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SOCIAL INSURANCE IN MARKET CONTEXTS: IMPLICATIONS OF THE STRUCTURE OF WORKERS' COMPENSATION FOR JOB SAFETY AND WAGES*

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Abstract

Social insurance programs whose costs are tied to particular behaviors represent more than simple income transfers between members of the economy. In the case of job safety insurance programs such as workers' compensation, in which the costs of the program are tied to the firm's safety records, the market incentives for safety that are created by the insurance program can be quite strong. At the same time, when those programs benefit injured workers, they simultaneously provide disincentives for safety and incentives for workers to extend periods of recovery and to file more claims.

We analyze these issues using a large data set on worker wages and characteristics, coupled with information on fatality risks and workers' compensation benefits. We find that workers' compensation insurance provides incentives for safety to firms that outweigh the

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moral hazard effects. We further find that the insurance provided to workers on unsafe jobs reduces the net compensation paid to these workers. In particular, workers' compensation benefits create a negative compensating differential that offsets the positive compensating differential that must be paid for exposure to job risks. This negative wage differential leads to a reduction in the wage bill that compensates employers for the cost of workers' compensation premiums. Reductions in fatality risks, and the resultant reduction in the wage, supplement the direct wage-benefit effect.

Key words: compensating differentials, job safety, workers' compensation, social insurance

The principal purpose of social insurance programs is generally to address the economic needs of individuals who have either suffered a drop in income or who experience increased demands on their resources, such as higher medical bills. Workers' compensation addresses each of these classes of needs for workers who experience an on-the-job injury. Workers' compensation provides at least partial income replacement for the earnings lost due to the injury, and it also covers associated medical expenses.

The ramifications of this and other social insurance efforts extend beyond these two redistributive effects. Particularly in the case of workers' compensation, it is important to consider the broader implications of the program since it operates in a market context. Six effects can be distinguished. First, because employers fund workers' compensation benefits through premiums linked at least in part to their firm's safety record, there is a safety incentive. Higher benefit levels increase the marginal cost of accidents to the firm, providing an incentive to increase the investment in health and safety capital.

Second, this reduction in risk in turn will affect workers' wages. Since workers generally receive a compensating differential for the risks they face, a reduction in these risks through the safety incentives created by workers' compensation will partially offset the added safety costs. This reduction will not be complete. If there were a full or more than full offset, firms would have already undertaken the investment induced by workers' compensation.

Third, workers' compensation exerts a direct effect on the wages a firm must pay its workers. Providing social insurance for job injuries will increase the attractiveness of risky employment to workers. For workers in hazardous jobs, there will be a negative compensating differential in response to the social insurance just as there would be to any other positively valued aspect of the job. Social insurance through workers' compensation is not a deadweight loss to workers. Rather, it constitutes

a valued component of the pay package. As a result, wages will decline in response to increases in benefits.

Fourth, workers' compensation will lead to a potential moral hazard problem for workers on the job. This ex ante moral hazard arises because workers' incentive to exercise care will be diminished, since insurance covers the financial and medical losses associated with the injury. To the extent that the losses represent irreplaceable effects on one's life and health, as with death or extensive permanent disability, there could be less of a moral hazard problem than if losses were purely financial. Dionne (1982) shows that, when the average coverage (wage replacement rate) is less than the optimal coverage, moral hazard will not present a problem for fatality insurance if the coverage does not cover direct utility losses or if incentives for safety are substantial.

The fifth effect concerns workers' incentives to return to work once injured. This ex post moral hazard problem arises because it is not economically feasible to monitor workers' employability perfectly and make payments contingent upon this status. Sixth, higher benefits will lead workers to file claims for accidents that may not have occurred or for off-the-job accidents.

This paper focuses on two general relationships that capture all of these effects — the effect of workers' compensation on fatality risk levels and the effect of workers' compensation on wages. The risk incentive effect includes the safety incentives for the firm net of any influence of moral hazard. The findings that we present, which indicate a beneficial effect of workers' compensation, run counter to the consensus in the literature, which is correctly summarized in the 1987 *Economic Report of the President* (p. 197): "A growing body of research has found that workers' compensation benefits have unfavorable effects on safety. Higher benefits appear to increase both the frequency of work injuries and the number of compensation claims filed." Our findings differ from the consensus primarily due to our focus on fatalities. As a consequence, moral hazard effects and reporting problems are minimal. Our findings will also differ in part because of our use of a new data series on occupational fatalities. These data are less susceptible to measurement error. Most important, they represent a severe accident category for which misrepresentation and moral hazard problems are less pronounced.

The second matter of interest concerns the wage effects of workers' compensation. We estimate both the direct wage offset due to the value workers place on social insurance, as well as the indirect wage benefit that arises through the fatality risk reduction induced by workers' compensation.

The analysis presented here provides an alternative perspective on the results in Moore and Viscusi (1989, 1990), which analyze the effects of experience rating on the firm's provision of safety. It focuses on the implications of the specific structure of workers' compensation across states, including benefit levels and benefit ceilings, and also on the role of the characteristics of workers and their jobs.

The organization of the paper is as follows. Sections 1 and 2 analyze the economic relationships involved and relate these economic effects to the specific components of the empirical analysis. Section 3 summarizes the variables used in the empirical analysis, which involve use of the University of Michigan Panel Study of Income Dynamics in combination with workers' compensation benefit information and death risk data. After discussing the estimation procedure in section 4, we present the estimates of the risk and wage equations in section 5. As indicated in sections 6 and 7, workers' compensation has dramatic effects, including substantial wage offsets and a reduction in the fatality rate, which could have been as much as 45% greater in the absence of the program. Workers' compensation clearly provides more than social insurance that simply transfers resources. It fundamentally affects the risk level and the compensation package.

1. A Conceptual Model of Worker and Firm Responses to Insurance Benefits

A complex array of influences operates among workers' compensation benefits, wages, and safety levels. Increases in accident insurance theoretically should induce two opposing effects. Increased benefits impose net additional financial costs on firms, leading them to devote more resources to providing safety. The extent of the safety incentive effect hinges on the extent to which additional accidents cause an increase in a firm's insurance premium through the experience-rating procedure. The incentive effect should be particularly strong for large firms, which either self-insure or are rated according to their own experience and thus pay most or all of the costs of the accident in terms of increased premiums.[1] Higher benefits also may produce an opposite influence on safety through moral hazard problems for covered workers. If the higher benefit levels on belance reduce injury risks, workers' compensation insurance could provide an effective means of regulating safety by acting as an injury tax.

