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Author(s): Douglas Gegax, Shelby Gerking, William Schulze
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PERCEIVED RISK AND THE MARGINAL VALUE OF SAFETY

Douglas Gegax, Shelby Gerking, and William Schulze*

Abstract—Two contributions are made toward understanding variation in marginal value of safety estimates from labor market studies. First, marginal safety values are obtained from direct measurement of workers' perceived job-related accidental death rates. Second, wage–risk relationships are explored for several categories of workers using the hedonic price method. Statistically significant relationships found for unionized, blue collar, and blue collar–unionized workers imply marginal safety values of 1.5, 1.18, and 2.10 million dollars, respectively. Further results in this paper suggest that alternative methods are needed to measure marginal safety values for workers in other categories.

I. Introduction

MARGINAL value of safety estimates from labor market studies exhibit substantial variation. The marginal value of safety for the average worker considered by Thaler and Rosen (1975) was approximately $578,000 (in 1983 dollars) while Garen (1988), after adjusting for potential endogeneity of job risk, found the corresponding value to be about $9.2 million (in 1983 dollars). This range increases still further when particular types of workers are analyzed. In Olson's (1981) study, unionized workers had a marginal value of safety of nearly $17 million (in 1983 dollars) whereas Dorsey and Walzer (1983) presented an equation in which the corresponding value for nonunion workers is negative and statistically significant. These anomalous findings for nonunion workers in addition to the general divergence in marginal value of safety estimates have complicated formulation of government policy and have initiated debates concerning which estimates are best supported, how seemingly vast differences between them can be explained; and whether the market for safety has failed.

This paper makes two contributions toward further understanding of these issues. First, marginal safety values are obtained from direct measurements of workers' perceived job-related accidental death risk. Risk perception data together with detailed information on labor market characteristics are collected by mail from a national random sample of U.S. residents. Although perceptions are difficult to measure and questionnaires are imperfect measurement instruments, the risk data collected still are arguably superior to those used in previous labor market studies. With few exceptions, previous estimates are based on fatal accident risks measured as industrial or occupational averages. Yet, perceived death risks may differ from actual death risks and particular jobs have greater or lesser risks than these averages.

Second, wage–risk relationships are explored for several categories of workers using the hedonic price method. Using the perceived risk measure, statistically significant relationships found for unionized, blue collar, and blue collar–unionized workers imply marginal safety values of $1.58 million, $1.18 million, and $2.10 million (in 1983 dollars), respectively. These values are lower by factors of between five and seven compared with those obtained using average industry fatal accident rates. In hedonic wage regressions for white collar and nonunionized workers, however, coefficients of perceived risk are not significant at conventional levels.

II. Data

Data were collected by a national mail survey during the summer of 1984 using Dillman's (1978) total design method. Survey materials were sent to: (1) a random sample of 3,000 U.S. household heads and (2) 3,000 additional household heads randomly selected from 105 counties which have disproportionately large concentrations of high-risk industries. In the second component, the

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* New Mexico State University, Las Cruces, University of Wyoming, Laramie, and University of Colorado, Boulder, respectively.

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sample included an equal number of households from the northeast, northcentral, west and south regions of the United States. Of the 6,000 questionnaires mailed, 749 (12.5%) were returned as undeliverable and a total of 2,103 were returned in completed form. Thus, the net response rate was approximately 40%. Not all completed questionnaires, however, could be used in the empirical analysis reported in section III. Responses were excluded from household heads who: (1) were retired, unemployed or otherwise not in the labor force, (2) received more than 20% of total income from transfer payments, (3) worked fewer than 1250 hours in 1983, (4) were self-employed, and (5) did not report their income. These exclusions reduced the number of useable responses to 737 observations.[1] (See Gerking, deHaan and Schulze (1988) for a more detailed discussion of the sample and the questionnaire.[2])

Several types of information were obtained from each respondent. First, the survey measured each household head's perceived risk of a fatal accident on his main job (*RISK*). Respondents were shown an illustration of a ladder with ten equally spaced steps. Each step denoted the number of annual job-related fatal accidents per 4,000 workers and seven example occupations from the Thaler and Rosen study were placed on the ladder according to their average levels of job-related risk of death. Respondents specified the step number that they felt most closely approximated risk of accidental death on their main jobs. Since the Thaler and Rosen examples were narrowly defined occupations, they had the advantage of offering the respondent clear reference points. Their use, however, had one potential shortcoming. Risks associated with these examples were based on actuarial data reporting excess deaths by occupation, a portion of which are associated with non job-related risk. This may have caused respondents to overestimate their risk of accidental death.

