Survival is a Luxury Good:
The Increasing Value of a Statistical Life

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Abstract

The value of changes in mortality risk is conventionally estimated by the marginal rate of substitution between income and mortality risk—the value per statistical life (VSL). Previous estimates of the income elasticity of VSL, obtained from meta-analysis of compensating-wage-differential studies and from contingent valuation, are typically less than one, often 0.3 to 0.5. We present new estimates based on a series of compensating wage differentials in a rapidly developing country, Taiwan. The series is estimated over a 16 year period during which per capita GNP increased two and half times and the occupational fatality rate in manufacturing decreased by half. Over this period, estimated VSL increased ten-fold, from about US$500,000 to US$5 million. The income elasticity of VSL is estimated as 2 to 3.

1. Introduction

The value of a statistical life (VSL) is defined as the marginal rate of substitution between income and mortality risk in a specified time period. VSL is important in determining whether reductions in mortality risk due to environmental, health, and safety regulations are welfare improving. Anticipated changes in VSL can be particularly important for evaluating policies with benefits that are anticipated to persist well into the future, such as regulations to reduce stratospheric-ozone depletion or global climate change. The relationship between VSL and income is also critical for benefits-transfer applications, such as estimating the value of reduced air pollution in developing countries using economic values estimated in industrialized countries.

Empirical evidence about the relationship between income and VSL is limited (Hammitt, 2000b). The most numerous and credible estimates of VSL come from studies of compensating wage differentials (Viscusi, 1993). These studies estimate wages as a function of occupational fatality risk, human-capital variables, and other factors. Because income (or the wage rate) is the dependent variable, it cannot be used as an explanatory variable, and so these studies typically do not provide information about income elasticity.

The income elasticity can be estimated by meta-analysis of compensating-wage-differential studies where the study populations differ in income, risk, and other factors, but these studies lack power. Liu et al. (1997) estimated the relationship between VSL, income, and occupational fatality risk for a sample of 17 compensating-wage-differential studies in the US and other industrialized countries. Their point estimate for the income elasticity is 0.54, with a standard error of 0.85. Mrozek and Taylor (1999) expanded on this approach by including multiple VSL estimates from each of 23 wage studies and controlling for the average wage, risk, and other factors. They report four specifications yielding estimated elasticities of VSL with respect to the wage rate between 0.50 and 0.88 with standard errors of 0.26 and above (a fifth model yields a negative but insignificant estimate).

Other estimates of VSL have been obtained using contingent valuation (CV) and other stated-preference approaches. These estimates are viewed as less credible because survey respondents may have inadequate opportunity or incentive to accurately determine their tradeoff between income and mortality risk. Moreover, CV estimates of willingness to pay (WTP) for different reductions in the probability of premature fatality typically vary less than proportionately to the probability change, which suggests that the results are not valid estimates of VSL (Hammitt and Graham, 1999; Hammitt, 2000a). Nevertheless, because CV studies elicit WTP directly, they can be used to estimate the income elasticity of VSL. Typical estimates range from 0.2 to 0.5. For example, Jones-Lee et al. (1985) estimated values of 0.25 to 0.44, and Mitchell and Carson (1986) estimated a value of 0.35. Corso, Hammitt and Graham (2000) tested alternative visual aids for communicating the risk change to respondents to evaluate which methods yield estimates of WTP that are nearly proportionate to the risk reduction, as standard theory requires. For the best-performing visual aid, the estimated income elasticity is 0.41.

Comparison of estimated VSL between countries with widely differing income levels can also provide information about the relationship between income and VSL, but there are few estimates of VSL outside the OECD countries. There are two previous compensating-wage-differential studies for Taiwan and two studies for India. Compared with US estimates of VSL (US$3 – 7 million; Viscusi, 1993), the Taiwan estimates suggest that income elasticity is substantially greater than one whereas the India estimates suggest it is less than one.

In Taiwan, Liu et al. (1997) estimated VSL in 1982 – 1986 as approximately US$450,000 using actuarial risk estimates. Liu and Hammitt (1999) estimated VSL in 1995 as US$620,000 (controlling for injury risk) and US$1.2 million (not controlling for injury risk), using worker's subjective risk estimates. Comparing these values with US estimates of VSL (US$3 – 7 million; Viscusi, 1993) suggests a much greater than proportional sensitivity to income, since Taiwanese income is about 2.5 times smaller than the US value. (Taiwan GNP per capita increased from about US$5,000 in the mid 1980s to US$10,000 in the mid 1990s. The contemporaneous US values were about US$18,000 and US$25,000.)

Simon et al. (1999) estimate VSL in India as approximately US$150,000 to US$350,000, and Shanmugam (1997) estimated VSL in one metropolitan area in India as approximately US$400,000. As the average income is about US$500 (Simon et al., 1999), these estimates suggest a income elasticity much less than one.

In addition, Hammitt and Zhou (2000) conducted a CV study of WTP for reductions in health risks in China. They estimated VSL in each of three regions (Beijing, Anqing, and the rural district near Anqing) as about US$4,000. In contrast, annual incomes range from about US$500 to US$2,000 across the three regions. Compared with the US and Taiwan values, these estimates suggest that income elasticity is substantially greater than one.

In this paper, we estimate VSL and its relationship to income using a new approach. We use data on occupational-fatality risk and wages to estimate VSL over time in a rapidly developing economy, Taiwan. Over the period we study, 1982 – 1997, Taiwanese real GNP per capita grew about 2.5 times and the occupational-fatality rate declined by half. Estimated VSL increased 10-fold, from about US$500,000 to US$5 million. The implied income elasticity is between about 2 and 3. (Section 2 provides additional information about our data.)

