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On the efficacy of construction site safety inspections

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ON THE EFFICACY OF CONSTRUCTION SITE SAFETY INSPECTIONS

by

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Abstract

The purpose of this paper is to measure the impact of onsite safety inspections on the frequency of work related injuries in the Alberta construction sector for the period 1987 to 1992. The data are disaggregated by sub-industry allowing different risk levels to be associated with different work activities. In addition, within the sample period there is a dramatic decrease in inspection activity providing a natural experiment into the necessity of continued inspection effort. We observe no measurable effect of onsite safety inspections altering the risk of accident and injury. Moreover, the decrease in inspection levels within the sample period is not associated with an increase in the number of work related injuries.

In more recent study, Gray and Scholz (1990) combined injury data collected by the US Bureau of Labor Statistics and OHSA inspection data, and found statistical evidence to indicate that both inspections and the threat of fines/convictions significantly reduced injury rates in the workplace. These results contrast sharply with the results reported in a Canadian study by Lanoie (1992a). This research studied the impact of safety inspections, penalties, experience rating and compensation benefits on the risk of workplace accidents in Quebec over the period 1983 to 1987. Lanoie's estimates suggest that at best, safety regulation led to only minor reductions in the frequency of accidents in the workplace. Furthermore, when Lanoie examined the impact of safety inspections and experience rating on the severity of injuries, he found that these interventions seem to be associated with an increase in average workdays lost per accident.

This paper attempts to contribute to the debate over the accomplishments of workplace safety regulation by examining the impact of safety inspections in Alberta by the department of Alberta Health and Safety upon the frequency of work related accidents in the Alberta construction sector. The data set available represents pooled cross section time series data for 27 sub-industries for the period 1987 to 1992. This data set is more disaggregated than the industry sector data used in Lanoie (1992a) and it is hoped that this will allow us to better identify variations in the riskiness of different work activities. What is more, unlike manufacturing where the place of production is the same over time, the location of construction worksites for a firm may change several times in one year. As a consequence, repeated set ups for worksites may represent a greater need for inspections and, also, may minimize the diminishing returns effect to the level of inspections found in the Smith (1979) study. In addition, and perhaps most interesting, in 1989 the level of safety inspection activity in Alberta dropped dramatically allowing a natural experiment for measurement of the necessity of continued inspection effort on the level of safety violations and work related injury.

2. Why Government Inspection of the Worksite?

In this section, a simple economic model is presented to explain government mandate and enforcement of safety regulations in the workplace.

For a given construction worksite, the probability that a worker is injured (ρ) and unable to work can be defined as a function of the "safety" capital (Ks) available on site and the inherent riskiness $(\in)$ of the job or

(1) $\rho = f(ks, \in)$

By investing in "safety" capital and thereby reducing the risk of injury the firm can change the probability that a worker is injured on the worksite. Investment in risk reducing "safety" capital, however, is costly in terms of direct monetary costs and indirectly through lost production due to workers having to spend more time (than without Ks) setting up the worksite. The cost of acquiring "safety" capital is $C(Ks)$, where $dC(Ks)/dKs \geq 0$.

A firm will invest in "safety" capital if in doing so it reduces the expected loss to revenue from worker accident and injury. The loss to revenue (R) from worker accident and injury (A) is $dR/dA = R^A \leq 0$. And the expected loss to revenue is $R^{A*}\rho$ or $R^{A*}f(Ks, \in)$. Firms will find it profitable to invest in "safety" capital until the expected marginal revenue benefit from reducing the probability of accident and injury is equal to the marginal cost of acquiring additional units of "safety" capital or

(2) $dC(ks)/dks = dR^{A*}f(ks, \in)/dks$

where ks is the level of "safety" capital that satisfies Equation (2).

The need for government intervention is brought about when at the level of firm safety investment ks the probability of worker accident and injury is greater than that deemed acceptable from society's viewpoint. This may well arise because of the divergence of government and firm objectives: The firm is interested in reducing the expected loss of revenue from worker accident and injury (Equation (2)) whereas, government is interested in reducing the social cost of accident and injury (i.e., reducing the probability of accident and injury on the worksite). The government may mandate some minimum level of "safety" capital say, $ks*$ and impose penalties to ensure compliance. A firm found under-investing in "safety" capital according to mandate (i.e., $ks < ks*$) is assessed penalties (F). However, because monitoring is imperfect there is only a probability (P_f) that a given firm will be inspected for violations, firms account for the expected penalty $(F * P_f)$ in determining investment in "safety" capital. Let $dC(ks*)/dks*$ be the marginal cost to the firm of compliance with the mandated level of "safety" capital when $ks < ks*$. Then, if

(3) $dC(ks*)/dks* > F * P_f$

it will not be in the interest of the firm to invest in additional "safety" capital beyond ks. Rather, it will be less costly to pay the expected fine on detection. The larger $F * P_f$, the more likely a firm will invest in the mandated amount of "safety" capital. The government can alter $F * P_f$ by either a larger fine or increasing the probability of observing firms in contradiction of mandate by increasing the number of worksite inspections.