[1] Evidence exists that the final sample of 737 observations may not be completely representative of the general population. In a paper using these same data, Dickie and Gerking (1987) note a recurring mail survey outcome that response rates are higher from more educated persons with higher incomes.

[2] An appendix is available from the lead author that provides: (1) a copy of the questionnaire, (2) and explanation of how all variables were constructed, and (3) tables of results for all regressions described. A diskette containing the raw data also is available.

TABLE 1.—MEANS AND STANDARD DEVIATIONS OF RISK BY SUBSAMPLE

Subsample	*N*	*RISK* Mean	*RISK* Standard Deviation
UNION-BLUE	178	3.922	2.498
UNION-WHITE	50	1.735	1.904
NONUNION-BLUE	217	2.969	2.284
NONUNION-WHITE	292	1.683	1.311
ALL UNION	228	3.443	2.544
ALL NONUNION	509	2.232	1.899
ALL WHITE	342	1.691	1.410
ALL BLUE	395	3.400	2.426
FULL SAMPLE	737	2.606	2.191

Table 1 shows means, standard deviations, and numbers of observations available for the full sample and for eight subsamples. White collar workers (*WHITE*) were managers, administrators, or professional and technical workers. Remaining workers were classified as blue collar (*BLUE*). *UNION* denotes membership in a labor union. These subsamples were selected in light of persistent empirical differences in marginal safety values between white and blue collar workers (Viscusi, 1979) and between union members and nonmembers. As shown in the table, average risk of accidental death at work perceived by blue collar workers is about double that perceived by white collar workers and the mean of *RISK* for union members is approximately 50% greater than for nonunion members. Unionized blue collar workers had the highest average level of perceived risk (3.922 in 4,000) while nonunionized white collar workers had the lowest average levels of perceived risk (1.683 in 4,000).

These perceived risk measures are roughly comparable to certain non-work related fatal accidents. Starr (1969) estimates the risks (fatalities/person-hour of exposure) associated with natural disasters (10^{-10}), firearms (10^{-9}), smoking (10^{-6}), and automobiles (10^{-6}). Given an average of 2000 hours worked per year, the full sample mean for *RISK* implies 3×10^{-7} fatalities/person-hour of exposure.

RISK has two features that warrant further explanation. (1) This variable may be a more accurate measure of individual self-assessed risk of death at work than average industry or occupation-based fatal accident rate variables used in previous empirical research. Several authors including Viscusi (1979) and Marin and Psacharopoulos (1982) have argued that average fatal accident rates for industrial or occupational categories may neither accurately reflect worker perceptions of the risks they face nor apply to workers whose risks differ from the average. (2) *RISK* is similar to a variable used by Viscusi and O'Connor (1984) in their study of the chemical industry. *RISK*, however, measures perceived fatal accident probabilities, whereas Viscusi and O'Connor were concerned with perceived rates of illnesses and injuries. Additionally, *RISK* is a disaggregated version of the *DANGER* dummy variable used by Viscusi (1979) and Viscusi and Moore (1987) wherein *DANGER* takes the value of 1 if a worker cites job-related health or safety risks. In the present study, *RISK* is used in marginal value of safety calculations, while Viscusi based his calculations on a measure of fatal accident rates by industry.

Second, data on annual labor earnings, exclusive of overtime pay, from the respondent's primary job in calendar 1983 were combined with data on hours worked during the same year to yield an hourly wage figure. This nominal wage variable was adjusted for regional price differences to form the dependent variable ($RWAGE$) used in the hedonic labor market analysis.

The survey also measures respondent's human capital (H), work environment (W), and personal characteristics (P). While they are not a major focus of the analysis, an example presented by Dickens (1984) suggests that these measures are crucial in isolating the wage premium received for working in risky jobs. Individual variables measured in H, W, and P are listed in table 2.[3]

III. Perceived Risk of the Value of Life: Hedonic Estimates

Hedonic labor market analysis uses equation (1)

$$RWAGE = f(RISK, H, W, P). \tag{1}$$

Holding constant the effects of H, W, and P, this equation establishes the market equilibrium locus between *RWAGE* and *RISK* given well-known assumptions. Estimates of this equation for the full sample and eight subsamples are presented below.