We estimate VSL and its relationship to income using several approaches, presented in Section 3. First, we estimate standard hedonic-wage equations for each of the 16 years for which we have data. Second, we estimate VSL under the assumption that workers predict the risk they face using an adaptive-expectations approach. This approach may be used to account for possible biases that result from the maintained assumption that workers accurately forecast future risk when they decide to accept or continue in a job. Third, we pool our data over time and estimate a reduced-form model in which VSL shifts with time or, alternatively, economic development as measured by real GNP per capita.

Section 4 estimates the income elasticity of VSL by examining the relationship between annual VSL estimates and average worker earnings or GNP per capita. Conclusions are in Section 5.

The income elasticity estimated here is an income elasticity of the virtual price of a good. They describe how WTP for a unit reduction in mortality risk depends on income. The income elasticity of a virtual price is not in general equal to the income elasticity of demand for a good. The relationship between the two values depends on several factors including the budget shares and cross-price elasticities of multiple goods (Flores and Carson, 1997).

Our estimates of the income elasticity of VSL are based on intertemporal comparisons within a population. To our knowledge, all previous estimates are based on cross-sectional comparisons between populations. Under standard theory, the two values should coincide, but there are factors that may lead to some divergence. One possibility is that, at least in the early stages of economic development, workers may not recognize that one of the goods they can purchase with their increased income is on-the-job safety. To the extent that workers perceive safety conditions in industry as immutable, they may direct their increasing incomes more toward consumer goods than occupational safety. This effect would tend to suppress the intertemporal income elasticity. Alternatively, if economic development is characterized by disproportionate growth in new, safer industries that are attractive to workers primarily because they are new or rapidly growing rather than because they are safer (e.g., microelectronics), firms in older, more hazardous industries (e.g., steel) may need to increase wages to retain workers. This effect would tend to bias the estimated income elasticity upward, since the additional compensation paid in hazardous industries is, by hypothesis, compensation for limited growth opportunities or other attributes other than risk. Another possibility reflects individuals' concern about consumption relative to reference groups (in addition to concern about absolute consumption). If occupational safety is less positional than the average good, the compensating-wage differential for safety may be larger if everyone in the reference group must pay for the improvement than when individuals can choose among safer and more hazardous jobs (Frank and Sunstein, 2000). With rapid economic growth, the losses in relative consumption due to choosing a lower-paying job may be mitigated, leading to a more rapid growth in wage differentials and a larger income elasticity of VSL.

2. Data

Our data cover the years 1982-1997. Data on worker income and personal characteristics are from the annual Taiwan Labor Force Survey (TLFS) conducted by the Taiwan Directorate-General of Budget, Accounting and Statistics. Each sample is drawn independently (individuals cannot be linked between years) using a two-stage stratified-random-sampling method. In the first stage, 515 administrative districts are selected as a random sample from strata defined by urbanization, industrial structure, and educational attainment. In the second stage, 19,600 households are selected from within these districts, and information is collected on the approximately 60,000 household members aged 15 years and above. The data include individual demographic and employment characteristics. For compatibility with our risk data, we include only individuals who are employed full time in the manufacturing sector, yielding a sample size of 6,912 to 10,092 workers per year.

Our risk data consist of annual industry fatality rates (deaths per 10,000 workers). The data were provided by the Taiwan Labor Insurance Bureau. The Bureau administers a compulsory insurance program under the Taiwan Labor Insurance Act, which requires that all industrial workers between the ages of 15 and 60 be insured. Fatality rates are constructed for each of 20 two-digit manufacturing industries. Rates are defined as the total number of work-related death claims divided by the total number of insured employees, which ranges between 2.0 million and 3.9 million over the period. Although an alternative risk measure, the fatality rate by occupation, may be preferred, such a measure is not available for Taiwan. Moreover, the effects of any bias arising from greater measurement error or confounding of persistent inter-industry wage differences with the risk measure (Leigh, 1995) should vary little over time, and thus have minimal effect on our estimates of how VSL changes with economic growth.

The means and standard deviations for selected variables used in the hedonic wage models are reported in Table 1. Reflecting the rapid economic growth of Taiwan over this period, the nominal hourly wage more than tripled, from NT$47 in 1982 to NT$155 in 1997 (the 1991 exchange rate is NT$25.75 = US$1). In contrast, the consumer price index increased by only 40%. Although total working hours per month decreased slightly over the period, annual earnings increased substantially. As shown in Fig. 1, real earnings increased by a factor of 2.2 over the period. Real GNP per capita increased somewhat more rapidly, by a factor of 2.6.

The demographic variables reveal a substantial maturing of the manufacturing workforce over the period. The average age increased from 29 to more than 35 years and the fraction of workers who are married increased from 45% to 63%. Mean experience in the current job increased from about 47 to 64 months. The average worker's education also increased, from about 8.7 to 10.5 years. This increase was stimulated by a nine year compulsory educational program established in 1968. Reflecting the success of this program, education increased most rapidly for 20 – 30 year old workers, from 7.6 years in 1982 to 12.2 years in 1997.

Occupational fatality risk declined substantially over the period. Table 2 lists the industries we study and their average mortality risk levels at the beginning and end of the period (four-year averages). Risk declined in all industries, by widely varying amounts. The largest proportional reduction (76%) occurred in the miscellaneous manufacturing category and the smallest reduction (12%) occurred in nonmetallic minerals. There is no apparent relationship between the proportional risk reduction and the risk level at the beginning of the period.