For safety inspections to impact on the accident and injury rate on the worksite it must be true that $ks < ks^*$ and hence there is a positive enforcement effect to detection. In this case, one would expect to observe more inspections resulting in proportionately more convictions and lower accident and injury rate. If firms comply such that $ks = ks^*$, then inspections of the worksite will do nothing to alter the accident and injury rate. If this is the case, we would expect to see high numbers of inspections and very few penalties or convictions and no change in the accident and injury rate. An absence of a positive inspection effect could also mean that the risk characteristics of the job site are relatively unalterable. In other words, Ks in Equation (1) has little or no effect on reducing the probability of accident and injury on the worksite and mandating ks^* and inspecting are costly exercises of relatively little benefit for workers. Thus, the impact of worksite inspections on reducing the probability of accident and injury is ambiguous and empirical measurement is necessary.

3. Occupational Health and Safety in Alberta

In Alberta, the department of Alberta Occupational Health and Safety (AOHS) enforces safety standards such as the height of handrails, shoring of trenches and safe handling procedures as laid out by the Alberta Occupational Health and Safety Act. While the AOHS provides safety education and training, the primary responsibility is to enforce safety standards with unannounced safety inspections, safety inspections at employer's request, employee's complaint or to investigate accidents.

In addition to monitoring and enforcing compliance with provincial safety standards through AOHS, the provincial government administers the Worker's Compensation Board (WCB), which provides "no fault" insurance against accident and injury on the worksite. In return for no fault accident insurance, employees forfeit the right to legal redress. Since 1987, the level of WCB compensation premiums by employers has been experienced rated, where premiums are based on individual firm history of accident and injury claims against WCB. Small firms are excluded from the experience rating programme and pay fixed WCB premiums. The WCB programme allows for diversification of risk from accident and injury and protects both employees and employers from catastrophic events.

By reducing the opportunity cost of not working, WCB benefits may provide an incentive for false claims.[1] This argument is supported by some research which shows a positive statistical relationship between compensation benefits received by prospective injured workers and injury rates (Bartel and Thomas 1985; Butler 1983; Butler and Worrall 1983; Chelius 1974, 1982). On the other hand, there appears to be no statistical relationship between compensation benefits and injury severity rates (Worrall and Appel 1982; Chelius and Kavanaugh 1988). As WCB benefits in Alberta have changed over the period of our study, we include in econometric specification a WCB variable to capture changes in compensation benefits on the reported level of accident and injury.

It is also possible that experience rating causes a decrease in accident and injury rate by providing incentives for large firms to invest in "safety" capital in order to reduce total premium payments (Chelius and Smith 1983; Ruser 1985; Worrall and Butler 1988; Bruce and Atkins 1992). On the other hand, large firms tend to be capital intensive and implement comprehensive safety programmes to protect capital assets regardless of experience rating. Statistically it is difficult to separate out the two effects. What is more, large firms may contract out certain hazardous activities thereby reducing the overall risk level to the firm. As compensation premiums are based on total payroll, firms have an incentive to transfer high risk activities to others and thus avoid increased compensation premiums over a large employee base. In our data sample, experience rating in each sub-industry is constant over the period of analysis and thus the effect of experience rating on accident and injury is captured simply as a fixed effect by a time trend (year) variable.[2]

The construction industry shows a high rate of accident and injury relative to other industrial sectors in Alberta. Construction sites tend to be temporary with frequent job site changes in any given year. As well, adverse weather conditions can increase the risk of accident and injury. In Figure 1, the lost time claim rate[3] is shown for the period 1987 to 1992 for the construction industry and three other industrial sectors; forestry, manufacturing and trade. The provincial average lost time claim rate over all industries is also included for comparison.

Relative to other sectors construction has the second highest lost time claim rate throughout the six year period from 1987 to 1992. In 1987, construction recorded 11.9 injury claims per 1000 workers, more than double the provincial average of 5.2 per 1000 workers. Forestry is the only industry sector with a higher claim rate, although the actual number of lost time claims is small relative to construction. Over this six year period there has been a general decline in lost time claim rates for the Alberta construction industry. By 1992, the lost time claim rate had declined to 6.7 per 1000 workers compared to a provincial average of 4.3 per 1000 workers. Nevertheless, construction maintains the ranking of the second most hazardous industry of employment in Alberta.

To reduce the severity and cost of accidents in the workplace AOHS initiated a Partnership Programme in 1988. This cooperative safety programme involving government, WCB and industry, is a voluntary proactive safety programme aimed at identifying hazards in the workplace and designed to encourage industry to be more responsible for safety enforcement. This programme is combined with on-site job inspections to identify potential risks and to reduce the number of accidents in the workplace.

