The Economic Value of Reducing Fatal and Non-Fatal Occupational Risks in Mexico City using Actuarial- and Perceived-Risk Estimates

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Abstract

Compensating wage differentials are used to estimate individuals' marginal rates of substitution between income and both fatal and non-fatal occupational-accident risks in the Mexico City Metropolitan Area. Data are obtained by in-person survey of almost 600 workers and include workers' perceived risks of fatal and non-fatal occupational accidents supplemented by actuarial-risk estimates from government statistics. Results using both actuarial- and perceived-risk estimates are reasonably consistent. Estimates of the value per statistical life are between US$235,000 and US$325,000, and estimates of the value per statistical non-fatal injury are between US$3,500 and US$11,000. These values are much smaller than corresponding estimates for high-income countries, but are consistent with the small number of prior estimates for lower-income countries.

1. Introduction

Benefit-cost analysis is often recommended to help determine whether interventions to improve health are worth the opportunity cost of the resources consumed. Although many estimates of the monetary value of reductions in health risk have been obtained for the United States and other high-income countries, there are only a few such estimates for lower-income countries. To provide information on monetary values in lower-income countries, and as part of an effort to evaluate interventions to improve health and safety in the Mexico City Metropolitan Area (MCMA), we estimate the monetary value of fatal and non-fatal risk reductions to MCMA residents.

A standard method for estimating rates of tradeoff between health risk and money is to estimate the rate at which workers' wages increase with higher occupational risk (e.g., Viscusi, 1993; Hammitt, 2000; Viscusi and Aldy, 2003). The underlying notion is that, controlling for workers' job qualifications and other job conditions, workers must be offered higher wages in order to work in more hazardous jobs. In choosing to accept or stay with his current job, a worker implicitly reveals that his willingness to pay (in the form of accepting a lower wage) for a safer job is less than the wage reduction associated with safer jobs, and that his willingness to accept compensation for greater risk is less than the incremental pay associated with more hazardous jobs.

We report the results of a compensating-wage-differential study of MCMA workers' rates of substitution between income and health risk. We estimate workers' rates of substitution between income and risks of both fatal and non-fatal occupational injury. Because workers' job choices are based on their perceptions of occupational risks, we estimate two sets of tradeoffs, based alternatively on workers' perceived risks of fatal and non-fatal occupational injury and on actuarial estimates of these risks by industry.

Overall, we find that wages are statistically associated with both perceived risks and with actuarial-risk estimates. Estimates of the rate of substitution between income and risks suggest the average workers' value per statistical life is between about US$235,000 and US$325,000 (2002 US dollars) and the average value per non-fatal occupational injury is between about US$3,500 and US$11,000. These values are much smaller than estimates for the United States and other high-income countries. If the difference in VSL is attributed to the difference in average income between Mexico and the United States, the implied income elasticity is about 1.5 to 2.0.

2. Survey Instrument and Administration

Data on workers' wages, personal and job characteristics, and on their perceived risks of occupational injury, were collected using in-person interviews. The survey was conducted in two waves, in October 2001 and April 2002. Eligible respondents were defined as individuals aged 18 years or older who had resided in the MCMA for at least one year. The residence limit was imposed to exclude workers who had recently migrated to the MCMA, and who might be less familiar with the range of job alternatives. Almost 600 individuals were contacted through their employer and interviewed outside their workplace. Workers were selected using a stratified random sampling approach. We initially selected industries spanning a range of occupational risks, and then randomly selected firms within these industries and workers within the firms. Respondents included construction workers, policemen, firemen, manufacturing workers, drivers, equipment operators, craftsmen, maintenance and cleaning workers, messengers, waiters and cooks.

Respondents were asked about their wage and perceived risks of fatal and non-fatal occupational injury. Risk perceptions were elicited by asking the respondent to mark the appropriate levels on scales representing fatal and non-fatal occupational risks. Each scale had 30 levels, with the annual occupational-injury risks labeled and actuarial risks associated with selected industries (not including the respondents' industries) printed on the scale. The fatal-accident risk scale ranged from 0 to 30 per 10,000 workers, and the non-fatal-injury risk scale ranged from 0 to 30 per 250 workers. Similar scales have been used in the United States by Gerking et al. (1988) and Gegax et al. (1991), and in Taiwan by Liu and Hammitt (1999). Using the worker's industry, we also obtained actuarial risks of fatal and non-fatal risks using Mexican government statistics. Other questions asked about the worker's wage, work experience, and whether the job required heavy physical effort or exposed the worker to heat, noise, or air pollution.

