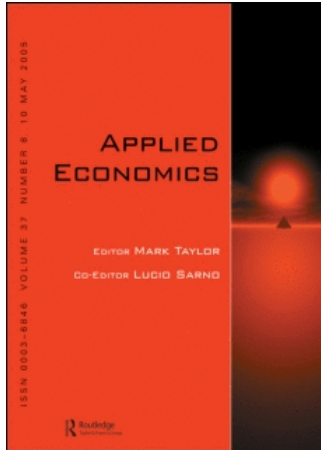


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# *A policy model of industrial accidents using economic and business activity variables*

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## I. INTRODUCTION

In a recent issue of *Applied Economics*, a multiple regression analysis of industrial accidents was considered from an economic standpoint (Steele, 1974). The present study, in addition to supplementing this literature, is concerned with quantitative evaluation of conditions and factors in the industrial environment that can affect the anticipated impact of various government programmes. Occupational safety and health, law enforcement, and environmental health professionals, all who require conceptual and empirical frameworks for evaluating program and policy impacts, should find this literature informative and useful.

### *Accidents and Economists*

Relevant economic analyses of accidents as phenomena extend from social pragmatism to the highly abstract, e.g., Eisner and Strotz (1961), Williamson *et al* (1967), and Conley (1976). Furthermore, economists have analyzed the general area of accidents and health with greater statistical sophistication than other professionals. Two common types of economic discussions concerning safety and health have evolved. Most statistical treatments have assumed the existence of a market. Other discussions have examined reasons for the non-existence of a market and theorize on the calculations required to create a market, as demonstrated by Mishan (1971), Schelling (1968), and Zeckhouser (1975). Authors of these latter discussions tend to use a philosophical tone while introducing institutional considerations and suggesting social accounting frameworks.

The basic focus of this study will be applied, and the studies cited above offer little in the way of direction. They have been presented, however, to indicate the bounds of possible discourse. In the following section, frameworks used to formulate regression models of industrial accidents are furnished.

## II. BACKGROUND

Steele (1974) presented a conceptual (theoretical) regression model based on an analogy between accidental injury of an employee and breakdown of a machine due to lack of maintenance. In the regression model, Steele (1974) examined the relationship between accidents and overtime hours worked in a representative week, and employment levels. His regression model broke down the employment variable into employment levels and labor scarcity factors, which could be measured by the ratio of unfilled vacancies to the unemployment level. Smith (1973) also has presented a regression model of industrial accidents. His model is based on a production function that, besides number of workers and number of machines, included as arguments the number of hours worked per worker and safety devices installed per machine. The Steele (1974) and Smith (1973) models are similar to the model examined in this paper and will be compared in section VI.

A primary objective of the present study is to develop a model capable of examining the extent of relationships between occupational safety and health (represented by variations in number, severity, and costs of accidents), labor force and business activity, and changes in inspection frequencies (performed by a governmental agency). This model was developed with a more definite empirical orientation than either that of Steele (1974) or Smith (1973). It must be emphasized that reported statistics, such as *t*-statistics, are considered gauges rather than as measures for making further statistical statements regarding significance or confidence. This is primarily because sequential testing of various models is performed on the same data set (Mosteller and Tukey, 1977). Accordingly, little attention is given in this paper to the interpretation of reported statistics.

An industry in Idaho – the lumber and wood products industry (Standard Industrial Classification (SIC) 2421) -- is used as a case study. This industry employs approximately 9,000 workers and has a substantial impact on Idaho's economy. Although the analyzed data is limited to this one industry, both data acquisition and quantitative analysis have general applications. This analysis approach can be applied to almost any industry, either on a state or national level. By analyzing at the four-digit industry state level, however, more meaningful policy conclusions are possible than when aggregated annual or semiannual two-digit industry national data are assessed. Two-digit industry data are usually all that are available in most other studies.

### *Policy Issues*

The effect that changes in 'non-OSHA' safety and health variables have on the number and severity of accidents that occur in a particular industry is an important issue. 'Non-OSHA' safety and health variables are frequently alluded to as factors that affect workplace safety and health levels, but over which the United States Occupational Safety and Health Administration (OSHA) has no direct control. These variables are important because if they can affect safety and health levels that exist in an industry, they also can affect the expected impact of government sponsored safety and health programmes. For example, if the number of inspections performed in an industry were increased dramatically, this might prove ineffective in reducing the severity and frequency of accidents; if in the interim, the level of business activity, the rate of new hires, or the number of overtime hours worked also has

increased. Knowledge of the effect that these variables have (if any) on levels of industrial occupational safety and health is required if a governmental agency such as OSHA is to effectively explain the impact, or lack of impact, of its programs and policies to interested parties, such as the U.S. Congress.