Table 1 shows the total number of inspections by AOHS over the period 1987 to 1992 for the 27 construction sub-industries examined here. In 1987 and 1988, the total number of inspections over all sub-industries was recorded at 3,015 and 2,993 respectively. This number dropped dramatically in 1989 to only 1,809 total inspections. The decline in inspections is a result of AOHS budget cuts and the implementation of the Partnership Programme. As shown in the table, not all sub-industries experienced a decline in inspections in 1989 but this natural experiment in reducing the level of inspections in many construction sub-industries allows the opportunity to measure the necessity of continued inspections on the level of safety violations and work related injury.

Conceivably many factors could influence policy makers' decisions as to what industries to inspect and how many inspections to carry out. They may decide to inspect less during economic downturns since there are fewer worksites and less work activity to inspect; they may inspect a specific sub-industry more this year if there has been a history of accident or death; they may allocate more resources to the larger sub-industries; or if they observe an increase in claims in the current year they may decide to inspect more. In Table 2, we report summary statistics averaged for the six year period 1987-1992 for each sub-industry showing number of inspections, man years of employment, lost time claims, lost time claim rate, number of deaths and number of convictions for safety violations. The vast majority of inspections (approximately 75 percent) were made in only three sectors; Buildings and Plants, Houses and Apartments, and Excavating and Bulldozing. These are not the riskiest construction industries as measured by the lost time claim rate (column four in Table 2) but they are by far the largest in man years of employment and in total number of claims. What is more, the majority of deaths in the construction industry were recorded in these three sectors.

4. The Empirical Model

In this section, our objective is to measure the impact of worksite inspections on reducing the risk of accident and injury for Alberta construction workers for the period 1987 to 1992. We measure the risk of accident and injury for each construction sub-industry by the corresponding number of lost time claims per 1,000 man years of employment. The data used in estimation are collected from the department of Alberta Occupational Health and Safety and from the Worker's Compensation Board of Alberta and, provides industry and sub-industry specific information for the Alberta construction sector. In empirical application, we pool observations but allow each sub-industry to potentially have a distinct claim rate process hence, provided claims are independent across time, the number of lost time claims per thousand man-years (K_{it}) in sub-industry i in year t is assumed to have the distribution

$$k_{it} \sim N\left(\mu_i(\theta), \sigma_i^2(\theta)\right)$$

where (θ) represents the functional parameters defining the mean and variance of the distribution.

We attempt to identify the parameters of the distribution and particularly the impact of worksite inspections on lost time claim rate. To control for business cycle influences on the decision to inspect we define a measure of inspection intensity (I_{it}) as the number of worksite inspections per thousand man-years in sub-industry i in year t. This is really the relevant policy measure for our study since it more accurately reflects the change in real resource expenditure. In modelling, we allow for a distinct inspection effect in each sub-industry.

The following linear equation is specified in our attempt to measure the parameters of the distribution

$$(4) \qquad \begin{aligned} k_{it} = {} & \beta_{Oi} + \beta_{Ii} I_{it} + \beta_{conv} CONV_{it} + \beta_{my} \Delta MY_{it} + \beta_{comp} COMP_t \\ & + \beta_{unemp} UNEMP_t + \beta_{year} YEAR_t + \varepsilon_{it} \end{aligned}$$

where k_{it} and I_{it} are defined above. $CONV_{it}$ is the number of convictions for safety violations providing a measure of the intensity of safety enforcing measures and ΔMY_{it} is the percentage change in man years of employment designed to capture the effect of turnover in the workforce on the risk of accident and injury. Two industry specific variables are included: $COMP_t$ the yearly average workers compensation payment per day as a measure of the moral hazard effect generated by compensation payments; and $UNEMP_t$ the yearly average unemployment rate in the Alberta construction industry to capture changes in employment conditions. The time trend variable $YEAR_t$ is included as a measure of the fixed effects such as the Partnership Programme and the lagged response of firms adjusting to experience rating. $\in_{it}$ is a random error term assumed non-autocorrelated over time but subject to sub-industry specific heteroscedasticity. Prior to estimation a log transform is taken of the dependent variable only. Consequently, the estimated parameters are to be interpreted as a relative change in lost time claims.

Using the current inspection rate in specifying Equation (4) is contrary to common practise in the literature where the lagged inspection rate is the variable of choice (See, Lanoie 1992a; Viscusi 1986). These studies have been primarily concerned with manufacturing industries where the worksite would be common across time. Thus, inspecting the workplace could have a cumulative effect captured by a lagged inspection variable. In the current study, the impact of inspections is expected to be worksite specific rather than industry specific. In the construction industry, the worksite changes contract to contract where at each site new scaffolding must be erected, safety equipment deployed, etc. Consequently, while a previously inspected worksite may have been safe, it is possible that workers under time constraint would not necessarily replicate the safety features of the previous site.[4] In this industry, a cumulative effect of worksite inspections is likely to be of marginal importance and current inspections is the relevant variable influencing the risk of worksite accident and injury.

