

THE FEASIBILITY OF AN "INJURY TAX" APPROACH TO OCCUPATIONAL SAFETY

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INTRODUCTION

The Occupational Safety and Health Act of 1970 was enacted at least in part because of a twenty-five per cent rise in the overall manufacturing injury rate between 1964 and 1969.¹ The congressional response was a mandatory standards approach to occupational injuries and disease. The Act also created a new agency, the Occupational Safety and Health Administration (OSHA), with the power to promulgate and enforce a variety of workplace standards. Failure by a firm to comply with OSHA's standards, as detected by unannounced inspections, was made punishable by fines up to \$1,000 for each violation.²

This standards approach is subject to several objections widely accepted among economists. First, standards may bear no relationship to hazards in a particular operation, yet compliance (at whatever cost) is mandatory.³ Second, by requiring a certain set of safety inputs rather than by penalizing an unwanted outcome, such as injuries, the standards approach does not encourage firms to seek other, perhaps cheaper, ways of reducing injuries. Third, the promulgated standards are so numerous (approximately 1,700)⁴ and workplaces so diverse, that one must question how comprehensive or knowledgeable inspections can be.⁵ In short, the standards approach is not generally compatible with the goal of achieving a given reduction in injuries in the least-cost manner.⁶

An "injury tax" approach to occupational safety and health, under which the government would levy a monetary penalty on firms for each work in-

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¹ U.S. DEP'T OF LABOR, *INJURY RATES BY INDUSTRY, 1969* (B.L.S. Rep. No. 389, 1971); U.S. DEP'T OF LABOR, *INJURY RATES BY INDUSTRY, 1964 AND 1965* (B.L.S. Rep. No. 342, 1968).

² Occ. Safety & Health Act § 17(b), 29 U.S.C. § 666(b) (1970).

³ The courts have ruled that the absence of previous injuries is not a defense against the requirement to comply with safety standards. OSHA, U.S. Dep't of Labor, *Violation Without Injury*, 2 *JOB SAFETY & HEALTH*, Feb. 1974, at 30.

⁴ 29 C.F.R. §§ 1910.1-309 (1973).

⁵ One indication that inspectors may find violations only of the limited set of standards with which they are familiar is that one per cent of the standards account for thirty-eight per cent of all citations. OSHA, U.S. Dep't of Labor, *Standards by Frequency of Violation*, Sept. 11, 1973 (OSHA internal printout).

⁶ This paper ignores the more basic question of the optimality of *any* government safety program. Rather, it is assumed that society has decided to reduce work injuries and therefore is seeking the least-cost method of achieving this reduction. While it is recognized that there are market incentives for safety independent of government programs, the assumption here is that a social decision has been made to reduce injuries below the level induced by private costs alone.

jury or case of disease, would not be susceptible to these objections, providing it could be demonstrated that employers would respond to market incentives in the safety and health area. The injury tax would penalize injuries directly, leaving the employer free to seek the minimum-cost method of achieving reduction. While he might decide his injury rate could be reduced most efficiently by adhering to the presently required standards, he would not be required to do so nor would his government-induced safety incentives be limited to such a response.

The purpose of this paper is to investigate the feasibility—politics aside—of the tax approach to occupational safety (occupational diseases are ignored). Specifically, two questions are posed: (1) is there evidence that firms would respond to an injury tax by taking the steps necessary to reduce injuries and, if so, (2) roughly how large would the average tax have to be to achieve given reductions in the injury rate? The answer to the second question, which involves the cost of reducing injuries, is also relevant in evaluating the current level of OSHA inspections and fines. Last year OSHA inspected one per cent of covered firms (with ten per cent of all employees) and assessed fines averaging \$169 per noncomplying firm or \$26 per violation,⁷ suggesting that OSHA implicitly believes injury reduction can be accomplished very cheaply.⁸

Answers to the two questions posed by this paper are developed by formulating a theory of work injuries (Part I), specifying an empirically testable version of that theory (Part II), and then reporting the results and policy implications of such a test (Part III). Finally, the major conclusions are summarized nonmathematically.

I

A THEORY OF WORK INJURIES

To test the hypothesis that the level of work injuries is responsive to market (or price) incentives, we will begin with a standard, profit-maximizing model of a firm whose workers are exposed to risk of injury. Under such a model the firm can accept higher injury rates and pay their associated costs (wage premiums to workers, damage to equipment, and extra costs of training workers) or it can purchase safety inputs (such as machine guards, training sessions, and protective clothing) in order to reduce injuries. The firm will choose a level of safety inputs—and, consequently, an injury rate—at which the marginal cost of reducing the injury rate equals the marginal savings from

⁷ OSHA, U.S. Dep't of Labor, *News Briefs*, JOB SAFETY & HEALTH. *News Briefs* is a regular feature of this OSHA trade periodical; the issues utilized for the purposes of this analysis were August through December in volume 1 (1973), and January through April in volume 2 (1974).

