An international analysis of workplace injuries

Analysis of workplace injuries in the United States and four other countries indicates that economic expansion can result in increases in workplace injury rates, however, safety measures have a counter effect and may lead to a net reduction in claim counts

Al-Amin Ussif

Declines in incidence rates for occupational injuries in the United States during the 1990s have presented economists, actuaries, and insurance executives with the difficult task of trying to explain the causes. According to Poteet and Didonato, employment is often associated with new or inexperienced workers who might be expected to have higher injury rates.[1] Nonetheless, counter forces are at work, leading to unprecedented and sustained improvement in workplace injury rates. Understanding what drives this improvement is a key to sustaining this good news. The decline in workplace injury rates during the 1990s is the longest in the history of workers compensation insurance in the United States. Conway and Svenson describe the recent decrease as dramatic, in light of the expected pattern on increased injuries during economic expansions.[2] Such a decline appears not to be confined only to the United States, but also to many other countries in Europe.

Previous studies have focused on the impact of the business cycle on Workers' Compensation claims.[3] Frequency of such claims measures the number of injury or claim[4] counts per an exposure base. That number is expected to rise during an economic expansion and accordingly fall during a contraction or sluggishness.[5] Recent studies have shown that changes in incidence rates are significantly correlated with annual changes in economic variables such as aggregate employment.[6]

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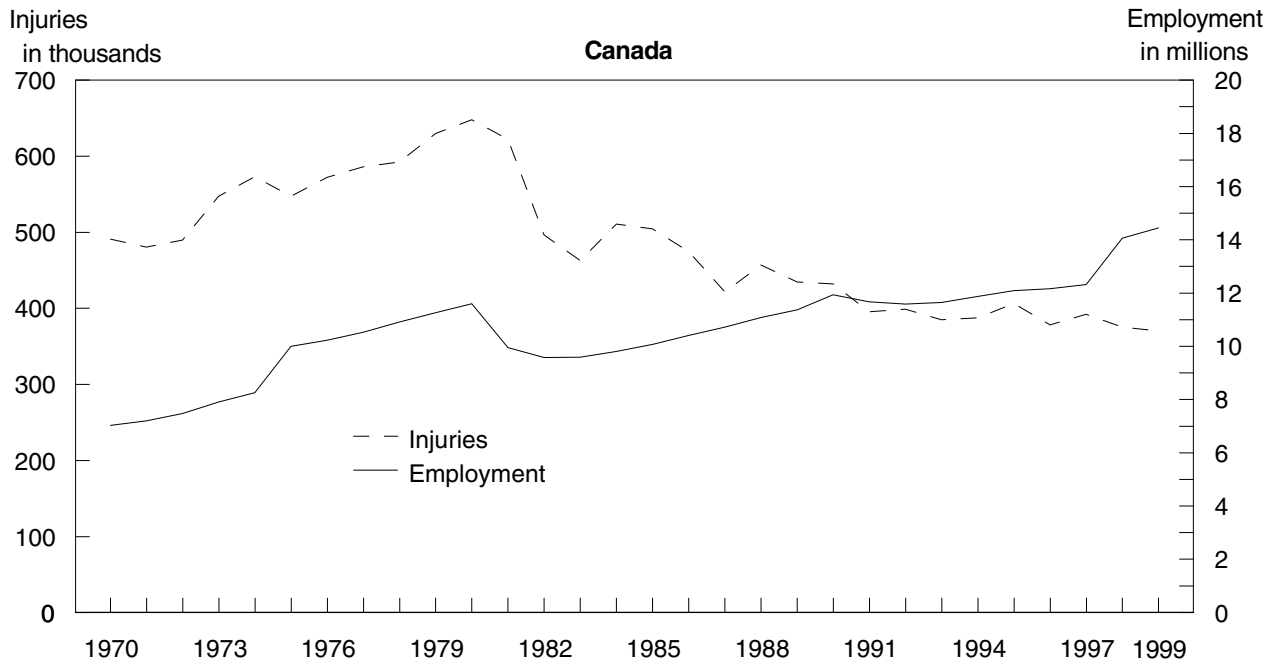
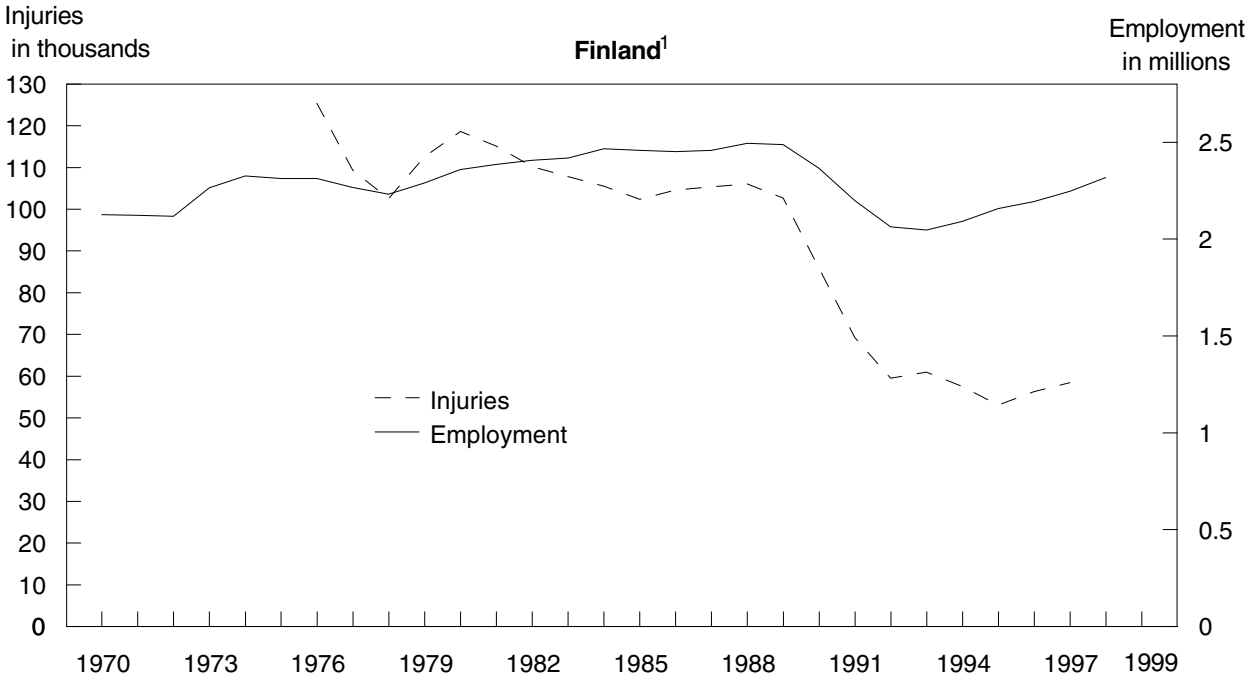
This article consists of a twofold focus. First, it investigates the impact of employment on injury counts in the United States, Canada, France, Finland, and Sweden, using both qualitative and analytical tools. These countries are chosen because of their data availability. And second, it introduces a measure of the aggregate effect of all factors that tend to mitigate workplace injuries and illnesses. Also, this article defines and estimates a new quantity called the "risk-to-safety ratio" and uses it as a criterion for ranking or grouping the countries. The basic idea is to derive an index that can be used to compare and contrast, for example, different occupations in terms of their performance in safety and risk. This index may be helpful to actuaries, insurers, and even regulators, because it would provide a better understanding of the risk that is being insured or covered, which is important to all parties in the insurance business. Specifically, actuaries would have more information to help them better forecast losses. Both insurers and regulators also will be better informed about the markets; that is, good and bad years may be predicted by either an increasing or decreasing trend.

