

AN ABSTRACT OF THE THESIS OF

Rainier H. Farmer for the degree of Master of Science in Public Health presented on April 29, 1991.

Title: The Impact of External Factors on Occupational Injury/Illness and Lost Workday Incidence Rates

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Dr. Annette M. Rossignol

Occupational injury and illness rates are used by employers and regulatory agencies to monitor the health and safety of workers. Changes in the rates are interpreted to reflect actions taken or not taken by the employer. The purpose of this study was to delineate external factors, those factors outside the control of employers, which influence occupational injury and illness rates. The results of this study are useful in interpreting changes in the occupational injury and illness rates as a function of changes in the external factors.

A review of the literature provided information on the type of external forces which would be expected to influence occupational injury/illness rates. The factors selected for the data analysis included economic indicators, regulatory budget and performance measures, firm size, and leniency in workers' compensation claim determination as measured by the proportion of denied claims.

Data were collected on the injury/illness incidence, lost workday case incidence, and lost workday rates for the state of Oregon for 1978 through 1987. Multiple linear regression models were constructed for each of the injury/illness rates using a step-down variable selection process to determine the predictor variables for each model. Separate models were constructed for each dependent variable using the values of the predictor variables for the same year and for the preceding year.

The results supported the hypotheses that the unemployment rate, gross state product, number of serious violations cited by OSHA, and percentage of claims denied by the Workers' Compensation Board influence occupational injury and illness rates. Total OSHA expenditures and the number of inspections conducted by OSHA in a given year demonstrated positive relationships with lost workday cases incidence and injury/illness incidence rates, respectively; the positive associations were contrary to the hypothesized relationships. Models can be constructed using data on external factors to predict injury/illness incidence, lost workday case incidence, and lost workday rates. The unemployment rate was the most useful variable in predicting occupational injury and illness rates.

**The Impact of External Factors on Occupational
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Rainier H. Farmer

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Professor of Public Health in charge of major

Redacted for Privacy

Chair of department of Public Health

Redacted for Privacy

Dean of the College of Health and Human Performance

Redacted for Privacy

Dean of Graduate School

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The Impact of External Factors on Occupational Injury/Illness and Lost Workday Incidence Rates

Introduction

Regulatory agencies and employers use a variety of statistics to monitor or describe the health and safety of workers. Legislators and other decision makers utilize the same set of measures in developing public policy, promulgating or revising statutes and allocating resources. Employers can incur significant costs in retrofitting, training, inspecting, and other activities associated with regulatory mandates. Likewise, governments must allocate scarce resources to the occupational health and safety effort at the expense of other programs. Due to the potential impact of decisions based on occupational health and safety statistics, it is important that the validity of these measures be explored.

Three measures commonly used to assess overall effectiveness of the health and safety effort at both the micro (organizational) and macro (state or federal) levels are the incidence rate for occupational injuries and illnesses, the lost workday case incidence rate and the lost workday rate. The occupational injury and illnesses incidence rate, defined as the number of cases of an injury or illness per 100 full-time employees for a given year, measures the frequency of occurrence of recordable accidents

or exposures resulting in injury or illness. The lost workday case incidence rate, expressed as the number of injuries or illnesses resulting in off-work and restricted work days per 100 full-time employees for a given year, is an indicator of the relative severity of injuries and illnesses. The lost workday rate, also a severity measure, is the number of actual number of days missed from work per 100 full-time workers each year due to occupational injuries or illnesses.

The underlying assumption in evaluating changes in any of the rates is that the observed changes are the result of actions taken or not taken by the employer or the regulatory agency. The objective of this study is to delineate external factors (those factors outside the control of the employer or regulatory agency) affecting the injury/illness incidence, lost workday case incidence, and lost workday rates. Factors to be studied include size of the firm (number of employees); Occupational Safety and Health Administration (OSHA) expenditures; performance measures for OSHA, including number of inspections, number of citations, and penalties; statewide economic indicators, including the unemployment rate and adjusted gross state product; and workers' compensation claim acceptance rate. The association between the selected factors and the incidence rates will be evaluated by reviewing the published literature for each factor and by performing an analysis of covariance for factors for which there is available data for

the State of Oregon from 1978 to 1987. For the factors that show a significant relationship with the incidence rates, possible mechanisms for the association will be discussed.

The results of this study will be useful in evaluating changes in incidence rates for a specific organization or for the State of Oregon as a whole. An injury/illness incidence, lost workday case incidence, or lost workday rate could conceivably be adjusted for any one or a combination of the significant external factors, providing for more meaningful assessment of efforts put forth by employers or regulatory agencies.

Literature Review

OSHA

The Occupational Safety and Health Act of 1970 mandated that a national system of safety standards be created and enforced. The Occupational Safety and Health Administration (OSHA), within in the Department of Labor, is responsible for promulgating the standards. The standards are enforced via inspections performed by OSHA; violations are cited and, for certain categories of violations, penalties assessed. Violations are designated, in increasing order of severity, as being de minimis, nonserious, serious, repeat, or willful.¹ Individual states are allowed to develop plans for administering occupational safety and health surveillance as long as the plans are "at least as effective" as OSHA.² The rationale behind the creation of OSHA was that adherence to the standards would create safer workplaces and thereby lower injury and illness rates.

To assess the actual impact of the occupational safety and health regulatory effort on injury/illness incidence and lost workday rates, it is necessary to identify the fraction of occupational injuries and illnesses that result from conditions which regulators are capable of monitoring. To be "OSHA-preventable," an injury or exposure resulting in an illness must be the result of the violation of a standard. Estimates of the proportion of occupational injuries traceable to violation of one or more standards range from

10 to 26%.^{3,4} If the percentage is further restricted to those injuries for which a detectable violation was implicated, the upper limit drops to 18%.⁵ Even these estimates may be high, since the criteria for designating an injury as being the result of a violation is that the violation was a factor in the accident, and not necessarily the sole cause.⁶ Thus, the maximum expected reduction in injury incidence rates under optimum enforcement is less than 30%. These estimates ignore the possible "ripple" effects which may be realized from safety efforts in non-compliance areas which would not have existed except for the need to comply with the OSHA standards.

Due to the time lag between exposure to a harmful agent and the manifestation of a recognizable occupational disease, it is difficult to determine the percentage of occupational illnesses that are caused by a violation of an OSHA standard. Accordingly, there are no available studies to quantify the fraction of occupational illnesses attributable to a violation of one or more OSHA standards.

The complex nature of the overall OSHA effort, including standard development and promulgation, enforcement activities, consultation, and indirect effects makes it difficult to derive a single statistic to measure the effect of OSHA activities on injury and illness rates. Several books have been published which combine statistical evaluation and qualitative analysis in an attempt to determine the impact of OSHA on occupational injuries and

illnesses.^{7,8,9}

In a study which received attention in the lay media, Seligman correlated budget expenditures for OSHA and lost workday rates for the U.S. and found a correlation coefficient of +0.9 for the period 1972 through 1982, suggesting that increased spending on OSHA resulted in an increase in the number of lost workdays per 100 workers for a given year.¹⁰ The analysis did not control for any confounding variables, such as increased reporting, changes in the workers' compensation system, or the effect of economic trends during the study period.