Socioeconomic characteristics were also obtained from survey respondents. These include age, sex, education, marital status, number of people in the workers' household, monthly personal income and monthly household income. Other questions asked about the respondent's health (e.g., whether he has a chronic disease, rates his current health as better or worse than average, expects to live to 75 years old) and health behaviors (e.g., whether he smokes and exercises regularly). Respondents were also asked about their use of marijuana and hard drugs.

3. Models and Results

Definitions, sample means and standard deviations of the variables used in the analysis are reported in Table 1. Because we sampled workers in relatively risky industries, almost 80 percent are male. Mean age is about 33 years, and mean education is about eight years. Experience with the current employer averages about 6 years and the average monthly wage is about 3,500 pesos (US$350).

Both actuarial and workers' estimates of occupational risks of fatal and non-fatal injury are obtained. The workers' estimates are obtained by asking respondents to report the fatal and non-fatal injury risks they face on scales with categories numbered 0 through 30, on which actuarial risks for illustrative industries are indicated. As shown in Figure 1, perceived risks are distributed across the full range of each scale, with some clustering of responses at the minimum and maximum values and at categories which are multiples of five. Perceived fatal risks are distributed more toward the lower end of the corresponding scale than are non-fatal risks. As the fatal-injury scale ranges from 0 to 30 per 10,000 workers, and the non-fatal-injury scale ranges from 0 to 30 per 250 workers, the distribution of fatal-injury risks is concentrated on much smaller probabilities than the distribution of non-fatal-injury risks. The actuarial-risk estimates are for the respondents' industries, based on Mexican government data from the Instituto Mexicano del Seguro Social. As reported in Table 1, the average perceived and actuarial estimates of the non-fatal injury risk are quite similar (annual rates of about 14/250 and 13/250, respectively), but the average perceived fatality risk is substantially larger than the corresponding actuarial estimate (about 12/10,000 and 3/10,000 per year, respectively).

Following conventional practice (e.g., Viscusi and Aldy, 2003), the hedonic-wage regressions are estimated by regressing the logarithm of the hourly wage on either perceived or actuarial estimates of risk and on human-capital variables (e.g., age, schooling, work experience, sex). Results using the actuarial- and perceived-risk variables are reported in Tables 2 and 3, respectively. Both tables report the same model specifications, differing only in the use of actuarial- or perceived-risk variables. Columns (1) – (3) report the results of a simple model including only the risk variables and basic human capital variables (years of schooling, work experience with current employer, age, age squared, and sex). Columns (4) – (6) supplement this basic specification by including indicator variables for occupation, workers' health, and other job characteristics that have statistically significant coefficients for most of the model specifications.

In theory, wage differentials should compensate for between-job differences in both fatal and non-fatal occupational risks, but in practice it is often difficult to estimate these effects separately, because fatal and non-fatal risks are positively correlated across jobs (the product-moment correlation coefficients for the actuarial- and perceived-risk variables are 0.76 and 0.64, respectively). Including only one of the risk variables is likely to overestimate compensation for that risk, because of omitted-variable bias.

Using either actuarial- or perceived-risk estimates, we obtain positive and statistically significant coefficients on the fatal and non-fatal risk variables when only one risk variable is included in the model (columns (1) and (2) of Tables 2 and 3). Using actuarial-risk estimates, the estimated coefficients of the fatal and non-fatal risk variables are about 15 percent smaller when both risk variables are included (column (3)), suggesting the omitted-variable bias is modest. In contrast, using both perceived-risk variables (column (3) of Table 3), the estimated coefficient on the fatal risk variable is insignificant and negative and the coefficient on the non-fatal risk variable is larger than when the fatal risk variable is omitted (column (2) of Table 3).

Estimated coefficients on the human-capital variables are not sensitive to the choice between actuarial- and perceived-risk variables nor to whether the fatal and non-fatal risk variables are included singly or jointly in the model. The coefficients that are statistically significant are consistent with expectations. The wage is positively associated with factors that increase productivity, such as schooling (5 percent for each year) and job experience (1.5 percent per year), and is larger for men than for women (about 15 percent). The significantly positive coefficient on age and significantly negative coefficient on age squared imply that the wage increases then decreases with age, peaking for ages between about 40 and 55 years.