Injuries and employment

Data for this analysis include annual observations on injury counts[7] and employment. The injury counts are cases with lost workdays, that is, inju-

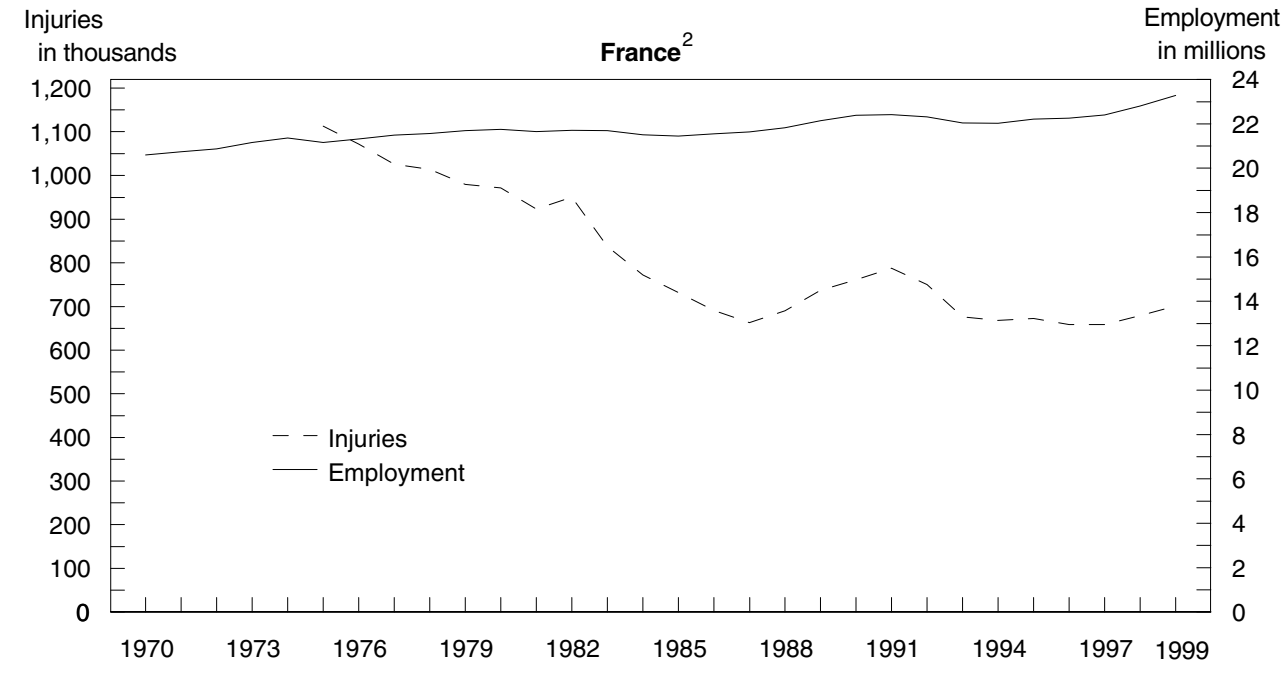
Chart 1. Workplace injury counts and employment by country, 1970–99