A comparison of safety enforcement expenditures per worker and corresponding accident frequency rates between Ohio and Michigan for the period 1960 through 1963 (pre-OSHA) revealed no significant differences between the two states in accident frequency rates, even though Ohio expenditures were triple those of Michigan (\$0.63 versus \$0.20 per worker per year).¹¹ A composite index, comprised of the safety budget and number of inspectors per worker, and indices of the extensiveness and strictness of standards for occupational safety in each of the states for the year 1967, was not related to injury frequency rates.¹²

Studies of the effect of OSHA inspections on injury/illness incidence rates have produced conflicting conclusions. Most analyses of aggregate data have found either no significant relationship between the number of inspections performed and the injury/illness incidence rate

for a given period^{13,14} or mixed results, with significant reductions for one year (1973) but not for the following year (1974).¹⁵ Mendeloff's study focusing on inspection effects for specific types of injury found significant reductions in injury rates as a result of OSHA inspections.¹⁶ The specific injury classes studied included classes most likely to be associated with a violation of a standard, i.e. caught in or between, slips and falls, eye injury, etc.¹⁷

Several factors may confound the relationship between the number of inspections and injury/illness incidence, lost workday case incidence or lost workday rates. One such factor is record keeping. One of the objectives of OSHA is to improve accident record keeping and reporting. Thus, a consequence of improved OSHA surveillance is an apparent rise in the reported injury/illness rate, even if the true rate remains constant or decreases. Although there is general agreement that this phenomena is taking place, no research has been published that quantifies the effect.

The skill of the inspectors in recognizing hazards or violations could have an impact on the quality of the inspections. Less experienced inspectors could be expected to miss subtle hazards that a more experienced inspector could identify. The recognition and correction of a higher proportion of the hazards present prior to the hazards causing an injury or illness should lower occupational injury/illness rates. The formative years of OSHA and

periods of rapid expansion are associated with a higher percentage of less skilled inspectors. There are no published studies that examine the experience level of OSHA inspectors and the quality or quantity of inspections.

The breadth and depth of inspections prescribed by OSHA's upper management conceivably could alter the effect of inspections on injury and illness rates. More thorough inspections could lower the rates via the mechanism identified above, i.e. by finding a greater proportion of the hazards that exist at a given site. In 1975, OSHA changed the emphasis of the inspection program by reducing the number of inspections in favor of performing more in-depth inspections.¹⁸ The implementation of the Target Industry Program (TIP) in 1973 was an attempt to concentrate on industries with high accident incidence rates, under the assumption that focusing on these high-risk industries would yield the greatest reduction in occupational injuries given the limited enforcement resources. Mendeloff challenged this assumption by stating that high-risk industries in general are characterized by a lower percentage of injuries caused by a detectable violation of a standard than for industry as a whole.¹⁹

A criticism of studies that conclude OSHA inspections have an insignificant effect based on examination of pre- and post-inspection injury/illness rates is that these studies do not account for the deterrence effect. The anticipation of being inspected might tend to lower the

baseline injury rate in industry.

The relative intensity of OSHA inspections can be measured using both the number and severity of violations cited and the penalties associated with the more serious violations. It should be noted that the shift in inspection emphasis that occurred in 1975 (cited above) was accompanied by a corresponding shift away from citing de minimis and nonserious violations towards greater emphasis on serious violations.²⁰ There have been no studies published relating the number or severity level of violations cited and occupational injury/illness incidence, lost workday case incidence, or lost workday rates.

The impact of OSHA penalties on injury/illness rates has been evaluated primarily by using econometric models to determine the potential financial impact of the penalties on a firm. The aim of these studies was to determine whether the expected penalties provided sufficient incentive for the affected firms to comply with OSHA regulations. For 1977, the expected cost of non-compliance was calculated to be \$3.90 before an initial inspection and \$20.06 after the initial inspection; the higher post-inspection value is due to the significantly higher penalties for repeat violations.²¹ The average penalty per violation in 1974 was reported to be \$24,²² although the trend since 1975 has been to increase in the average fine per violation.²³ All of the studies which have examined OSHA penalties conclude that the expected cost of non-compliance does not provide adequate

incentive to comply with OSHA standards given the costs (not cited) of back-fitting and other activities required to conform to OSHA regulations. These conclusions are based on average values; the possibility of large fines for any given firm probably elicits a greater level of compliance than would be represented by the average values. The conclusions also ignore the substantial increase in penalties associated with repeat, willful, and failure-to-abate (\$1000/day) penalties, as well as the possibility of criminal prosecution for management personnel in the event of a death resulting from a willful violation, falsifying records, etc.²⁴ The effect of failure-to-abate penalties is weakened by the ability of the firm to suspend the penalty pending appeal of the violation²⁵ and the fact that the failure-to-abate penalty is only applied for a maximum of ten days.²⁶ Other non-monetary "penalties", notably public and worker relations, also provide an incentive for firms to comply with OSHA regulations.

There are no published studies that explore the relationship between magnitude or frequency of penalties and injury/illness incidence, lost workday case incidence, or lost workday rates.

Size of Firm

Although the size of a firm is not an external factor (to the firm) in the strict sense, it is a parameter over which neither the safety manager nor regulatory personnel have any control. Thus, the effect that firm size has on

injury/illness rates is of interest in interpreting these rates for a given firm relative to other firms in the same industry classification.

There is only one published study that addresses the relationship between firm size and injury/illness rates specifically.²⁷ Leigh used Bureau of Labor Statistics occupational injury and illness incidence rate data for 28 manufacturing industry classifications for 1982. The 28 industry classifications were chosen based on the availability of data for all eight size categories. Analysis of the data revealed a non-normal distribution, with low values of injury/illness incidence rates for the smallest (1-19 employees) and largest (>2500 employees) firms, with a peak at the 50-99 size category and a long tail to the right. The reported differences between injury/illness rates for the size categories were significant at the $p(z)=.05$ level, and were controlled for percent production workers, percent women, weekly hours, and weekly earnings.²⁸

Mechanisms suggested for the lower rates in larger firms include better interviewing and screening of candidates for employment and increased spending on safety and health relative to medium size firms. The former explanation would be valid for employers utilizing back screening programs given the high representation of back injuries in the overall injury rate; prospective employees with a history of back problems would be screened out by

such programs prior to employment. The lower rates documented for small firms may be due to under-reporting, since smaller firms receive less scrutiny from OSHA; due to enhanced selection of workers, since in very small firms the owner can "hand-pick" from friends and relatives; or due to an owner-operator maintaining a safe workplace since any hazards may place the owner in danger.²⁹ Of the possible explanations cited only the hypothesis of better screening and interviewing in larger firms has been empirically tested and verified.³⁰

Although the study cited above is the only published study examining the effect of firm size directly, several studies have used firm size as a variable in multiple linear regression models of injury/illness incidence rates.^{31,32,33} The reported regression coefficients are small negative values, suggesting a slight reduction in injury/illness incidence rates as firm size increases. It should be noted that the assumed linear relationship is only valid when firm size is greater than 50 employees based on Leigh's findings.