Given our econometric objective, the use of current inspections may pose a problem if the decision to inspect is based, in part, on the current claim rate i.e., the number of inspections in a given year is a function of or endogenous to the claim rate in that year. Under such conditions the Least Squares estimates of the parameters in Equation (4) will be both biased and inconsistent. Hausman (1978) has suggested a convenient procedure for testing endogeneity in model specification. In the current application, the null hypothesis is that the inspections variable is exogenous with the alternative being endogenous. The procedure requires the use of two alternative estimators generating separate estimates of the inspections coefficient. One estimate $\left({}^{LS}\beta_{Ii}\right)$ has the property of being both consistent and efficient under the null but not being consistent under the alternative and, the other estimate $\left({}^{IV}\beta_{Ii}\right)$ has the property of being consistent under both the null and alternative but not being efficient under the null. The Least Squares (LS) estimator satisfies the former and a Instrumental Variable (IV) estimator satisfies the latter. In testing, the null hypothesis is

$$H_o: {}^{IV}\beta_{Ii} - {}^{LS}\beta_{Ii} = 0$$

A Chi-square statistic is used in testing.[5]

The instrument used in the IV estimator is generated from the following regression

(5) $$I_{it} = \gamma_0 + \gamma_I I_{it-1} + \gamma_{conv} CONV_{it} + \gamma_{unemp} UNEMP_t + \gamma_{my} \Delta MY_{it} + \gamma_{death} DEATH_{it} + \theta_{it}$$

where I_{it-1} is lagged inspections, $CONV_{it}$, $UNEMP_t$ and ΔMY_{it} are as defined above and $DEATH_{it}$ is the number of deaths by accident in each sub-industry. ϑ_{it} is a random error term. In estimating Equation (5), we assume that I_{it} is best described by a censured normal distribution with the censoring point at zero (i.e., non-negative inspection levels). A Tobit procedure is used in estimation and the predicted value of I_{it} is the chosen instrument.

We approach the empirical application in two stages; first, Equation (4) is defined as an aggregate model where worksite inspections have a common effect over all sub-industries. We test and correct sub-industry specific heteroscedasticity and then, a Hausman procedure is applied to test for endogeneity in the aggregate inspections variable. From this, a Wald statistic is generated and used to measure the necessity of continued inspection effect on the level of lost time claims resulting from the reduction in number of inspections in 1989. Second, Equation (4) is disaggregated to allow for a sub-industry specific inspections effect and a Hausman test for endogeneity applied to each sub-industry. Finally, a Wald statistic measuring for a continued inspection effect after 1989 is applied to each sub-industry separately.

In Table 3, the results for the aggregate lost time claims model are presented. The first column in the table reports the initial estimates of the aggregate model. The predicted errors in this equation are used to test for heteroscedasticity across sub-industries. A variety of tests are used and show that no claim can be made to a constant variance across sub-industries.[6] Thus, the equation is transformed by a weighted measure of the share of the estimated variance associated with each sub-industry, which will impose a constant variance in estimation. The estimates of the transformed model are shown in column two of the table.

The first order of business is to test for endogeneity of the inspections variable. Applying the Tobit procedure to Equation (5) with 18 limit observations, we generate the IV for current inspections and re-estimate Equation (4). The squared correlation between observed and expected Tobit values of the inspection variable is 0.799. The IV estimated equation corrected for heteroscedasticity is reported in column 3 of Table 3 and the results of the Hausman endogeneity test shown at the bottom of the table. The Hausman statistic is measured at 1.458 and is compared to a critical Chi-square value at the 95 percent level with one degree of freedom of 3.84. Consequently, a null hypothesis of exogeneity of the inspections variable can not be rejected in the aggregate model. It is possible that aggregating across sub-industries has masked the endogeneity for individual sub-industries but, at least, in the aggregate empirical application the current inspections variable is appropriate.