Columns (4) – (6) of Tables 2 and 3 supplement the basic model by including the occupational, health, and job characteristic variables that have statistically significant coefficients in most specifications. The estimated coefficients suggest that construction workers and drivers are paid about 20 percent and 40 percent more, and maintenance and cleaning workers are paid about 30 percent less, than other workers with similar age, education, and job experience. Workers are paid about 10 percent more for jobs that expose them to unusual cold, and about 10 percent less for jobs that expose them to unusual heat. Workers suffering a chronic disease appear to be paid about 15 percent more than others, although the estimated coefficient is significant at only the 10 percent level.

Including these additional variables has only a modest effect on the estimated coefficients of the actuarial-risk variables (Table 2), but a larger effect on the estimated coefficients of the perceived-risk variables (Table 3). The stability across model specifications of the estimated coefficients of the actuarial-risk variables suggests the corresponding estimates of the rate of substitution between income and risk are more robust than the estimates based on the perceived-risk variables.

The rate of tradeoff between money and mortality risk is typically summarized as the value per statistical life (VSL). This is defined as an individual's marginal rate of substitution between money and mortality risk, conventionally measured per unit change in risk. VSL is estimated by dividing the estimated incremental annual compensation by the incremental annual risk.[1] The analogous value per statistical non-fatal injury (VSI) is calculated is a similar manner.

Estimates of VSL and VSI are reported in Table 4. These estimates are based on the corresponding regression models reported in Tables 2 and 3. Using the actuarial-risk variables, VSL is estimated between US$235,000 and US$325,000. The smallest of these values, from column (6), is perhaps the most defensible of these point estimates as the corresponding model controls for non-fatal risk and also for job type and other job characteristics. Using the perceived-risk variables, the only statistically significant estimate of VSL, US$235,000 (column (1)), is comparable to the estimates using the actuarial-risk variables. Estimates of the value per statistical non-fatal injury (VSI) range from about US$3,500 to US$11,000.

Our estimates of VSL are very small compared with estimates for the United States and other high-income countries, which are in the range of US$4 – 9 million (Viscusi and Aldy, 2003). Attributing the entire difference to differences in income between the United States and Mexico suggests an income elasticity of about 1.5 to 2.0,[2] substantially larger than conventional estimates of around 0.5 (Hammitt, 2000; Viscusi and Aldy, 2003).

There are few compensating-wage-differential estimates of VSL or VSI for lower-income countries. In a comprehensive survey, Viscusi and Aldy (2003) report estimates from Taiwan, Korea, and India. As shown in Table 5, studies in South Korea and Taiwan have examined populations with somewhat larger incomes than our sample and have obtained estimates of VSL (and one estimate of VSI) that are roughly consistent with our results, accounting for the income differences. In contrast, despite the much smaller average income in India, estimates of VSL and VSI from those studies are much larger than our estimates.

5. Conclusions

Estimates of the monetary value of reducing mortality and morbidity risks have been obtained by comparing wages received for jobs which differ in fatal and non-fatal accident risk. The results obtained using workers' perceptions of their occupational risk and actuarial-risk estimates are similar, with estimates of the value per statistical life ranging from about US$235,000 to US$325,000, and values per statistical non-fatal

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[1] Estimated incremental annual compensation = [exp(β) – 1] * average monthly wage (US$355.5) * 12 months/yr, where β is the estimated coefficient on the risk variable. The annual risk increment is 1/10,000 for fatal injuries and 1/250 for non-fatal injuries.

[2] Using per capita GNI as a measure of average income, a range of US$4 – 9 million for VSL in the United States, and a range of US$235,000 – 325,000 for VSL in Mexico, yields an implied income elasticity of 1.4 – 2.0. (GNI per capita is US$37,600 in the United States and US$6,230 in Mexico; World Bank, 2004.)

injury of US$3,500 to US$11,000. These estimates are very small compared with estimates for the United States and other high-income countries, but are compatible with prior estimates for South Korea and Taiwan.

References

Gegax, D., S. Gerking, and W. Schulze, “Perceived Risk and the Marginal Value of Safety,” *Review of Economics and Statistics* 73: 589-596, 1991.

Gerking, S., M. DeHaan, and W. Schulze, “The Marginal Value of Job Safety: A Contingent Valuation Study,” *Journal of Risk and Uncertainty* 1: 185-200, 1988.

Hammitt, J.K., “Valuing Mortality Risk: Theory and Practice,” *Environmental Science and Technology* 34: 1396-1400, 2000.

Kim, S.-W., and P.V. Fishback, “The Impact of Institutional Change on Compensating Wage Differentials for Accident Risk: South Korea, 1984-1990,” *Journal of Risk and Uncertainty* 18: 231-248, 1999.