Empirical results of estimating a semi-logarithmic version of equation (1) by ordinary least squares for the full sample are reported in table 2.[4] As shown, the H, W, and P variables performed roughly as expected with generally significant coefficients and correct signs. The coefficient of *RISK*, however, was not significant at conventional levels, although it had the expected sign (positive). Disregarding the low t-statistic, this coefficient implies an illustrative marginal safety value of \$807,176 which is near the low end of the range of estimates cited in the introduction. This figure is obtained by (1) noting that $\partial \ln(RWAGE)/\partial RISK = .00815$, (2) multiplying that figure by an assumed 2,000 hours of work per year, (3) multiplying the result by 4,000 (the denominator of the risk measure) and (4) multiplying again by the average level of *RWAGE* in 1983 dollars (\$12.38).

Aside from the possibility that the coefficient of *RISK* is truly zero, there are at least two reasons why the perceived risk variable may have performed poorly in the table 2 regression. First, as demonstrated by Cropper, Deck, and McConnell (1988), poor performance may be due to misspecifying the functional form of the wage equation. As a consequence, the table 2 regression was re-run using three alternate specifications. (1) The dependent variable was subjected to a Box and Cox (1962) transformation. The estimated transformation coefficient was not significantly different from zero; the value implicitly assigned by assuming a semi-logarithmic model. (2) A quadratic term in *RISK* was added to the table 2 regression. In this specification, neither the coefficients of the linear nor the quadratic terms were significantly different from zero. (3) *RISK* was disaggregated into 10 dummy variables indicating the rung on the ladder marked by the respondent. None of these dummies had coefficients significant at conventional levels. The data,

[3] One of the referees pointed out that related studies have included a measure of worker compensation benefits in the hedonic wage equation (e.g., Viscusi and Moore, 1987; Dorsey and Walzer, 1983). These authors argue that the worker can be compensated for job-related risks ex ante through compensating wage differentials or by insurance arrangements providing ex post cash payments. Questions about worker compensation benefits would have been appropriate to the survey and lack of these data represents a possible deficiency in this study.

[4] Since the sample was composed of data drawn from two different populations, a Chow (1960) test was carried out on the table 2 equation to determine whether pooling was warranted. The null hypothesis of equality between the two sets of slope coefficients was not rejected at the 5% level.

TABLE 2.—EFFECT OF PERCEIVED RISK ON LN(*RWAGE*)[a]