We are now interested in measuring the necessity of continued inspection effort on the level of worksite risk. The observations are divided into two sub-samples based on observations before and after 1989. The first sample has 54 observations and the second sample has 108. Using a Wald statistic we test the null hypothesis that there is no difference in the inspections coefficient between the two periods. Or in other words, the decline in the number of inspections observed in the Alberta construction industry after 1989 has had no substantial effect on the level of risk and number of accidents in the construction industry. The Wald statistic is distributed as a Chi-square with one degree of freedom. The calculated value is 0.8547 compared to a critical value of 3.84 at the 95% confidence level. Consequently, the data provide no evidence that the reduction in the number of worksite inspections in the aggregate model after 1989 has had a statistical impact on the number of lost time claims.[7]

From these results, the constant variance equation reported in column 2 of Table 3 employing the current level of inspections as a predetermined regressor seems appropriate to evaluate risk of accident and injury in the Alberta construction industry over the period of analysis. However, prior to discussing the results we comment briefly on the variable percentage change in man-years (ΔMY_{it}). This variable is included in specification because of a prior belief that substantial changes or turnover in the work force may alter the risk of accident and injury (i.e., a large number of new or inexperienced workers; or fewer workers assigned an allocated job). It is unclear whether this effect will increase or decrease the risk of accident and injury, but our purpose is to provide a better specification of Equation (4) by including a proxy to capture dynamic effects of changeover in the workforce. Empirically, the inclusion of the variable is supported by summary statistics that show an improvement in model fit by doing so.[8] Thus, the variable is maintained in model specification.

In evaluating our "best" aggregate model (column 2 Table 3), we comment first on the inspection and conviction variables. In both cases, the variables show no statistical importance at conventional evaluation levels but, what is more, the inspection variable has the wrong sign i.e., if you hold the prior belief that safety inspections should reduce risk of accident and injury. It is worth noting, that through out the many different variations of model specification the inspection variable showed the robust quality of never being negative and statistically important. In other words, the data set used here does not support a decline in risk of accident and injury attributable to the number of worksite inspections. On the other hand, the conviction variable which is measured to have a negative impact thereby reducing the risk of accident and injury sometimes showed statistical significance under alternative model specification but we claim no robustness to this finding. Consequently, we read these aggregate results to indicate that government safety efforts through inspections and convictions have had little or no effect on changing the risk of accident and injury in the Alberta construction industry over the period of study.

Commenting on the estimated coefficients of the remaining variables, the coefficient on $COMP_t$ shows a possible moral hazard effect associated with WCB benefits increasing the lost time claims rate.[9] Changes in compensation benefits are associated with an increased claim rate suggesting bogus claims are being filed. The estimated coefficients for both unemployment $(UNEMP_t)$ and turnover of the labor force (ΔMY_{it}) indicate that the work environment and changes in employment conditions are important determining factors of risk of accident and injury in the Alberta construction industry. This implies that the risk of accident and injury is not only related to the inherent characteristic of the worksite but also, to provincial economic factors and to the dynamic effects of workforce turnover. Finally, the negative and statistically significant $YEAR_t$ coefficient appears to show a reduction in risk of accident and injury due to the Partnership and Experience Rating programs in Alberta.[10] It is worth noting that these results are generally robust over alternative specifications of the model and appear to tell a consistent story as to changes in lost time claims rate. However, our principle interest is in the role of inspections impacting on number of lost time claims and we turn now to the results of the estimated disaggregate model which allows sub-industry specific inspection effects.

In Table (4), the first column reports the initial estimates of the coefficients of the inspection variable for each of the 27 sub-industries in Equation (4).[11] The estimated equation is corrected for a heteroscedastic error structure. The purpose of dissaggegating the inspections variable is to allow different risk levels of accident and injury by sub-industry, however, the results of this initial equation show little if any variation in the impact of inspections on altering risk levels. Of the 27 coefficients, 26 are statistically unimportant at the 95 percent level and the remaining one (Plants and Buildings) shows a statistically significant positive relationship between inspections and risk level. Presumably, this result is a statistical anomaly due to sampling variation in the data with no practical significance.

It is possible that the initial results obtained are caused by endogeneity problems in the inspections variable. To investigate this possibility, the disaggregated Tobit equation (Equation 5) is estimated and an IV generated for the inspections variable for each sub-industry. The results for this equation corrected for heteroscedasticity are reported in column 2 of Table 4 and the individual sub-industry Hausman[12] results are reported in column 3. The Hausman statistics show that of 27 tests 8 reject the null hypothesis of exogeneity. It is interesting that of the eight sub-industries testing endogenous, the largest sub-industry by man-years (excavating and bulldozing) is not among this group. However, buildings and plants which show the largest number of claims and accidental deaths does test positive for an endogenous current inspections variable. Of the remaining sub-industries showing endogeneity all are small in man-years and claim rate, and appear to have nothing that identifies them to the characteristic of endogeneity.

From these results, our choice is either to use an IV for only those sub-industries showing endogeneity in the current inspections variable or over all sub-industries. To be consistent across sub-industries we choose the latter procedure. Consequently, the IV estimates reported in column 2 are the preferred results and are used in a Wald testing procedure to measure the impact on risk of accident and injury from the decline in the number of inspections in 1989. Because the aggregate Wald statistic showed no statistical effect we carry out the current testing on a sub-industry level and report the results in column 4 of Table 4. The results over all sub-industries show a consistency in that the decline in number of inspections has had no measurable impact in altering the risk of accident and injury. At both the aggregate and sub-industry level our results fail to measure a direct impact of worksite safety inspections on the number of lost time claims.

