correction of this bias. The following section presents the theoretical framework of the hedonic wage model. Section 2 reports the estimation strategy, while Sects. 3 and 4 present the data and the main results. We end the paper with conclusions in Sect. 5.

2 Theoretical framework

The labor market's risk compensation theory lies within the interaction between labor supply and demand. It is assumed that workers perceive a positive utility contribution from the wage rate w, and a negative utility contribution from the labor risk r they face at their jobs. Furthermore, the utility associated with a "healthy" state, $U(w)$ is greater than that associated with a "non-healthy" state, $V(w)$ at the same w level and the marginal utility of the income is strictly positive: $U'(w) > 0$ and $V'(w) > 0$ (Viscusi 1993). On the other hand, firms must deal with the direct costs of labor, w and the costs of providing safety. In order to maintain a constant profit, any costs to improve safety must be afforded by reducing wages and vice versa.

The interaction between the demand and supply of labor at different levels of risk determines the hedonic wage equation $w(r)$, whose slope $w'(r)$ corresponds to the marginal willingness to accept a higher risk or the marginal willingness to pay for safety. When r is the fatal-accident probability, then $w'(r)$ corresponds to the marginal VSL, while if r is the non-fatal accident probability, $w'(r)$ represents the marginal VSI.

To determine the VSL and the VSI, we estimated the hedonic wage function using a semi-logarithmic linear functional following Viscusi and Aldy (2003) suggestion. Since we used information from the labor market, there was a selection bias problem originating from the fact we could not observe the wages of those people which were not in the market. If we had ignored this selection bias, we would have implicitly assigned a value equal to zero to the wage rate of people outside the market. This would have been unacceptable because their reservation wage may have been greater than the equilibrium wage, and, therefore, they would have voluntarily decided not to work. Including these people in the sample with a value of zero for their wage would have been incorrect, but discarding these observations from the sample would also have been inappropriate (McConnel et al. 2006). The selection bias problem can be solved using the two-step method proposed by Heckman (1979). This model consists of, first, estimating a participation equation using the entire sample, and then, estimating a wage equation which uses not only the observations of participants in the labor market, but also includes as an explanatory variable the Inverse Mills Ratio which controls for participation in the labor market.

Another difficulty dealt with in this paper is the endogeneity problem discussed by Garen (1988). This issue arises for two reasons. First of all, as safety is a normal good, wealthy workers will choose safer jobs. This implies that wages and risk levels are simultaneously determined. Second, there may be unobserved worker characteristics that could influence the risk perception and, therefore, alter the risk premium. We used a Hausman test (Hausman 1978; Wooldridge 2002) to detect endogeneity between wages and risk levels and corrected endogeneity using a two stages least square estimation. To select instruments, we used the strategy chosen by Garen (1988) and Timmins and Murdock (2007). Following Garen, our auxiliary equations regressed the risk levels against determinants of the risk level perception (Instrumental variables). The instruments are correlated with the perceived job risk (fatal and non-fatal), but do not explain the perceived wage rate. The variables consist of individuals' characteristics, including no labor income and some factors affecting risk perception, such as number of children under 6, the spouse's level of education, a dummy variable explaining whether or not the spouse is employed, and a dummy variable indicating whether or not the spouse is disabled. The risk aversion variables are proxy variables showing how the workers perceived the risk at their jobs, since we had no variables that could directly measure people's risk aversion. The variables should indicate the individual's level of maturity in his/her life cycle and, therefore, his/her desire to have a safer job (Garen 1988). On the other hand, following Timmins and Murdock (2007), we added two additional exogenous variables to the wage equation: the average number of employees in all other firms in the same economic sector activity and its squared value. These variables should be correlated with the risk variable of each firm. Basically, when workers choose to work in a firm, they consider, at least partially, the level of these other variables. For example, the size of the firm in terms of number of workers could induce more workers to choose this firm (if it is a proxy for solvency of the firm for example), therefore, this will affect the risk level in that firm (more workers affect the calculation of the risk factor). However, the value of the number of workers in other firms will not affect the determination of the wages and rents in the selected firm. Therefore, they should not be included in the structural equations that determine this variable. In fact, to the degree that they are truly exogenous, as assumed, they should be uncorrelated with the error terms in the wage equation. Thus, the conditions for valid instruments, at least in principle, are fulfilled.