Explanatory Variable	Definition	Coefficient (t-statistic)
A. Risk Variable		
RISK	Perceived risk of a fatal accident at work. Takes on an integer value from 1 to 10 deaths per 4,000 workers annually.	0.00815 (1.07)
B. Human Capital Variables		
SCHOOL 1	1 if schooling ended in grades 1–8; 0 otherwise.	−0.292 (−2.76)
SCHOOL 2	1 if schooling ended in grades 9–11; 0 otherwise.	−0.216 (−2.67)
SCHOOL 3	1 if schooling ended in grade 12; 0 otherwise.	−0.166 (−3.12)
SCHOOL 4	1 if schooling ended with a trade school program; 0 otherwise.	−0.77 (−1.20)
SCHOOL 5	1 if schooling ended with some college; 0 otherwise.	−0.107 (−2.29)
SCHOOL 6	1 if schooling ended with BS or BA and/or graduate training or degrees; 0 otherwise.	—[b]
YRSPO	Years worked in present occupation.	−0.0013 (−0.680)
YRSFT	Years worked full-time since age 18.	0.0066 (1.76)
YRSPE	Years worked for present employer.	0.0079 (3.96)
C. Work Environment Variables		
*RQSCHL*1	1 if 0–8 years of schooling are required for present job; 0 otherwise.	−0.273 (−2.91)
*RQSCHL*2	1 if 9–11 years of schooling are required; 0 otherwise.	−0.233 (−2.74)
*RQSCHL*3	1 if 12 years of schooling are required; 0 otherwise.	−0.117 (−2.16)
*RQSCHL*4	1 if some college is required; 0 otherwise.	−0.110 (−2.13)
*RQSCHL*5	1 if one or more college degrees are required; 0 otherwise.	—[b]
WKEXP	1 if work experience or special training required for present job; 0 otherwise.	0.080 (2.00)
SUPER	Number of persons supervised on primary job.	0.00043 (2.44)
GOVT	1 if public sector employee; 0 otherwise.	−0.034 (−0.892)
UNION	1 if union member; 0 otherwise.	0.091 (2.61)
YRSQUAL	Years required to become fully trained and/or qualified on primary job.	0.024 (5.06)
MILES	Road mileage from home to place of work.	0.0026 (2.56)
NUMBER	Number of employees at primary work place.	0.000030 (3.28)
CENTRAL	1 if primary job site is in a central city or suburban area; 0 otherwise.	0.061 (1.72)
SERVICE	1 if employed as a service worker; 0 otherwise.	−0.201 (−3.15)
LABOR	1 if employed as a laborer; 0 otherwise.	0.0028 (0.040)
TRANS	1 if employed as a transportation operator; 0 otherwise.	−0.060 (−0.685)
EQUIP	1 if employed as an equipment operator; 0 otherwise.	−0.071 (−0.974)
CRAFT	1 if employed as a craft worker; 0 otherwise.	−0.095 (−1.69)
CLERIC	1 if employed as a clerical worker; 0 otherwise.	−0.130 (−1.78)
SALES	1 if employed as a sales worker; 0 otherwise.	−0.089 (−1.36)
MANAGE	1 if employed as a manager or administrator; 0 otherwise.	−0.011 (−0.256)
PROF	1 if employed as a professional or technical worker; 0 otherwise.	—[b]

TABLE 2.—(continued)

Explanatory Variable	Definition	Coefficient (t-statistic)
D. Personal Characteristic Variables		
AGE	Years of age.	−0.0014 (−0.374)
RACE	1 if white; 0 otherwise.	0.017 (0.292)
SEX	1 if male; 0 otherwise.	0.192 (4.50)
DISAB	1 if physical or nervous conditions limit amount or type of work that can be done; 0 otherwise.	−0.065 (−1.26)
VET	1 if respondent is veteran.	0.042 (1.24)
LIVE	1 if respondent lives in a central city or suburban area; 0 otherwise.	−0.091 (−2.72)
CONSTANT		2.07 (11.25)

[a] $R^2 = 0.42$.
[b] Denotes omitted dummy variable.

then, provide little evidence that the market equilibrium *RWAGE-RISK* locus is misspecified in the full sample regression.

A second explanation for poor performance of *RISK* lies in possible differences between occupational groups that are masked when the entire sample is considered. Separate regressions were estimated for the eight subsamples defined in table 1. Selected results are presented in the left-hand portion of table 3 showing coefficients and t-statistics of *RISK*. A Chow (1960) test statistic of $F(83,618) = 1.456$ indicates that the null hypothesis of no wage structure shifts over the *UNION-BLUE*, *UNION-WHITE*, *NONUNION-BLUE*, and *NONUNION-WHITE* subsamples can be rejected at the 5% level. Table 3 shows that in the *UNION-BLUE* and *ALL UNION* regressions, the coefficient of *RISK* is positive and statistically significant at less than the $2\frac{1}{2}\%$ level using a 1-tail test and is significant at the 5% level using a 1-tail test in the *ALL-BLUE* regression. In the nonunion equations, coefficients of *RISK* have small t-statistics. Thus, only union members and blue collar workers apparently are able to capture a wage premium for accepting greater levels of perceived risk; marginal value of safety estimates for these workers are: (1) *MVS(UNION-BLUE)* = \$2,103,120, (2) *MVS(ALL UNION)* = \$1,580,544, and (3) *MVS(ALL BLUE)* = \$1,180,304.[5] Also, similar to the results of Viscusi (1979) who used average industry risk, the perceived risk variable performs better in the *ALL BLUE* regression than in the *ALL WHITE* regression.