To illustrate the direct effect of benefits on safety levels conceptually, consider a simple model in which firms choose the level of safety, $s \in (0, 1)$, to maximize profits. Safety enters the profit function through the safety cost function $c(s)$, where $c_s > 0$ and $c_{ss} > 0$, and through the expected value of output, sv. The safety level also affects profits through its effect on expected wages, sw, and expected benefits, $(1 - s)b$. In this simplified variant of the model we abstract from the dependence of w on s and b. The unit profit function is

$$\pi = sv - c(s) - sw - (1 - s)b,$$

where v is the unit of output. The first-order condition for a maximum with respect to s is

$$\pi_s = v - c_s - w + b = 0.$$

Note that, in order for the firm to make nonnegative profits, it must be true that $v > w$. The costs of safety improvements to the firm include the increased wage bill and the safety expenditures, while the benefits depend on the insurance level, b, and on the value of output, v. Totally differentiating the first-order condition yields

$$\frac{ds}{db} = \frac{1}{c_{ss}} > 0,$$

which is positive given the assumption $c_{ss} > 0$. The curvature of the safety-benefit relationship is theoretically ambiguous, since the second-order effect

$$\frac{d^2s}{db^2} = \frac{-1}{c_{ss}^2} c_{sss}$$

depends upon the sign of the third derivative of the safety cost function.

Extensions of this simple model that are explored in the empirical analysis include recognition of moral hazard and the feedback effects of benefits and risks on wages. If there are feedback effects of benefits and risks on wages the benefit-induced safety expenditures are partially financed by wage reductions on two margins — wages will fall in response to both lower risks and higher benefits. In the empirical analysis we estimate these "financing" effects. More importantly, we estimate the effect of benefits on fatality rates and find results that suggest that moral hazard does not play a dominant role in the determination of fatality risks. Workers' compensation benefits exert significant downward pressure on fatality risk levels. This effect decreases with benefit increases.

To analyze the effects of the two types of moral hazard, introduce the worker reaction function, which measures the extent of the worker's risk-taking $e = e(s, b)$, where $e_s > 0$, $e_b > 0$. The safety level now depends on firm expenditures on safety, s, benefit levels, b, and on the worker's reaction to s and b, $e(s, b)$, which firms will take into account in determining expenditures on safety.

Let $p^*(s, b) = p(s, e(s, b)) \in (0, 1)$ indicate the probability that a worker remains "uninjured," net of moral hazard effects. The assumptions concerning p are $p_s > 0$ and $p_e < 0$. Let $p_s^* = p_s + p_e e_s > 0$ denote the situation in which the moral hazard effect described in Viscusi (1979) is not dominant, while $p_s^* < 0$ indicates a serious moral hazard problem. Furthermore, $p_b^* = p_e e_b < 0$, so that the effect of benefit increases on the frequency and duration of claims decreases the probability that a worker works.

The dependence of wages on risks and benefits is captured by the wage function $w = w(s, b)$, where w_s, $w_b < 0$ reflect the desirability of both insurance and safety to workers. The profit function for the most general version of the model is

$$\pi = p^*(s, b)\,v - c(s) - p^*(s, b)\,w(s, b) - (1 - p^*(s, b))\,b.$$

The first-order condition is

$$\pi_s = -c_s + (b + v - w)p_s^* - p^* w_s = 0. \tag{1}$$

Equation 1 consists of three terms: the marginal cost of safety, $-c_s$, the marginal profitability of safety expenditures, $(b + v - w)p_s^*$, and worker expenditures on safety, $p^* w_s$. The last two terms in equation 1 are critical for interpreting the comparative static result to follow. The first of these, $(b + v - w)p_s^*$, represents the net change in profits that results from changes in accident rates. The remaining term, $p^* w_s$, equals the wage savings due to increased safety, since w_s is the implicit price of safety to the worker, and p^* is the quantity of safety. In other words, $p^* w_s$ equals expenditures by the worker on safety.

Totally differentiating equation 1, the effect of an increase in benefits on the level of safety is

$$\frac{ds}{db} = H^{*-1}((w - v)p_{sb}^* - p_s^*(1 + \eta)) + H^{*-1}p_s^* w_b + H^{*-1}(w_s p_b^* + p^* w_{sb}), \tag{2}$$

where η is the benefit elasticity of p_s^*, and H^* is the Hessian matrix for the problem.

It seems plausible that marginal changes in the safety level will induce a greater shirking reaction on the part of workers the higher the benefit

level, so that $e_{sb} > 0$. Since $p_e < 0$, p_{sb}^* is < 0, and the first term in equation 2, $H^{*-1}(w - v)p_{sb}^*$ is positive, given $w < v$.

The second term depends on η, the elasticity of p_s^* with respect to benefits. If p_s^* and the elasticity are both positive, then $-H^{*-1}p_s^*(1 + \eta)$ is positive. If p_s^* is greater than zero, and η is negative, then $-H^{*-1}p_s^*(1 + \eta)$ is still positive if the elasticity is less than one in absolute value. If there is significant shirking due to the firm's provision of safety ($p_s^* < 0$), the term $-H^{*-1}p_s^*(1 + \eta)$ is negative, and benefit increases may decrease safety levels.

The third term in equation 2, $H^{*-1}p_s^* w_b$ is also positive if there is not a substantial moral hazard problem ($p_s^* > 0$). The final term, which represents the effect of a benefit increase on worker expenditures on safety, is negative. Thus, the total impact of benefit changes on risk levels is indeterminate when moral hazard is considered.