### III. VARIABLES EXAMINED

From an economic and policy making vantage point, the most important independent variable to examine is monthly changes in average medical payments received by accident victims. It is also the dependent variable that can be related most logically to certain independent variables. In total, five dependent variables were examined as part of the original analysis. These included:

- (1) Total medical payment (*MED*)
- (2) Average medical payment per accident (*SEV*)
- (3) Total workdays lost (*LOSTWK*)
- (4) Average workdays lost per accident (*AVLOST*), and
- (5) Total number of accidents (*NUMBER*).

All data were monthly statistics, and were obtained from State Workers' Compensation Records. Data were collected for 35 months, from January, 1972 to November, 1974.

The first set of explanatory variables to be included in the analysis was:

- (1) Number of accessions (*ACC*),
- (2) Index of overtime hours worked (*OVT*)
- (3) Aggregate level of employment (*EMP*)
- (4) Number of new hires (*NHR*)
- (5) Index of capacity (*CAP*)
- (6) Aggregate level of production (*PROD*)
- (7) Number of inspections (*INSP*)

Variables 1 through 4 measure changes in labour force activity. Variables 5 and 6 measure changes in business activity, and variable 7 is a measure of OSHA activity.

The following organizations supplied the corresponding monthly variable statistics:

- (1) Western Wood Products Association – *PROD* and *CAP*;
- (2) OSHA Management Information Systems – *INSP*;
- (3) State of Idaho Department of Employment – *NHR*, *ACC*, and *EMP*; and
- (4) State of Idaho Workers Compensation Records – *OVT*.

### IV. SPECIFICATION OF AN *A PRIORI* MODEL

The first independent variable to be examined is inspections, and average medical payments seems the most appropriate variable to choose as the dependent variable when analyzing the impact of inspections. If inspectors optimally allocate their time, then it is reasonable to

expect that they would cite and draw attention to those conditions within any industry that are most hazardous; that is those conditions that result in the most costly and severe accidents. As a result, inspections should have a greater impact on the number of severe accidents than on the total number of accidents. Accordingly, for a model to include inspections, inspections should relate to a measure of severity (average medical payments per case) more than to a measure of occurrence frequency. The initial form in which inspections are included in the model is the *absolute number* of inspections during the current time period, and the first difference form lagged one time period.

$$I_1 = INSP_t$$

$$I_2 = INSP_{t-1} - INSP_{t-2}$$

Inspections are lagged one time period because, after being inspected, firms need time to purchase and install new safety equipment, and to make necessary adjustments in work procedures to increase workplace safety. The form of this lag, therefore, is dependent upon knowledge of safety equipment purchases, and changes in work procedures required to comply with safety standards. There is, however, no definitive reason for limiting the lag to one month.<sup>1</sup> Two months might have been more appropriate. As a first choice, one month seemed the most reasonable time period to consider. However, if a change in attitude is being evaluated or if costly equipment purchases are required, a much longer distributed lag might be required to evaluate the effect of inspections. The empirical nature of this analysis becomes clear as soon as such considerations are understood.<sup>2</sup>

In addition, there is a good possibility that the penetration rate (the number of firms inspected as compared to the number of firms in an industry) might not be sufficient to evaluate the effect of inspections on an industry. The penetration rate might have to achieve some undetermined level before inspections can reasonably be expected to have any noticeable effect throughout an industry.

The second independent variable to be entered into the model is a capacity measure, in accordance with the thorough examination of the relationship between capacity and accidents as performed by Steele (1974).

$$\text{Capacity (CAP)} = \frac{V + NO - INV}{NO}$$

$V$  = Unfilled orders

$NO$  = New orders

$INV$  = Inventory

Specification of this 'capacity' variable is not ordinary, and it might be better to call this variable the 'backlog ratio' variable, because it represents the backlog of orders as a proportion of new orders. As this ratio increases within an industry, it becomes necessary to bring more human and machine resources into operation to satisfy the build-up in demand.

<sup>1</sup> Similar arguments apply to the form in which new hires, accessions, and capacity are entered into the model

<sup>2</sup> This comment regarding the empirical nature of this analysis is appropriate to the inclusion of any and every variable in our model.

In this sense, the variable is analogous to a capacity variable and may be a better measure for changes in this type of business activity than a normal 'capacity' variable.