Finally, we used White's asymptotic estimator for the variance and covariance matrix to prevent possible heteroskedasticity problems. Hence, four regressions were necessary in order to estimate the log-wage equation.

Following Heckman's (1979) selectivity bias correction approach, a probit model was estimated in the first stage. The empirical form is shown in Eq. 1.

$$Prob(w_i > 0|Y_i) = F(\delta Y_i'), \tag{1}$$

where $w_i > 0$ only if the individual i is working, Y_i, is a vector of characteristics that determines the probability of participation of the ith individual and δ is a vector of parameters to estimate. After the estimation of Eq. 1, the Inverse Mills Ratio was calculated and then, in a second stage, it was used as a regressor in the log-wage estimation.

Then we estimated the simultaneous equation system given by Eqs. 2–4.

$$p_i = \delta_1 S_i' + \varepsilon_{1i} \tag{2}$$

$$q_i = \delta_2 S_i' + \varepsilon_{2i} \tag{3}$$

$$\ln(w_i) = c + \beta X_i' + \alpha Z_i' + \gamma_1 p_i + \gamma_2 q_i + \varphi\lambda(\alpha_i) + \varepsilon_{3i} \tag{4}$$

Equation (2) is the auxiliary equation for fatal risk (p), Eq. (3) is the auxiliary equation for non-fatal risk (q), S is a vector of characteristics that determines the individual risk perception (including a constant), $ln(w)$ is the natural logarithm of the wage, c is a constant, X denotes a worker-individual characteristics vector, Z represents a job characteristics vector and $\lambda(\alpha)$ is the inverse Mills ratio. The subscript i indicates that the data corresponds to the ith worker. The vectors δ_1, δ_2, β, α and the scalars c, γ_1, γ_2 and are the regression parameters and ε_{1i}, ε_{2i}, and ε_{3i} are iid errors. According to Viscusi (1993), γ_1 and γ_2 are the monetary willingness to accept a marginal increase in the fatal and non-fatal risks, respectively.

3 Data

Measures of risk for the year 2006 were provided by the Chilean Safety Association. This is one of the three "mutual securities" in Chile which manages social work accident insurance. It is also the only agency in Chile that provides public statistics about workplace accidents. Thus, for the risk data, we used this agency's published measures of fatal and non-fatal risks according to industry. Then, we matched this risk data to the corresponding industry of each worker in the sample.

According to Viscusi and Aldy (2003), the dominant approach in the literature is to use risk data categorized by industry or occupation. To allow more variability between workers, some studies have used risk data by occupation and by industry (Riera et al. 2007). For Chile, there are no work accidents rates available by occupation, so we used the dominant approach: industry data. We used 8 industry group classifications. This disaggregation follows what has been done in the literature (Viscusi 1993; Viscusi and Aldy 2003). For the fatal risk variable, we used a 1/10,000 workers ratio and for the non-fatal risk variable, we used a 1/100 workers ratio.

The industries with the highest fatal risk ratio were mining, transportation, and construction, while those with the highest non-fatal risk ratio were construction, transportation, and manufacturing. Our non-fatal injury rates considered both: serious and non-serious injuries. This was, however, the only data available.

For individual characteristics, we used data from the 2006 Chilean National Socio-Economic Survey.