The sample-average mortality rate (weighted by industry employment) is reported in Table 1. As shown in Fig. 2, the industry-average risk is somewhat larger than the sample-average risk, reflecting the disproportionate allocation of workers to safer industries. Both the sample-average and the industry-average risk declined by almost half over the period. Although the occupational fatality risk early in the period was well-above the US level of about 1 per 10,000 workers (Viscusi, 1993), the risk at the end of the period is only modestly above that level.

3. Estimated Value per Statistical Life

We estimate VSL and its relationship to income using several approaches. We begin by estimating standard hedonic-wage equations for each of the 16 years for which we have data. These equations describe the wage rate as a function of occupational risk and worker characteristics. Second, we account for uncertainty about industry risk. At the time a worker accepts a job, or decides to continue in a job, the risk he faces is uncertain. The conventional approach estimates the wage differential for the realized risk, which implicitly assumes the worker accurately forecasts the risk for the upcoming period. As an alternative, we assume that workers forecast the risk using an adaptive-expectations approach. Finally, we pool our data over time and estimate VSL as a function of time and, alternatively, economic growth.

3.1 Standard Hedonic Regression

For each of the 16 years, we estimate a standard semi-logarithmic hedonic wage function defined as:

$$log(WAGE_i) = \alpha + \beta(RISK_i) + \gamma Z_i + \varepsilon_i \quad (1)$$

where WAGE is an individual's hourly wage rate, RISK is the occupational-mortality rate he faces, and Z is a vector of individual characteristics including sex, age, marital status, education, working experience, squared terms for education and working experience, and six occupation dummies (professionals, senior managers, clerical supervisors and office administrators, clerks and salespersons, service workers, craft and related operators, drivers and mobile operators). The error term is assumed to be independently and identically distributed.

Parameter estimates are reported in Table 3. The hedonic-wage function fits reasonably well, with adjusted R^2 values of about 0.5 for each year. The coefficient on RISK, which is of primary interest, is positive and significantly different from zero in all cases with t-statistics between 2.1 and 10. Coefficients on the other variables are generally significant and stable across years. Controlling for other factors, males are paid about one-third more than females and married workers are paid about 10% more than unmarried workers. The wage rate increases at an increasing rate with education, and increases at a decreasing rate with experience in the current job. The effect of age is small in absolute value and not significantly different from zero in some years.

The corresponding VSLs are reported in column (1) of Table 4. VSL is calculated as the ratio of the incremental annual earnings (using the sample average wage rate and working hours per month) to the increase in occupational fatality risk,

$$VSL = \hat{\beta} * \overline{WAGE} * \overline{HOURS} * 12 / (1/10{,}000). \quad (2)$$

It is converted to 1991 NT$ using the Taiwan Consumer Price Index and then to US$ at the 1991 exchange rate of NT$25.75 = US$1. Estimated VSL increases sharply in the early part of the period from US$410,000 in 1982 to about US$4.5 million in 1991. In the later part of the period, it fluctuates between about US$4 million and US$5 million, except for the lower value of US$3.3 million in 1997.

3.2 Estimates Using Predicted Risk

At the time a worker decides whether to begin a job, or continue in his current job, the fatality risk is uncertain. The standard approach implicitly assumes that workers accurately forecast the risk they face. As an alternative, we consider the case where workers forecast the risk for the next year using an adaptive-expectations approach. Under this approach, workers are assumed to estimate the risk in industry i and year t using observed risks over the preceding two years,

$$RISK_{i,t} = \delta_0 + \delta_1\, RISK_{i,t-1} + \delta_2\, (RISK_{i,t-1} - RISK_{i,t-2}) + \nu_{i,t}. \qquad (3)$$

Equation (3) is estimated using OLS and industry fixed effects. As shown in Table 5, the parameter estimates for the two specifications are similar. The adjusted R^2 are about 0.75 and the estimated coefficients are significantly different from zero, with estimates of δ_1 greater than zero and estimates of δ_2 less than zero. Equation (3) can be expressed as

$$RISK_{i,t} = \delta_0 + (\delta_1 + \delta_2)\, RISK_{i,t-1} - \delta_2\, RISK_{i,t-2} + \nu_{i,t}. \qquad (3')$$

In this form, it is clear that predicted risk is an increasing function of risk in each of the previous two periods, with greater weight on the more recent period.

The hedonic wage function (2) is re-estimated substituting predicted values of $RISK_{i,t}$ for the realized values. The results are quite similar to those shown in Table 3. The corresponding estimates of VSL are reported in columns (2) and (3) of Table 4. Like the estimates obtained using the standard approach, these estimates increase from values near US$500,000 at the beginning of the period to values of US$4 million to US$5 million by the end of the period. Most of the increase occurs by 1991, with little apparent trend in the second half of the period.

3.3 Estimates Using Pooled Data

As an alternative to the independent annual estimates, we pool our data over time and estimate the wage-risk premium as a function of time or, alternatively, economic growth. We estimate

$$log(WAGE_{it}) = \alpha_0 + \alpha_1 G_t + \alpha_2 G_t^2 + \alpha_3 RISK_{it} + \alpha_4 (RISK_{it} * G_t) + \alpha_5 (RISK_{it} * G^2) + \gamma Z_i + \varepsilon_i\,. \qquad (4)$$

The variable G is a measure of economic growth, defined alternatively as (year – 1990) or as the logarithm of real per capita GNP minus its mean value. (The mean values are subtracted to reduce correlation between G and G^2.) The estimated values of α_4 and α_5 provide information about the change in VSL with economic growth. Positive estimates of α_4 and α_5 suggest that VSL increases with growth at an increasing rate. The estimated values of α_1 and α_2 provide information about how wages change with economic growth.