The expected relationship between frequency, and severity of accidents and capacity is positive. When capacity is approached, machinery that has been laying idle (most often old machinery) is brought into use. Because the probability of malfunction is greater for old machinery and because the worker is not familiar with the operation of the machine, the expected result is an increase in the frequency and severity of accidents, reflected by a positive relationship between capacity and accidents. In the model, capacity will be entered in the same manner as the inspection, new hire, and accession variables.

$$C_1 = CAP_t$$

$$C_2 = CAP_{t-1} - CAP_{t-2}$$

An increase in the number of new hires is frequently cited as a cause for an increase in the number of accidents. Because new hires are unfamiliar with machinery in a workplace and lack knowledge of the hazardous situations that exist in an industry, there is a greater probability of them having a severe accident.<sup>3</sup> The form in which new hires is entered into our model is:

$$N_1 = NHR_t$$

$$N_2 = NHR_{t-1} - NHR_{t-2}$$

The total number of accessions (which varies from new hires in that it includes workers not actually new to the industry, such as those coming off of a layoff) is the next variable entered into our model. The form in which this variable enters the model is:

$$A_1 = ACC_t$$

$$A_2 = ACC_{t-1} - ACC_{t-2}$$

An index of overtime hours worked is then entered. Overtime work is often cited as a cause of increases in the frequency and severity of accidents. The index was derived by dividing the average hours worked by accident victims per month, by eight hours. For example, if 8.5 hours was the average number of hours work by accident victims during the month of January, the index of overtime hours worked for January would be  $8.5/8 = 1.0625$ . The form of the variable is:

$$O_1 = OVT - OVT_{t-1}$$

This seems the only valid form for the overtime variable, because the amount of overtime hours worked last period or the period prior to that would hardly seem relevant to this period's accident experience. If overtime has any impact on accidents, it will be evident immediately.

<sup>3</sup> Relating new hires to severity, rather than to just frequency, may prove less than satisfactory, however, preliminary analysis using discriminant and cluster analysis (as part of another project) indicates a much stronger relationship between new hires and frequency, rather than severity.

The exact form of the models to be tested, which includes all the variables discussed up to this point, is:

$$\begin{aligned} \text{Model I (a) } MED &= f(I_1, I_2, C_1, C_2, N_1, N_2, A_1, A_2, O_1) \\ \text{I (b) } SEV &= f(I_1, I_2, C_1, C_2, N_1, N_2, A_1, A_2, O_1) \\ \text{I (c) } LOSTWK &= f(I_1, I_2, C_1, C_2, N_1, N_2, A_1, A_2, O_1) \\ \text{I (d) } AVLOST &= f(I_1, I_2, C_1, C_2, N_1, N_2, A_1, A_2, O_1) \\ \text{I (e) } NUMBER &= f(I_1, I_2, C_1, C_2, N_1, N_2, A_1, A_2, O_1) \end{aligned}$$

These models include inspections, and 24 time periods are available for testing.

All the variables entered in models I measure specific changes in labour force and business activity. Production (*PROD*) and employment (*EMP*) are more aggregated measures of activity which introduce an expanded and, in a certain sense, a distinct framework for analysis. Therefore, separate models are specified to test these variables. In the next section, production and employment will be examined separately and only then will they be combined into a more general regression equation. This general equation will include both aggregate variables and specific labour force and business activity variables.

## V. RESULTS

In the examination of the above listed series of equations, which included all the specific measures of labor force, business and OSHA activity, only those equations with total number of accidents as the dependent variables performed well.<sup>4</sup> Equations with medical payments *MED* and average medical payments *SEV* as dependent variables performed very poorly. In these equations signs were often wrong, coefficients were not consistent from equation to equation, and *t*-statistics often would have indicated acceptance of the 'null hypothesis.' The only exception was inspections lagged one time period ( $INSP_{t-1} - INSP_{t-2}$ ). For this variable, the sign was correct and the *t*-statistic indicated 'significance' at the 1 per cent level with average payments and total payments as the dependent variable, and at the 5 per cent level with average time lost as the dependent variable. This result is consistent with the statement that: to make the type of changes necessary to reduce the frequency of severe accidents, time is required, and that a lagged form of the variable is required to achieve this.

Model I(e), with total number of accidents as the dependent variable, performed quite well, with the exceptions that the constant term was especially 'significant' and that all the lagged values of the independent variables were of the wrong sign. This latter result is an indication that, if our theory is correct, past values for capacity and new hires are related to the number of accidents currently being experienced, then, the relationship for these variables is more complex than can be expressed by first order difference terms. The results for this regression run are given below. The new hires variable seems to be especially interesting.