The variables were grouped into five categories:

– *Individual characteristics*: included years of education (ESC), labor experience in years ($EXPER$), the square of the labor experience ($EXPER2$), a dummy variable for gender which takes the value 1 for males ($GENDER$), the number of children in the household under 6 years old ($CHILD6$), an interaction term between gender and number of children under 6 years old ($GENCHILD$), a dummy that takes the value 1 if the individual was married ($MARRIED$), the spouse's years of education ($ESCSPOUSE$), a dummy variable that takes the value 1 if the spouse was working at the time ($JOBSPOUSE$), a dummy variable that takes the value 1 if the spouse had any incapacitating illness ($ILLSPOUSE$), the number of persons in the household ($PERSONS$) and the non-labor income in dollars ($NONLABINC$). Finally, we included the Inverse Mills Ratio calculated for each individual ($MILLS$).

Table 1 Descriptive statistics of the risk level by industry sector

Industry	N^{o} of Cases	Percent (%)	Fatal risk (1/10,000 workers ratio)	Non-fatal risk (1/100 workers ratio)
Agriculture, forestry and fisheries	24,459	29.20	0.986	8.106
Mining	1,914	2.29	3.574	3.175
Manufacturing	9,728	11.61	0.584	8.922
Construction	6,893	8.23	2.426	9.769
Electricity, gas and water	511	0.61	0.000	6.106
Trade	12,892	15.39	0.576	5.177
Transportation, storage and communication	4,904	5.86	2.944	9.061
Services	22,456	26.81	0.406	4.775
Total	83,757	100		

Source: Chilean Safety Association and Chilean National Socio-Economic Survey
Note: All figures correspond to the year 2006

- *Training and job formation*: contained a variable for the number of years in the last job ($YEARSJOB$), the number of hours worked monthly ($HOURS$), a dummy variable that takes the value 1 if the person was working in a full-time job ($FULLTIME$), a dummy variable that takes the value 1 if the person had a job contract ($CONTRACT$) and a dummy variable that takes the value 1 if any training course was taken by the respondent ($TRAINING$).
- *Firm attributes*: included a set of dummy variables that describes the number of people working in the firm. The ranges were 1 person, 2–5, 6–9, 10–49, and 50–199 people. Firms with more than 200 people were the control group. We also included the variable $SIZE\_ALT$: the average size of other firms in the same economic sector (in which the individual was not working) and the variable $SIZE\_2$ that was the square of $SIZE\_ALT$, both were used as instruments as explained in the theoretical section.
- *Geographic location*: corresponded to dummy variables for the 15 areas of the Chilean Administrative Division with the "Metropolitan Region of Chile" (Santiago) being the control group.
- *Labor risk*: included the estimated fatal and non-fatal risks (FR and NFR) and its estimated values (FR_EST and NFR_EST) per economic sector.

The descriptive statistics for the dataset is shown in Tables 1 and 2

4 Results

The hedonic wage estimates had the expected signs and parameters. Years of education and labor experience had a positive effect on wages, while the square of the labor experience negatively affected wages. Equation 4 corresponded to the two stages of the OLS estimation. The compensating wage premiums were positive and statistically significant for both fatal and non-fatal injuries. Only the second firm size and

Table 2 Data description

Variable	Mean	Standard deviation
Dep. Var		
LOG_WAGE	12.191	0.883
Individual characteristics		
ESC	11.041	3.949
EXPER	23.158	14.772
EXPER2	754.483	833.478
GENDER	0.609	0.488
CHILD6	0.154	0.420
GENCHILD	0.110	0.363
MARRIED	0.461	0.499
ESCSPOUSE	6.429	6.131
JOBSPOUSE	0.354	0.478
ILLSPOUSE	0.034	0.182
PERSONS	4.280	1.808
NONLABINC	25,833.790	123,547.4
Training and job information		
YEARSJOB	7.221	9.420
HOURS	44.649	15.194
FULLTIME	0.675	0.469
CONTRACT	0.612	0.487
Firm and alternative sizes		
SIZE_1	0.204	0.403
SIZE_2_5	0.167	0.373
SIZE_6_9	0.056	0.230
SIZE_10_49	0.183	0.387
SIZE_50_199	0.138	0.345
SIZE_ALT	65.087	11.432
SIZE_2	4,367.04	2,046.321
Geographic location		
R_01	0.011	0.104
R_02	0.014	0.118
R_03	0.029	0.169
R_04	0.016	0.124
R_05	0.038	0.191
R_06	0.101	0.301
R_07	0.054	0.228
R_08	0.058	0.233
R_09	0.107	0.309
R_10	0.050	0.218
R_11	0.021	0.143