⁸ A profit-maximizing firm will only comply with OSHA standards if the costs of compliance are less than the expected costs of noncompliance. A National Association of Manufacturers survey found that firms with 100 to 500 employees (the size OSHA typically inspects) estimate it would cost \$104,000 to comply with OSHA standards. Although these figures must be discounted to some extent because of the political warfare between government and business over safety legislation, the magnitude of the discrepancy between the cost of compliance and the expected penalties for noncompliance is remarkable. See *What Does It Cost to Comply With OSHA?*, OCCUPATIONAL HAZARDS, Oct. 1973, at 114.

the reduction. The injury rate consistent with profit-maximization will be shown to vary across firms (or industries) with the costs of reducing injuries, the savings from such reduction, and the degree of danger inherent in the technologies involved.⁹

More formally, consider the firm attempting to maximize its profits, V , which can be represented by the following equation:

$$(1) V = P_Q Q(L, K) - W(a)L - cL - P_S SL - rK$$

where P_Q = price of output, Q ;

L = man-hours of labor hired;

K = capital (except safety inputs);

W = wage rate;

r = rental price of capital;

a = injury rate = I/L , where

I = number of injuries;

S = safety inputs per man-hours hired,¹⁰ and P_S = unit price of such inputs;

c = cost per injury (except compensating wage differential).

Note that $aL = I$, the number of injuries, and that W is a function of a . Specifically, we assume that $dW/da > 0$; that is, we assume workers must be paid a compensating wage differential in order to induce them to accept dangerous jobs. The costs of injuries represented by c (assumed to be a constant for the firm) include lost production time of the victim and other workers, damage to equipment, training costs of replacement workers, and administrative costs. The following relationship is also assumed:

$$(2) a = a(S), da/dS < 0, d^2a/dS^2 > 0.$$

The total cost, M , of injuries to the firm can be expressed as

$$(3) M = a(dW/da)L + cL.$$

Because $a = I/L$, equation (3) can be rewritten in terms of I :

$$(4) M = (dW/da)I + cI.$$

Although L^* , K^* , and S^* —the profit maximizing levels of inputs—are simultaneously derived from all three first-order conditions for profit-maximization, it is especially informative to assume L and K are fixed and look at the first-order condition with respect to S :

$$(5) dV/dS = -L (dW/da) (da/dS) - cL (da/dS) - P_S L = 0.$$

With elementary manipulation the above can be rewritten as

$$(6) dW/da + c = -P_S (dS/da),$$

where the left-hand side equals dM/dI (see equation 4).

⁹ Chelius, *An Empirical Analysis of Safety Regulation*, in 3 SUPPLEMENTAL STUDIES FOR THE NATIONAL COMMISSION ON STATE WORKMEN'S COMPENSATION LAWS 53 (1973), and Russell, *Pricing Industrial Accidents*, in *id.* at 27, attempt to relate the injury rate to workmen's compensation costs. Russell's study could not establish a strong linkage primarily because workmen's compensation premiums are relatively inelastic with respect to injuries. Chelius related injury rates to workmen's compensation benefit levels across states and obtained perverse results, perhaps because higher benefits reduce the cost of injury to the employee, thereby reducing incentives for caution. See also Chelius, *The Control of Industrial Accidents: Economic Theory and Empirical Evidence*, 38 LAW & CONTEMP. PROB. 700 (1974).

¹⁰ To avoid unnecessary complications, the model does not assume hours per worker to be subject to the firm's control in maximizing profits.

Equation (6) specifies the determinants of S^* , the optimal level of safety inputs, as illustrated in panel A of Figure 1. To determine the injury rate, a^* , consistent with profit-maximization requires the specification of the relationship between a and S , as illustrated in panel B of Figure 1. The profit-maximizing injury rate in firm x , a^*_x , is less than that of firm y , because for equal levels of S , $a_y > a_x$. To express this notion in more formal terms, we may say that the risk, R , inherent in the technology employed by firm y exceeds that in the techniques employed by firm x . Thus, the influence of inherent risk on a^* must explicitly be taken into account along with the "market" influences on S^* .

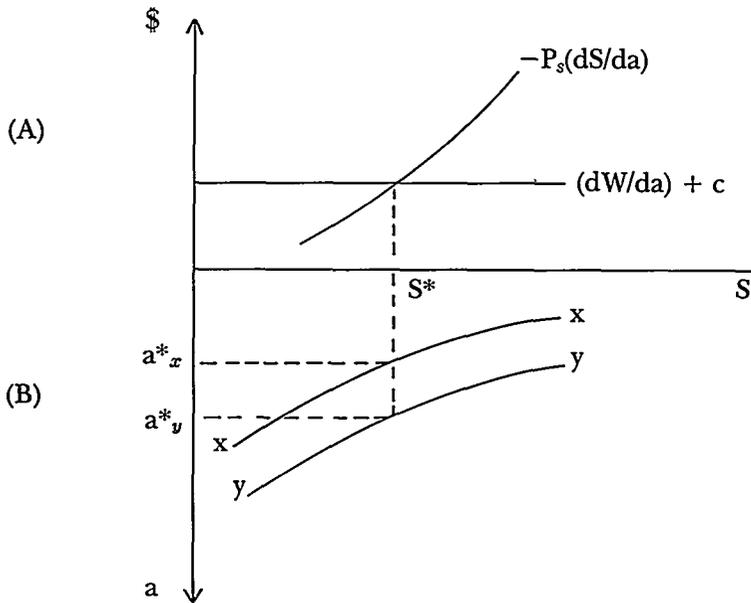
In sum, then, theory leads us to expect a^* to vary across firms (or industries) negatively with dM/dI and positively with P_s and R :¹¹

$$(7) a^* = a^* [(dM/dI), P_s, R].$$

Assuming that a , the observed injury rate, equals $a^* + e$ (stochastic error term) and that equation (7) can be approximated by a linear form, we can obtain the following generalized estimating equation:

$$(8) a = \alpha (dM/dI) + \beta P_s + \gamma R + e.$$

FIGURE 1



DETERMINATION OF "OPTIMAL" INJURY RATE

¹¹ R affects a^* directly, as shown in panel B of Figure 1. However, in general, R will indirectly influence a^* —not necessarily in the same direction—through dS/da , an element of the marginal cost on injury reduction (along with P_s). If $a(S) = RS\lambda$, a functional form possessing the characteristics assumed in equation (2) if $\lambda > 0$, it can readily be shown that

(i) $a^*_x/a^*_y = (R_x/R_y) / (1 + \lambda)$.