Results highlighting the role of unions in securing a compensating wage differential for fatal accident risks are common in the empirical literature (Marin and Psacharopoulos (1982) and Dillingham and Smith (1983) are notable exceptions). Viscusi (1979) has argued that because unions are more or less permanent institutions, they are better able to accumulate and disseminate information about safety hazards than are individual workers who frequently change jobs. Moreover, collective bargaining provides opportunities to negotiate financial tradeoffs for job safety, an important aspect if safety is a quasi-public good for which individuals understate their true preferences.

A related explanation for the difference in performance of risk across subsamples lies in the lower mean values of this variable reported by nonunion as compared with union members (see table 1). By serving as a conduit for information, unions may heighten awareness of safety hazards, but the possibility remains that they represent workers in the most risky jobs. For example, workers in the *ALL NONUNION* subsample had a relatively low mean value of *RISK* and 81% of these workers reported a value for *RISK* lying on the first three steps of the risk ladder. Therefore, *RISK* may have insufficient variation to precisely estimate a coefficient of this variable. Also, the marginal product of fatal accident risk may be

[5] The calculations shown are made using the mean 1983 wage for each group, rather than the average wage for the entire sample. These means are: (1) \$11.43 for *UNION-BLUE*, (2) \$11.76 for *ALL UNION*, and (3) \$10.39 for *ALL BLUE*.

TABLE 3.—COEFFICIENTS OF *RISK* AND *FATAL* FOR EIGHT SUBSAMPLES

	RISK		*FATAL*	
Subsample	Coefficient	t-statistic	Coefficient	t-statistic
UNION-BLUE	0.0230	2.678[b]	0.4272	2.062[b]
UNION-WHITE	0.0241	0.727	0.7712	0.923
NONUNION-BLUE	0.0087	0.586	0.4104	1.385
NONUNION-WHITE	−0.0180	−0.971	−0.2475	−0.732
ALL UNION	0.0168	1.981[b]	0.5033	2.516[b]
ALL NONUNION	0.0028	0.241	0.0932	0.420
ALL WHITE	−0.0086	−0.538	−0.0953	−0.312
ALL BLUE	0.0142	1.651[a]	0.4228	2.277[b]
FULL SAMPLE	0.00815	1.066	0.2636	1.638

[a] Denotes significance at the 5% level using a one-tail test.
[b] Denotes significance at the 2-1/2% level using a one-tail test.

zero on many white collar and nonunion jobs. As a result, if workers dislike risk, firms will not supply this characteristic and no wage premium exists for the hedonic method to measure.

If white collar and nonunion members have positive marginal values of safety which are not measured by the hedonic method, sample composition is a serious issue. Hedonic marginal value of safety estimates based on restricted samples actually may be more useful than those based on a national random sample. Alternative methods, such as contingent valuation in which the compensation–risk tradeoff is assessed directly, may be superior in assessing the marginal value of safety of workers exposed to low levels of risk. Gerking, deHaan, and Schulze (1988) find that contingent valuation bids for reduced job-related fatal accident risk are roughly equal for union vs. nonunion members and for white collar vs. blue collar workers.

IV. Comparison with an Average Industry Risk Measure

The above estimates are compared with those obtained from a more traditional measure of fatal accident rates (*FATAL*) obtained from Bureau of Labor Statistics data on work-related deaths per thousand employees in SIC two-digit industries. *FATAL* was matched to sample respondents based on their industry of employment and substituted for *RISK* in regressions specified otherwise identically to those previously reported. A least squares regression of *RISK* on *FATAL* yields

$$\widehat{RISK} = \underset{(22.1)}{2.11} + \underset{(8.6)}{6.94}\,FATAL; \qquad R^2 = .093 \tag{2}$$

where t-statistics are shown in parentheses. Thus, *RISK* is positively related to *FATAL* at conventional significance levels; however, variation in *FATAL* explains only about 9% of variation in *RISK*.

The right-hand portion of table 3 presents coefficients and t-statistics of *FATAL* which are similar to corresponding results for *RISK*. For example, based on a Chow-test statistic of $F(83{,}618) = 1.437$, the null hypothesis of no structural shifts in the wage equation across the *UNION-BLUE*, *UNION-WHITE*, *NONUNION-BLUE*, and *NONUNION-WHITE* subsamples again is rejected at the 5% level. Also, the coefficients of *FATAL* in the *UNION-BLUE*, *ALL UNION*, and *ALL BLUE* regressions are significantly different from zero at least at 5%, while coefficients of *FATAL* are insignificant in all other regressions. Thus, the coefficients of *FATAL* and *RISK* are significantly different from zero in the same three subsamples.