The remaining estimated coefficients for the disaggregated IV procedure are shown in the bottom half of Table 4. These results are consistent with the aggregate results reported in Table 3 and for one exception, no further comments are required. The exception is the convictions coefficient, which now is measured to be both negative and significant showing that convictions for safety violations may play an important role in reducing the risk of accident and injury. The importance of this finding is diminished somewhat in noting that convictions are not proactive in reducing the probability of accident and injury but rather occur only after the violation is identified. Moreover, in the six year period examined only 11 of 27 sub-industries suffered convictions for safety violations (see, Table 2). Convictions in a court of law are difficult to obtain, time-consuming and costly but, nonetheless, this tool does appear to achieve the desired effect of getting violators to comply with safety regulations and to reduce the risk of accident and injury.

5. Summary Comments and Conclusions

The purpose of this paper is to empirically determine the impact of onsite safety inspections in reducing the risk of accident and injury in the Alberta construction industry for the period 1987 to 1992. The data set is disaggregated by sub-industries within construction allowing for different risk levels for different work activities. The location of construction worksites change frequently and this may require continuous inspections at each site to maintain safety standards even if past sites have been deemed safe. In addition, the sample period covered shows a dramatic decrease in inspection activity providing a natural experiment into the necessity of continued inspection effort to maintain safety levels. Thus, we consider the data set available for the construction industry to offer a rich source of information to evaluate the impact of onsite safety inspections.

We measure the risk of accident and injury by the number of lost time claims in each sub-industry. The current level of inspections, the number of convictions for safety violations and industry variables are used in specifying the econometric model. Econometrically, we are concerned with both heteroscedasticity of the error structure and endogeneity of the current inspections variable used in model specification. In an aggregate model of the construction sector an endogenous inspections variable is statistically not a problem, however, in the disaggregated sub-industry model endogeneity is observed and a Tobit generated instrumental variable is used in the corrected model. In any case, both the aggregate and sub-industry models show that current inspections have no substantial impact in altering the risk of accident and injury. Moreover, the decrease in the level of inspections that occurred in the data set is not associated with an increase in risk of accident and injury. In fact, the opposite is observed with an associated decrease in risk levels.

It is possible that the absence of an inspections effect could mean that construction firms have acquired that level of "safety" capital necessary under mandate. However, given that we do observe a decline in risk associated with number of convictions for safety violations this seems unlikely. More plausible perhaps is that inspections are impotent in altering the inherent riskiness of construction activities at least beyond some initial safety level once achieved.

Other results of the study show that the level of accident and injury is related to general provincial economic conditions and to dynamic changes in the workforce for each sub-industry. As well, there is evidence that proactive safety programmes between government and industry, and experience rating in setting compensation premiums by firms may be important elements in reducing the risk of accident and injury on the worksite.

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[1]That is, a moral hazard effect introduced by the WCB program. See Risa (1995) and Lanoie (1991) for a discussion of moral hazard in occupational health and safety.

[2]The time trend variable is preferable to a zero-one variable by allowing for lagged adjustment to experience rating by firms.

[3]Estimated as the number of lost time claims per thousand man-years of employment.

[4]Although dangerous, there are incentives for workers to cut corners and compromise safety.

[5]Let $Q = {}^{IV}\beta_{Ii} - {}^{LS}\beta_{Ii}$, then the appropriate test statistic is $M = Q'\left(V_{IV} - V_{LS}\right)^{-1} Q$, where V is the corresponding variance-covariance matrix of the two different estimates. M is distributed as Chi-square with one degree of freedom.

[6]For example, a Wald statistic used to test the null hypothesis that each sub-industry explains a constant share of the estimated variance is calculated to be 181.09 with 26 degrees of freedom. The critical Chi-square is 38.88 at the 5% level and the null is rejected.

[7]The Wald statistic is supported by a t-statistic result on a dummy variable that allows for differences in the inspections coefficient between the two sub-samples. The estimated coefficient on the inspections dummy shows no statistical difference between the two sub-samples at standard significant levels.

[8]A number of summary statistics show an improvement in model fit by including the variable "percentage change in man-years"; The Akaike Information Criterion is measured at 1.9498 without the variable included by decreases to 1.7315 with the variable included, Schwarz Criterion from 0.7821 to 0.68238, Akaike Final Prediction Error from 1.9499 to 1.7316, and the Log of the Likelihood value from -150.05 to -143.35.