In short, with the above functional form, the profit-maximizing injury rate rises with increases in R .

II

EMPIRICAL SPECIFICATION

Empirical estimation of α is of particular interest for our purposes, because α indicates the response of the injury rate to an increase in the marginal cost of injuries. The sign and significance of $\hat{\alpha}$ will indicate whether market incentives influence the injury rate. The size of $\hat{\alpha}$ can be used to roughly assess the levels of injury taxes required to reduce injury rates by given amounts.

We turn now to the task of empirically identifying R , P_s , and dM/dI . In specifying an estimable version of equation (8), it is necessary to use data at the industry level of aggregation, because a sufficiently rich microfile simply does not exist. Therefore, the data used relate to thirty manufacturing industries selected solely on the basis of data availability.

A. Empirical Specification of R

The two major groups of influences on R are the personal characteristics of workers employed and the physical characteristics of their jobs and plant. Studies have consistently shown that younger workers are more likely to be injured than older ones, with the rate peaking in the 18-25 age group. Some studies attribute the age-injury profile to job experience, some to the risk-taking associated with youth, and some to both.¹² Prudence suggests, therefore, that proxies for both age and experience be included among the measurable determinants of R . Our measure of age (A) corresponds to the percentage of workers in the industry under 26 years of age. The rate of new hires (NH) for the industry is our proxy for the proportion of inexperienced employees.

An analysis of work injuries in 1971 found that 22.6 per cent were the result of handling objects, 20.4 per cent were due to falls, and 13.6 per cent involved being struck by falling objects.¹³ All three kinds of injuries are more likely to occur when materials are being moved, especially when being moved by hand. Further, extremes in such environmental conditions as lighting, noise, temperature, and humidity are also believed to increase the risk of injury.¹⁴ A study of occupational characteristics¹⁵ by Lucas¹⁶ found that within each race/sex group lower-paying occupations were more apt to require the climbing, stooping, and heavy lifting associated with moving objects by hand; the lower-paying occupations were also more likely to expose workers to extremes of heat, light, noise, and other hazards. Finally, Lucas found that females and whites were exposed to the above hazards less than

¹² A. R. HALE & M. HALE, A REVIEW OF INDUSTRIAL ACCIDENT RESEARCH LITERATURE 35 (1972); J. SURRY, AN ANNOTATED BIBLIOGRAPHY FOR INDUSTRIAL ACCIDENT RESEARCH AND RELATED FIELDS 14 (1969); Oi, *On the Economics of Industrial Safety*, 38 LAW & CONTEMP. PROB. 669 (1974).

¹³ NATIONAL SAFETY COUNCIL, ACCIDENT FACTS 31 (1972).

¹⁴ J. SURRY, *supra* note 12, at 86-98.

¹⁵ 2 MANPOWER ADMINISTRATION, U.S. DEP'T OF LABOR, DICTIONARY OF OCCUPATIONAL TITLES (3d ed. 1965), was used to obtain a variety of characteristics associated with 295 occupations.

¹⁶ R.E.B. Lucas, *Working Conditions, Wage-Rates and Human Capital: A Hedonic Study*, 1972 (unpublished doctoral dissertation in M.I.T. Library).

males and blacks.¹⁷ These findings suggest that the wage rate (W) and the percentages of the work force which are female (F) and nonwhite (B) can be used to proxy exposure to hazardous working requirements and conditions.¹⁸

In addition to the nearly 57 per cent of work injuries associated with handling objects, falls, and being struck by falling objects, another 17 per cent involved machinery or vehicles. Exposure to machines and vehicles may be measured by horsepower per production worker (HP), which rises as both the number and power of machinery and vehicles per worker increases. We shall also control for the percentage of production workers (PW) among the total.¹⁹

B. Empirical Specification of P_s

Gordon²⁰ hypothesizes that there are economies of scale in the provision of such inputs as safety committees, first-aid stations, safety directors, and safety training programs. While the proportion of total safety costs that is attributable to these inputs is unknown, it seems reasonable to suppose that the per-worker price of safety inputs (P_s) falls to some degree as firm size increases. Thus, average firm size (FS) is included as a crude proxy for P_s .²¹

¹⁷ *Id.* at 138, 403-11.

¹⁸ Employing the wage rate as a proxy for exposure to environmental or job hazards raises questions of how much of this exposure is inherent in the technology (the choice of which is assumed to be independent of the cost of injuries), how much is due to the greater incentives employers have to safeguard skilled workers, and whether the two factors can be separated at all. In the context of this paper, these questions are moot, because, as will be shown, the wage variable will pick up the effects of both factors. In the case of noise, heat, and so forth, the two factors of "inherent" and "induced" risk may well be hopelessly intertwined. The requirements of climbing, stooping, and strength may well be inherent in low-skilled occupations, because skilled workers undoubtedly have a comparative advantage in precision processing of materials as opposed to simply moving them; a similar argument can be made with respect to females.