Economic Indicators

The degree to which changes in economic factors affect occupational health and safety rates has been studied at both the macro and micro levels. In general, the studies focus on the effect of the business cycle in general or specifically on changes in employment level. Parameters correlated with indices of occupational health and safety include unemployment rate, accession rate (number of new

hires per unit time), growth rate, and output per employee.

The impact of changes in the employment level are based on the premise that recently hired employees are more likely to be injured than their experienced co-workers. Conversely, during downturns in the economic cycle, less experienced workers are the first to be laid off, leaving a higher overall experience level in the workforce. This phenomena has been verified empirically.^{34,35,36}

Direct measures of the relationship between the accession rate and injury/illness rates reveal a significant positive relationship.³⁷ The association between changes in the employment level and injury rates is less pronounced, although still positive, possibly due to the recall of experienced workers as opposed to new hires during periods of labor force expansion³⁸ or to the reluctance of labor to pursue improvements in safety during contraction, as will be discussed in the next paragraph.

When the examination of the effect of economic changes is expanded to include the business cycle as a whole, competing factors have been identified which exert opposing forces on injury/illness rates at the same point in the cycle. The impact of the overall experience level as a function of changes in employment was explored above. The intensity of work is increased during economic upswings, manifested in faster production rates, more overtime, crowded and congested work facilities, and utilization of older, possibly less safe, equipment; these measures of

intensity have been implicated in increases in injury/illness rates.^{39,40,41,42} The effects of production rates and overtime hours on injury rates have been tested and verified.⁴³ The only counter-cyclical influence on injury/illness rates is the degree to which labor exerts pressure to improve safety within an organization.^{44,45} Workers, whether unionized or not, are less likely to seek improvements in safety during periods of economic contraction, due to a real or perceived threat to job security in pursuing such improvements.⁴⁶ The study by Robinson (1978) is the only research which has separated out the effect of labor power by controlling for the number of new hires and output per employee in examining unemployment rates, and has reported a negative relationship for this correlate.⁴⁷

Overall, the pro-cyclical forces have a stronger influence than the counter-cyclical labor power factor when examining the relationship between the business cycle and indicators of occupational health and safety. Studies of both injuries and fatalities (which are less prone to reporting differences than injuries) have revealed a positive correlation between business cycle measures and injury and fatality rates.^{48,49,50}

Workers' Compensation

Recently, there has been considerable attention given in both the lay media and in scientific journals to the impact that workers' compensation systems and their

components have on injury/illness incidence, lost workday case incidence, and lost workday rates. A comprehensive exploration of the different workers' compensation systems and their components is beyond the scope of this study. This section will discuss the basic concepts relevant to understanding the relationship between workers' compensation and its impact on occupational injury/illness rates, and the empirical findings concerning these topics.

Workers' compensation systems were developed in response to the increase in occupational injuries brought about by the industrial revolution and the inability of the tort system to deal efficiently with the increased number of claims. The model used in the United States is one of no-fault insurance, whereby an employee injured on the job is compensated for time lost at work via payment of a fixed percentage of the worker's salary during convalescence and reimbursement for all medical costs associated with the occupational injury or illness. The insurance system was developed to provide speedy and equitable compensation to injured workers as opposed to the inconsistent awards and prolonged process characterized by the tort system. Under the no-fault model, there is no need to determine liability for either the worker or the employer.

The insurer may be a private entity, a government agency, or a quasi-government agency. A worker suffering from an occupational injury or illness submits a claim to the insurer describing the nature of the injury and the

circumstances leading to the injury or illness. The validity of a claim is based on a determination that the worker was injured or ill and that the worker's employment contributed to the injury or illness. The insurer determines the validity of the claim and compensates the employee in accordance with the standards developed by each state. Claims are categorized by outcome as being a fatality, permanent total disability (PTD), permanent partial disability (PPD), temporary total disability (TTD), temporary partial disability (TPD), or medical only. Injuries which require only first aid treatment are not reported or compensated under workers' compensation.

The four basic goals of workers' compensation systems are as follows:

- 1) Broad coverage of employees and work related injuries and diseases;
- 2) To pay for medical and rehabilitation costs associated with an occupational injury or illness;
- 3) To provide substantial protection against interruption of income;
- 4) To encourage employers to provide safe workplaces.

The goals just cited were reaffirmed in 1972 by the National Commission on State Workers' Compensation Laws in its report to the President. Since the goal of providing safe workplaces is no more important than wage replacement or medical cost reimbursement, changing workers' compensation systems to lower injury/illness rates can be done only to

the extent that the changes do not diminish the worker's ability to be justly compensated for time lost and medical costs.

The primary mechanism whereby employers are encouraged to provide safe workplaces is the experience rating system. A base premium per worker-hour for workers' compensation insurance is determined for all firms within a two digit SIC code. The base premium is then adjusted for each firm based on the individual firm's lost workday case incidence rate for the previous three years. The three-year moving average is used to smooth out changes in the rate due to random variation. Due to the large fluctuations in the lost workday case incidence rate for smaller firms which can result from a minor change in the absolute number of recordable injuries or illnesses, experience rating is not used for firms below a certain size. For medium to large firms, the experience rating system provides a financial incentive to lower the number of lost time accidents. This incentive increases as workers' compensation premiums escalate.

A component of the workers' compensation systems which has been shown to have a significant effect on injury/illness rates is the percentage of the employee's wage which is paid during recovery from an occupational injury or illness, commonly known as the replacement rate. The replacement rate is fixed by state statute, and varies from 60 to 100% within the United States.⁵¹ Econometric

studies, which model the decision making of workers under varying workers' compensation parameters (replacement rate, waiting period, etc), have shown a significant positive relationship between the replacement rate and the frequency and severity of occupational injuries.⁵² A number of studies have been performed using regression analysis of replacement rates and the corresponding injury frequency and severity rates for different states, yielding mixed results. All of the studies reported a positive relationship between the benefit level and injury frequency rates.^{53,54,55,56} The studies where indices of claim severity were evaluated showed a positive relationship between replacement rate and claim severity in one study,⁵⁷ a negative relationship between the replacement rate and the number of lost workdays per case in the second study,⁵⁸ and no significant relationship between the number of lost workdays and the replacement rate in the same study.⁵⁹ An analysis in which injury frequency rates were compared for a group of workers before and after a reduction in the replacement rate (from 100 to 70%) revealed a positive relationship between the replacement rate and the number of injuries resulting in greater than seven days of lost time.⁶⁰ It should be noted that, although not affecting the integrity of studies comparing replacement rates, any stated replacement rate may underestimate the true replacement rate due to the lower costs experienced by recovering workers (e.g. commuting, child care, etc.) and the availability of other forms of

financial assistance (e.g. food stamps).⁶¹ Any underestimation of the replacement rate would have an impact on economic studies which attempt to model worker behavior under various workers' compensation systems.