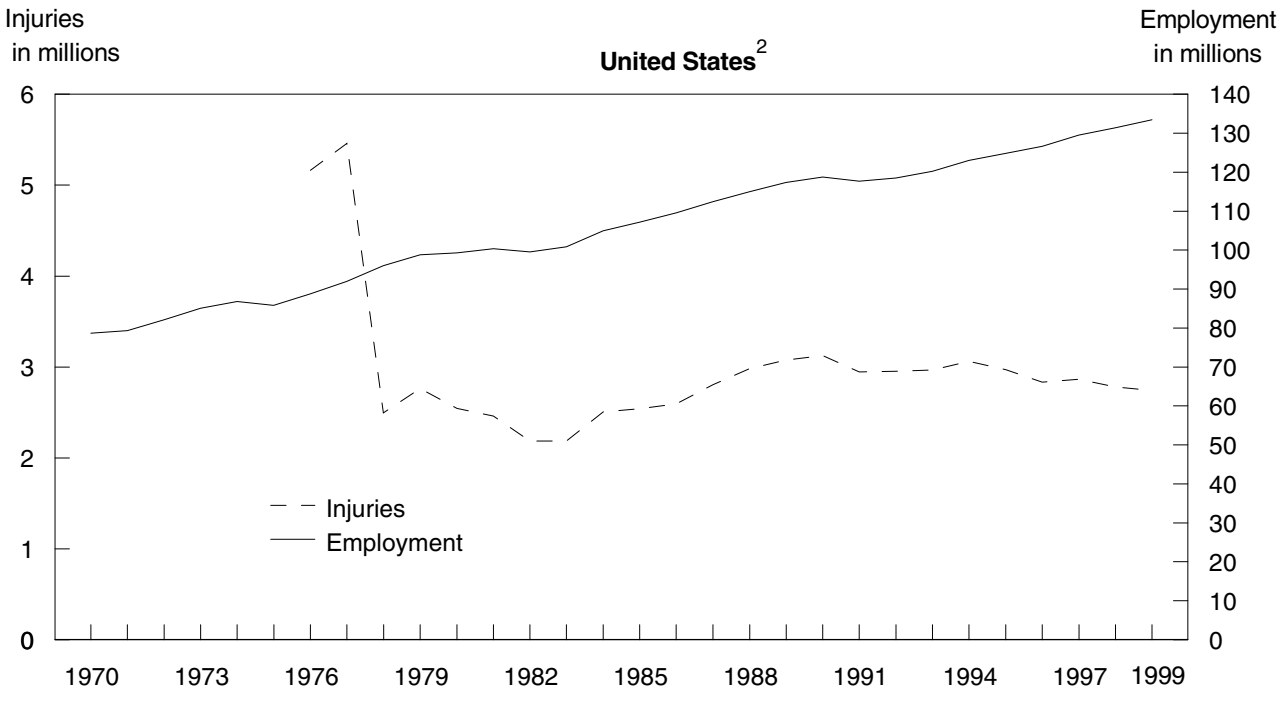




See notes at end of chart.

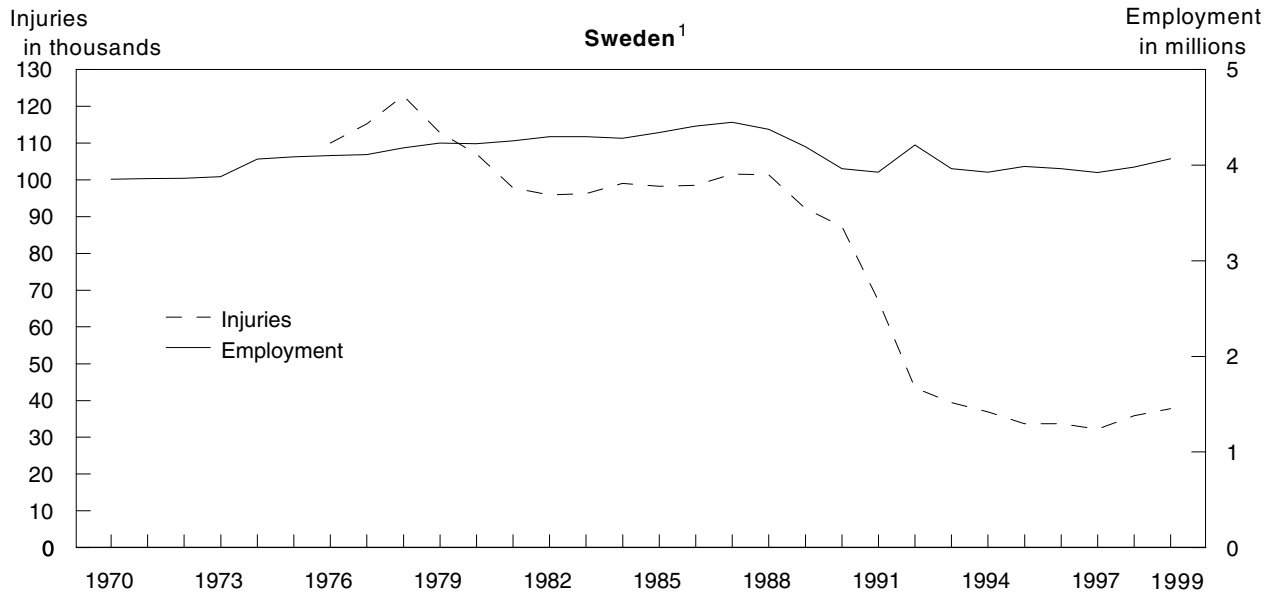
Chart 1. Continued—Workplace injury counts and employment by country, 1970–99





See notes at end of chart.

Chart 1. Continued—Workplace injury counts and employment by country, 1970–99



[1] Injury data from 1970 to 1975 were not available.
[2] Injury data from 1970 to 1974 for France were not available.
SOURCE: Compiled by the Bureau of Labor Statistics and from the International Labor Organization Web site on the Internet at: **http://laborsta.ilo.org/applv8/data/ssm8/e/ssm8.html.**

ries resulting in days away from work. The data for Canada, Finland, France, the United States, and Sweden[8] are used because they have a reasonable number of observations with no data voids. Note that the sources of the data are different, but are comparable.[9]

Many variables that may be contributing to the recent reduction in the number of cases of reported occupational injuries are not readily available. In fact, some of these variables are rather difficult to measure. For example, it is difficult to measure the value of employer workplace safety initiatives or even the effect of technology on the decline in frequency of injuries, and so forth. Therefore, this analysis proposes a proxy for the aggregate effect of these hard-to-measure variables. The basic hypothesis in this article is that the effect of these variables is nondecreasing on average, while information (such as warnings of hazardous materials in work areas, and signs indicating wet floors), technology, and safety measures have been increasing over time. The state of these variables also could be deteriorating due to, for example, old fashioned technology and lack of incentives for employers to promote safety. (This could be realized in some developing countries where working conditions have rather deteriorated over time.)