Marginal value of safety estimates using *FATAL* are roughly five to seven times larger than those obtained using *RISK*. Considering the three cases where coefficients of *FATAL* were significant at 5%:

(1) *MVS*(*UNION-BLUE*) = \$9,761,220,
(2) *MVS*(*ALL UNION*) = \$11,837,610, and
(3) *MVS*(*ALL BLUE*) = \$8,785,784.

In comparison, Viscusi's (1979, p. 249) *LOGEARNING* results for blue collar workers based on industry death risk imply a marginal safety value of about \$2.8 million (in 1983 dollars). However, the discrepancy between this estimate and the corresponding one implied in table 3 is explained partly by differences in mean annual earnings in the two samples. In Viscusi's sample, mean annual earnings (in 1983 dollars) were \$11,968, whereas in the present sample the mean hourly blue collar wage (\$10.68) multiplied by an assumed 2,000 hours of work per year yields a corresponding value of \$21,361. A possible explanation for this difference is that individuals in Viscusi's sample worked, on average, fewer than the 2,000 annual hours assumed here.

Discrepancies between marginal value of safety estimates using *FATAL* and those obtained using *RISK* parallel those found in the literature. The survey instrument used to obtain the self-assessed *RISK* measure utilized example occupations based on actuarial data while *FATAL* was based on average fatality rates by industry. The highest marginal value of safety estimates generally are associated with industry-specific risk measures and the lowest estimates with occupational-specific risk variables (Dillingham, 1985; Marin and Psacharopoulos, 1982).

As mentioned above, individuals in this study possibly overestimated levels of risk faced (at least when compared to industry average data) which in turn led to lower marginal value of safety estimates. However, Dillingham (1985) argues that the "best guess" range in marginal value of safety estimates is \$1.37–\$2.74 million (in 1983 dollars). Industry risk measures such as *FATAL* are based on average employment rather than full-time equivalent with the former being greater than the latter. Thus, average employment based measures would be expected to understate risk (relative to a full-time equivalent employment measure) suggesting an upward bias in resulting marginal value of safety estimates. Also, he found evidence that measures such as *FATAL* reflect industry-specific effects in addition to fatal accident risk, thus leading to an additional source of upward bias in its coefficient. When Dillingham included dummy variables for both industry and occupation, he found that the coefficient of his fatal injury rate variable became insignificant. This result also occurred in the present study for subsample regressions using *FATAL*. Yet, when both industry and occupation dummies are included in the *UNION-BLUE* and *ALL UNION* subsample regressions, coefficients of *RISK* remain positive and significantly different from zero at the 5% level using a one-tail test. Coefficient values are 0.021 and 0.015, respectively. The coefficient of *RISK* was positive but not significantly different from zero at conventional levels when both sets of dummies are included in the *ALL BLUE* subsample regression.

V. Conclusion

This paper reports marginal value of safety estimates based on a new data set collected from a national random sample mail survey of U.S. household heads. An important feature of this survey is that it directly measures respondent's perceived risk of accidental death on the job.

Many investigators have deplored the quality of available aggregate industry and occupational risk data and have instead advocated measuring individual perceptions of risk. Hedonic results indicate that for unionized workers, blue collar workers, and unionized blue collar workers, the marginal value of safety using the perceived risk measure lies in the range \$1.18–\$2.10 million (1983 dollars). These results are roughly consistent with Dillingham's (1985) "best guess" range of \$1.37–\$2.74 million (in 1983 dollars), but are substantially lower than those obtained using an industry average risk measure. For white collar and nonunionized workers, however, the marginal value of safety is not significantly different from zero. Further analysis reveals that the vast majority of these workers perceive few, if any, life threatening hazards on their jobs. Also, the marginal product of fatal accident risk may be zero on many white collar and nonunion jobs. As a result, if workers dislike risk, firms will not supply this characteristic and no wage premium exists for the hedonic method to measure. Alternative methods such as contingent valuation, therefore, are needed to measure the marginal value of safety for persons in low or no risk jobs.

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