Three basic mechanisms have been used to explain the relationship between benefit level and injury/illness rates. The first explanation is temporal, i.e. benefit rates are increased in response to rising injury/illness incidence rates to provide greater incentives for prevention. This argument has not proven to be valid in light of empirical evidence, such as switching the benefit level from an exogenous variable to an endogenous variable in regression analyses⁶², and the examination of injury rates before and after changes in the replacement rate.⁶³

The second proposed mechanism is behavioral in nature. The theory advanced is that given a higher replacement rate, workers are more likely to engage in unsafe behaviors, either consciously or unconsciously.^{64,65} The difficulty with this theory, assuming conscious intent, is that it ignores the non-monetary injury costs to the worker, such as pain and the inability to engage in pleasurable activities. The explanation for the observed association which appears to have the greatest validity is that boosting benefit levels increases the likelihood that a worker will file a claim for a "marginal" injury, either an injury which may not prevent a worker from performing the duties associated with his/her job, or an injury which was not work-related,

i.e. a fraudulent claim. Higher benefit levels may provide an added economic incentive for workers to take time off for chronic problems which diminish performance but do not prevent them from doing their job.

A factor in a worker's decision whether to file for a marginal claim is the perceived probability that the claim will be accepted. Under the no-fault system, the burden of proof on the worker filing the claim is to prove injury or illness, via a medical practitioner's diagnosis, and to demonstrate that the injury or illness was a result of the worker's employment. Critics of workers' compensation systems attribute increases in injury/illness rates and claim costs to increasing leniency in granting claims. In the case of injury determination, certain soft-tissue injuries, notably strains and sprains, are diagnosed based on the patient's report of pain or restriction of movement; this method of diagnosis conceivably could result in exaggerated or fraudulent claims of injury. Associating the injury or illness with employment is difficult for many types of injuries (e.g. sprains and strains), and is based largely on the injured worker's statements and verification by the worker's supervisor. The scope of injuries and illnesses which are compensable will also affect both total claim costs and injury/illness rates reported under the workers' compensation system. An example frequently cited in the lay media is the increase in stress-related claims.

The decision concerning whether to file a marginal

workers' compensation claim might be based on the expected return (benefit level) and the probability of realizing the return (leniency). Increases in either benefit level or leniency would be expected to lead to an increase in the number of injury and illnesses reported. The importance of the leniency and benefit level factors should not be overstated. First, although the reported number of injuries and illnesses may increase, the underlying true injury and illness rates may remain constant. Second, these two factors have their greatest impact on minor or marginal claims, and become irrelevant in cases of obvious injury or in cases where the injury or illness was clearly due to the individual's employment.

The effect of changes in benefit levels was discussed previously. The concept of leniency does not lend itself to quantitative analysis, and thus there are no empirical studies addressing the effect of claim determination judgements on injury/illness rates.

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Regression Analysis

Introduction

Studies performed by various researchers have shown associations between occupational injury/illness rates and an assortment of independent variables. The independent variables studied can be divided into two categories: internal and external. Internal factors, including age distribution of the workers, gender, wages, amount of overtime, percent of budget spent on safety, etc., are firm-specific and, to a certain extent, within the control of management. External factors, the focus of this study, are those variables which are not within the control of the safety manager. External forces that could influence injury/illness rates include regulatory effort, fluctuation in the economy, changes in the workers' compensation system, and firm size. Delineating the relationships between measures of these forces and indicators of occupational injury/illness frequency and severity facilitates the understanding of the strength of the forces on occupational injury/illness rates and provides a basis for predicting injury/illness rates based on changes in the external factors.

This study examined the relationships between occupational injury/illness rates and selected external factors using injury/illness rate statistics and data from various agencies in the state of Oregon for the period 1978

through 1987.

Methods

The injury/illness rate and firm size data were obtained from annual surveys performed by the Oregon Department of Insurance and Finance (ODIF), Accident Prevention Division (now called Oregon OSHA). The regulatory performance data was obtained from the ODIF Information Management Division, Research and Analysis Section. Oregon OSHA expenditure data were obtained from the ODIF Budget Division. Workers' Compensation claim determination data were obtained from the Oregon Workers' Compensation Department. Employment statistics were obtained from the Oregon Department of Labor, Employment Division. Figures for the gross state product were obtained from the Oregon Economic Development Department. Analysis of the data was performed using multiple linear regression on three dependent variables, including the occupational injury/illness incidence rate, lost workday cases incidence rate, and lost workday rate. The independent variables included in each of the regression models were determined using a step-down selection process. Table 1 presents the range and arithmetic means for the independent variables.

Injury/illness Rates

The Occupational Safety and Health Act of 1970 required employers to record worker injuries and illnesses in a prescribed format whenever the injury or illness was not treatable with first aid alone. Each case is classified as to whether or not time was lost from work, and the total

Table 1
Range and Arithmetic Mean for Independent Variables

Variable	Range	Mean
Unemployment (annual rate)	6.0 - 11.5	8.6
Gross State Product ¹ (\$10 billion)	3.20 - 3.95	3.63
Inspections (1000)	4.916 - 11.31	6.532
Violations (1000)	1.752 - 3.629	2.662
Penalties ¹ (\$100,000)	4.136 - 13.11	7.466
OSHA expenditures ¹ (\$ million)	5.38 - 6.11	5.70
Workers' Compensation (% denied claims)	3.06 - 7.83	5.71

Notes: 1. Adjusted for inflation using Consumer Price Index for Western States, 1982-1984=100.

days lost recorded for each case.

The Accident Prevention Division (APD), Research and Analysis Section of ODIF conducts an annual survey of Oregon businesses using a methodology prescribed by the U.S. Department of Labor Bureau of Labor Statistics (BLS). Questionnaires are mailed to a sample of firms within a three-digit SIC category; the sample size for each unit is determined using historical data on variation in the incidence rates for the unit. Total questionnaires distributed ranged from 7,917 to 9,118; response rate varied from 97 to 99%. An additional 10-13% of the responses were excluded due to the firm going out of business, out of the scope of the survey, duplicate mailings, etc. The questionnaire requests information on number of employees, type of business activity, month of first State or Federal OSHA inspection, and a tabulation of occupational injuries and illnesses by type, i.e. fatalities, lost workday cases, and nonfatal cases without lost workdays. Information is also collected regarding the nature of occupational illnesses and the number of lost workdays or days of restricted activity. To minimize any reporting effects that might result from employers' fear of reprisal from the regulators, the respondents (private sector employers) are not identified.¹

The injury/illness incidence rate for a given year is calculated for three digit SIC code categories using data collected by the survey. In addition, a composite rate is

reported for the private sector as a whole. The formula for the injury/illness incidence rate is given as:

$$IR = \frac{N \times 200,000}{EH}$$

where: IR = Incidence rate

N = Number of injuries and/or illnesses

EH = Total hours worked by all employees
during the calendar year

200,000 = Base for 100 full-time equivalent
workers (working 40 hours per week,
50 weeks per year)