The greater exposure of nonwhites to risk may reflect discrimination. Indeed, it will be interesting to see if, controlling for wages, nonwhites have higher injury rates. Becker's theory of discrimination predicts that nonwhites will receive lower wages for the same work where segregation is impossible if employers or fellow employees are prejudiced. G. BECKER, *THE ECONOMICS OF DISCRIMINATION* (2d ed. 1971). A simple corollary to this hypothesis is that, with wages held constant, nonwhites will be found in the more disagreeable and risky jobs.

¹⁹ Little is known about the relationship between injuries and fatigue. M. SCHULZINGER, *THE ACCIDENT SYNDROME* 29-33 (1956), notes the diurnal cycle of work injuries (10 a.m. and 3 p.m. peaks), but J. SURRY, *supra* note 12, at 114-15, and A.R. HALE & M. HALE, *supra* note 12, at 45-48, emphasize work rates rather than fatigue in explaining this cycle. In addition, data from Pennsylvania indicate that the injury rate does *not* rise during overtime hours, when workers are presumably most fatigued. See Oi, *supra* note 12. However, Smith, *Intertemporal Changes in Work Injury Rate*, in INDUSTRIAL RELATIONS RESEARCH ASSOCIATION, *PROCEEDINGS OF THE TWENTY-FIFTH ANNIVERSARY (ANNUAL WINTER) MEETING 167 (1973)*, found a positive intertemporal relationship between injury rates and overtime. Initial experimenting with the use of overtime hours per week in the current study could not demonstrate a positive relationship between injuries and overtime; therefore, overtime hours worked was not among our proxies for R .

²⁰ J.B. GORDON, A. AKMAN & M. BROOKS, *INDUSTRIAL SAFETY STATISTICS: A RE-EXAMINATION* 149 (1971).

²¹ Firm size also is a good proxy for the degree to which workmen's compensation premiums reflect actual injury experience. However, as indicated in note 9 *supra*, the elasticity of the premium with respect to experience is very low for all but the largest firms. Hence, the strength of the experience-rating factor may not be measurable.

Unions, too, may reduce P_s by providing information to firms on hazards or by increasing the safety-consciousness of their members. We include the percentage of workers who are unionized (U) to reflect this effect. Other than as modified by FS and U, we assume P_s to be constant across industries.

C. Empirical Specification of dM/dI

Referring back to equation (4) we can see that dM/dI is hypothesized to equal dW/da (the marginal compensating wage differential) plus c (a constant cost per injury due to machine damage, lost time, administrative costs, and the costs of training replacements). Estimation of dW/da is discussed first—and in some detail—because it involves estimating a wage equation with risk of injury included as an independent variable.²²

In the absence of full *ex post* compensation for injuries, one would expect workers to obtain *ex ante* compensation in the form of wage premiums sufficient to cover the losses imposed on them by injuries. If the wage premiums were not sufficient to cover these losses, workers would not be attracted to the industry or firm because their net wage would be higher elsewhere. More formally, the equilibrium condition which must hold across industries, assuming risk neutrality and homogeneous preferences among workers, is

$$(9) W_{ij} - E(L_{ij}) = W^n(H_j, Z_j),$$

where W_{ij} is the gross (observed) wage of the i^{th} worker in the j^{th} class of workers, W^n his net wage stated as a function of human capital (H) and other variables (Z), and $E(L)$ is his expected uncompensated losses from injury.

$E(L)$ is assumed to be the sum of the expected losses of three levels of injuries: death, permanent impairment and temporary disability (levels A, B and C, respectively). The probability of being killed during any hour of work is $P^A a$, where a is the hourly injury rate and P^A is the fraction of injuries resulting in death; the probabilities of incurring nonfatal injuries are similarly calculated. We assume the losses associated with each level of injury are proportional to the wage rate; for example, the losses associated with death are $r^A W$. Substituting these definitions into equation (9) we obtain

$$(10) W_{ij} [1 - a_{ij} (r^A P^A_{ij} + r^B P^B_{ij} + r^C P^C_{ij})] = W^n(H_j, Z_j).$$

Assuming the reduction in gross wages due to expected injury-related losses is less than 50 per cent, we can use the approximation $\ln(1 + x) = x$ in rewriting (10) as

$$(11) \ln W_{ij} = r^A P^A_{ij} a_{ij} + r^B P^B_{ij} a_{ij} + r^C P^C_{ij} a_{ij} + \ln W^n(H_j, Z_j).$$

Equation (11) suggests an estimating equation where an individual's wage (in logarithms) is regressed against the probability of his sustaining an injury resulting in death, permanent impairment, and temporary disability, plus the

²² A more detailed development of the compensating differential estimates is contained in R. SMITH, COMPENSATING WAGE DIFFERENTIALS AND HAZARDOUS WORK (Dep't of Labor, Office of the Ass't Secretary for Policy, Evaluation, and Research, Office of Evaluation Technical Analysis Series Paper No. 5, 1973).

determinants of his net wage (in logarithms). Data on W_{ij} and the determinants of W^n , were obtained for 3,183 white males from the May 1967 Current Population Survey,²³ which contained supplemental data on wage rates and union membership collected as part of the Survey of Economic Opportunity. The independent variables included as determinants of W^n were virtually the same as those used by Oaxaca²⁴ in an earlier study using the same data: education, experience, union membership, class of worker, occupation, demographic characteristics, geographical dummies, migration variables, and in one specification, industry dummies. Table A of the Appendix lists these variables and their estimated coefficients.