Table 2 continued

Variable	Mean	Standard deviation
R_12	0.050	0.218
R_13	0.005	0.072
R_14	0.010	0.097
Labor risk		
FR	0.966	0.883
NFR	6.597	2.044

Source: Chilean National Socio-Economic Survey 2006
Note: Variables: LOG_WAGE: natural logarithm of the monthly wage in dollars of 2006. ESC: years of education, $EXPER$: labor experience in years, $EXPER2$: $EXPER$ squared, $GENDER$: dummy (1 for male), $CHILD6$: the number of children under six years old in the household, $GENCHILD = GENDER \times CHILD6$, $MARRIED$: dummy (1 if person is married), $ESCSPOUSE$: years of education of the spouse, $JOBSPOUSE$: dummy (1: spouse is currently working, $ILLSPOUSE$: dummy (1: spouse has any incapacitating illness), $PERSONS$: number of persons in the household, $NONLABINC$: non-labor income in dollars of 2006, $YEARSJOB$: years in last job, $HOURS$: hours worked monthly, $FULLTIME$: dummy (1: person currently working full time), $CONTRACT$: dummy (1: person has a job contract), $TRAINING$: dummy (1: person had taken job trainee courses), $SIZE\_i\_j$: person working in a firm with i to j employees, $SIZE\_ALT$: average employees in all the other firms, $SIZE\_2 = (SIZE\_ALT)^2$. R_k: person working at the kth "region" according to the Chilean territorial division, FR job fatal risk (1/10,000 ratio), *NFR* non-fatal risk (1/100 ratio)

two geographic location variables were non-significant in Eq. 4. Equation 4a in Table 3 corresponded to the uncorrected estimation of the wage equation, in which the actual risk levels were used. In this case, we found a positive and statistically significant fatal risk premium; however, we found a negative non-fatal compensation. One regional variable and one variable indicating firm size were non-significant. The adjusted R squared neared 0.4 in both equations, which is relatively good for wage equations.

Estimations of auxiliary equations 1–3 are presented in Table 4 and estimations for the wage equations are presented in Table 3. The estimated parameters for the auxiliary participation model had the theoretically expected signs and all the variables were significant at a 1 % significance level. The estimators for the instrumental risk variables also had signs in accordance with economic theory. All the variables were significant at a 5 % significance level, but marital status, spouse illness, and some geographical dummies were not significant in Eq. 2. Non-labor income was significant at a 10 % level. In Eq. 3, all the variables were significant at a 5 % significance level, but the experience, the square of the experience, the 6–9 firm size and some geographical dummies were not significant. The adjusted R^2 were 0.28 and 0.26, respectively, and the F test was highly significant.

Cross-sectional VSL studies that use the instrumental variable (IV) approach for addressing the problem of endogeneity have applied Garen's method (1988). Example of these are those reported by Kochi (2007): Arabsheibani and Marin (2001), Gurdenson and Hyatt (2001), and Siebert and Wei (1994). Here, we followed the same line as the other IV studies, but we also added the instruments suggested by Timmins and Murdock (2007).