The rates for an individual firm are thus standardized, using the factor of 200,000, for 100 employees working 40 hours a week for 50 weeks per year. Similar rates are calculated for lost workday cases incidence and lost workdays. The formula for the two rates is identical as that used to calculate the injury/illness incidence rate, except for the substitution of only lost workday cases or total lost workdays for the number of cases in the preceding formula. Table 2 presents the injury/illness incidence, lost workday case incidence, and lost workday rates for Oregon from 1978 through 1987. The injury/illness incidence rate provides a measure of the frequency of occupational injuries and illnesses; the lost workday case incidence and lost workday rates reflect the severity of the injury/illness events. The lost workday case incidence

Table 2
Occupational Injury/illness Rates for Oregon
1978-1987

Year	Injury/illness Incidence Rate	Lost Workday Cases Incidence Rate	Lost Workday Rate
1978	14.0	7.1	124.7
1979	12.8	7.2	122.2
1980	11.3	6.5	116.4
1981	10.4	5.7	106.1
1982	9.5	5.1	97.8
1983	9.8	5.2	98.3
1984	10.6	5.6	107.6
1985	10.5	5.5	115.9
1986	10.7	5.7	116.3
1987	10.9	5.6	123.8

Notes: 1. Rates are number of events per 200,000 man-hours.
2. Maximum relative standard errors for injury/illness and lost workday cases incidence rate is 2%; for lost workdays, 4%.

Source: Oregon Occupational Injury and Illness Survey, Oregon Department of Insurance and Finance, 1978-1987.

rate is used by Oregon OSHA to schedule inspections.

Graphs of the three rates, shown in Figure 1, show similar trends for the injury/illness incidence, lost workday case incidence and lost workday rates. A steady decline is evident for all three rates from 1978 through 1982; the rates then begin an upward trend that continues through 1987, the end of the study period.

Oregon OSHA

The effect of the regulatory effort was assessed using both budgetary data for the Accident Prevention Division (APD), the agency responsible for enforcement of OSHA regulations, and by using specific performance indicators, including number of inspections, violations, and total penalties.

The total APD budget was provided for two-year periods by the Budget Section, Oregon OSHA, from unpublished data. The figures provided were the legislatively approved budget totals, except for the 1977-79 and 1983-85 bienniums, for which the Governor's recommended budgets were used due to the unavailability of the actual budget figures. According to agency personnel, the actual budgets for the two bienniums probably did not differ significantly from the Governor's Recommended Budget.²

Each biennial budget covered two fiscal year periods; the fiscal year for Oregon begins July 1 and ends June 30.

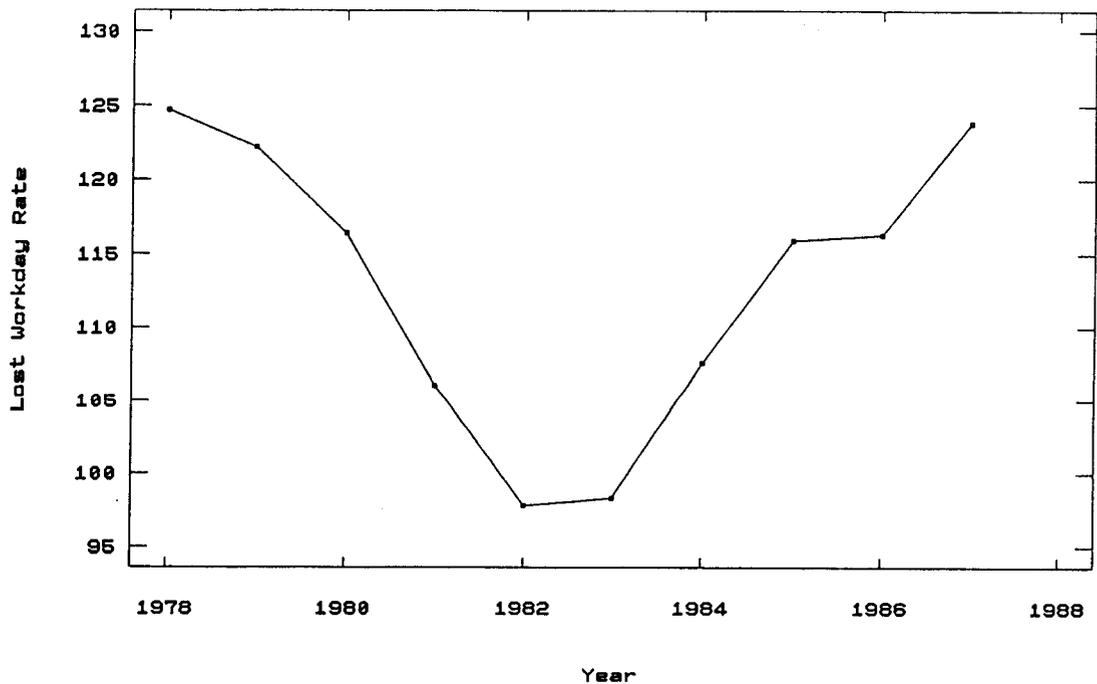
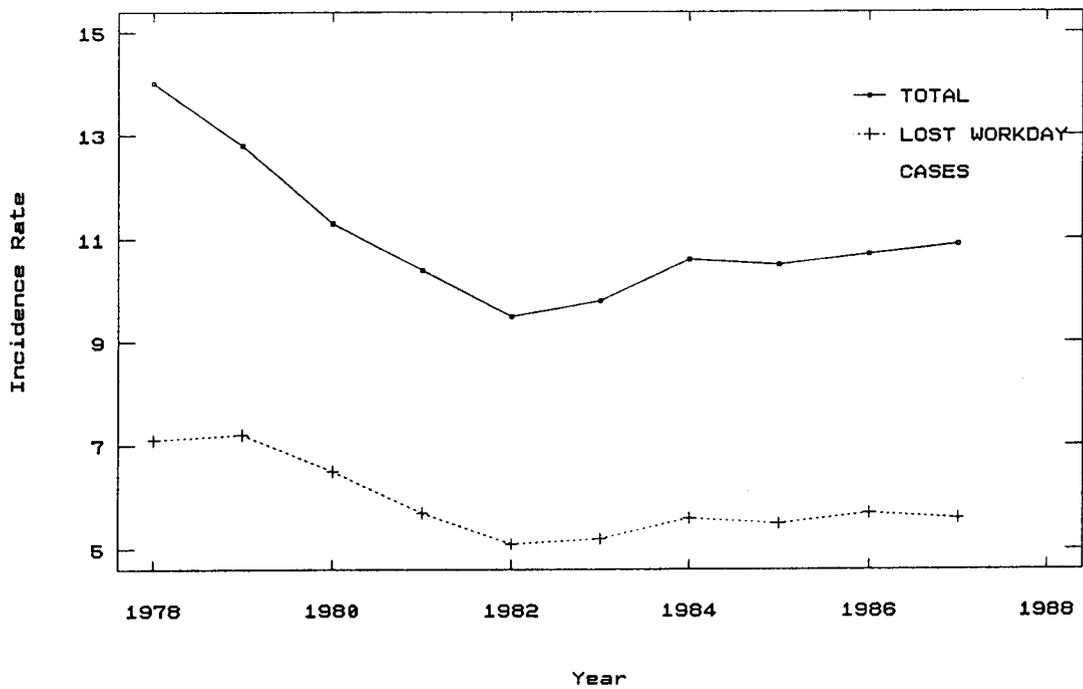


Figure 1. Injury/illness incidence, lost workday case incidence, and lost workday rates for Oregon, 1978-1987.