The probability of injury assigned to each individual was the average for the industry in which he works.²⁵ The industry rate, a , is the frequency rate (disabling injuries per million man-hours) corrected to an *hourly* basis, that is, the published frequency rate divided by 1,000,000 so that hourly wages could be stated as a function of hourly risks. P^A , P^B , and P^C were also obtained from published sources.²⁶ The estimated coefficient of each injury variable corresponds to r^A , r^B , and r^C ; the estimates are summarized in Table I. Specifications I and II are similar, except that the latter includes industry group dummies and the former does not.²⁷ The results suggest the presence of a compensating differential related to the probability of death, where *ex post* compensation to the employee is impossible, but cast doubt on the existence of such differentials for the more easily-compensable lesser injuries. The differential related to death is plausibly large, lending credibility to the estimates.²⁸

To construct industry estimates of dW/da , we note, from equation (11), that for industry k

$$(12) (dW/da)_k = W_k (d \ln W/da)_k = W_k (r^A P_k^A + r^B P_k^B + r^C P_k^C).$$

The results in Table I, plus equation (12) suggest two alternative methods of estimating $(dW/da)_k$:

$$(13) (dW/da)_{k1} = W_k (1.238P_k^A + .075P_k^B + -.006P_k^C) \times 10^6, \text{ or}$$

$$(14) (dW/da)_{k2} = W_k (.636P_k^A) \times 10^6.$$

²³ Unpublished files, U.S. Bureau of the Census, Dep't of Commerce.

²⁴ Oaxaca, *Male-Female Wage Differentials in Urban Labor Markets*, 14 INT'L ECON. REV. 693 (1973).

²⁵ Using industry averages to represent risks facing individuals poses an errors-in-variables problem, potentially biasing the coefficients toward zero. Given the lack of firm-specific injury data cross-tabulated by occupation, however, the problem is unavoidable. R. Thaler & S. Rosen, *The Value of Saving a Life: Evidence From the Labor Market* (paper presented at the National Bureau of Economic Research Conference, Washington, D.C., Nov. 30, 1973), estimate compensating differentials using actuarial data on a few occupations, but using such data here would make it impossible to translate the results into estimates of dW/da across industries. Their measure of risk is, of course, also subject to measurement error.

²⁶ Data on a , P^A , P^B , and P^C were obtained by SIC code from U.S. DEP'T OF LABOR, *INJURY RATES BY INDUSTRY, 1966 AND 1967* (B.L.S. Rep. No. 360, 1969). The data were then converted to Census codes for purposes of analysis.

²⁷ The test including industry group dummies is the more stringent for compensating wage differentials because the differentials must, in effect, be estimated solely from intra-group variations in injury rates.

²⁸ Although an extrapolation so far outside the observed range of the "death risk" variable is speculative in the extreme, it is instructive to note that a job involving certain death would command a wage rate of between \$1.8 and \$3.3 million—close enough to infinity to be credible.

TABLE I
ESTIMATES OF PROPORTIONATE COMPENSATING
WAGE DIFFERENTIALS

	Estimates (t values) of		
	γ^A	γ^B	γ^C
Specification I	1.238 × 10 ⁶ (6.97)	.075 × 10 ⁶ (2.57)	-.006 × 10 ⁶ (-3.79)
Specification II	.636 × 10 ⁶ (2.40)	-.033 × 10 ⁶ (-.85)	-.002 × 10 ⁶ (-1.31)

Both methods yield the same average compensating differential, and it was decided to employ both methods to determine the sensitivity of our estimates to changes in the construction of dW/da . The method represented by equation (13) resulted in negative values of dW/da for some industries—values which are inadmissible a priori. Negative values were therefore constrained in some formulations to equal zero in order to ensure that only calculations which made economic sense were employed.²⁹

No new variables are defined to capture the effects of c , the other component of the marginal cost of injuries. The potential costs of damage to equipment across industries is adequately proxied by the horsepower variable (HP). Replacement costs and the costs of lost production time due to injuries are proportional to the wage rate,³⁰ giving still further reason to believe that injury rates would be lower in high wage industries. We assume administrative costs associated with injuries are constant across industries. Thus, $\alpha(dM/dI)$ in equation (8) is expressed as
(15) $\alpha(dM/dI) = \alpha(dW/da) + \alpha\phi_1HP + \alpha\phi_2W + \alpha\phi_0$,
where ϕ_0 , ϕ_1 , and ϕ_2 are unobservable constants imbedded in c .

D. Estimating Equation

The discussion above suggests the following version of equation (8):
(16) $a_k = \beta_0 + \alpha(dW/da)_k + \beta_1W_k + \beta_2HP_k + \beta_3NH_k + \beta_4A_k + \beta_5\bar{F}_k$
 $+ \beta_6PW_k + \beta_7B_k + \gamma_1FS_k + \gamma_2U_k + e_k$.

As noted earlier, α is the parameter of primary interest because it is an estimate of how responsive the injury rate is to a change in the cost of an injury. (β_0, β_1 , and β_2 include α —see equation (15)—but α cannot be

²⁹ A third method of constructing estimates of dW/da —involving the use of the insignificant coefficients in Specification II (Table I)—was rejected because it yielded negative values for dW/da in twenty-seven of thirty industries. However, even this method results in essentially the same ordering of industries by dW/da , and estimates using this method resulted in coefficients of the same size and sign, but not significance, as those using the other methods.