Results are shown in Table 6 using realized (current) risk values as well as predicted risk (using alternatively OLS and fixed-effect specifications). The results suggest that wages have increased with both time and per capita GNP (estimates of α_1 are significantly greater than zero). The rate of increase has slowed as a function of time (estimates of α_2 in columns (1), (3), and (5) are significantly less than zero), but increased as a function of per capita GNP. The interactions between G and RISK are positive and highly significant, confirming earlier results that show VSL increasing over the period. The estimates of α_5 suggest that VSL is a convex function of growth, although the estimates using the fixed-effect predicted risks are not significantly different from zero (columns (5) and (6)). The estimated coefficients of the worker's other characteristics are similar to those seen in the independent estimates such as those shown in Table 3.

Estimates of VSL from the pooled model are reported in columns (4) – (9) of Table 4. These are similar to the estimates obtained using the independent hedonic-wage functions, except the values increase more smoothly over the period.

4. Income Elasticity of VSL

The various time-series estimate of VSL reported in Section 3 all show a dramatic increase over the sample period. Representative estimates are illustrated in Fig. 3. The two series based on independent estimates for each year, using current risk and predicted risk (fixed-effect specification) show a sharp increase through 1991 and substantial fluctuations in later years. The two series based on the pooled data show a smooth increase over the entire period.

To evaluate the income elasticity of VSL, we examine the relationship between estimated VSL and per capita GNP. To reflect possible changes in VSL associated with baseline risk, we test the effect of including the sample average occupational risk in the model. We estimate the model

$$log(VSL_t) = b_0 + b_1\, log(LGNP_t) + b_2\, RISK_t + \boldsymbol{e}_t \qquad (5)$$

where $LGNP_t$ is the logarithm of real per capita GNP and $RISK_t$ is the sample mean risk in year t.

Results are shown in Table 7. For the models excluding the average occupational risk, the estimated elasticity with respect to per capita GNP ranges from 2.5 to 3.1. Alternative estimates using annual earnings in place of per capita GNP or using a first-order autoregressive error term are quite similar (results not shown).

The elasticity estimates from the specifications including the average risk are similar, between 2.1 and 2.8. However, the estimated coefficient on average risk is never statistically significant. In all but one case, its sign is less than zero, contrary to expectation. Under the standard theoretical model, VSL increases with baseline risk because the opportunity cost of spending decreases (Jones-Lee, 1974; Weinstein et al., 1980; Pratt and Zeckhauser, 1996; Hammitt, 2000b). In a cross-sectional analysis, a negative coefficient could reflect a selection effect, if samples with higher mean risk include a disproportionate share of low-VSL individuals. In this context, the selection effect would imply that high VSL workers have left the Taiwanese manufacturing sector over this period, even though average risk fell by half. If true, this implies that our estimates of income elasticity are biased downward.

The income elasticity can also be estimated directly from the pooled models in Table 6. From eqn. (4), the elasticity of VSL with respect to economic growth G can be calculated as α_4 / α_3. From Table 6, the corresponding estimates using per capita GNP as the growth measure are 2.22, 2.53, and 1.47 (from columns (2), (4), and (6), respectively). These estimates are comparable to the values obtained in Table 7, except the last value (1.47) which is somewhat smaller.

5. Conclusions

Using a unique data set including annual wage and occupational fatality risk estimates over a 16 year period in Taiwan, we have examined how VSL increases with economic growth. This period is one of rapid economic growth combined with increases in workplace safety: earnings more than doubled while average risk declined by half. The estimated rate of substitution between income and risk increased about ten-fold. The estimated income elasticity of VSL is between about 2 and 3. This value is much higher than found in previous studies, which have generally found values less than one.

Although our estimate is much larger than estimates from previous studies, it is based on what is generally viewed as the most credible method for estimating rates of substitution between risk and income, the compensating-wage-differential study. Our estimates reflect real economic behavior by a large population facing a significant mortality risk.

Our estimated income elasticity is based on intertemporal comparisons, in contrast with the cross-sectional comparisons on which all previous estimates rely. Under standard theory, the two values should coincide. To the extent that there is a difference, the intertemporal estimate appears more relevant to estimating the value of environmental and other policies that provide benefits far into the future.

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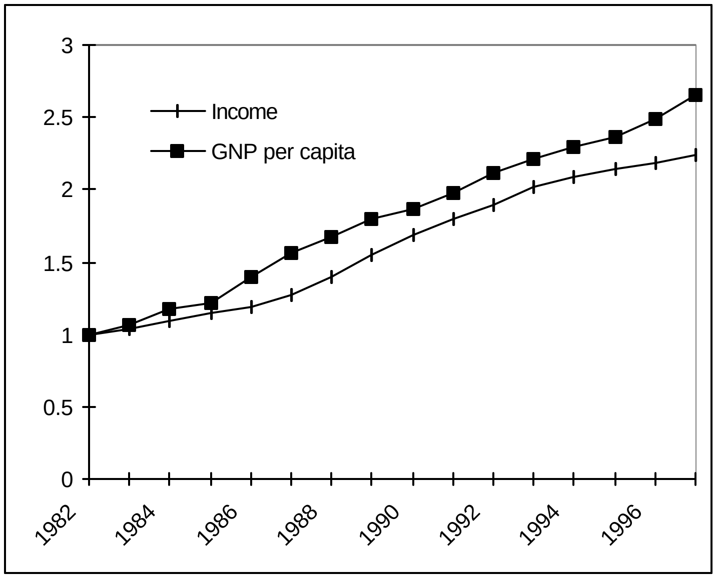