The importance of moral hazard is illustrated most clearly by analyzing the solution to the problem when there are no wage-risk or wage-benefit feedbacks (i.e., $w_s = w_b = w_{sb} = 0$). In this case, profits are

$$\pi = p^*(s, b)\,v - c(s) - p^*(s, b)\,w - (1 - p^*(s, b))\,b,$$

and the optimal level of s is given by the first-order condition

$$\pi_s = -c_s + p_s^*(v - w) + p_s^* b = 0,$$

or

$$-c_s + (b + v - w)p_s^* = 0.^2 \tag{3}$$

Equation 3 illustrates the interactive relationship between benefits and wages that exists on the firm side. If $p_s^* > 0$, so that moral hazard is not serious, a necessary condition for a positive level of safety is that the value of a healthy worker, output plus benefits, exceeds wages. Given some level of $b + v$, increases in w reduce the optimal level of s, as healthy workers become relatively more expensive. The effect of a benefit increase on safety in equation 3 is

$$\frac{ds}{db} = H^{*-1}((w - v - b)p_{sb}^* - p_s^*).$$

The sign of this term thus depends on both p_{sb}^* and p_s^*. Rearranging terms,

$$\frac{ds}{db} = H^{*-1}(w - v)p_{sb}^* - H^{*-1}p_s^*(1 + \eta).$$

As discussed above following equation 2, equation 4 is ambiguous in sign. As noted in the introduction, most empirical research has found a negative overall relationship.

Table 1. Summary of Main Mechanisms of Influence

Explanatory Variable	*Nature of Effect on Risk Level*
Workers' compensation	Negative accident cost incentive effect, positive moral hazard effect.
(Workers' compensation)^2	Curvature of workers' compensation-risk relationship. Positive if marginal cost of safety is increasing.
	Nature of Effect on Wage Rate
Risk level	Positive compensating wage differential.
Workers' compensation	Negative compensating wage differential.
Workers' compensation-benefit	Captures workers who are above the benefit maximum.
Maximum binding interaction	Increased magnitudes of effects of benefits on wages.

2. Overview of the Economic Relationships

The empirical analysis focuses on two equations — a risk equation and a wage equation. Although neither of these equations is unprecedented in the literature, several of the key variables that we include are new. In addition, our focus on a new set of death risk data is also novel. Here we discuss the economic forces reflected in the main variables of interest. Table 1 provides a summary of these influences.

All of the variables of interest in the risk equation are related to workers' compensation. The funding mechanism for workers' compensation creates safety incentives for firms that should increase the safety level provided. Even for relatively small firms, which are not perfectly experience-rated, the insurance underwriting procedures create some link between workplace conditions and insurance premiums.[3]

A potentiallly offsetting influence is that of ex ante moral hazard, as more generous benefit levels will lead workers to decrease their level of care. This aspect of worker behavior is just as unambiguous theoretically as is the opposite safety incentive effect for employers. In addition, there are a number of studies indicating that more generous benefits lead to ex post moral hazard through more extended periods of recovery and possible over-reporting of injuries.[4] These abuses are likely to be more responsive to the benefit level than the fatality rate, which is the subject

of this study. Although one cannot rule out the possibility of a dominant moral hazard effect on theoretical grounds, the high estimated value of life that workers receive through wage-risk tradeoffs suggests that it is highly implausible that workers would endanger their lives to a substantial degree because of more generous ex post compensation that will benefit their surviving heirs. Our working hypothesis is that higher benefits will lower fatality risk levels, so that the workers' compensation variable should have a negative sign in the risk equation.

The second variable of interest — the square of the workers' compensation variable — pertains to the nonlinearity of the effect of workers' compensation on risk. This relationship is highly complex once all feedback effects, such as moral hazard, are taken into account. However, in the simple model of the firm's safety decisions it was shown that the square of workers' compensation should have a positive effect on safety if the marginal cost curve for safety is rising at an increasing rate. Evidence regarding the marginal costs of compliance with OSHA standards for arsenic and cotton dust exposures presented in Viscusi (1983, 1985) indicates that the marginal cost curve for safety increases very steeply at low risk levels. To the extent that this pattern holds more generally, the negative risk incentive effect of workers' compensation should be dampened at higher benefit levels.

The final aspect of workers' compensation that will be considered is the structure of benefit payments. Under the institutional structure of the existing workers' compensation systems, increases in the benefit ceiling are costly to firms only if the benefit ceiling is binding. Figure 1 illustrates the effect of a benefit increase in three distinct cases. In the first case, the standard replacement rate for wages leads to benefits below the ceiling (CAP), as at wage W_1, and an increase in the benefit maximum to CAP′ has no effect on workers' compensation costs, WC_1. If two-thirds of the wage is just equal to or slightly above the ceiling, as at wage W_2, an increase in the benefit cap from CAP to CAP′ causes an increase in insurance costs from WC_2 to WC_2' that is less than CAP′ − CAP. In the final case, a firm that pays a very high wage, W_3 or greater, pays the full cost of the increase in the benefit cap, $WC_3' - WC_3$. The predicted effect of workers' compensation on high-wage firms who pay the full cost of increases in WCOMP is therefore greater than that of low wage firms who receive less than a one-for-one effect of CAP increases in the intermediate wage range (W_2) and experience no effect if their workers are in the low wage range (W_1). More generally, in a world of uncertainty over wages and hours, an increase in the maximum will affect expected costs for all workers. The negative risk incentive effect of workers compen-