<sup>4</sup>The equation with average time lost as the dependent variable performed fairly well and may warrant further research.

$$\begin{aligned}
 & \text{NUMBER} = 164.274 - 1.15441_1 + 0.13981311_2 + 21.6397C_1 - 16.0183C_2 \\
 & \text{Standard error} \quad (11.2914) \quad (1.59219) \quad (1.13865) \quad (14.6993) \quad (16.1657) \\
 & t\text{-statistic} \quad (14.5486) \quad (-0.72504) \quad (0.122788) \quad (1.47216) \quad (-0.990880) \\
 & \quad \quad \quad + 0.912848N_1 - 0.304173N_2 - 0.172214A - 0.012575A_2 + 18.80770_1 \\
 & \text{Standard error} \quad (0.280349) \quad (0.297032) \quad (0.201691) \quad (0.188085) \quad (29.8199) \\
 & t\text{-statistic} \quad (3.25611) \quad (-1.0240) \quad (-0.853850) \quad (-0.0668616) \quad (0.630710) \\
 & R^2 = 0.7063 \\
 & F - \text{Statistic} (9, 15) = 4.00819 \quad (1) \\
 & \text{Durbin-Watson statistic (adjusted for 0 gaps)} = 1.7514 \\
 & \text{Sum of squared residuals} = 6433.05 \\
 & \text{Standard error of the regression} = 20.7092 \\
 & \text{Number of observations} = 25
 \end{aligned}$$

These results prompted specification of a new equation which excluded the lagged variables in their present form. Before this step is taken, however, the total employment and total production aggregate variables are examined. In Equation 2, total number of accidents are regressed on total production. In Equation 3, total number of accidents are regressed on total employment. The assessed data covered the entire thirty-five months of available data.

$$\begin{aligned}
 & \text{NUMBER} = 61.2032 + 0.884737 \text{ PROD} \\
 & \text{Standard error} \quad 40.7931 + 0.263021 \\
 & t\text{-statistic} \quad 1.5003 + 3.36375 \\
 & R^2 = 0.2553 \\
 & F - \text{statistic} (1, 33) = 11.3153 \\
 & \text{Durbin-Watson statistic (adjusted for 0 gaps)} = 1.1229 \quad (2) \\
 & \text{Standard error of the regression} = 32.1222 \\
 & \text{Number of observations} = 35
 \end{aligned}$$

$$\begin{aligned}
 & \text{NUMBER} = -245.296 + 0.0510245 \text{ EMP} \\
 & \text{Standard error} \quad 78.4895 \quad 0.0090359 \\
 & t\text{-statistic} \quad -3.12520 \quad 5.64687 \quad (3) \\
 & R^2 = 0.4914 \\
 & F - \text{Statistic} (1, 33) = 31.8879 \\
 & \text{Durbin-Watson statistic (adjusted for 0 gaps)} = 1.6861 \\
 & \text{Standard error of the regression} = 26.5460 \\
 & \text{Number of observations} = 35
 \end{aligned}$$

An examination of the above results indicates that the equation with total employment, as the independent variable, performs better than the total production equation. Because only 26 months of data are available for testing our principal equation and since the employment equation performed better, only employment in current and lagged value terms will be included in a retest of our principal regression equation.

The results obtained from testing Equations 1 to 3 indicated that a respecification of our original equation was required. Therefore, Equation 4 was formulated. The form of this



equation is:

$$NUMBER = f(I_2, C_1, N_1, O_1, G, EMP) \quad (4)$$

where  $C_1$ ,  $N_1$ , and  $EMP$  indicate current values for capacity, new hires and total employment respectively and

$$\text{where } I_2 = INSP_{t-1} - INSP_{t-2}$$

$$O_1 = OVT_t - OVT_{t-1}$$

$$G = EMP_{t-1}$$

Test results are listed below.

$$\begin{aligned} NUMBER &= 60.3452 - 0.762555I_2 + 27.8535C_1 + 0.370699N_1 \\ \text{Standard error} & \quad (80.0804) \quad (0.864709) \quad (13.4089) \quad (0.143591) \\ t\text{-statistic} & \quad (-0.753558) \quad (-0.881864) \quad (2.07725) \quad (2.58163) \\ & \\ &= 1.58550I_1 + 0.020450G + 0.069212 EMP \\ \text{Standard error} & \quad (26.4756) \quad (0.01499) \quad (0.017307) \\ t\text{-statistic} & \quad (0.059887) \quad (1.36408) \quad (0.39907) \\ & \\ R^2 &= 0.71 \\ F\text{-Statistic} & (6,19) = 7.34881 \\ \text{Durbin-Watson statistic} & \text{ (adjusted for 0 gaps) } = 2.4473 \\ \text{Sum of squared residuals} & = 6623.64 \\ \text{Number of observations} & = 26 \end{aligned} \quad (5)$$

All signs in this equation are correct, a negative sign for inspections and a positive sign for the remaining coefficients. The 't-statistics' for a new hires and capacity variables are significant at the 1 per cent and the 2.5 per cent levels, respectively. The 'Durbin-Watson statistic' indicates that the hypothesis of zero correlation cannot be rejected. Results of this test are both interesting and encouraging.