Fig. 1. Growth of real income and real GNP per capita

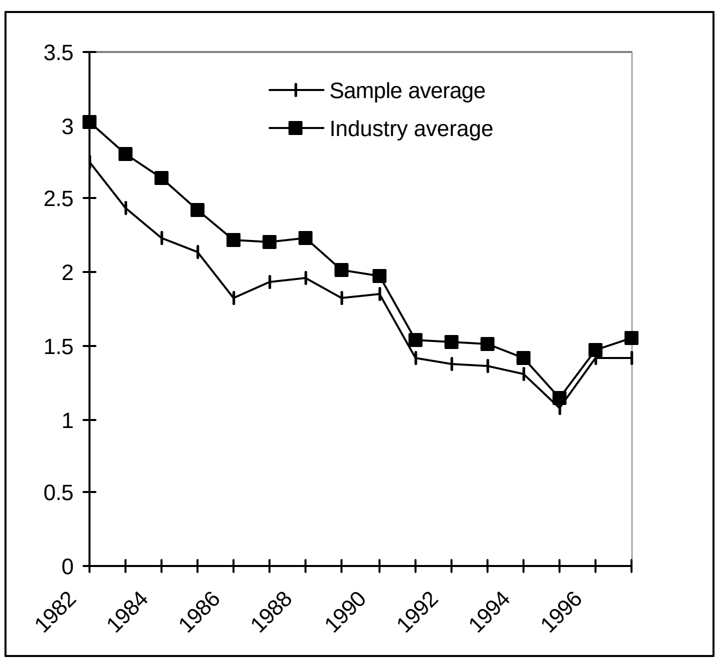

Fig. 2. Manufacturing-sector occupational fatality risk

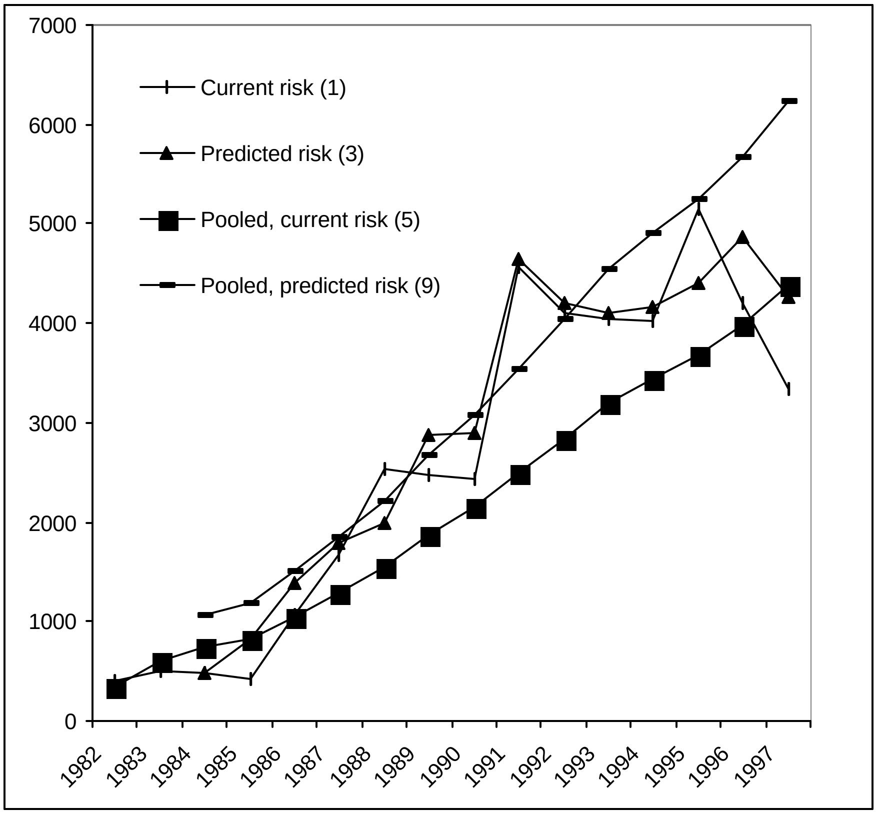

Fig. 3. Trends in Value per Statistical Life

Note: Numbers in parentheses correspond to columns in Table 3.