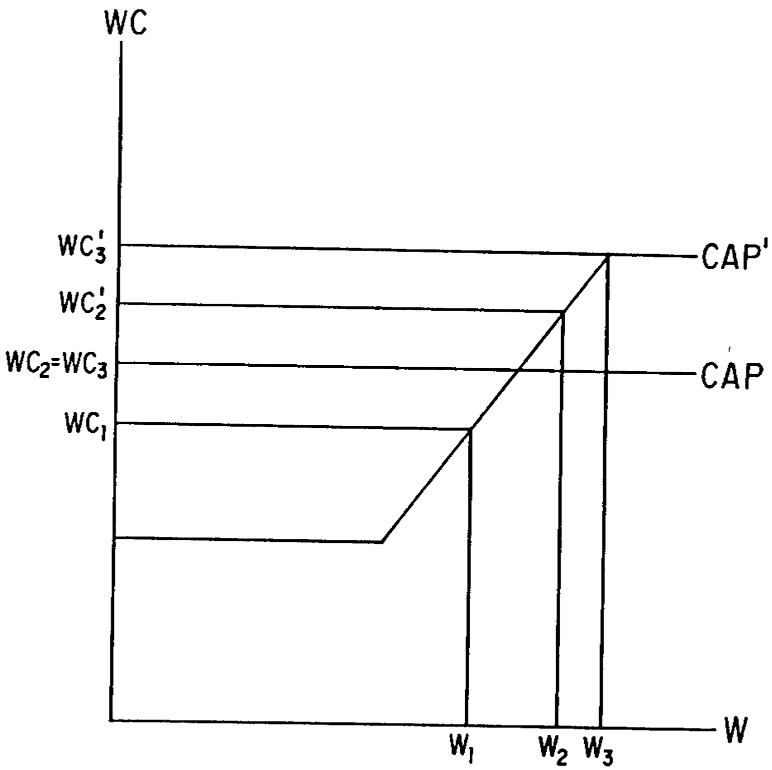

Figure 1. The effect of changes in the benefit ceiling (CAP) on the costs of workers' compensation (WC), given the wage level (W).

sation should be greater for workers at firms for which the cap is a binding constraint.

The variables included in the wage equation represent less complex influences. Wages should increase with the risk level, following Adam Smith's proposition that hazardous jobs will command compensating differentials. For economically similar reasons, higher levels of the benefit maximum should lead to a wage reduction. The extent of the reduction will depend upon whether the ceiling is binding. Ex post compensation for job risks should decrease the level of ex ante compensation required. The extent of the offset depends on the attractiveness of the insurance provided, which is determined by factors such as the degree of insurance loading.

3. The Sample and the Variables

Our primary data source in this study is the University of Michigan Panel Study of Income Dynamics (PSID). These survey data provide much of the information related to the worker and his job, which we augment using information on risk levels and workers' compensation. The PSID is a longitudinal survey that provides information on the characteristics of workers and their jobs for the years 1968–1984. We will focus on the 1982 survey year since it includes the state and industry information needed to establish a precise matching of the workers in our sample with the primary variables of interest — the job risk and workers' compensation variables, and also for comparability with our related research. The 1982 survey year also represents the midpoint of the time period covered by the risk data we will use. The PSID has been widely used in labor economics, including previous applications of the compensating differential model, such as Viscusi (1979) and Moore and Viscusi (1988, 1989, 1990a,b).

Our empirical analysis focuses on the national random sample of workers included in the PSID. We exclude the PSID subsample pertaining to low-income workers since this oversampling distorts the worker mix. The 1982 survey year pertains to labor market outcomes for 1981. The sample that we analyze, which is identical to the sample in More and Viscusi (1988), contains 1349 observations. The workers excluded from the sample were farmers and farm managers, workers who are not household heads, government employees (for whom no risk data are available), blacks, and cases with missing data. The variable definitions and sample characteristics appear in table 2.

The demographic variables are quite extensive, including information on the worker's sex (FEMALE dummy variable (d.v.)), family status (i.e., number of dependent children (KIDS), and marital status (MARRIED d.v.). The human capital variables included in the analysis pertain to health impairments (HEALTH d.v.), years of formal schooling (EDUCATION), and acquired training that is either general (EXPERIENCE and its square) or specific (JOB TENURE and its square). The extensive set of education and training variables precludes the inclusion of an age variable. Three regional dummy variables (NEAST, NCENT, and SOUTH d.v.'s) are included to reflect interregional differentials in wages and the cost of living. We include as an urban variable CITY, which increases with the size of the largest city in the worker's area.

The measure of pecuniary compensation is the worker's hourly wage

Table 2. Definitions of the Variables and Sample Characteristics

	Mean (Std. Dev.)	
FEMALE	0.15 (0.36)	Sex dummy variable (d.v.): 1 if worker is female, 0 otherwise.
KIDS	0.99 (1.15)	Number of dependent children
MARRIED	0.72 (0.45)	Marital status d.v.: 1 if worker has ever been married, 0 otherwise.
HEALTH	0.07 (0.26)	Health status d.v.: 1 if worker has a serious physical or nervous condition that limits the amount of work he can do, 0 otherwise.
EDUCATION	12.98 (2.50)	Number of grades completed.
EXPERIENCE	11.91 (10.56)	Years worked full time since age 18.
JOB TENURE	4.97 (6.21)	Years worked on current job.
NEAST	0.22 (0.41)	Region d.v.: 1 if worker lives in the Northeastern U.S.: 0 otherwise.
NCENT	0.31 (0.46)	Region d.v.: 1 if worker lives in the Northcentral U.S.: 0 otherwise.
SOUTH	0.27 (0.44)	Region d.v.: 1 if worker lives in the Southeastern U.S.: 0 otherwise
CITY	331.90 (378.92)	City size variables in 1,000's. (size of nearest city)
WAGE	7.01 (2.42)	Computed after-tax hourly wage, 1981.
UNION	0.28 (0.44)	Union status d.v.: 1 if worker's job is covered by a collective bargaining agreement, 0 otherwise.
BLUE	0.52 (0.50)	Collar color d.v.: 1 if worker is in a blue collar occupation, 0 otherwise.
RISK	7.92 (9.74)	NTOF risk variable. Number of fatal accidents per 100,000 workers in the worker's industry on a state-specific basis.
WCOMP	219.44 (67.59)	Weekly benefits for temporary total disability under state workers' compensation program.
REPRATE	0.89 (0.46)	Workers' compensation weekly after-tax wage replacement rate.

(WAGE) for 1981 and its natural logarithm (lnWAGE). These measures are superior to annual earnings variables frequently used in compensating differential studies. Since workers' compensation benefits are tax exempt, ideally one should place wages and workers' compensation on comparable after-tax terms. We have done this by putting the wage variables in after-tax dollars, based on the marginal tax rate reported by PSID members.

The job characteristic variables pertain to whether the worker is covered by a collective bargaining agreement (UNION d.v.) and whether the worker is in a blue-collar job (BLUE d.v.). The blue-collar variable reflects the influence of omitted job characteristics correlated with blue-collar occupations.