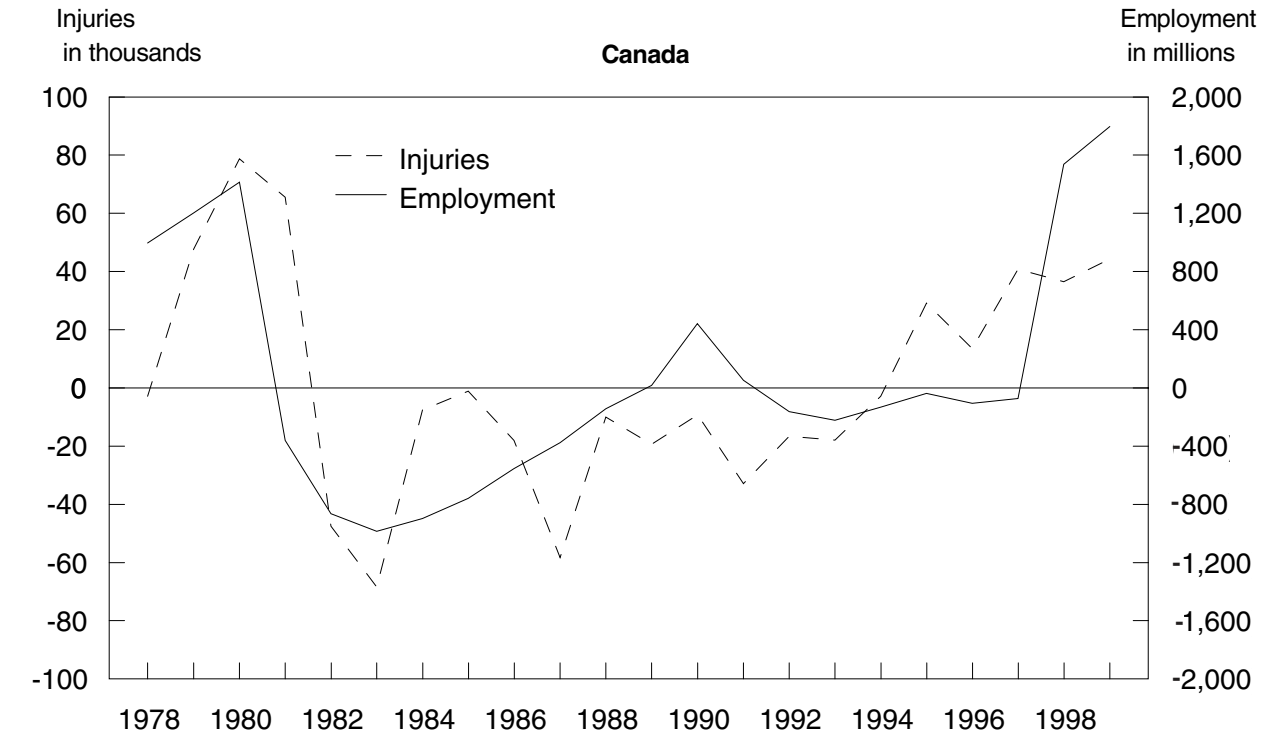
To give some insight into the dynamics of injuries or claims and employment, chart 1 illustrates the series for Canada, Finland, France, the United States and Sweden, over time. The charts show that employment has generally trended upwards in most of the countries, however; it declined during the 1990s in Finland and Sweden. These countries had a slowdown in their economies in the 1990s. Note also that U.S. employment has very strong growth over the entire period, compared with Canada and France having some significant downturns in the 1980s.

Mainly, for all the countries in this study, there is a slow, long-run, downward evolution in occupational injuries. It is important to note that the decrease in injuries in Canada started in the 1980s and continued even as employment continued to grow. The United States, however, seems to have lagged behind the rest of the countries. The downward surge started in the 1990s, while France, for instance, had been experiencing a decline since the mid-70s. This may be driven by, for example, increased technology and improvements in the quality of the workforce. However, declines in employment have almost always been followed by a decline in injuries. (See chart 1 for Sweden to illustrate this case.) In fact, the temporary drop in injuries in the United States during the early 1980s was attributed to the concurrent effects of the recession.[10]

Measures of economic activity

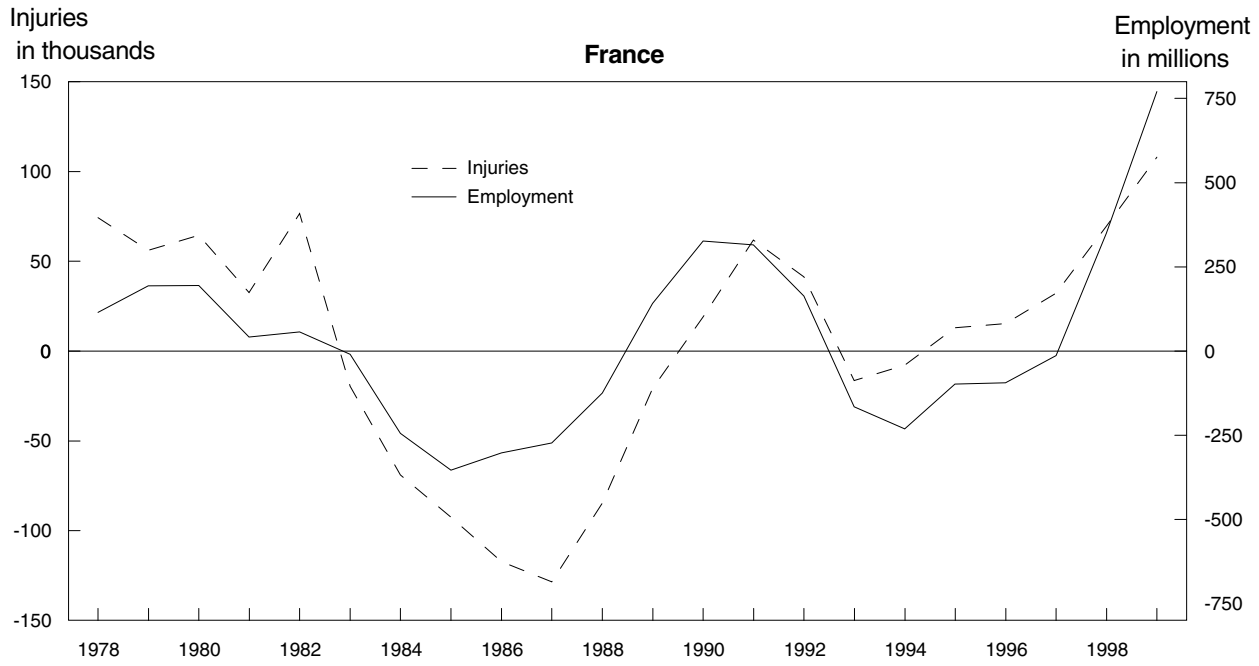
As mentioned earlier, injury counts vary with the level of economic activity. Not only does this hypothesis make intuitive sense, it is supported by many previous and recent