Table 1. Sample Statistics

YEAR	WAGE	RISK	SEX	AGE	MARRIED	EDU	EXPER	HOURS	N
1982	47.27	2.75	0.55	28.95	0.45	8.68	46.56	193.92	7,963
	(23.34)	(1.32)	(0.49)	(11.22)	(0.49)	(3.46)	(57.02)	(24.70)	
1983	50.06	2.44	0.54	29.67	0.48	8.75	46.88	193.16	8,047
	(27.19)	(1.17)	(0.49)	(11.47)	(0.49)	(3.55)	(57.81)	(24.37)	
1984	52.02	2.24	0.54	30.33	0.50	8.84	46.79	195.02	9,233
	(26.92)	(1.06)	(0.49)	(11.54)	(0.49)	(3.60)	(58.18)	(25.90)	
1985	55.24	2.14	0.54	30.55	0.52	8.91	46.55	193.49	9,130
	(28.12)	(1.03)	(0.49)	(11.19)	(0.49)	(3.61)	(56.75)	(25.10)	
1986	57.63	1.82	0.53	30.77	0.53	8.95	48.20	193.74	9,295
	(30.74)	(1.44)	(0.49)	(11.13)	(0.49)	(3.56)	(58.50)	(26.98)	
1987	61.19	1.93	0.53	31.09	0.54	9.18	48.35	195.66	10,092
	(32.78)	(1.03)	(0.49)	(11.00)	(0.49)	(3.60)	(56.91)	(26.93)	
1988	68.15	1.96	0.54	31.76	0.55	9.32	51.62	194.22	9,904
	(34.09)	(0.90)	(0.49)	(11.01)	(0.49)	(3.55)	(59.68)	(24.31)	
1989	79.56	1.83	0.55	32.26	0.57	9.45	54.47	192.57	9,407
	(39.91)	(0.85)	(0.49)	(10.88)	(0.49)	(3.53)	(61.80)	(24.34)	
1990	91.64	1.85	0.56	32.74	0.58	9.55	54.71	190.05	8,492
	(45.65)	(0.85)	(0.49)	(10.75)	(0.49)	(3.51)	(58.68)	(22.33)	
1991	101.25	1.42	0.55	33.20	0.59	9.61	54.90	190.42	8,123
	(48.09)	(0.68)	(0.49)	(10.80)	(0.49)	(3.45)	(61.56)	(21.17)	
1992	112.11	1.37	0.56	33.83	0.58	9.74	58.64	189.65	7,805
	(53.61)	(0.52)	(0.49)	(10.80)	(0.49)	(3.46)	(61.91)	(22.76)	
1993	122.56	1.36	0.56	34.37	0.61	9.81	60.85	190.06	7,684
	(73.51)	(0.67)	(0.49)	(10.87)	(0.48)	(3.50)	(64.20)	(21.61)	
1994	131.54	1.31	0.56	34.73	0.62	9.87	63.78	189.73	7,485
	(62.23)	(0.62)	(0.49)	(10.72)	(0.48)	(3.50)	(66.16)	(23.08)	
1995	142.89	1.07	0.56	35.22	0.63	10.04	65.51	186.26	7,275
	(78.50)	(0.51)	(0.49)	(10.77)	(0.48)	(3.56)	(66.94)	(31.58)	
1996	151.27	1.42	0.57	35.46	0.63	10.31	69.89	185.10	6,912
	(79.63)	(0.74)	(0.49)	(10.62)	(0.48)	(3.57)	(72.41)	(31.40)	
1997	155.45	1.41	0.58	35.71	0.63	10.48	964.05	185.76	7,276
	(78.15)	(0.71)	(0.49)	(10.62)	(0.48)	(3.52)	(73.43)	(28.52)	

Notes: Standard deviations in parentheses. Variable definitions: WAGE: hourly wage rate (NT$); RISK: annual mortality rate per 10,000 workers; SEX: 1=Male, 0=Female; AGE: age in years; MARRIED: 1=married, 0=other; EDU: years of schooling; EXPER: months of working experience at current job; HOURS: working hours per month; N: number of observations.

Table 2. Risk by Industry

Industry	Average RISK (1982-1985)	Average RISK (1994-1997)	Decrease (%)
Primary Metal	6.93	2.64	62
Lumber and Furniture	3.94	1.72	56
Nonmetallic Mineral	3.79	3.35	12
Paper and Printing	3.62	1.34	63
Transportation	3.54	1.85	48
Food	3.06	1.05	66
Beverages and Tobaccos	3.06	1.05	66
Machinery	2.62	1.59	39
Chemicals [a]	2.48	1.47	41
Chemical Products [a]	2.48	1.47	41
Petroleum and Coal [a]	2.48	1.47	41
Rubber [a]	2.48	1.47	41
Plastic [a]	2.48	1.47	41
Metal Products	2.24	1.57	30
Miscellaneous	1.86	0.45	76
Textiles	1.55	0.90	42
Apparel	1.55	0.90	42
Leather	1.50	0.82	45
Electrical and Electronic	1.42	0.80	43
Precision Instruments	1.36	0.55	60

Notes: RISK is defined as fatalities per 10,000 workers. a. The risk data for these five industries are available only as an aggregate.