Two key variables of interest pertaining to job risks and workers' compensation benefits were constructed using information that was matched to workers in the PSID. Our death risk measure uses a new set of death risk data that became available in 1987. The National Institute for Occupational Safety and Health (NIOSH) has undertaken The National Traumatic Occupational Fatality (NTOF) project to obtain a more accurate assessment of fatality risks. As we indicate in Moore and Viscusi (1990a), this measure yields a higher risk level than does the Bureau of Labor Statistics (BLS) data. In addition to this difference, there is also evidence of substantial measurement error in the BLS data. Our results suggest that the NTOF data represent a superior risk measure.

The NTOF data also are better suited to analyzing workers' compensation since benefit structures vary by state, and the NTOF data are also available on a state-specific basis. Since most previously published risk data do not reflect state differences, use of such measures to analyze workers' compensation creates problems.[5] Use of the national data level BLS risk data introduces potentially major errors by ignoring interstate variation in industry levels.[6] Use of the NTOF Survey avoids these difficulties since these fatality rates were based on a census of occupational fatalities during the years 1980–1985 and are classified by both state and industry.

We will denote the NTOF risk measure by RISK, which is the average number of fatalities per 100,000 workers for the years 1980–1985. This variable is available by state and by industry. The mean fatality rate for the PSID sample is 7.8 deaths. This risk level is almost 50% higher than BLS death rates for this period.

The second key variable that must be constructed is the measure of workers' compensation benefits.[7] Most previous studies have generally used the benefits for the most frequent type of claim — temporary total disabilities — as a proxy for the ex ante level of all types of benefits, including those for temporary total, permanent total, and permanent partial disabilities, and for fatality benefits. In Viscusi and Moore (1987) we document the high correlations among the various benefit categories. This correlation makes separation of the effects of each benefit component difficult. Regardless, the relative uniformity of maxima across categories and the fact that compensating differentials are generated ex ante for insurance against any type of injury make this benefit category a reasonable measure for workers' compensation.

The basic workers' compensation insurance variable — WCOMP — equals weekly maximum insurance benefits for temporary total disability, as reported annually by the United States Chamber of Commerce (1982). The variable WCOMP is matched to workers only by state, but it is calculated on a worker-specific basis using benefit formulas that adjust for such factors as marital status and family size. The other insurance variable is REPRATE, which equals the weekly after-tax wage replacement rate:

$$\text{REPRATE} = \frac{\text{WCOMP}}{\text{WAGE} \times 40}$$

where WAGE is the hourly after-tax wage. The structure of workers' compensation benefits is captured by the binary variable D, which equals 1 if two-thirds of the workers' weekly wage exceeds the maximum and equals zero otherwise.

4. The Empirical Framework

The empirical model consists of a two-equation system, with the natural logs of the wage rate and of the risk level serving as the two dependent variables. In the risk equation, the subscript i denotes worker i (including the intercept), X_{ij} is explanatory variable j for worker i, and ε_{Ri} is the random error term.

The first equation pertains to determination of the risk level, and is of the form

$$\begin{aligned}\ln\text{RISK}_i = {} & \sum_{j=0}^{J} \alpha_j X_{ij} + \phi_1 D_i \text{WCOMP}_i + \phi_2 D_i \text{WCOMP}_i^2 \\ & + \phi_3(1 - D_i)\,\text{WCOMP}_i + \phi_4(1 - D_i)\,\text{WCOMP}_i^2 + \varepsilon_{Ri}. \qquad (5)\end{aligned}$$

The wage equation to be estimated is

$$\begin{aligned}\ln\text{WAGE}_i = {} & \sum_{k=0}^{K} \beta_k X_{ik} + \gamma_1 \text{RISK}_i + \delta_1 D_i \text{RISK}_i \times \text{REPRATE}_i \\ & + \delta_2(1 - D_i)\,\text{RISK}_i \times \text{REPRATE}_i + \varepsilon_{wi}. \qquad (6)\end{aligned}$$

In our formulation wages, risks, and workers' compensation are interrelated in the following manner. The WAGE variable enters the RISK equation through the variable D only. The WAGE variable does not appear separately in the risk equation since, in the hedonic system, we can express the risk as a function of characteristics of the worker or the firm.[8] The RISK variable enters the wage equation directly to test for compensating differentials. Workers compensation affects both wages and risks directly, and also affects wages indirectly through the risk equation. The two-equation system is estimated using two-stage least squares, with WAGE, RISK, and D treated as endogenous.

The analysis in sections 1 and 2 indicates that if the safety incentive effect dominates the role of moral hazard, the expected coefficient signs are $\phi_1 < 0$, $\phi_2 > 0$, $\phi_3 < 0$, and $\phi_4 > 0$. Workers' compensation should reduce the risk level ($\phi_1, \phi_3 < 0$) at a diminishing rate ($\phi_2, \phi_4 > 0$). This reduction should be greater for higher wage workers. If moral hazard offsets the safety incentive effect the net effect of workers' compensation will be to raise fatality risk ($\phi_1, \phi_3 > 0$), so that the results also serve as a test of the moral hazard dominance hypothesis. Furthermore, if the effects of WCOMP are pronounced when $D = 1$, we would also expect $|\phi_1| > |\phi_3|$ and $|\phi_2| > |\phi_4|$. However, the differential effects are more likely to appear in the wage equation, since the WAGE variable is worker-specific.

Equation 6 represents the lnWAGE equation. In equation 6 the RISK variable is expected to have a positive effect, using the familiar compensating differential rationale. This effect should not depend on the value of the variable D. In Viscusi and Moore (1987) we show that the theoretically appropriate benefit measure interacts benefits with the risk measure, because insurance benefits are only of value to the worker at positive risk levels. Equation 6 therefore interacts the NTOF fatality risk measure with the replacement rate measure. A wage offset from workers' compensation is expected, so that the predicted workers' compensation coefficients, δ_1 and δ_2, are negative. Thus the lnWAGE equation hypotheses are $\gamma_1 > 0$, $\delta_1, \delta_2, < 0$, and $|\delta_1| > |\delta_2|$.