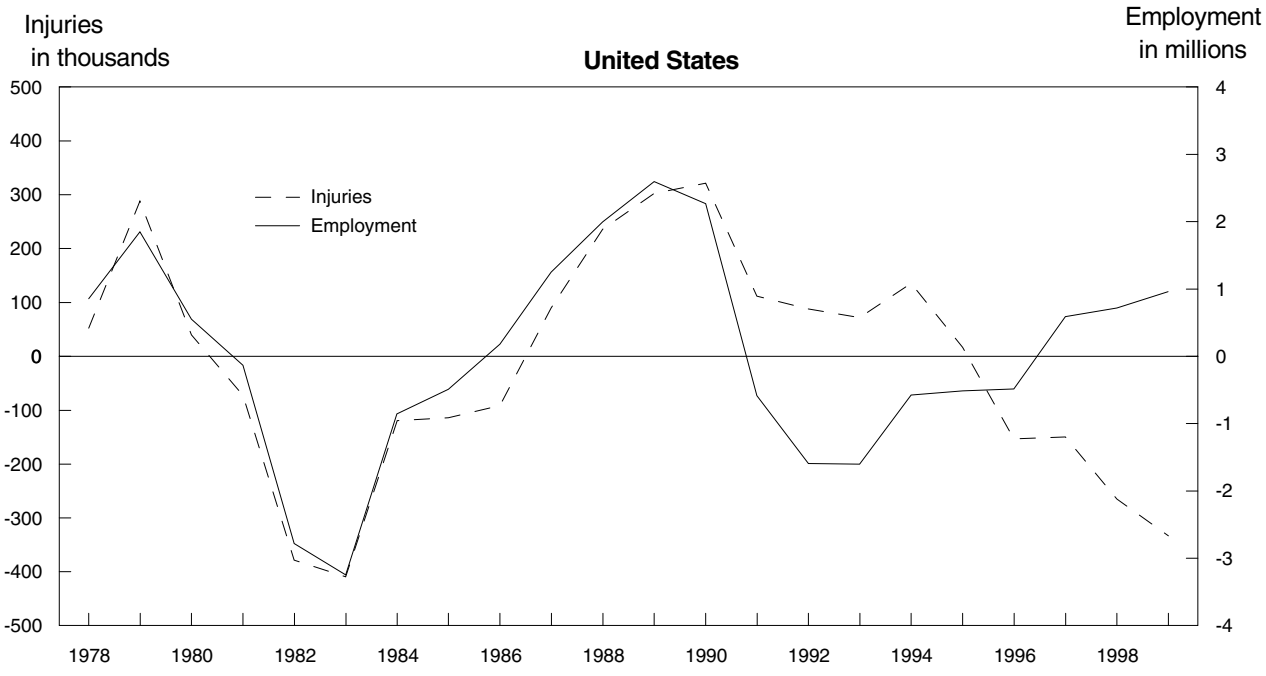
Chart 2. **Detrended employment and workplace injuries, by country, 1978–99**



See notes at end of chart.

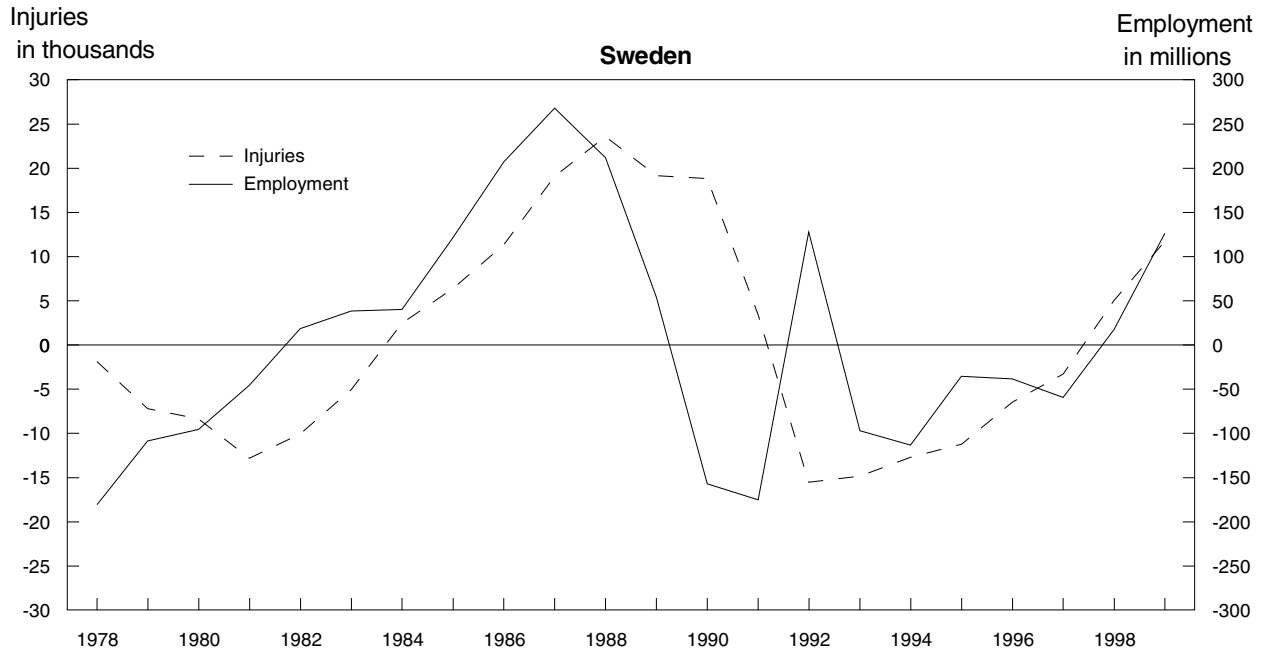
Chart 2. Continued—Detrended employment and workplace injuries, by country, 1978–99





See notes at end of chart.