Table 3. Selected Parameter Estimates of Hedonic Wage Models, 1982-1997

	Independent Variables									
YEAR	RISK	SEX	AGE	MARRIED	EDU	EDU^2	EXPER	$EXPER^2$	Adj. R^2	F-value
1982	0.008	0.295	0.002	0.094	0.005	0.001	0.003	$-0.71*10^{-5}$	0.48	532.01
	(2.92)	(37.20)	(4.98)	(10.61)	(1.41)	(5.08)	(24.23)	(15.50)		
1983	0.009	0.309	0.001	0.115	0.007	0.001	0.003	$-0.63*10^{-5}$	0.49	526.91
	(2.99)	(38.04)	(2.78)	(12.55)	(2.01)	(4.52)	(22.78)	(-13.37)		
1984	0.008	0.307	0.001	0.089	0.008	0.001	0.003	$-0.67*10^{-5}$	0.47	552.92
	(2.64)	(40.50)	(1.44)	(10.74)	(2.47)	(4.01)	(25.32)	(-15.41)		
1985	0.007	0.313	0.001	0.086	0.006	0.001	0.003	$-0.74*10^{-5}$	0.47	551.47
	(2.15)	(42.18)	(1.73)	(10.52)	(1.94)	(4.64)	(26.53)	(-16.71)		
1986	0.017	0.335	0.001	0.098	0.011	0.001	0.003	$-0.69*10^{-5}$	0.49	602.63
	(7.33)	(44.87)	(2.07)	(12.03)	(3.30)	(4.75)	(27.40)	(-17.16)		
1987	0.026	0.337	-0.001	0.082	0.005	0.001	0.003	$-0.62*10^{-5}$	0.49	660.41
	(8.09)	(46.98)	(-1.19)	(10.48)	(1.53)	(5.36)	(27.47)	(-14.54)		
1988	0.036	0.361	$-0.26*10^{-3}$	0.095	0.005	0.001	0.003	$-0.48*10^{-5}$	0.51	690.45
	(10.12)	(52.05)	(-0.63)	(12.32)	(1.50)	(6.00)	(23.27)	(-11.58)		
1989	0.032	0.379	$-0.11*10^{-3}$	0.074	0.002	0.001	0.002	$-0.43*10^{-5}$	0.49	618.27
	(7.96)	(51.62)	(-0.25)	(9.23)	(0.61)	(6.35)	(25.85)	(-15.39)		
1990	0.028	0.373	$-0.44*10^{-3}$	0.092	0.003	0.001	0.002	$-0.51*10^{-5}$	0.49	556.64
	(6.96)	(48.57)	(-0.91)	(11.10)	(0.78)	(5.57)	(19.59)	(-10.24)		
1991	0.050	0.377	$0.33*10^{-4}$	0.065	0.011	0.000	0.002	$-0.33*10^{-5}$	0.47	524.98
	(9.38)	(47.09)	(0.06)	(7.55)	(2.51)	(3.04)	(20.54)	(-10.61)		
1992	0.043	0.367	$-0.41*10^{-3}$	0.077	0.003	0.001	0.003	$-0.57*10^{-5}$	0.48	516.73
	(6.09)	(45.00)	(-0.81)	(8.80)	(0.70)	(5.17)	(19.96)	(-11.08)		
1993	0.039	0.396	$-0.88*10^{-3}$	0.078	0.008	0.001	0.002	$-0.48*10^{-5}$	0.51	583.41
	(7.12)	(47.70)	(-1.73)	(8.88)	(1.80)	(4.96)	(19.49)	(-9.74)		
1994	0.038	0.400	$-0.33*10^{-3}$	0.078	0.006	0.000	0.002	$-0.41*10^{-5}$	0.51	569.50
	(6.53)	(49.58)	(-0.67)	(9.08)	(1.48)	(4.22)	(17.85)	(-8.22)		
1995	0.048	0.363	0.001	0.076	0.018	0.000	0.002	$-0.35*10^{-5}$	0.49	502.33
	(6.33)	(42.17)	(2.74)	(8.24)	(4.09)	(2.61)	(15.46)	(-6.98)		
1996	0.037	0.357	0.002	0.069	0.005	0.001	0.002	$-0.27*10^{-5}$	0.51	523.00
	(7.13)	(40.95)	(4.29)	(7.63)	(1.14)	(5.65)	(14.70)	(-5.91)		
1997	0.029	0.343	0.002	0.063	0.001	0.001	0.002	$-0.23*10^{-5}$	0.49	498.01
	(5.75)	(41.94)	(5.23)	(7.22)	(0.40)	(6.06)	(4.07)	(-5.71)		

Note: t-statistics in parentheses.

Table 4. Estimated Value per Statistical Life Obtained from Alternative Models (1991 US$1,000)

YEAR	GDP/ capita	Annual estimates			Pooled Data					
		Current risk	Predicted risk		Current risk		Predicted risk			
			OLS	Fixed Effects			OLS		Fixed Effects	
					T	GNP	T	GNP	T	GNP
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1982	4.30	412			572	113				
1983	4.60	502			720	190				
1984	5.06	483	253	491	590	230	1,059	729	1,119	868
1985	5.26	419	588	817	486	262	1,103	784	1,268	989
1986	6.01	1,064	1,255	1,388	401	365	1,162	989	1,411	1,321
1987	6.72	1,677	1,657	1,782	361	504	1,294	1,364	1,612	1,707
1988	7.19	2,541	1,927	1,995	368	642	1,511	1,767	1,882	2,078
1989	7.71	2,477	3,105	2,881	429	831	1,827	2,344	2,230	2,566
1990	8.03	2,432	3,148	2,899	548	992	2,209	2,842	2,599	2,980
1991	8.53	4,573	4,782	4,655	729	1,201	2,638	3,523	2,959	3,471
1992	9.09	4,105	4,554	4,199	985	1,438	3,133	4,325	3,325	4,000
1993	9.50	4,036	4,419	4,102	1,345	1,669	3,761	5,106	3,763	4,522
1994	9.88	4,024	5,215	4,166	1,758	1,848	4,368	5,737	4,112	4,900
1995	10.19	5,144	5,241	4,410	2,264	2,012	5,064	6,314	4,485	5,245
1996	10.72	4,203	6,164	4,866	2,848	2,246	5,814	7,171	4,849	5,704
1997	11.39	3,330	5,162	4,257	3,534	2,547	6,664	8,290	5,243	6,278

Note: The values in column (1) are calculated using the parameter estimates in Table 3. The values in columns (2) and (3) are obtained from independently estimated annual wage equations analogous to those in Table 3, substituting predicted risk (obtained using the estimates of Table 5) for realized risk. The values in columns (4) – (9) are obtained from parameter estimates in columns (1) – (6) of Table 6.