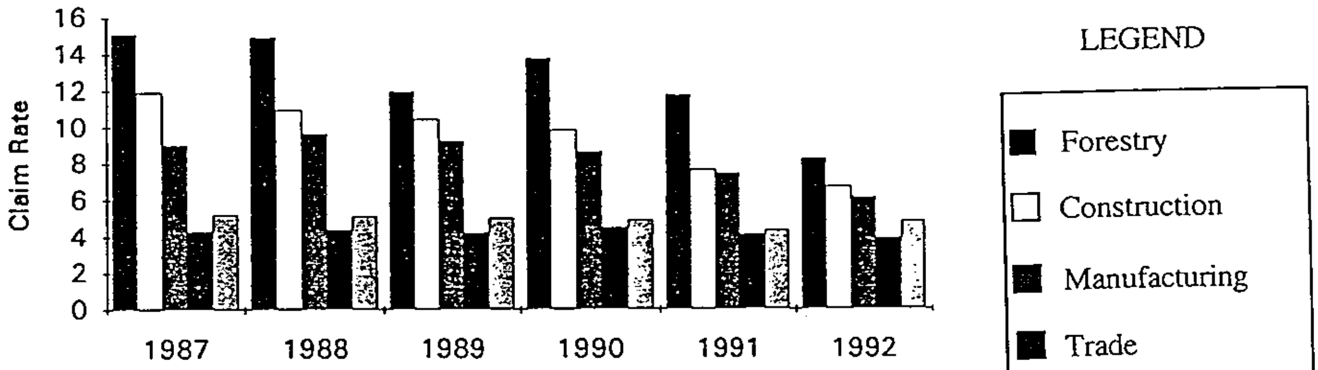
[9]The estimated coefficient on $CONV_{it}$ is statistically significant at the 90 percent confidence level.

[10]Of course, the time trend variable $YEAR_t$ will capture all yearly fixed effects including those not identified in the model.

[11]As the constant term across sub-industries is uninteresting we do not report these estimates.

[12]The critical Chi-square value is 3.84 at the 95 percent level with one degree of freedom.

Figure 1 The Lost Time Claim Rate* in Four Industrial Sectors in Alberta, 1987 to 1992



*The lost time claim rate is the ratio of lost time claims by man years of employment.
Source: Alberta.Worker's Compensation Board Annual Report

TABLE 1 - ANNUAL NUMBER OF INSPECTIONS BY SUB-INDUSTRY IN THE ALBERTA CONSTRUCTION INDUSTRY, 1987 TO 1992

Sub-Industries	1987	1988	1989	1990	1991	1992
Plants & Buildings	1206	1178	712	629	567	407
House/Apartments	251	280	278	234	834*	1020*
Prefab Structures	39	60	34	15	8	10
Phone/Cable	10	10	3	3	8	7
Pipelines	30	0	32*	37*	19*	13*
Paving & Surfacing	40	54	49	54	53	28
Excavating & Bulldozing	658	702	355	385	388	212
Roofing	79	63	40	36	61	47
Drywall	79	84	32	37	68	37
Concrete	88	80	44	69	53	38
Precast Concrete	27	19	25*	11	8	7
Plumbing	127	113	45	43	46	25
Painting	25	35	23	13	23	14
Electrical	67	85	28	28	36	25
Bricklaying	128	95	33	30	26	13
Drilling	4	4	4	10	2	3
Structural Steel	23	16	9	10	12	10
Heavy Machinery	21	18	13	18*	14	12
Carpet & Lino	4	2	0	3*	4*	3*
Acoustical Material	10	4	0	0	1	0
Sprinkler	7	10	2	2	2	0
Metal Siding	30	43	18	21	44*	17
Moving Buildings	0	0	1	0	0	0
Demolition	2	3	1	5*	3	3
Pilings/Caisson	41	23	15	9	8	9
Plastic Film & Heat.	0	0	0	2	0	0
Insulation (Mechanical)	22	12	13*	14*	31*	13*
Total Inspections	3015	2993	1809	1718	2319	1973

*Actual inspections which are greater than 1988 level.

Source: Alberta Occupational Health & Safety. Number of OH&S Inspections by year and Industry, Information Services Alberta Labour, August, 1993.