Table 3 Results, wage equations

Equation Dep. Var	Equation 4 LOG-WAGE (2SLS)		Equation 4a LOG-WAGE	
	Coefficient	t value	Coefficient	t value
Constant	8.929	111.08	9.443	154.45
Individual characteristics				
ESC	0.141	58.70	0.132	59.30
EXPER	0.040	20.69	0.040	22.24
EXPER2	−5.792E−4	−14.20	−5.869E−4	−15.38
GENDER	0.247	13.85	0.366	30.16
MILLS	1.580	10.56	1.454	10.51
Training and job information				
YEARSJOB	0.012	22.93	0.011	22.47
HOURS	0.013	35.25	0.014	38.64
FULLTIME	−0.248	−18.05	−0.248	−18.40
CONTRACT	0.082	6.20	0.043	3.58
TRAINING	0.221	17.01	0.199	16.06
Firm sizes				
SIZE_1	−0.087	−4.68	−0.143	−7.92
SIZE_2_5	−0.020	−1.31	−0.063	−4.29
SIZE_6_9	−0.056	−2.78	−0.071	−3.64
SIZE_10_49	−0.056	−4.64	−0.058	−4.91
SIZE_50_200	−0.036	−2.65	−0.009	−0.72
Geographic location				
R_01	−0.425	−10.50	−0.427	−10.69
R_02	−0.152	−4.52	−0.133	−4.08
R_03	−0.126	−4.38	−0.095	−3.43
R_04	−0.195	−7.49	−0.162	−6.37
R_05	−0.296	−14.27	−0.271	−13.50
R_06	−0.291	−20.64	−0.275	−20.32
R_07	−0.193	−13.48	−0.164	−11.79
R_08	−0.252	−16.24	−0.244	−16.09
R_09	−0.334	−26.69	−0.324	−26.79
R_10	−0.346	−19.43	−0.332	−19.53
R_11	−0.344	−14.35	−0.324	−14.08
R_12	−0.191	−11.63	−0.167	−10.60
R_13	0.032	1.22	0.063	2.54
R_14	−0.047	−1.25	−0.039	−1.08
Labor risk				
FR_EST	0.183	14.92		
NFR_EST	0.044	6.13		

Table 3 continued

Equation Dep. Var	Equation 4 LOG-WAGE (2SLS)		Equation 4a LOG-WAGE	
	Coefficient	t value	Coefficient	t value
FR			0.067	12.05
NFR			−0.011	−4.20
N		83,757		83,757
R^2		0.38		0.41

White estimator for the covariance matrix

Note: Variables: LOG_WAGE: natural logarithm of the monthly wage in dollars of 2006. ESC: years of education, $EXPER$: labor experience in years, $EXPER2$: $EXPER$ squared, $GENDER$: dummy (1 for male), $CHILD6$: the number of children under six years old in the household, $GENCHILD = GENDER \times CHILD6$, $MARRIED$: dummy (1 if person is married), $ESCSPOUSE$: years of education of the spouse, $JOBSPOUSE$: dummy (1: spouse is currently working, $ILLSPOUSE$: dummy (1: spouse has any incapacitating illness), $PERSONS$: number of persons in the household, $NONLABINC$: non-labor income in dollars of 2006, $YEARSJOB$: years in last job, $HOURS$: hours worked monthly, $FULLTIME$: dummy (1: person currently working full time), $CONTRACT$: dummy (1: person has a job contract), $TRAINING$: dummy (1: person had taken job trainee courses), $SIZE\_i\_j$: person working in a firm with i to j employees, $SIZE\_ALT$: average employees in all the other firms, $SIZE\_2 = (SIZE\_ALT)^2$. R_k: person working at the k-th "region" according to the Chilean territorial division, FR: job fatal risk (1/10,000 ratio), NFR: non-fatal risk (1/100 ratio). The suffix "_EST" stands for estimated values

As Kochi (2007) emphasizes, the instrumental variable approach generally reports unstable and unreliable results due to problems caused by weak instruments. Thus, we tested the validity of our instruments. We compared the first-stage F statistic reported in Table 4 with the critical value determined by the number of instruments and the number of endogenous repressors reported by Stock and Yogo (2005). We therefore rejected the null hypothesis that our instruments are weakly correlated with the included endogenous variables. Following Kochi (2007), our estimates should not be affected by problems of stability and reliability. Nevertheless, we found that depending on the instruments we used, the results changed greatly.