Source: Oregon Occupational Injury and Illness Survey, Oregon Department of Insurance and Finance, 1978-1987.

The total budgets for each biennium were divided into four half-year values; the half-year values were then tallied to provide budget figures for calendar years. The assumption that spending levels were constant within the biennium is valid according to agency personnel.³ The calendar year values then were adjusted for inflation using the Consumer Price Index (1982-84=100) for Western states (OR, WA, CA, AK, HI).⁴ The adjusted APD budget levels are given in Table 3.

Oregon OSHA maintains internal records of the number of inspections, number of citations, and the total dollar value of penalties assessed for each month. The agency reports these data summarized for each federal fiscal year.⁵ To analyze the data based on calendar years, the raw monthly data were obtained from the Research and Analysis Section of Oregon OSHA and compiled into a calendar year format.

The number of inspections performed for a given year provides a measure of the presence of the regulators in the field, and, by extension, the likelihood that any single firm was inspected. The hypothesis is that as the number of inspections performed increases, the injury/illness rate should decrease due to a higher degree of compliance with safety and health standards. The deterrent effect is subject to variation (because of administrative decisions) depending on the industries or groups of industries which receive a larger relative proportion of the inspections.

Table 3
Budgeted Expenditures for OR-OSHA, 1978-1987
Adjusted for Inflation

Year	Budgeted Expenditures	Adjusted Dollars ¹
1978	\$3,973,100	\$6,112,460
1979	4,346,180	5,986,470
1980	4,719,250	5,665,370
1981	5,292,230	5,758,680
1982	5,865,210	6,021,780
1983	5,775,730	5,834,070
1984	5,686,260	5,488,670
1985	5,834,820	5,402,610
1986	5,983,390	5,414,830
1987	6,146,210	5,377,260

Notes: 1. 1982-84=100

Source: Oregon Department of Insurance and Finance, Budget Section

The number of violations in a specific category (serious, de minimus, etc.) cited for a given inspection reflects both the intensity of the inspection and the judgment of the inspector concerning the severity of the violations discovered. The number of serious violations cited for a given year was the data set used in this analysis, since non-serious violations have smaller penalties attached, and de minimus violations carry no monetary penalty and thus would not have the same deterrent effect. The hypothesis is one of a negative relationship, that is, the injury/illness rates should decrease as the number of serious violations increases.

The penalties associated with violations provide an economic incentive for employers to maintain compliance with health and safety standards. Thus, as the total dollar value of penalties increases, the injury/illness rates are expected to decrease in the same or subsequent years. The actual penalty paid for a given violation is determined after an appeal process, and is often decoupled from the year in which the violation took place. For this reason, the proposed penalties were used in this study. The dollar values of the penalties for each year were adjusted to 1982 dollars using the Consumer Price Index for Western states.⁶

Economic Factors

Data were collected on two different measures of

economic activity for the state: the unemployment rate and the total economic output (gross state product). The unemployment data were provided from unpublished sources by the Oregon Employment Division; figures for the gross state product were provided by the Oregon Department of Economic Development.

Several authors have identified increases in injury rates associated with increases in the accession rate, or rate of new hires.^{7,8,9} Data on the accession rate were not available for the state of Oregon; the unemployment rate was chosen as a surrogate for the accession rate. Since reductions in unemployment represent recalled workers as well as new hires, use of the unemployment rate may underestimate the effect of the accession rate on injury/illness rates.

The Oregon Employment Division collects employment data from a monthly household survey. The average unemployment rate is calculated for each calendar year from the monthly data; the annual unemployment rate was used in the analysis.

In addition to the new-hire effect, researchers have identified other business cycle forces that may have an impact on injury/illness rates. Specifically, increases in the number of hours worked and the rate of production, both of which precede the hiring of new workers, have been associated with higher injury/illness rates.^{10,11,12,13} To estimate the effect of these work intensity forces, data were collected on the gross state product (GSP) for Oregon

for the period 1978-87. The gross state product values were provided by the Oregon Economic Development Department from unpublished data. The GSP is generated by the U.S. Department of Commerce's Bureau of Economic Analysis. All of the values were corrected for inflation using the Consumer Price Index for Western states.¹⁴ The value for the 1987 GSP was not yet available at the time this study was performed. The value was predicted using a regression on personal income and GSP for 1978-86 and personal income data for 1987.

Workers' Compensation

The effects that Workers' Compensation (WC) systems have on occupational injury/illness rates has received considerable attention. Two of the factors that have been identified as having a significant impact on the injury/illness rates are the wage replacement rate, which has been studied extensively,^{15,16,17,18,19} and leniency in claim determination, both in the type of claims and the assignability of an injury or illness to the workplace. The impact that the overall leniency of WC systems has on occupational injury/illness rates has not been examined empirically. The wage replacement rate remained constant in Oregon during the study period, and thus was not included in the analysis. To estimate the relative leniency in the Oregon WC system from year to year, the percentage of denied claims was calculated for each year from unpublished data provided by the Oregon Department of Insurance and Finance,

Research and Analysis Section. Although it is the best available statistic, a rise in the percentage could be the result of a higher number of "borderline" claims being filed, rather than a measure of the leniency of the system. The hypothesis under evaluation is that as the fraction of denied claims increases, there should be a corresponding decrease in the injury/illness rates.

Size of Firms

The size of a firm has been shown to be correlated with injury rates in a study involving firms of different size within the same industrial classification.²⁰ The reported association was curvilinear (inverted U). In addition, several studies have included firm size as an independent variable in multiple linear regression models of occupational injury rates; the studies report a negative regression coefficient for firm size.^{21,22,23} The annual Oregon Occupational Injury and Illness Survey includes data on injury/illness incidence rates stratified by ten size categories (seven prior to 1981). Due to the non-linear relationship reported by Leigh and the preliminary examination of the size-specific injury/illness incidence rates for this study, firm size was excluded as an independent variable from the linear regression analysis. A plot of the mean injury/illness rate for 1978 through 1987 by size category is given in Figure 2.