Liu, J.-T., and J.K. Hammitt, “Perceived Risk and Value of Workplace Safety in a Developing Country,” *Journal of Risk Research* 2: 263-275, 1999.

Liu, J.-T., J.K. Hammitt, and J.-L. Liu, “Estimated Hedonic Wage Function and Value of Life in a Developing Country,” *Economics Letters* 57: 353-358, 1997.

Shanmugan, K.R., “The Value of Life: Estimates from Indian Labor Market,” *Indian Economic Journal* 44: 105-114, 1996/97.

Shanmugan, K.R., “Valuations of Life and Injury Risks,” *Environmental and Resource Economics* 16: 379-389, 2000.

Shanmugan, K.R., “Self Selection Bias in the Estimates of Compensating Differentials for Job Risks in India,” *Journal of Risk and Uncertainty* 22: 263-275, 2001.

Viscusi, W.K., “The Value of Risks to Life and Health,” *Journal of Economic Literature* 31: 1912-1946, 1993.

Viscusi, W.K., and J.E. Aldy, “The Value of a Statistical Life: A Critical Review of Market Estimates Throughout the World,” *Journal of Risk and Uncertainty* 27: 5-76, 2003.

World Bank, *World Development Report 2004: Making Services Work for Poor People*, World Bank, Washington, D.C., 2004.

Table 1. Descriptive Statistics
(sample size = 594)

Variable	Definition	Mean	Std. Dev.
Log wage	Natural logarithm of wage (pesos/hour)	2.735	0.564
Fatal (actuarial)	Annual risk of fatal accident (per 10,000)	3.039	5.924
Fatal (perceived)	Annual risk of fatal accident (per 10,000)	11.593	9.383
Non-fatal (actuarial)	Annual risk of non-fatal accident (per 250)	13.321	5.738
Non-fatal (perceived)	Annual risk of non-fatal accident (per 250)	13.744	9.021
Schooling	Years of schooling	8.182	2.495
Experience	Years working with current employer	5.927	7.160
Age	Age in years	33.335	10.376
Male	1 if male, 0 if female	0.793	0.406
Construction	1 if construction worker, zero otherwise	0.281	0.450
Driver	1 if driver, zero otherwise	0.096	0.295
Maintenance	1 if maintenance or cleaning worker, zero otherwise	0.086	0.280
Chronic	1 if respondent has chronic disease, zero otherwise	0.067	0.251
Cold	1 if job exposures worker to unusual cold, zero otherwise	0.048	0.500
Heat	1 if job exposures worker to unusual heat, zero otherwise	0.756	0.430

Table 2. Compensating-Wage-Differential Estimates using Actuarial-Risk Variables

Variable	(1)	(2)	(3)	(4)	(5)	(6)
Fatal	0.0076**		0.0066**	0.0060*		0.0055*
	(0.0033)		(0.0033)	(0.0032)		(0.0032)
Non-fatal		0.0066*	0.0055		0.0040	0.0033
		(0.0040)	(0.0040)		(0.0039)	(0.0039)
Schooling	0.0492***	0.0508***	0.0493***	0.0408***	0.0421***	0.0409***
	(0.0096)	(0.0097)	(0.0097)	(0.0093)	(0.0093)	(0.0093)
Experience	0.0178***	0.0199***	0.0181***	0.0162***	0.0179***	0.0164***
	(0.0040)	(0.0041)	(0.0040)	(0.0034)	(0.0034)	(0.0034)
Age	0.0321**	0.0292**	0.0304**	0.0244**	0.0225*	0.0233**
	(0.0126)	(0.0127)	(0.0127)	(0.0114)	(0.0116)	(0.0116)
Age^2	-0.0004**	-0.0003**	-0.0003**	-0.0003**	-0.0002*	-0.0003*
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Male	0.1742***	0.1831***	0.1705***	0.1448***	0.1521***	0.1430***
	(0.0481)	(0.0487)	(0.0489)	(0.0446)	(0.0446)	(0.0452)
Construction				0.1996***	0.1949***	0.2026***
				(0.0462)	(0.0463)	(0.0465)
Driver				0.3258***	0.3276***	0.3249***
				(0.0997)	(0.0995)	(0.0998)
Maintenance				-0.3371***	-0.3374***	-0.3327***
				(0.0736)	(0.0744)	(0.0745)
Chronic				0.1634*	0.1660*	0.1602*
				(0.0896)	(0.0887)	(0.0896)
Cold				0.1184***	0.1200***	0.1126***
				(0.0393)	(0.0397)	(0.0396)
Heat				-0.0793*	-0.0775*	-0.0787*
				(0.0440)	(0.0442)	(0.0442)
Intercept	1.4964***	1.4446***	1.4531***	1.6832***	1.6493***	1.6580***
	(0.2322)	(0.2349)	(0.2336)	(0.2227)	(0.2246)	(0.2238)
R^2	0.1589	0.1580	0.1620	0.2587	0.2571	0.2598
RMSE	0.5203	0.5206	0.5198	0.4909	0.4915	0.4910