Finally, the VSL and the VSI results were calculated using the average wages and the parameters obtained from the estimations in Table 3 using the formula $\gamma_1 \times \bar{w} \times 12 \times 10,000$ to calculate the VSL and $\gamma_2 \times \bar{w} \times 12 \times 100$ to calculate the VSI, where $\bar{w}$ is the average monthly wage, as suggested by Viscusi and Aldy (2007). Since we expressed our job fatal risk measure in a one to 10,000 ratio and our non-fatal risk measure in a 1 to 100 ratio, we had to multiply each coefficient by 10,000 and by 100 to obtain the VSL and VSI, respectively. The results of these calculations are presented in Table 5.

The estimated VSL, without the endogeneity correction, was US$4.63 million dollars. However, the parameter associated to the non-fatal risk was negative, and the VSI could not be directly estimated using this model. After correcting with the 2SLS approach, our estimated VSL increased by almost a factor of three, reaching US$12.83 million dollars. Among the few studies that report corrected VSLs, Garen (1988) claimed that the corrected value can duplicate the uncorrected one, while Hwang et al. (1992) proposed that the new value can be up to ten times higher than the uncorrected

Table 4 Results, wage auxiliary estimations

Equation Dep. Var	Equation 1 PART (probit)		Equation 2 FR (2SLS)		Equation 3 NFR (2SLS)	
	Coefficient	t value	Coefficient	t value	Coefficient	t value
Constant	0.234	3.19	−0.378	−4.06	−1.911	−10.54
Individual characteristics						
ESC	0.045	14.38	−0.040	−19.10	−0.151	−30.91
EXPER	0.038	16.05	−0.004	−2.58	−0.007	−1.75
EXPER2	−0.001	−21.50	9.610E−5	2.87	1.11E−6	0.02
GENDER	0.279	11.67	0.390	32.33	1.177	40.25
CHILD6	−0.303	−7.78	0.072	3.70	0.179	3.62
GENCHILD	0.241	4.30	−0.072	−3.06	−0.128	−2.27
MARRIED	−0.099	−3.68	0.016	1.34	0.079	2.86
ESCSPOUSE	0.009	2.62	0.005	4.13	0.010	3.32
JOBSPOUSE	0.098	3.19	−0.073	−5.11	−0.195	6.17
ILLSPOUSE			−0.023	−0.89	−0.072	−1.21
PERSONS	0.053	8.50				
NONLABINC	−3.85E−7	−3.16	8.79E−8	1.77	−1.76E−8	−0.16
MILLS			−0.793	−7.43	−1.454	−5.55
Training and job information						
YEARSJOB			−0.006	−12.01	−0.004	−3.04
HOURS			0.005	15.71	0.006	8.36
FULLTIME			−0.062	−4.63	−0.018	−0.58
CONTRACT			−0.154	−11.15	−0.485	−15.52
TRAINING	0.340	7.85	−0.105	−7.33	−0.283	−8.53
Firm sizes						
SIZE_1			−0.206	−11.57	−0.815	−19.83
SIZE_2_5			−0.158	−9.55	−0.368	−9.70
SIZE_6_9			−0.081	−3.55	0.001	0.02
SIZE_10_49			−0.015	−0.94	0.065	1.84
SIZE_50_200			0.087	5.12	0.348	9.26
SIZE_ALT			0.022	10.58	0.257	60.30
SIZE_2			4.76E−5	4.41	−0.002	−69.39
Geographic location						
R_01			0.019	0.42	0.040	0.37
R_02			0.159	3.70	0.012	0.14
R_03			0.152	4.59	0.139	1.97
R_04			0.166	6.40	0.298	4.65
R_05			0.152	7.16	0.317	6.53
R_06			0.095	6.23	0.195	5.54
R_07			0.101	6.40	0.950	16.64
R_08			0.048	2.96	0.426	10.57