In the empirical analysis of the compensating differential model, a number of issues arise with respect to the estimation of the model. Most importantly, the model itself consists of a regression of wages on job risks and benefit levels, all of which reflect the utility maximizing choices of workers. Since unobservable worker characteristics such as ability are correlated with all of these choice variables, ordinary least-squares estimates of compensating differential wage equations may not yield unbiased estimates of the wage-risk and wage-benefit tradeoffs. A similar problem arises when aggregate data are matched to workers in the sample and taken as a measure of the risk a particular worker faced in his job. The measurement error caused by this, in conjunction with the ability bias described above, exerts a downward influence on the estimated coefficients and tends to inflate the estimated standard errors.[9]

Our solution to this problem is similar to Biddle and Zarkin (1988). We use a standard wage equation that consists of the human capital variables (HEALTH, EDUCATION, JOB TENURE, JOB TENURE^2, EXPERIENCE, and EXPERIENCE^2), location variables (NEAST, NCENT, SOUTH, CITY), job-related variables (BLUE, UNION), and personal characteristics (KIDS, MARRIED, FEMALE, BLACK), and instrumented values of the endogenous right-hand side variables. Instrumental variables include all possible interactions of the exogenous variables, and the included variables. Unlike Biddle and Zarkin, we do not include interaction terms that appear significant in a variable selection process. The estimated coefficients on the key variables in each equation do not appear to be sensitive to the exclusion of these interactions. We therefore report the results from the simpler regressions only, as the coefficient estimates are easier to interpret.[10]

We use a similar procedure to estimate the risk regression. Individual and job characteristics, excluding the location measures, are included in the regression. The excluded higher order terms enable us to identify the coefficients of this regression.

5. Estimates of the RISK and WAGE Equation

5.1. RISK Equation

Table 3 presents estimates of the RISK and WAGE equations given by equations 5 and 6. The regressions restrict the WCOMP coefficients to be equal across values of the dummy variable, D.

Consider first the variables in the RISK regressions other than those related to workers' compensation. It is often argued in the wage-risk trade-off literature that wealth effects, ability, and worker characteristics lead workers to sort themselves into jobs with different risks. In terms of the explanatory variables in table 2, proxies for lifetime wealth such as

Table 3. Two-Stage Least-Squares Estimates of the Risk and Wage Equations[a] Coefficients (Standard Errors)

Independent Variable[a]	*RISK*	*WAGE*
KIDS	0.018	0.029[a]
	(0.023)	(0.008)
MARRIED	−0.011	0.064[a]
	(0.078)	(0.024)
HEALTH	−0.135	−0.081[a]
	(0.094)	(0.028)
EDUCATION	−0.036[a]	0.041[a]
	(0.012)	(0.004)
FEMALE	−0.271[a]	−0.206[a]
	(0.090)	(0.028)
UNION	0.056	0.150[a]
	(0.058)	(0.019)
JOB TENURE	−0.004	0.008[a]
	(0.005)	(0.003)
	----	−0.73E-3
		(1.11E-3)
EXPERIENCE	−0.004	0.019[a]
	(0.003)	(0.003)
	----	−3.95E-4[a]
		(0.78E-4)
BLUE	0.194[a]	−0.065[a]
	(0.063)	(0.024)
WCOMP	−5.78E-3[a]	−1.25E-2[a]
	(1.88E-3)	(0.31E-2)
WCOMP^2	8.57E-6[a]	----
	(3.83E-6)	
RISK	----	1.42E-2[a]
		(0.28E-2)
INTERCEPT	2.852[a]	1.147[a]
	(0.296)	(0.069)
Summary *Statistics*		
R^2	0.082	0.476
x^2	92.2	85.58

[a] Statistically significant at the 0.05 confidence level, one-tailed *t*-test (critical value = 1.645).

EDUCATION and MARRIED, which are both positively related to wealth, should reduce RISK, since job safety is a normal good. This is empirically supported in the RISK regression, where the effect of EDUCATION is negative and highly significant. Marital status also has a negative effect, but it is not statistically significant. The variable KIDS, which measures the number of dependent children, has no discernible effect on RISK.

An extensive theoretical literature analyzes the relationship between risks and age, particularly as it relates to a worker's learning about risk. The theoretical propositions in these learning models are supported empirically in quit rate studies (Viscusi, 1979) and a reservation wage rate study (Viscusi, 1984). Risk equations have been estimated for other risk variables in Viscusi (1979), but the analysis of state-industry death risk variables in table 3 addresses a more refined risk measure.

In the table 3 results, EXPERIENCE has a negative effect on risks that is significant at the .10 confidence level. This could reflect the sorting of workers into safer jobs as they observe working conditions over time. There is not a similar JOB TENURE effect, which is probably due to the nature of the risk variable, which is only industry-specific. Increases in job tenure for a given level of experience will have no effect on one's industry risk level, though one's job-specific risk may change.

The FEMALE dummy variable is negative and highly significant in the RISK equation, indicating that women tend to work on safer jobs. On the other hand, HEALTH impairments are not strongly related to RISK. The impact of UNION status does not indicate a strong effect. The remaining coefficient, BLUE, is positive and significant, as expected.

The table 2 results indicate that workers' compensation on balance serves as a safety incentive mechanism. The WCOMP variable, which has the expected negative sign and strong statistical significance, is associated with a large impact on safety. Insurance costs exert strong downward pressure on fatal accident rates. The nonlinearity of the WCOMP effect is also very strong, as is evidenced by the positive coefficients for $WCOMP^2$. This result is consistent with the evidence that the marginal cost of providing safety rises at an increasing rate.[11]

5.2. WAGE Equation

Table 3 also presents estimates of equation 6. In table 3 the RISK and REPRATE efects are not allowed to vary across values of D. Alternative specifications are discussed below.

Workers with KIDS have higher wages and limitations caused by HEALTH impairments decrease wages. The rate of return to education is about four percent, and JOB TENURE and EXPERIENCE increase wages, the latter at a decreasing rate. Workers who are FEMALE are paid significantly lower wages. The UNION coefficient of about 15% is consistent with most other studies.