## VI. COMPARISONS WITH OTHER STUDIES

It is appropriate to compare the quantitative output of this study with that of Smith (1973) and Steele (1974). Steele's principal time series regression equation uses the same dependent variable that is used in the principal regression equation in this study. It is as below:

$$A_{pt} = a + b \frac{V_{yt}}{U_t} + cT_{yt} + dE_{yt} - eS_t$$

coefficients relevant to this study were  $+0.20^T + 0.0043^E$  (for the timber industry)  
 t-statistics 0.29 0.87

$p$  = all factory processes

$y$  = manufacturing industry

$t$  = time in quarters, 28 time periods

$A$  = number of reported accidents

$V$  = unfilled vacancies

$U$  = number of unemployed

$T$  = hrs. ('000) of overtime worked in a representative week (positive in all industries)

$E$  = employment (positive in 6 of the 9 industries)

$S$  = third quarter seasonal dummy

In one test, Steele (1974) examined the timber industry; an industry somewhat analogous to the lumber and wood products industry examined in this study. Variable  $A$ ,  $T$ ,  $E$  are similar, respectively, to variables *Number*,  $O_1$ ,  $EMP$  in this study. In Steele's study, the most consistent relationship was found with the overtime variable. In fact, in the nine industries tested, only the overtime coefficient obtained for the timber industry proved insignificant. It is more difficult, however, to comment on the quantitative output for the employment variable.

Smith's (1973) principal regression equation used the injury frequency rate for U.S. manufacturing as the dependent variable, and is as follows:

$$A_t = b_0 + b_1 E_t + b_2 K_t' + b_3 X_t' + b_4 H_t' + b_5 O_t' + e_t'$$

coefficient relevant to this study were	$-4.89E + 1.37H'$	$0.1160'$
t-statistics	(3.92) (0.26)	(0.312)

$E_t$  = average hourly real earnings

$K_t'$  = ratio of 'real net value of capital equipment to employees'  
(in thousands of dollars per employee)

$X_t'$  = percentage of nonproduction to total employees

$H_t'$  = accession rate

$O_t'$  = average weekly hours, and

$e_t'$  = stochastic disturbance term

$n$  = 25 time periods

Variables  $H_t'$  and  $O_t'$  are similar, respectively, to variables  $N_1$  and  $O_1$  in this study. Results obtained from the present study are consistent with Smith's (1973) results. Considering that Steele (1974), and Smith (1973) and the present study all yield similar results, this adds validity to the results obtained in any one study examined individually and to the general hypothesis.

## VII. CONCLUSION

The modelling approach presented in this paper is not causal and is not intended to be. It is a policy approach to modelling. The objective of this approach is to identify industrial environmental forces that have been associated in the past with changes in the number of accidents.

Models similar to the one presented might be termed 'anticipatory' models. These models are anticipatory because they allow a policy maker to begin to anticipate the impact of his actions. For example, if inspections doubled or tripled in an industry, what would be the expected impact? The answer to this question depends upon whether factors such as new hires and business activity have remained constant, have doubled or have increased by some known per cent.

Inspections are an instrument available to a governmental agency, such as OSHA, as a means for decreasing the frequency of occupational accidents. Other instruments are education and consultation. These instruments must be evaluated in relation to conditions existing in the industrial environment, where they are expected to have an impact. This paper presents a framework for making this evaluation.

Although this model is somewhat successful, much work remains. One means of improvement might be different functional forms for the lagged variables, other than first-order difference terms. Some form of a distributed lag might be required for proper specification, because certain specific types of changes in capacity, rates of new hires, and total production rates can be expected to have a noticeable impact on the number of accidents occurring in one industry and not in another. As a result, much work remains to be done in terms of quantitative methodology, but the task is certainly worth pursuing, especially because a by product of such research will be a more precise specification of conceptual frameworks commonly employed to analyze accidents from a policy standpoint.

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