Table 5. Parameter Estimates of the Predicted Risk Model

Variable	OLS	Fixed Effect
Constant	0.1917	
	(2.957)	
$RISK_{t-1}$	0.5279	0.4322
	(9.949)	(7.703)
$RISK_{t-1}$-$RISK_{t-2}$	0.3093	0.2477
	(6.175)	(4.760)
Adj. R^2	0.75	0.76
N	280	280

Note: t statistics in parentheses.

Model: $RISK_{i,t} = \delta_0 + \delta_1 RISK_{i,t-1} + \delta_2 (RISK_{i,t-1} - RISK_{i,t-2}) + \nu_{i,t}$

Table 6. Selected Parameter Estimates of Hedonic Wage Model Using Pooled Data (1982-1997) and Industry Fixed Effects

	Current Risk		Predicted Risk			
			OLS		Fixed Effects	
	T (1)	GNP (2)	T (3)	GNP (4)	T (5)	GNP (6)
Intercept	3.753	3.663	3.732	3.692	3.727	3.691
	(405.68)	(379.58)	(365.32)	(346.89)	(367.44)	(366.77)
T	0.053		0.0545		0.0553	
	(111.72)		(83.15)		(92.87)	
T^2	-0.00133		-0.00229		-0.00198	
	(-12.16)		(-13.34)		(-12.25)	
LGNP		0.866		0.878		0.915
		(113.34)		(74.65)		(85.47)
$LGNP^2$		0.4418		0.393		0.462
		(17.248)		(9.55)		(11.82)
RISK	0.00651	0.00995	0.0263	0.0333	0.031	0.0352
	(3.28)	(5.37)	(9.58)	(12.83)	(11.18)	(13.30)
RISK*T	0.00127		0.00282		0.00199	
	(4.53)		(6.86)		(5.72)	
$RISK*T^2$	0.00332		2.81e-4		4.43e-5	
	(6.82)		(3.21)		(0.55)	
RISK*LGNP		0.0221		0.0842		0.0519
		(4.97)		(10.74)		(7.88)
$RISK*LGNP^2$		0.0188		0.0885		0.216
		(1.64)		(4.15)		(1.10)
SEX	0.355	0.356	0.359	0.359	0.359	0.359
	(172.31)	(172.63)	(164.09)	(163.98)	(163.67)	(163.54)
AGE	0.00613	6.30e-4	4.26e-4	4.45e-4	4.28e-4	4.47e-4
	(5.10)	(5.25)	(3.32)	(3.47)	(3.34)	(3.48)
MARRIED	0.0898	0.0908	0.0874	0.0878	0.0874	0.0878
	(42.02)	(42.49)	(38.60)	(38.73)	(38.60)	(38.71)
EDU	0.00703	0.00689	0.00717	0.00732	0.00725	0.00742
	(7.01)	(6.87)	(6.67)	(6.79)	(6.74)	(6.88)
EDU^2	0.00104	0.00105	0.00104	0.00103	0.00103	0.00102
	(19.15)	(19.30)	(17.91)	(17.72)	(17.87)	(17.65)
EXPER	0.00227	0.00226	0.00223	0.00223	0.00223	0.00223
	(101.37)	(101.19)	(94.97)	(94.80)	(94.89)	(94.71)
$EXPER^2$	-2.28e-6	-2.32e-6	-2.22e-6	-2.29e-6	-2.21e-6	-2.29e-6
	(-101.82)	(-103.87)	(-94.25)	(-97.53)	(-94.23)	(-97.47)
Adjusted R^2	0.6356	0.6359	0.6190	0.6177	0.6190	0.6176
F-value	8334	8343	6834	6799	6835	6797
σ	0.3228	0.3227	0.3219	0.3224	0.3218	0.3224
N	133,807	133,807	117,797	117,797	117,797	117,797

Notes: t statistics in parentheses. T = year – 1990; LGNP = log(per capita GNP) – mean[log(per capita GNP)]. Columns (1) and (2) are estimated using the original mortality rate. Columns (3) and (4) are estimated using the risks predicted from the OLS estimates in Table 5, and columns (5) and (6) use the fixed effects estimates in Table 5.

Table 7. Estimated Relationship between Value per Statistical Life and GNP per capita

	(1a)	(1b)	(3a)	(3b)	(5a)	(5b)	(9a)	(9b)
Intercept	-16.8482	-9.1541	2.423	4.087	-21.239	-17.385	-12.870	-14.760
	(-5.448)	(-0.929)	(4.46)	(2.14)	(-27.77)	(2.23)	(-22.44)	(-5.86)
LGNP	2.8405	2.2679	2.609	2.122	3.125	2.838	2.531	2.667
	(11.173)	(3.059)	(10.06)	(3.56)	(49.69)	(16.90)	(53.99)	(14.54)
RISK		-0.4121		-0.395		-0.206		0.133
		(-0.824)		(-0.91)		(-1.82)		(0.77)
F-value	124.84	61.32	101.1	50.3	2469	1441	2915	1408
σ	0.30	0.31	0.243	0.244	0.076	0.071	0.044	0.045
Adj. R^2	0.89	0.88	0.89	0.88	0.99	0.99	0.99	0.99
N	16	16	14	14	16	16	14	14

Notes: t statistics in parentheses. LGNP = log(GNP per capita). Columns (*a) and (*b) estimated for VSL from column (*) of Table 4.