In the equation reported in table 3, there is strong statistical evidence of a positive tradeoff between lnWAGE and RISK. The estimates of the coefficients γ and δ indicate that a 1/100,000 increase in the death risk will change wages by 1%, taking into account the effect of the risk change on expected benefits. The associated implicit value of life is $5.1 million in 1986 prices. This result is quite robust. As indicated in our sensitivity analyses the rate of trade-off net of the workers' compensation replacement rate is .2%.

The benefit structure variable D, which measures the effect of changes in the benefit ceiling conditional or whether a worker is above or below the ceiling, has an important effect on the wage equation coefficients δ_1 or δ_2. As expected, increases in the maximum are more highly valued by workers for whom the maximum is binding, so that $|\delta_1| > |\delta_2|$. The benefit structure variable did not lead to differences in the WCOMP coefficients in the RISK equation, probably due to differences in the level of aggregation of the variables RISK and D.

5.3. Other Issues Relating to the Estimation Procedure

The results in table 3 are quite strong in terms of their statistical significance, and the RISK and INSURANCE variables perform consistently with our a priori expectations. The estimation techniques are not typical, however, as previous research has relied almost exclusively on ordinary least squares (OLS) estimation of single equation models. To compare our results with the more standard OLS estimates, equations 5 and 6 were also estimated using OLS. The results indicated that in both the RISK and lnRISK regressions the coefficients on the insurance variables, WCOMP and $WCOMP^2$, are practically identical to the coefficients estimated using two-stage least squares in terms of their signs and significance levels.

6. Safety and Wage Effects

The empirical results indicate that there are statistically significant wage and risk effects of workers' compensation. The magnitude of these influences is also of considerable economic and policy interest. Consider first the effect on safety. Based on the estimates of equation 5, a decrease in benefits to zero would increase the average risk level by 3.53 deaths per 100,000 workers, which is an increase of 45%.

The RISK effects of workers' compensation also imply a wage adjustment, since risks and wages are positively related. Based upon the wage equation estimates in table 3, a one unit increase in the RISK level will increase the after-tax hourly wage by 2.2 cents, or about 45 dollars per year. If workers' compensation benefits were eliminated entirely and the risk level rose by 3.53, annual wages would rise by about $160.

The table 3 results also indicate that benefits exert downward pressure on fatality rates that diminishes as benefits rise. Setting the derivative of the benefit effect equal to zero and solving for WCOMP yields a value of $336. Of the states in our sample, Connecticut, Illinois, Iowa, Maine, and Wyoming had benefit ceilings in excess of this amount.

The effect of workers' compensation on wages consists of two components — a direct wage offset for the social insurance and a wage offset for the reduced risk level. The estimates in table 3 imply that the direct wage effect will be the larger of the two wage effects of workers' compensation.

Based on the coefficients in table 3, we can calculate the full wage effect of a benefit increase, i.e., the direct wage offset plus the wage decrease resulting from the diminished risk. For a worker with an hourly wage equal to $7, wages fall by about 8 cents per week per dollar of additional benefits. This effect consists primarily of the 1.25% reduction due to the direct effect of benefits on wages, but also includes a wage reduction of 0.03% a week due to the indirect effect of benefits on risks and risks on wages. In the absence of benefits, a linear extrapolation of these figures implies that wages would be $1,100 higher. The direct wage offset is consequently many times greater than the wage offset due to the reduced risk.

The total impact of workers' compensation on wages consist of two parts — the $1,100 wage offset from higher benefits and the $160 savings due to risk reduction. This difference in financial incentives for safety is evidenced in the greater safety impact of workers' compensation, compared with OSHA. The $160 per worker wage reduction is almost three times greater than the reported per worker expenditures on health and safety for the year 1981 of $57, expressed in 1986 prices, but these expenditure figures are highly speculative.[12] The $1,100 wage offset and the additional $160 offset from risk reduction also exceeds the $261 average cost of workers' compensation premiums per worker.[13]

7. Conclusion

Because workers' compensation is a social insurance program that operates within a market context, it has broad economic effects on the behavior of firms and prospective beneficiaries of the insurance. Workers' compensation is not a simple income transfer. Rather, it represents a targeted insurance effort that enhances the attractiveness of hazardous jobs by reducing the income loss associated with these positions. Since workers value this social insurance there is a substantial wage offset, which in turn diminishes the premium cost to firms.

The second class of effects stems from the safety incentives created by the funding arrangements. Since workers' compensation premiums dwarf the magnitude of penalties levied by OSHA, it is not surprising that workers' compensation has a greater safety incentive effect net of the influence of any moral hazard. Indeed, death risks could have been almost 50% greater in the absence of this program. There is also a small wage reduction that firms experience because of this decreased risk.

Perhaps the main lesson from this analysis of workers' compensation is that social insurance efforts have far reaching effects that should be taken into account in program design.[14] Society is not simply transferring money in these programs. It is also establishing powerful incentives for safety. Indeed, these incentives appear to be a driving force in promoting worker safety.

In addition, the frequent complaints by firms about the rising premium levels may be overstated. These premiums translate into benefits for which workers willingly accept substantial wage cuts. An attractive social insurance program that operates through the market will be at least partially self-financing.[15]

Notes

1. See Ruser (1985), and Moore and Viscusi (1989, 1990).
2. Note that $p_s^* > 0$ is a necessary condition for an interior solution to this problem.
3. For analyses of the role of experience rating, see Ruser (1985) and Moore and Viscusi (1989).
4. See Butler and Worral (1985) and Kniesner and Leeth (1987).
5. In those studies that have analyzed the impact of workers' compensation on injury rates, Butler (1983) uses time series data on risks and benefits within a single state (South Carolina) to circumvent this problem. Chelius (1982) uses unpublished data on two-digit (SIC) manufacturing industries for 36 states, and Ruser (1985) uses BLS injury data for 25 three-digit manufacturing industries across 41 states. Of the three studies, only Butler attempts to analyze the combined impact of benefits on both injury rates and wages.

6. In the NTOF data, the average risks within one-digit SIC industry classifications are typically 2–5 times the size of their standard errors, so that the interstate risk variation is more pronounced for some industries than for others.