³⁰ See Oi, *Labor as a Quasi-Fixed Factor of Production*, 70 J. POL. ECON. 538 (Supp. 1962), for evidence that hiring and training costs rise with wages.

identified separately in them.) Our development of equation (16) suggests the following sign expectations:

$$\hat{\alpha}, \hat{\beta}_1, \hat{\beta}_5, \hat{\gamma}_1, \hat{\gamma}_2 < 0$$

$$\hat{\beta}_2, \hat{\beta}_3, \hat{\beta}_4, \hat{\beta}_6, \hat{\beta}_7 > 0.$$

Data on injuries, wages, horsepower, production workers, new hires, and firm size were obtained for 1963 from the *Census of Manufactures*³¹ and *Employment and Earnings*;³² data on females, nonwhites, age, and unionization relate to 1960 and were obtained from Pencavel³³ and the 1960 *Census of Population*.³⁴

III

RESULTS AND IMPLICATIONS

Equation (15) was estimated using the two-stage least squares (TSLS) estimator because of the simultaneity between W and a .³⁵ The results are presented in Table II, with ordinary least squares (OLS) estimates displayed for comparative purposes. Rows A through F of Table II present the results from estimating the model as originally specified. The estimates of α (the coefficient of dW/da) all have the expected sign, are significant, and are generally of the same magnitude. The coefficients of the wage rate (W), insignificantly negative in the OLS estimates, become larger (absolutely) and significant at least at the .10 level in the TSLS estimates. The estimated coefficient of the horsepower, new hires, percentage female, percentage non-white, percentage production worker, and firm size variables all consistently display their expected signs; all but the last two are usually significant at the .05 level. Only the age and unionization variables have unexpected signs; however, the standard errors almost always equal or exceed the estimated coefficients on these variables.³⁶

Because the risk and safety input price variables were necessarily specified in a rather ad hoc fashion it was thought prudent to exclude those which apparently did not serve as adequate proxies and re-estimate the equations to determine the effects on $\hat{\alpha}$, if any, of initial misspecification. Lines G

³¹ 1, 3 U.S. BUREAU OF THE CENSUS, DEP'T OF COMMERCE, CENSUS OF MANUFACTURES, 1963 (1966).

³² U.S. BUREAU OF LABOR STATISTICS, DEP'T OF LABOR, BULL. NO. 1312-9, EMPLOYMENT AND EARNINGS: UNITED STATES, 1909-72 (1973).

³³ J. PENCAVEL, AN ANALYSIS OF THE QUIT RATE IN MANUFACTURING INDUSTRY (1970).

³⁴ 2 U.S. BUREAU OF THE CENSUS, DEP'T OF COMMERCE, U.S. CENSUS OF POPULATION: 1960. SUBJECT REPORTS. INDUSTRIAL CHARACTERISTICS (Final Rep. No. PC(2) -7F, 1967).

³⁵ In addition to the exogenous variables in equation (16), the following were employed in creating an instrument for W : percentage of workers in the operative and laborer category, whether the industry manufactured durables or non-durables, and the estimated value of $\ln W/da$.

³⁶ The negative findings with respect to firm size and age are of particular interest because of the zero-order inverse correlation between these variables and injury rates. Firm size, measured across industries may capture very little of the scale economies or workmen's compensation incentives that exist in larger firms within industries. Our results do suggest, however, the tentative hypothesis that the zero-order inverse correlation of age and injuries reflects the combined effects of low wages and the lack of experience associated with being newly hired.

TABLE II
ESTIMATES OF EQUATION (17)

Specification of dW/da	Method	Estimated Coefficient (Standard Error) On:											R ²
		Constant (β ₀)	dW/da (α)	W (β ₁)	HP (β ₂)	NH (β ₃)	A (β ₄)	F (β ₅)	PW (β ₆)	B (β ₇)	FS (γ ₁)	U γ ₂	
A EQUA. (13) (Constrained)	OLS	6.50 (15.22)	-59* × 10 ⁻³ (.16) × 10 ⁻³	-2.51 (4.43)	.13* × 10 ⁻² (.06) × 10 ⁻²	1.95* (1.05)	-26.07 (34.54)	-7.73* (2.43)	.14** (.09)	92.56* (22.70)	-.05 × 10 ⁻¹ (.08) × 10 ⁻¹	.38 (6.66)	.90
B EQUA. (13) (Unconstrained)	OLS	10.55 (13.41)	-53* × 10 ⁻³ (.11) × 10 ⁻³	-3.73 (3.87)	.13* × 10 ⁻² (.04) × 10 ⁻²	2.24* (.94)	-29.28 (30.54)	-9.22 (2.13)	.13** (.08)	83.53* (20.14)	-.05 × 10 ⁻¹ (.07) × 10 ⁻¹	-1.21 (5.85)	.92
C EQUA. (14)	OLS	15.06 (17.86)	-75* × 10 ⁻³ (.38) × 10 ⁻³	-4.99 (5.12)	.11* × 10 ⁻² (.07) × 10 ⁻²	2.39* (1.29)	-24.21 (40.86)	-8.63* (2.82)	.07 (.11)	102.91* (27.41)	-.03 × 10 ⁻¹ (.10) × 10 ⁻¹	1.84 (8.01)	.87
D EQUA. (13) (Constrained)	TSLS	38.34 (26.90)	-58* × 10 ⁻³ (.19) × 10 ⁻³	-13.05** (8.47)	.15* × 10 ⁻² (.07) × 10 ⁻²	2.14* (1.20)	-43.74 (41.04)	-10.35* (3.25)	.01 (.13)	80.37* (27.16)	.03 × 10 ⁻¹ (.01) × 10 ⁻¹	9.70 (9.69)	.87
E EQUA. (13) (Unconstrained)	TSLS	29.94 (21.24)	-54* × 10 ⁻³ (.12) × 10 ⁻³	-10.11** (6.62)	.15* × 10 ⁻² (.05) × 10 ⁻²	2.38* (1.01)	-40.74 (33.99)	-10.81* (2.62)	.05 (.11)	76.03* (22.38)	-.00 × 10 ⁻¹ (.09) × 10 ⁻¹	4.54 (7.79)	.91
F EQUA. (14)	TSLS	55.00** (31.49)	-95* × 10 ⁻³ (.45) × 10 ⁻³	-17.90* (9.73)	.16* × 10 ⁻² (.09) × 10 ⁻²	2.82* (1.52)	-50.23 (49.72)	-11.78* (3.78)	-.11 (.17)	90.71* (32.75)	.08 × 10 ⁻¹ (.13) × 10 ⁻¹	14.27 (11.81)	.82
G EQUA. (13) (Constrained)	TSLS	25.43* (10.99)	-49* × 10 ⁻³ (.17) × 10 ⁻³	-8.09* (4.07)	.13* × 10 ⁻² (.16) × 10 ⁻²	1.86* (.99)	-9.51* (2.74)	-9.51* (2.74)		99.04* (23.11)			.87
H EQUA. (13) (Unconstrained)	TSLS	24.16* (8.89)	-50* × 10 ⁻³ (.12) × 10 ⁻³	-7.79* (3.26)	.14* × 10 ⁻² (.05) × 10 ⁻²	2.10* (.88)		-10.22* (2.32)		95.19 (19.91)			.90
I EQUA. (14)	TSLS	27.31* (12.29)	-67* × 10 ⁻³ (.34) × 10 ⁻³	-9.01* (4.58)	.11** × 10 ⁻² (.07) × 10 ⁻²	2.19* (.11)		-10.39* (2.95)		101.00* (25.82)			.85