Chart 2. Continued—Detrended employment and workplace injuries, by country, 1978–99



NOTE: For Finland, the employment figure for 1999 was unavailable at the time of publication.
SOURCE: Compiled by the Bureau of Labor Statistics and from the International Labor Organization Web site on the Internet at: **http://laborsta.ilo.org/applv8/data/ssm8/e/ssm8.html.**

studies. Furthermore, it is expected that increases in employment *a priori* will result in increases in frequency of occupational injuries. Such an expectation is consistent with economic theory and previous empirical research.[11]

Labor quality. In the 1990s, however, the situation is different, because, both workers' compensation claim counts and frequency have generally declined, while employment increased in the United States. The question now is: do increases in employment still result in increases in frequency? It is true that when employment increases, the tendency is that frequency will increase holding all other factors constant. However, there are other factors that could mitigate the full effect of employment increases. It is hypothesized that full employment is often associated with new workers who might be expected to have higher injury rates. Nonetheless, other forces are at work, leading to unprecedented and sustained improvement in workplace injury rates.[12] For example, the injury rates of say, 100 workers in a safe and less hazardous workplace will, with all probability, be lower than the rates for an unsafe and risky workplace. Another factor that could lessen the effect of employment increases on injury rates is the quality of the workforce, measured by educational level and training. The quality of the workforce has been increasing over the last several decades. In the United States, the labor quality index, which measures the amount of education and training has been improving since 1948.[13]

Detrending the counts. To support the economic theory of the business cycle effects on injury counts, we use a detrending technique to measure the true effect of employment on injury rates. Detrending removes the effect of other variables. This method is very important because in time series analysis two variables that are trending upward or downward might appear to be related even though they are not. It is quite common to see employment being negatively correlated with occupational injuries because researchers have ignored the effects of other variables. This is known as spurious or false correlation.

Chart 2 displays detrended employment and injury counts for each country, showing the "true" association between the two series, net of a linear trend. The charts, in fact, confirm the hypothesis that injury counts increase with volume of employment. For all the countries, the direction of the movements is the same. Note that the United States, however, seems to be different from the other countries during the mid- to late 1990s. This difference may be explained by a one-time change probably due to legislative reforms in the 1990s.[14]

Calculating correlation. This study also includes partial

correlation analysis to calculate the correlation coefficients between injuries and employment by first controlling for the trend in the data. The results also indicate that injury counts are positively correlated with employment. The following text tabulation illustrates correlation coefficients between detrended employment and claim counts, and shows that the correlation is highest in France, with the United States and Canada very close behind, and lowest in Finland and Sweden:

	Canada	*Finland*	*France*	*United States*	*Sweden*
Correlation	0.6328	0.4546	0.8027	0.6263	0.4818

It is clear that employment and injuries do move together after controlling for linear trend. Although correlation does not necessarily imply causality, it gives an idea of the degree and direction of association between variables.

Econometric analysis

Using a relatively simple econometric model, we posit a linear multiple regression model that includes two key variables: *employment*, as a measure of exposure or risk of injuries and *trend*, as an aggregate of all variables that have the tendency to reduce, if not minimize, the probability of worker injuries. For example, electronic devices (that help to detect the presence of hazardous materials at workplaces), protective coats, and ergonomic workstations are safety devices that are used to reduce workplace injuries. The model is thus given by:[15]

$$Injury_i = Intercept + \alpha_1 Employment_i + \alpha_2 Trend_i + \varepsilon_i \quad (1)$$

where α_1 and α_2 are the partial regression coefficients of the *Employment* and *Trend* variables and are approximate measures of risk and safety respectively. Epsilon (ε) is a noise series with mean zero and a constant variance. "One important property of this model is parsimony, that is, a model is important if it explains much by little."[16] All things being equal, a model should be as simple as possible.

The employment variable is included as a measure of overall economic activity or measure of production. *A priori*, the expected sign on the coefficient is positive. Both intuition and economic theory support such an expectation. For example, higher levels of production, other factors held constant, may be associated with an increase in injuries.

Note also that the full effect of exposure cannot be realized in a world that is technologically advanced and where information is easily accessible.

The model explicitly assumes two things. First, that exposure (that is, the number of workers) causes occupational injuries. This means that the reason there are occupational injuries is that people are employed and are vulnerable to some kind of risk. In an ideal world where people get all they need without having to work, employees would not need workers' compensation insurance.

During an economic expansion, several factors that tend to increase accident risks are at play. In an expansionary period, more workers are added to the workforce, the speed of production increases, less trained and inexperience workers are also added to the workforce. Note that lack of experience becomes more important in occupations such as construction, mining, and transportation because these jobs, tend to have high incidences of workplace injuries.[17] Several studies have documented the procyclicality of workers' compensation insurance claims to the business cycle.[18]

The second hypothesis assumes that certain factors such as safety measures, initial job training, technology, legislative reforms,[19] and so forth tend to mitigate workplace injuries. These factors are often unobservable or difficult to quantify. Although their contributions to the workplace are widely acknowledged, safety measures are difficult to model for most economists.[20] For our purpose, we use a trend variable as a proxy for all the "injury reducing" variables. Note also that the use of trend in the model helps to guard against spurious correlation between injury counts and employment. The sign on the trend variable may be positive or negative, depending on whether safety or technology, for example, are deteriorating or improving over time. We assume that these factors should be improving for the countries in this study because they are developed countries. In addition, one important advantage of this model is that we avoid the issue of modeling ratios, because doing so might lead to spurious correlations.

To make cross-country comparison easier, we perform an additional regression analysis by using frequency per 100 workers as the dependent variable, and the employment-population ratio and trend variable as independent variables.[21] This is achieved by adjusting equation (1). (See appendix.)

Results

To compare workplace injury by country, we take the results of the regression using injury frequency per 100 workers. The result that the more workers employed, the higher the injury rate, is as expected, because the employment-population ratio has a positive sign. (See table 1.) This captures the business cycle effects, which is greatly affected by injury fre-

Table 1. Coefficient estimates of the adjusted Regression model using frequency as the dependent variable

Country	Coefficient	
	Employment-Population	Trend
Canada	0.341	–1.061
Finland	501	–.574
France	.489	–.514
Sweden	362	–.645
United States	2.121	–1.975

Table 2. Summary statistics for occupational injuries by country, 1970–99

Statistic	Canada		Finland		France		United States		Sweden	
	Employment	Injury	Employment	Injury	Employment	Injury	Employment	Injury	Employment	Injury
Mean	11,227	467	2,314	90	21,953	775	112,970	2,745	4,160	78
Standard deviation	1,093	88	145	24	379	121	11,139	297	179	32
Coefficient of variation	.097	.188	.063	.267	.017	.156	.099	.102	.0430	.410
Minimum	9,583	375	2,046	53	21,450	658	96,048	2,186	3,922	22
Maximum	14,968	648	2,494	119	22,805	1,014	131,464	3,127	4,449	123

quency in the United States and slightly affected in Canada. Trends have the greatest effect in the United States and Canada, but for the three European countries trends have a slightly lower effect.