7. Previous analyses have utilized a range of measures that include the weekly wage replacement rate [Chelius 1982, Viscusi and Moore 1987, and Arnould and Nichols 1983], weekly benefits (Ruser, 1985), annual payments by industry (Butler, 1983), and workers' compensation premium rates (Dorsey and Walzea 1983). Butler attempts to separately identify the effects of each type of benefit with some success and also constructs a benefit index using principal components analysis.

8. Moore and Viscusi (1989) analyze a RISK equation with firm characteristics.

9. See Brown (1980), Duncan and Holmlund (1983), and Moore (1990) for analyses of these problems.

10. The results of this estimation were reported in an earlier version of this paper.

11. Technically speaking, the estimation should take into account the fact that the dependent variable is grouped. One solution to this problem (the random effects model) requires longitudinal data, which we do not utilize in the study. An important finding in Ruser (1990) is that the results in our RISK equation are replicated using microdata on fatality risks.

12. Actual expenditures on employee safety and health in 1981 for all businesses, reported by McGraw-Hill (1983), were 5,120.4 million dollars. The total civilian labor force in 1981 included 106,940 workers, as reported by the Council of Economic Advisers (1987). Safety expenditure data are taken from The McGraw-Hill Survey of Investment in Employee Safety and Health (1986).

13. Total premiums paid for 1981 equal $22.9 billion dollars reported in Price (1984), for per worker premium costs of $214 in 1981 prices, and $261 in 1986 prices.

14. See Weiler (1986).

15. See Moore and Viscusi (1989).

References

Arnould, R. J., and L. M., Nichols. (1983). "Wage-Risk Premiums and Workers' Compensation: A Refinement of Estimates of Compensating Wage Differential," *Journal of Political Economy* 91(2), 332–340.

Biddle, J., and G. Zarkin. (1988). "Worker Preferences and Market Compensation for Job Risk," *Review of Economics and Statistics* 77, 660–667.

Butler, R. J. (1983). "Wage and Injury Rate Response to Shifting Levels of Workers' Compensation." In Worrall, John, D., ed., *Safety and the Workforce: Incentives and Disincentives in Workers' Compensation*, 61–86, Ithaca, NY: Industrial and Labor Relations Press.

Butler, R. J., and J. D. Worrall. (1985). "Work Injury Compensation and the Duration of Nonwork Spells," *Economic Journal* 95, 714–724.

Brown, C. (1980). "Equalizing Differences in the Labor Market," *Quarterly Journal of Economics* 94(1), 113–134.

Chelius, J. R. (1982). "The Influence of Workers' compensation on Safety Incentives," *Industrial and Labor Relations Review* 35(2), 235–242.

Council of Economic Advisers. (1987). *Economic Report of the President*, Washington, D.C.: U.S. Government Printing Office.

Dionne, G. (1982). "Moral Hazard and State-Dependent Utility Function," *J. of Risk and Insurance* 48(3), 422–435.

Dorsey, S., and N. Walzer. (1983). "Workers' Compensation, Job Hazards, and Wages," *Industrial and Labor Relations Review* 36(4), 642–654.

Duncan, G. J., and B. Holmlund. (1983). "Was Adam Smith Right After All? Another Test of the Theory of Compensating Wage Differentials," *Journal of Labor Economics* 1(4), 366–379.

Kniesner, T. J., and J. D. Leeth. (1987). "Separating the Reporting Effects from the Injury Rate Effects of Workers' Compensation. A Hedonic Simulation," Center for the Study of Business Regulation Working Paper No. 87–10, Duke University, Durham, North Carolina.

Moore, M. J., and W. K. Viscusi. (1988). "Doubling the Estimated Value of Life: The Implications of New Occupational Fatality Data," *Journal of Policy Analysis and Management* 7(3), 476–490.

Moore, M. J., and W. K. Viscusi. (1989). "Promoting Safety Through Workers' Compensation: The Efficacy and Net Wage Costs of Injury Insurance," *RAND Journal of Economics* 20(4), 499–515.

Moore, M. J., and W. K. Viscusi. (1990a). *Compensation Mechanisms for Job Risks: Wages, Workers' Compensation, and Product Liability*. Princeton, NJ: Princeton University Press.

Moore, M. J., and W. K. Viscusi. (1990b). *Have Increases in Workers' Compensation Benefits Paid for Themselves?* David Appel and Philip Borba eds. Dordrecht: Kluwer Academic Publishers.

Moore, M. J. (1990). "The Impact of Measurement Error and Ability Bias Estimates of Compensating Differentials." Working paper, Duke University, Durham, North Carolina.

Price, D. N., (1981) "Workers' Compensation Program Experience" *Social Security Bulletin*, 47(4), 8–12.

Ruser, J. W. (1985). "Workers' Compensation Insurance, Experience Rating, and Occupational Injuries," *RAND Joural of Economics* 16(4), 487–503.

Ruser, J. (1990). "The Impact of Workers' Compensation Insurance on Occupational Injuries and Fatalities: Reporting Effects and True Safety Effects." BLS Working Paper.

U.S. Chamber of Commerce. (1982). *Analysis of Workers' Compensation Laws*, 1982 Ed. Washington, D.C.: U.S. Chamber of Commerce.

Viscusi, W. K. (1979). *Employment Hazards: An Investigation of Market Performance*. Cambridge, MA: Harvard University Press.

Viscusi, W. K. (1983). *Risk by Choice: Regulating Health and Safety in the Workplace*. Cambridge, MA: Harvard University Press.

Viscusi, W. K., and C. O'Connor. (1984). "Adaptive Responses to Chemical Labeling: Are Workers Bayesian Decision Makers?" *American Economic Review* 74(5), 942–956.

Viscusi, W. K. (1985). "Cotton Dust Regulation: An OSHA Success Story?" *Journal of Policy Analysis and Management* 4(3), 325–343.

Viscusi, W. K., and M. J. Moore. (1987). "Workers' Compensation: Wage Effects, Benefit Inadequacies, and the Value of Health Losses," *Review of Economics and Statistics* 69(2), 249–261.

Weiler, P. (1986). "Legal Policy for Workplace Injuries." American Law Institute Report, American Law Institute, Philadelphia, PA.