*Denotes significance at the .05 level, and ** significance at the .10 level, with one-tail tests. One-tail tests are employed on all estimated coefficients, because a priori sign expectations are assigned to each. Significance tests in the context of two-stage least squares (TSLS) are only approximate, however.

through I of Table II display the re-estimation results. The estimates of α maintain their size and significance, as do the remaining variables. Overall, the estimates of α are encouragingly robust with respect to size and significance under varying estimating techniques, methods of calculating dW/da , and specifications of the estimating equation.

Both the sign and the significance of $\hat{\alpha}$ are consistent with the hypothesis that, across industries, work injury rates are inversely correlated with the cost to employers of injuries. In other words, employers do seem to be responsive in their safety efforts to the cost of injuries. It would therefore appear that, other things being equal, an injury tax would result in a reduction of the injury rate.

By how much a specified injury tax would reduce the average injury rate can be deduced, at least roughly, from the point estimates of α . Table III presents estimates of injury rate reductions for a variety of fines; alternative estimates of $\hat{\alpha}$ —corresponding to the lowest, highest, and average (absolute) values estimated—are used in an attempt to define the likely range of response.

TABLE III
ESTIMATED REDUCTION IN THE MANUFACTURING
INJURY RATE BY SELECTED INJURY FINES
(1970 Average Injury Rate = 15.2)

Fine Per Injury	Estimated Reduction (% Reduction) in Injury Rate		
	Minimum = $.49 \times 10^{-3}$	Maximum = $.95 \times 10^{-3}$	Average = $.62 \times 10^{-3}$
\$ 500	.24 (1.6%)	.48 (3.2%)	.31 (2.0%)
1,000	.49 (3.2%)	.95 (6.4%)	.62 (4.1%)
2,000	.98 (6.4%)	1.90(12.5%)	1.24 (8.2%)
4,000	1.96(12.9%)	3.80(25%)	2.48(16.3%)

Table III suggests that substantial fines are required to reduce the injury rate by even moderate amounts. A per injury fine of \$2,000, for example, would have been required to reduce the 1970 average manufacturing injury rate to its 1968 level of 14.0 (using the average $\hat{\alpha}$). To achieve a reduction in the injury rate of 10 per cent would appear to require a fine somewhere between \$1,600 and \$3,100 per injury. Thus, our findings, as summarized in Table III, suggest that reductions in the injury rate below present levels would be very costly to employers.

Are the above implications, derived from our estimates of α , credible? Interestingly enough, our estimated fine of \$1,600 to \$3,100 per injury for a one-time, 10 per cent reduction in the injury rate brackets the typical estimated per injury cost of complying with OSHA standards—standards which the agency hopes will yield at least initially a 10 per cent reduction in injury rates.³⁷ The National Association of Manufacturers survey found that

³⁷ U.S. Dept of Labor, Program Memorandum: Occupational Safety and Health 4 (mimeo, 1972).

firms with fifty employees—the average number of employees for manufacturing firms is sixty—estimated the cost of complying with the Act to be \$33,000.³⁸ Given that such firms have around 1.5 injuries per year (assuming a frequency rate of 15 per million man-hours), and positing an 8 per cent interest rate, we estimate that OSHA compliance costs per injury in a typical manufacturing firm are about \$1,800. While this correspondence of figures should not be given too much weight because no one knows what compliance with OSHA standards would do to injuries³⁹ or whether the compliance cost figures are biased, it is nevertheless encouraging that our estimates are so close to those of a program of similar intent.