Evidence from the data also suggests that the United States and Canada are somewhat similar in many ways. We attempt to provide some explanation to support this observation. The reason the United States and Canada are similar may be explained by the dynamics of the economies of these countries, compared with the other group. A critical study of the employment data for these countries reveals a strong and persistent growth in the United States and Canada. The growth is rather mild and relatively stable in France, Finland, and Sweden. From 1970 to 1999, employment increased by 70 percent in the United States and by 110 percent in Canada, compared with 13 percent for France, 9 percent for Finland, and 5 percent for Sweden. Clearly, growth in population and immigration may account for some of the differences observed between the two groups especially, in the case of the United States. Table 2 provides some additional summary statistics of the data, including the standard deviations and the unitized risk or coefficient of variation of occupational injuries by country. For example, looking at the coefficient of variation for injuries, the United States has the smallest estimated coefficient of variation. Canada has an estimate that is comparable to that of France, while Sweden and Finland have the largest coefficient of variation. In general, the European countries have relatively smaller coefficient of variation for employment than their North American counterparts. This again reflects the rates at which employment has been growing in these regions.

THIS ARTICLE USES A SIMPLE MODEL to analyze occupational injury data for the United States, Canada, France, Finland, and Sweden. These countries are selected because of data availability. The results confirm that economic expansion exerts an upward pressure on injury claim counts. It also finds that the United States has lagged behind the rest of the countries in the decline in injuries, but seems to be catching up. Trends are a significant factor in the model for all countries.

The findings in this article provide interesting issues for employers, insurers, and policyholders. Further research needs to be done to extend the connection between employment growth and increased safety measures to a more dynamic approach. This will allow us to calculate annual changes in the indices of safety and risk at workplaces. It may also be useful if a baseline or a frontier analysis is used to judge performance. □

Notes

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[1] C. Poteet, and T. Didonato, *Journal of Workers' Compensation*, 2001, pp. 72–85.

[2] Hugh Conway, and Jens Svenson, "Occupational injuries and illnesses rates, 1992–96; why they fell," *Monthly Labor Review,* November 1998, pp. 36–58.

[3] R. E. Hartwig, W. J. Kahley, W. J. Restrepo, and T. E. Retterath, "Workers Compensation and Economic Cycles: A Longitudinal Approach," Paper presented at the November 1997 meeting of the Casualty Acturarial Society, available on the Internet at: **www.casact.org/pubs/proceed/proceed97/** (visited Mar. 8, 2004).

[4] Note that injuries and claims are used here interchangeably.

[5] Hartwig and others "Workers Compensation and Economic Cycles," 1997.

[6] *California Indemnity Claim Frequency Analysis* (California Workers' Compensation Institute, WCIRB, 2000).

[7] The injury counts are compensated injuries from insurance establishments in each country except for the United States. For the United States, the data are from the Survey of Occupational Injuries and Illnesses (a survey of establishments).

[8] The data employed in this analysis are obtained from the International Labor Office Web site: **www. laborsta.ilo.org**.

[9] In addition, population estimate data for these countries were

obtained from the Centers for Disease and Control Web site: **www.apps.nccd.cdc.gov**.

[10] See Conway and Svenson "Occupational injuries and illnesses rates," 1998.

[11] Kahley, *California Workers' Compensation Claims Frequency Forecast* (California Workers' Compensation Institute, 2000); Hartwig and others, "Workers Compensation and Economic Cycles," 1997; and Max D. Kossoris, "Changes in Frequency rates in Injury and Employment in Manufacturing," *Monthly Labor Review*, vol. 57, October 1943, pp. 773–74.

[12] Poteet and Didonato, *Journal of Workers' Compensation*, 2001.

[13] Ho and Jorgenson calculate the labor quality index in M.S. Ho and D.W. Jorgenson, *The Quality of the U.S. Workforce*, 1948–95, Kennedy School of Government Harvard University Cambridge, 1999, available on the Internet at: **www.ksg.harvard.edu/cbg/ptep/laborjbes.pdf**.

[14] Conway and Svenson point to the legislative reforms motivated by compensation payments and a growing awareness of workplace hazards by unions, employers and the insurance industry. See Conway and Svenson, "Occupational injuries and illnesses rates," 1998. Further research into this anomaly may be worth pursuing.

[15] The referee has suggested a good way of performing this regression by using the injury rates and normalizing the employment numbers using the total population. I agree that this is an innovative way of doing the analysis and thank the referee for his help.

[16] Milton Friedman, "The Methodology of Positive Economics," in *Essays in Positive Economics* (Chicago, IL, University of Chicago Press, 1953), p. 14.

[17] Data on the incidence of occupational injuries by industry.

[18] Hartwig and others "Workers Compensation and Economic Cycles," 1997.

[19] Legislative reforms may have a one-time significant effect on occupational injuries.

[20] Hartwig and others, "Workers Compensation and Economic Cycles," 1997.

[21] This was suggested by the referee who peer-reviewed the manuscript.

Appendix: Results from empirical analysis

The standardized (beta) coefficients

The beta coefficient measures change in standard deviations expected in the dependent variable if the explanatory variable changes by one standard deviation. Hence, it measures the relative importance of the independent variables in a multiple regression model. For a model with two explanatory variables: x_1, x_2 and a dependent variable y, the standardized coefficient (α^*)is defined as:

$$\hat{\alpha}_i^* = \hat{\alpha}_i \frac{s_{x_i}}{s_y} \quad i = 1,2 \qquad (2)$$

where α's are the usual coefficients of the regression equation and the s_x, s_y are the standard deviations of the independent and the dependent variables. The standardized coefficient adjusts the estimated slope parameter by the ratio of the standard deviation of the independent variable to the standard deviation of the dependent variable.[1] This is a unit-free coefficient, making it possible to compare the impact of each variable in a regression equation.