Notes: Huber robust standard errors in parenthesis.
*, **, *** indicate p-value < 0.1, 0.05, 0.01

Table 3. Compensating-Wage-Differential Estimates using Perceived-Risk Variables

Variable	(1)	(2)	(3)	(4)	(5)	(6)
Fatal	0.0055**		-0.0016	0.0011		-0.0040
	(0.0025)		(0.0036)	(0.0024)		(0.0033)
Non-fatal		0.0089***	0.0102***		0.0045*	0.0075**
		(0.0025)	(0.0036)		(0.0025)	(0.0034)
Schooling	0.0495***	0.0503***	0.0495***	0.0421***	0.0421***	0.0422***
	(0.0096)	(0.0097)	(0.0096)	(0.0093)	(0.0093)	(0.0093)
Experience	0.0188***	0.0192***	0.0188***	0.0177***	0.0175***	0.0175***
	(0.0039)	(0.0039)	(0.0040)	(0.0034)	(0.0034)	(0.0034)
Age	0.0273**	0.0293**	0.0272**	0.0233**	0.0217*	0.0216*
	(0.0126)	(0.0126)	(0.0126)	(0.0115)	(0.0117)	(0.0116)
Age^2	-0.0003**	-0.0003**	-0.0003**	-0.0003*	-0.0002*	-0.0002*
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Male	0.1524***	0.1713***	0.1525***	0.1526***	0.1396***	0.1387***
	(0.0485)	(0.0484)	(0.0484)	(0.0445)	(0.0450)	(0.0448)
Construction				0.1909***	0.1936***	0.1941***
				(0.0460)	(0.0457)	(0.0456)
Driver				0.3254***	0.3212***	0.3289***
				(0.0990)	(0.0987)	(0.0988)
Maintenance				-0.3368***	-0.3081***	-0.3080***
				(0.0751)	(0.0755)	(0.0756)
Chronic				0.1676*	0.1608*	0.1649*
				(0.0895)	(0.0884)	(0.0872)
Cold				0.1245***	0.1162***	0.1204***
				(0.0393)	(0.0400)	(0.0396)
Heat				-0.0798*	-0.0816*	-0.0780*
				(0.0443)	(0.0441)	(0.0442)
Intercept	1.4931***	1.4926***	1.4937***	1.6793***	1.6742***	1.6710***
	(0.2304)	(0.2324)	(0.2305)	(0.2235)	(0.2227)	(0.2220)
R^2	0.1726	0.1617	0.1729	0.2558	0.2599	0.2618
RMSE	0.5160	0.5194	0.5164	0.4919	0.4906	0.4904

Notes: Huber robust standard errors in parenthesis.
*, **, *** indicate p-value < 0.1, 0.05, 0.01

Table 4. Estimated Value per Statistical Life, Injury

	(1)	(2)	(3)	(4)	(5)	(6)
Actuarial Risk						
Life	325,000**		282,000**	257,000*		235,000*
Injury		7,000*	5,900		4,300	3,500
Perceived Risk						
Life	235,000**			47,000		
Injury		9,500***	10,900***		4,800*	8,000**

Note: Values calculated using coefficients from indicated columns of Table 2 (actuarial risk) and Table 3 (perceived risk).
*, **, *** indicate p-value < 0.1, 0.05, 0.01

Table 5. Comparison of Estimated VSL and VSI with Other Studies (2000 US$)

Study	Country	Average income	VSL (thousands)	VSI (thousands)
This study	Mexico	4,300	230 - 330	4 - 11
Kim and Fishback (1993)	South Korea	8,100	800	
Liu et al. (1997)	Taiwan	5,000 – 6,100	200 – 900	
Liu and Hammitt (1999)	Taiwan	18,500	700	50
Shanmugan (1996/7)	India	780	1,200 – 1,500	
Shanmugan (2000)	India	780	1,000 – 1,400	150 – 560
Shanmugan (2001)	India	780	4,100	350

Note: Data from Viscusi and Aldy (2003), Tables 4 and 5(b).

Fig. 1. Perceived Occupational Risk