Our estimated fines—and their results—can also be compared with estimates of average injury costs to the employer to obtain some idea of the implied injury rate elasticity. The National Safety Council estimates that the average employer cost of a disabling work injury is around \$4,000, not including property damage.⁴⁰ Let us arbitrarily assume that the average cost, with property damage included, is \$4,500. To obtain a 10 per cent reduction in injuries would require, according to our estimates, a 35 to 70 per cent increase in the average cost of injuries—an implied elasticity of injuries with respect to their average cost of between .30 and .15. These elasticities are certainly of a reasonable order of magnitude, and the difficulty in reducing the injury rate they imply would seem to be supported by other evidence. Oi cites a Wisconsin study of safety inspection effectiveness which asserts that 75 per cent of all industrial accidents result not from some continuing hazard, but rather from random events such as machine breakdowns, power failures, faulty materials, or unpredictable acts by employees.⁴¹ If only 25 per cent of injuries can be reduced by employment of safety inputs, one would expect the low elasticities we estimate.

CONCLUSION

This paper has attempted to analyze the feasibility of replacing the current standards approach to occupational safety with an injury tax approach, which would require employers to pay a financial penalty for each injury occurring in their workplaces. In particular, the study sought to determine (1) whether injury rates across industries are inversely correlated with injury costs, other things being equal, and (2) what sizes of taxes would be required to achieve given reductions in the injury rate. The general conclusions which appear supportable are that the injury rate is indeed sensitive to the costs of injury, but that the taxes required to reduce these rates by even moderate amounts would have to be very large.

To base an occupational safety policy on only the findings presented here would, of course, be premature. The data used necessarily related to the

³⁸ *What Does It Cost to Comply With OSHA?*, *supra* note 8.

³⁹ The implication of note 8 *supra*, is, however, that compliance with OSHA standards will not occur until after inspection has revealed a violation.

⁴⁰ See NATIONAL SAFETY COUNCIL, *supra* note 13, at 23-25.

⁴¹ See Oi, *supra* note 12.

early and middle 1960's, and replication of the study as soon as data from the 1972 *Census of Manufactures* is available would obviously be advisable. Furthermore, a tax approach would probably be most effective if fines were related to injury severity, and estimates of the required differentials among severity levels were outside the scope of this study. Finally, only work injuries, not illnesses, were studied. Nevertheless, this initial analysis of the tax approach suggests that such an approach is promising, and the results can serve as a benchmark for future studies.

Appendix

TABLE A
ESTIMATES OF WAGE EQUATION*
DEPENDENT VARIABLE = $\ln(\text{WAGE})$

Independent Variables	Specification	
	I	II
Constant	-.158 (-2.50)	-.232 (-3.54)
Education	.046 (16.02)	.045 (15.51)
Experience	.018 (9.31)	.017 (9.08)
Experience ²	$-.026 \times 10^{-2}$ (-6.97)	$-.025 \times 10^{-2}$ (-6.88)
Union	.102 (6.63)	.098 (6.36)
Deaths per 10 ⁶ man-hours	1.238 (6.97)	.636 (2.40)
Permanent impairments per 10 ⁶ man-hours	.075 (2.57)	-.033 (-.85)
Temporary impairments per 10 ⁶ man-hours	-.006 (-3.79)	-.002 (-1.31)
Firm size	$-.003 \times 10^{-3}$ (-.09)	$-.016 \times 10^{-3}$ (-.55)
<i>Class of Worker:</i>		
Government	-.103 (-2.63)	-.121 (-3.08)
Self employed	-.123 (-2.34)	-1.20 (-2.29)
<i>Occupation:</i>		
Professional worker	.206 (5.53)	.186 (4.90)
Manager	.175 (4.63)	.190 (5.01)
Clerical	-.048 (-1.21)	-.057 (-1.40)
Craftsmen	.045 (1.31)	.028 (.79)
Operatives	-.081 (-2.36)	-.090 (-2.60)
Service workers	-.218 (-4.82)	-.131 (2.73)
Laborers	-.108 (2.58)	-.115 (-2.73)
Part-time	-.296 (-8.87)	-.269 (-8.05)

<i>Demographic Characteristics:</i>		
Health problem	.096 (4.01)	.094 (3.99)
Spouse present	.177 (7.26)	.170 (7.03)
Spouse absent	.224 (1.78)	.199 (1.59)
Widowed	.115 (1.64)	.118 (1.70)
Divorced	.118 (2.61)	.114 (2.55)
<i>Size of Urban Area:</i>		
SMSA < 250,000	.067 (2.67)	.066 (2.64)
SMSA 250-500,000	.111 (4.31)	.097 (3.77)
SMSA 500-750,000	.161 (6.03)	.153 (5.76)
SMSA > 750,000	.172 (8.77)	.167 (8.51)
<i>Region:</i>		
Northeast	.125 (6.35)	.121 (6.19)
North Central	.134 (7.03)	.124 (6.52)
West	.150 (6.73)	.149 (6.72)
<i>Migration:</i>		
Recent migrant	.006 (3.01)	.005 (2.57)
Years since migration	-.0013 (-.66)	-.0008 (-.40)
(Years since migration) ²	.006 × 10 ⁻² (1.39)	.006 × 10 ⁻² (1.26)
<i>Industry:</i>		
Construction	—	.233 (5.03)
Durable manufacturing	—	.193 (5.47)
Non-durable manufacturing	—	.131 (3.96)
Wholesale trade	—	.164 (3.87)
Business and repair services	—	.025 (.47)
Personal services	—	-.174 (-2.49)
R ²	.45	.46
Std. Error of estimate	.370	.366

*t values in parentheses.