Risk-to-safety measure

The sigma ratio $\sigma - ratio$. To put a value on the relative importance of the two explanatory variables in the model, we propose the use of the ratio of the coefficient of exposure, that is, employment to the trend coefficient in absolute value. The sigma ratio is thus defined as:

$$\sigma = abs(\frac{\alpha_1^*}{\alpha_2^*}) \qquad (3)$$

The sigma-ratio is a crude relative measure of how organizational entities (countries, occupations, industries) perform in terms of exposure versus injury mitigation at workplaces. In this analysis, we focus on quantifying the aggregate effects of, for example, technology, information, and so forth. Although direct measures are not readily available, estimates can be found to at least provide some idea of their contributions. By comparing the ratios (equation 2) for different occupations or industries, it may be possible to infer which occu-

Table A-1. Estimates of the regression equation

Country	Coefficients			
	Intercept	Employment	Trend	Adj-R2
Canada	266332.18 (3.02)	0.0346 (2.53)	–16.36 (–7.94)	0.87
Finland	–64.385 (–2.94)	.078 (11.27)	–2.578 (–11.36)	.96
France	–3187.0 (–3.55)	.194 (4.63)	–27.30 (–8.10)	.80
Sweden[1]	–60.81 (–.68)	.0436 (2.94)	–3.898 (–6.29)	.85
USA[1]	–7124 (–4.11)	.1016 (5.48)	–145.36 (–4.39)	.82

[1] Results for this country were corrected for first order serial correlation and did not improve the Durbin-Watson Statistics.
NOTE: *T*-values are in parenthesis.

Table A-2. Estimates of the beta coefficients and the calculated sigma ratio

County	Beta coefficients		
	Employment	Trend	Sigma-ratio
Canada	0.3543	–1.1462	0.3091
Finland	.4766	–.6519	.6325
France	.6738	–1.3858	.4313
Sweden	.2516	–.7445	.3641
United States	3.7604	–3.0089	1.2498

NOTE: Because the variables are normalized, the intercept is zero.

pation or industry is riskier than the other. It is assumed that the larger the sigma-ratio, the more the risk of injury. In assessing the performance of entities, the smaller the value of sigma, the better. Note however, that if the trend coefficient is positive, which is indicative of a deteriorating condition in safety and other hazards, the opposite is true. Even though the model in this article is relatively simple, it is possible to extend the analysis in various ways. The basic idea is to derive some index that may enable us to compare and contrast, for example, different occupations in terms of their performance in safety and risk. Similar annual indices have been derived in many areas.[2] Another commonly employed index is the Lerner index for the estimation of market powers.[3]

Interpretation of the results

Table A-1 presents the usual regression coefficients and their *t*-values. Results are corrected for serial correlation[4] except for the countries noted. The trend is the aggregate of all variables that have the tendency for reducing the risk of workplace injuries. The introduction of a trend variable in the model helps to avoid a spurious association between the dependent and independent variables. This is one method of detrending time series variables to ensure that relations are not false. To further ensure that the relationship between employment and injury counts is not bogus, we conducted stationarity tests for all the time series variables. A time series is weakly stationary if its statistical properties, such as the mean and variance are independent of time. An analysis of the variables for all the countries indicates that the time series variables are all first order stationary. That is, taking the first difference results in stationary series.

Estimates of the regression coefficients are generally plausible. They all have the expected signs consistent with economic theory. The employment variable, which is a measure of economic activity, has a positive sign. This means that the more intensive the rate of production the more likely accidents and injuries could occur, that is, exposure in terms of numbers and length of period worked, leading to increases in injury rates.

Statistically, the estimate of the coefficient of employment for each country is highly significant at the 5-percent significance level. The results indicate that holding other variables constant, a change of 1 unit in the employment level will lead to a 0.1-unit change in the number of injuries for the United States. Similarly, for Finland, a change of 1 unit in the employment level will lead to a 0.078-unit change in the number of injuries and so forth. On average, Canada appears to have the least change in injuries for every additional 1 unit of workers, compared with France has the biggest change, holding other things constant. The model appears to have a significant explanatory power for all the countries. More than 80 percent of the variation in injuries is explained by the employment and trend variables.

Table A-2 contains the estimates of the beta coefficients and the calculated sigma ratio.

The standardized coefficients describe the relative importance of the independent variables in the three variable regression equation. They are unit free and thus allow us to compare the impact of the explanatory variables.

In terms of standard deviation, a 1-standard deviation change in employment will result in a 0.45-standard deviation change in injuries for Finland. For the United States, a 1-standard deviation change in employment will lead to a 3.8-standard deviation change in injuries. This is an interesting result and needs further discussion. This seems to suggest that the risk is highest in the United States, compared with the risk in other countries, all factors remaining constant. We notice however, that the beta coefficient of the trend is also very high, which means that technology and other factors are also keeping pace with the high risk, hence dampening the full effects of the exposure.

Of particular interest is the sigma-ratio for the United States. Although the beta coefficient on trend is quite high, the ratio is still high because of the effect of employment, which is associated with an explosive growth over the last three decades. Notice that this method can be used to group industries, countries, or occupations in terms of their characteristics, such as the size of their per standard deviation increase in injuries compared with the others.

Notes to the appendix

[1] See R. S. Pindyck and D. L. Rubinfeld, *Econometric Models and Economic Forecasts* 4th edition, 1997.

[2] For instance, see the index of work force quality in M. S. Ho and D. W. Jorgenson, *Quality of the U.S. Workforce,* 1999, on the Internet at: **www.ksg.harvard.edu/cbg/ptep/laborjbes.pdf**. Also see the Malmquist productivity index, S. Malmquist, in many productivity analyses, *Index Numbers and Indifference Surface*, Trabajos de Estatistica, 1953 , pp. 209–42 .

[3] See A. M. Ussif, Nonparametric Approach for Testing Market Power in the U.S. Food Processing Sector, Master thesis paper (Reno, Nevada, University of Nevada, 1998).

[4] This occurs if errors at one time period are correlated with errors of ensuing period.