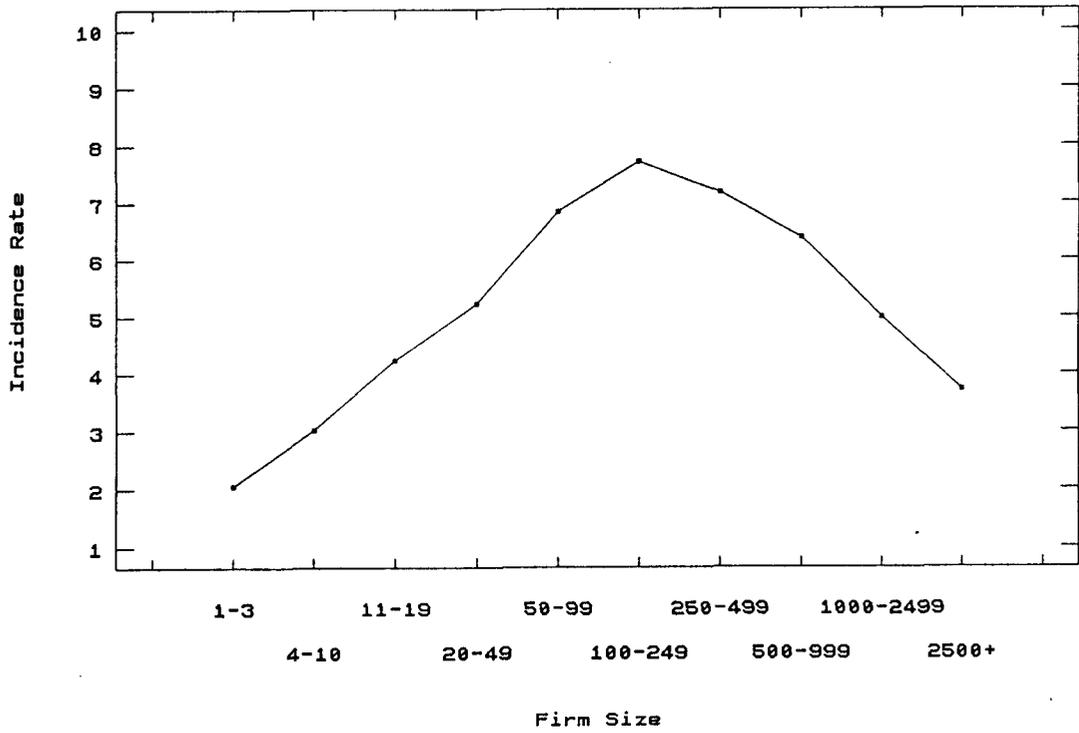


Figure 2. Plot of mean injury/illness incidence rate by firm size, Oregon, 1978-1987.

Results

Injury/illness Incidence Rate

Table 4 presents the results of the linear regression analysis with the injury/illness incidence rate as the dependent variable. None of the independent variables were eliminated using the step-down variable selection process using an F-to-remove ratio of 4.0. Examination of the correlation matrix for the independent variables showed a strong positive correlation between the gross state product (GSP) and unemployment variables, possibly distorting the regression model. A second variable selection and multiple regression run was performed excluding the GSP variable. The second run resulted in elimination of all of the variables except unemployment, workers' compensation (WC) and inspections. The workers' compensation variable then was removed from the model. The resulting R^2 , adjusted for the degrees of freedom, was 0.93. The R^2 value for the model including workers' compensation was 0.98; thus an insignificant amount of predictive capability was lost by eliminating the WC variable. The results of the second regression model are given in column 1 of Table 4.

A third regression model was constructed allowing the independent variables to lag one year, i.e. the 1980 injury/illness incidence rate was matched with the 1979 values for the independent variables, to examine the possibility of constructing a predictive regression equation. The same step-down elimination variable selection

Table 4
Multiple Regression Results for Injury/illness
Incidence Rate

Independent Variables	Regression Coefficient [90% Confidence Interval]	
	1	2 (a)
Unemployment (annual rate)	-0.35 [-0.50, -0.19]	-0.48 [-0.58, -0.38]
Inspections (1000)	0.45 [0.30, 0.61]	(b)
Violations (1000)	(b)	-0.87 [-1.2, -0.55]
Constant	11.07	17.21
R ²	0.93	0.93
P-value	<0.0001	0.0002

(a) values of the independent variables were regressed with values of the dependent variable for the following year

(b) variable was not selected for model

procedure used for the previous analysis eliminated none of the independent variables. The OSHA expenditure, GSP, and penalties variables showed a high degree of collinearity with several of the independent variables. The second model was constructed excluding expenditures, penalties and GSP, yielding unemployment percentage and violations as the significant predictor variables. The results for the predictive model are presented in column 2 of Table 4. The R^2 value for the model is 0.93 (adjusted for degrees of freedom); the F-ratio for the ANOVA analysis for the full regression was statistically significant ($p=.0002$).

Lost Workday Cases Incidence Rate

The variable selection and multiple regression model using the lost workday cases incidence rate as the dependent variable resulted in GSP, inspections, violations, penalties, OSHA expenditures, and workers' compensation as the selected variables using the F-to-remove ratio of 4.0, with an R^2 value of 0.99 (adjusted for degrees of freedom). The inspections, violations, penalties, and OSHA expenditures variables were removed to provide a more concise model. The R^2 value for the final model was equal to 0.93; the F-ratio from the ANOVA on the full regression was statistically significant ($p<0.0001$). The results for the final model are given in column 1 of Table 5. Allowing the independent variables to lag one year resulted in unemployment and OSHA expenditures being incorporated in the model. The results for the predictive model are summarized

Table 5
Multiple Regression Results for Lost Workday Cases
Incidence Rate

Independent Variables	Regression Coefficient [90% Confidence Interval]	
	1	2 (a)
GSP (\$10 billion)	2.0 [1.4,2.5]	(b)
Workers' Compensation (claims ratio)	-0.29 [-0.37,-0.20]	(b)
Unemployment (annual rate)	(b)	-0.31 [-0.41,-0.21]
OSHA Expenditures (\$ million)	(b)	0.86 [0.19,1.5]
Constant	0.42	3.6
R ²	0.93	0.85
P-value	<0.0001	0.002

(a) values of the independent variables were regressed with values of the dependent variable for the following year

(b) variable was not selected for model

in column 2 of Table 5.

Lost Workdays

The initial variable selection and multiple regression model with the lost workday rate as the dependent variable yielded unemployment, inspections, penalties and OSHA expenditures as the variables entering the model. The correlation matrix showed a high degree of collinearity between OSHA expenditures, unemployment, and inspections. A second model was constructed excluding the inspections variable, resulting in unemployment selected as the only variable included in the model. The results of the second variable selection/multiple regression model are listed in column 1 of Table 6. The R^2 value for the full regression was 0.94, adjusted for the degrees of freedom. The F-ratio for the ANOVA analysis for the full regression was statistically significant ($p < .0001$).

The independent variables were allowed to lag one year in the third model. Collinearity between GSP, penalties, and inspections and the other independent variables forced construction of another model excluding GSP, penalties, and inspections as candidate variables. The resulting multiple regression model included unemployment, violations, and the workers' compensation ratio as the selected variables. The R^2 value for the full regression was 0.80, adjusted for the degrees of freedom. The results are summarized in column 2 of Table 6.