Table 4 continued

Equation Dep. Var	Equation 1 PART (probit)		Equation 2 FR (2SLS)		Equation 3 NFR (2SLS)	
	Coefficient	*t* value	Coefficient	*t* value	Coefficient	*t* value
R_09			0.035	2.68	0.239	7.69
R_10			0.062	3.37	0.343	7.88
R_11			0.109	4.31	0.364	6.33
R_12			0.078	4.23	0.498	11.78
R_13			0.135	4.25	0.472	6.39
R_14			0.055	1.33	0.039	0.40
N	96,663		N	83,757	83,757	
Chi	96.78		R^2	0.28	0.26	
			F	541.76	542.31	

White estimator for the covariance matrix

Note: Variables: $PART$: dummy (1 if person is working). ESC: years of education, $EXPER$: labor experience in years, $EXPER2$: $EXPER$ squared, $GENDER$: dummy (1 for male), $CHILD6$: the number of children under six years old in the household, $GENCHILD = GENDER \times CHILD6$, $MARRIED$: dummy (1 if person is married), $ESCSPOUSE$: years of education of the spouse, $JOBSPOUSE$: dummy (1: spouse is currently working, $ILLSPOUSE$: dummy (1: spouse has any incapacitating illness), $PERSONS$: number of persons in the household, $NONLABINC$: non-labor income in dollars of 2006, $YEARSJOB$: years in last job, $HOURS$: hours worked monthly, $FULLTIME$: dummy (1: person currently working full time), $CONTRACT$: dummy (1: person has a job contract), $TRAINING$: dummy (1: person had taken job trainee courses), $SIZE\_i\_j$: person working in a firm with i to j employees, $SIZE\_ALT$: average employees in all the other firms, $SIZE\_2 = (SIZE\_ALT)^2$. R_k person working at the kth "region" according to the Chilean territorial division

Table 5 Value of statistical life and injury for Chilean market in US$ of 2006

Endogeneity	Non-corrected	Corrected[a]
VSL	4,625,958	12,826,520
VSI	$-7,710$	30,840

Note 1: VSL is the value of a statistical Life
Note 2: VSI is the value of a statistical injury
[a] Endogenetiy is corrected using Instrumental Variables for the risk rates

one. We reported the same phenomena: in our estimation, the corrected VSL increased almost three times. This result is not surprising, because introducing instruments into the VSL estimation increases the variance of the risk parameter and the VSL estimate. For example, Knieser et al. (2012) found an increase from 5 million, in the baseline model, to 7.5 million of the VSL for American workers using panel data estimation, but their estimates are no longer significant in the IV model. The estimation range was 0.7–9.4 million and it moved to the range of −0.1 to 13.3 million dollars after the IV correction. In our case, the point estimate increased by a higher proportion, but was still significant. We also found a positive estimation of VSI of US$30,840.

As expected, the non-corrected VSL was lower than Viscusi and Aldy's (2003) estimates for the United States, which mostly ranged between US$5 and US$12.2

million dollars. At the same time, it was greater than both Miller's (2000) calculations for Chile, which ranged between US$0.8 and US$1.2 million, and Bowland and Beghin's (2001) estimates for Chile, which averaged US$872,383 dollars.

Finally, there is no consensus on the figures for the VSI range. However, our result of US$30,840 lies within the range of Viscusi and Aldy's (2003) results, which ranged from US$20,000 to US$70,000.

5 Conclusion

We have estimated the VSL and VSI for Chilean workers using labor market data. Our estimated values were lower than those reported by Viscusi and Aldy for the United States and other developed countries, but higher than those indirectly estimated by Miller (2000) and Bowland and Beghin (2001).

We have taken into account the selection bias problem and the endogeneity of wages and risk levels, finding a large bias when the endogeneity problem was not taken into account. This is crucial since the estimation of workers' perceived risk levels relies on actual labor risks, and these results depend on the reliability of this data. Further research should be focused on the quality and disaggregation of the figures (for example, by sub-sector or gender) in order to have more variability in the dependent variable for the 2SLS estimation.

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