Table 6
Multiple Regression Results for Lost Workday Rate

Independent Variables	Regression Coefficient [90% Confidence Interval]	
	1	2 (a)
Unemployment (annual rate)	-5.2 [-6.0, -4.4]	-6.0 [-8.1, -3.9]
Workers' Compensation (claims ratio)	(b)	4.1 [1.6, 6.6]
Violations (1000)	(b)	-6.1 [-12, -0.54]
Constant	158	158
R ²	0.94	0.80
P-value	<0.0001	0.01

(a) values of the independent variables were regressed with values of the dependent variable for the following year

(b) variable was not selected for model

Discussion

Of the independent variables analyzed, unemployment appears to be the most useful for predicting occupational injury/illness rates. The unemployment variable was included in five of the six regression models. The relationship was negative in all cases, consistent with previous studies at both the micro and macro levels, each of which reported negative relationships.^{24,25,26} The negative relationship between unemployment and occupational injury/illness rates has been attributed to the overall experience level in a firm; less experienced employees are more likely to become injured or ill at work than their more experienced counterparts. The relationship was stronger in the models which incorporated a one-year "lag time" ("predictive model"), suggesting that employers might reduce the impact of increases in employment by adjusting safety training investments a year in advance in response to current employment trends.

The gross state product (GSP) variable was included in the lost workday cases incidence model, and demonstrated a positive regression coefficient. The positive relationship is consistent with findings from previously published studies.^{27,28,29,30} None of the models included both the GSP and unemployment variables; this was expected since both are measures of economic activity.

The regression coefficient for the number of inspections performed by OR-OSHA was positive in the

injury/illness incidence rate model, suggesting that the rate of injuries and illnesses increases as OSHA inspections become more frequent. It seems doubtful whether inspections actually increase accident frequency; the higher rates are more likely due to an increase in the number of injuries and illnesses reported due to improvements in record keeping brought about by the inspections.

Of the OR-OSHA parameters included in the study, the number of serious violations reported was the most useful in predicting occupational injury/illness rates. The violations variable showed a strong negative association in the predictive models for the injury/illness incidence rate and lost workday rate. The negative relationship between the number of serious violations cited and the Injury/illness rates may indicate that the number of violations cited has a deterrent effect, causing employers to increase safety efforts in response to more aggressive enforcement. From the analysis, it appears that violations may be a stronger motivator for employers than the penalties assessed. The apparent relationship between the number of violations and the three rates is meaningful considering that the proportion of injuries resulting from a violation of a standard has been reported to range from 10 to 26%.^{31,32} Thus, although only a fraction of the potential hazards are corrected due to a violation being cited, the added deterrent effect may elicit a higher level of compliance, and thereby lower rates of injuries and

illnesses in the workplace. Because the violations variable exhibited significant negative relationships in two of the three predictive models for occupational injury/illness rates, while the inspection variable showed a positive coefficient in the injury/illness incidence rate model, the results from this study suggest that performing fewer inspections to allow for greater depth for each inspection performed may reduce the illness/injury rates more than increasing inspection frequency. The lack of a significant negative coefficient for penalties may indicate a need for higher penalties to encourage compliance.

The Workers' Compensation variable (percentage of denied claims) was the only variable to demonstrate regression coefficients of both signs. The negative coefficient in the lost workday cases incidence model was consistent with the hypothesis that as the WC system becomes more lenient (percentage of denied cases decreases), there is a corresponding increase in the reported number of lost time injuries and illnesses. The positive coefficient for the lost workday rate model was not expected, and is difficult to explain. It would be expected that, as a greater number of borderline cases are denied, the lost workday rate would decrease. As was mentioned earlier, the results for the WC variable are only valid if the proportion of borderline claims remained constant over the study period, an assumption that was not verified in this study.

Overall, the results of this study suggest that

occupational injury and illness rates are influenced by external factors. The best predictor variable for all three dependent variables, for both the current year and subsequent years, is the unemployment rate.

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Conclusions and Recommendations

The results of the regression analysis on data from the State of Oregon, and results from previously conducted studies, support the development of models capable of predicting occupational injury and illness rates from various external factors. The strong relationship between the unemployment rate and the measures of injury/illness frequency and severity suggest that any evaluation of changes in injury/illness rates, whether at the micro (firm) or macro (state or federal) level, must control for changes in employment. Indices of economic growth (e.g. gross state product, etc.) have been positively correlated with injury/illness rates in other analyses; the results from the regression on Oregon data confirm the relationship for the lost workday cases incidence rate.

Neither the number of inspections conducted by OSHA nor the penalties assessed appear to significantly impact occupational injury/illness rates. The number of serious violations cited showed a deterrent effect in the regression analysis of Oregon data; none of the previously published studies reported a relationship between violations cited and changes in injury/illness rates. The inability to establish a negative relationship between injury/illness rates and either inspections or penalties suggests that current inspection frequencies and penalties may be inadequate to encourage compliance or other safety related activities

(training, self-inspection, etc.). A positive relationship was observed between OSHA expenditures and the lost workday cases incidence rate in predictive regression model for Oregon data, consistent with one other study that reported a similar relationship between Federal OSHA expenditures and the lost workday rate.¹ It has not been established that the relationship is causal. The apparent correlation may be due to a confounding variable, economic growth, which has demonstrated a positive correlation with occupational injury/illness rates in this and previously published studies. OSHA expenditures would be expected to increase during periods of economic expansion as tax revenues increase; however, the increased spending on the regulatory effort may not be able to offset the effect of economic expansion and the corresponding increase in occupational injury/illness rates.

The replacement rate used for calculating the compensation for lost income in workers' compensation cases has demonstrated a positive correlation with injury/illness incidence rates; mixed results have been reported for severity measures. No conclusions can be drawn concerning the effect of leniency in workers' compensation claim determination on injury/illness frequency or severity measures due to the lack of published evidence and the conflicting results for the lost workday case incidence and lost workday rates in the regression analyses performed for this study.

Firm size demonstrated a curvilinear relationship with injury/illness incidence rates in this and one previous study. Use of firm size in linear models is valid only if firms of greater than 50-100 employees are included in the study.

The results of this study support the hypothesis that external factors have a significant impact on occupational injury/illness rates, thereby allowing for the construction of statistical models with a high predictive capability. The predictor variables are different for measures of injury/illness frequency and severity; therefore, separate sets of variables should be used to predict injury/illness incidence, lost workday case incidence, and lost workday rates.

The results of this study suggest that further research should be conducted in the following areas:

- The effects of reforms in Workers' Compensation systems on occupational injury/illness rates.
- The relationships at the micro (firm) level between OSHA inspection frequency and size of penalties and occupational injury/illness rates to assess the adequacy of inspection frequency and penalties assessed.
- The relationship between OSHA consultative efforts and occupational injury/illness rates.
- The mechanisms which cause the differences in injury/illness incidence rates among firms of different

size (number of employees).

- The effects of changes in the demographics of the workforce on occupational injury/illness rates.
- The impact of changes in the unemployment rate within specific industry classifications on occupational injury/illness rates.

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