TABLE 2 - SAFETY STATISTICS, AVERAGE VALUES 1987 TO 1992, BY SUB-INDUSTRY IN THE ALBERTA CONSTRUCTION INDUSTRY

Sub-Industries	Inspections	Man Years	Claims	Claims Rate	Deaths	Convictions
Plants & Buildings	782.83	9615.7	692.82	72.70	3.33	5.83
House/Apartments	482.83	7857.0	687.8	88.32	1.67	0.33
Prefab Structures	27.67	224.83	35.00	152.49	0.33	0.0
Phone/Cable	6.83	45.67	0.99	10.14	0.0	0.0
Pipelines	21.83	1675.70	114.06	71.97	1.0	2.17
Paving & Surfacing	46.33	1217.30	68.00	57.22	1.0	0.0
Excavating & Bulldozing	450.00	10078.00	625.17	61.95	3.17	2.00
Roofing	54.33	1369.50	206.22	151.90	0.67	0.0
Drywall	56.17	2203.80	256.5	118.22	0.17	0.0
Concrete	62.00	1416.70	166.92	117.31	0.17	0.50
Precast Concrete	16.17	92.50	7.00	77.19	0.17	0.0
Plumbing	66.00	3386.00	256.77	75.72	0.83	1.17
Painting	22.17	1797.00	117.59	66.37	0.0	0.0
Electrical	44.83	5947.20	330.81	55.63	1.0	0.0
Bricklaying	54.17	767.00	106.35	137.42	0.33	0.50
Drilling	4.50	56.5	1.83	34.22	0.17	0.67
Structural Steel	13.30	269.50	42.51	156.39	0.17	0.33
Heavy Machinery	16.00	727.50	75.67	103.46	0.0	0.50
Carpet & Lino	2.67	2040.50	109.52	55.41	0.0	0.0
Acoustical Material	2.50	114.00	8.20	73.50	0.0	0.0
Sprinkler	3.83	295.83	28.66	96.74	0.0	0.0
Metal Siding	28.83	829.33	73.36	88.78	0.50	0.0
Moving Buildings	0.17	36.33	5.99	168.74	0.0	0.0
Demolition	2.83	105.83	5.94	60.94	0.0	0.17
Pilings/Caisson	17.50	221.50	27.33	115.24	0.17	0.0
Plastic Film & Heat.	0.33	23.50	0.74	29.35	0.0	0.0
Insulation (Mechanical)	17.50	867.67	54.21	61.64	2.67	0.0

Source: Alberta Occupational Health & Safety *Lost Time Claim rates, Construction Industries Alberta, 1987-1991*, Research & information Development Planning & Research Branch, Sept./92; Alberta Occupational Health & Safety *Nature of Offence 1986-1992*, Occupational Health & Safety Program Support Services Legislative Affairs, Aug./93; Alberta Occupational Health & Safety *Number of OH&S Inspections by Year and Industry*, Informational Services Alberta Labour, Aug./93.

TABLE 3 - AGGREGATE INSPECTIONS EQUATIONS FOR THE ALBERTA CONSTRUCTION INDUSTRY, 1987 TO 1992

Estimated Coefficients	Least Squares Estimates	Generalized Least Squares Estimates[a]	Instrumental Variable Estimates[b]
I[c]	0.0014 (0.0001)[d]	0.00037 (0.0009)	-0.0002 (0.0012)
CONV	-0.0026 (0.0026)	-0.0077 (0.0106)	-0.0044 (0.011)
COMP	0.403 (0.0027)*	-0.0035 (0.0026)	0.0037 (0.0026)
ΔMY	-0.011 (0.023)	-0.0265 (0.0118)*	-0.025 (0.012)*
UNEMP	-0.024 (0.0005)*	-0.002 (0.0003)*	-0.002 (0.0003)*
YEAR	-0.167 (0.032)*	-0.074 (0.017)*	-0.077 (0.017)*
CONSTANT	335.58 (63.85)*	151.98 (34.03)*	157.73 (35.09)*
Hausman Test			1.458
Log of Likelihood	-149.201	-143.348	-143.405

[a]Corrected for sub-industry heteroskedasticity.
[b]Tobit predicted instrumental variable for I.
[c]I is number of inspections per thousand man years, CONV is number of convictions for safety violations, ΔMY is percentage change in man years of employment, COMP is yearly average workers compensation payment per day, UNEMP is yearly average unemployment rate in the Alberta construction industry and YEAR is a time trend year variable.
[d]Standard error in parenthesis, *statistically significant at the 95% level.

TABLE 4 - SUB-INDUSTRY INSPECTIONS EQUATIONS FOR THE ALBERTA CONSTRUCTION INDUSTRY, 1987 - 1992

Estimated Coefficients	Generalized Least Squares Estimates[a]	Instrumental Variables Estimates[b]	Hausman[c]	Wald[d]
I[e]				
Plants & Buildings	0.0179 (0.006)	0.138 (0.0052)*	61.10*	2.47
House/Apartments	-0.0003 (0.004)	0.0029 (0.0113)	1.46	0.85
Prefab Structures	0.0005 (0.001)	-0.0013 (0.0041)	9.78*	0.21
Phone/Cable	0.026 (0.031)	-0.0201 (0.0461)	4.45*	0.03
Pipelines	-0.0123 (0.016)	0.0333 (0.0189)	23.07*	1.59
Paving & Surfacing	0.004 (0.019)	0.0119 (0.0175)	1.94	1.36
Excavating & Bulldozing	0.0061 (0.01)	0.0057 (0.0144)	0.05	0.26
Roofing	0.0047 (0.01)	0.0066 (0.0162)	1.05	0.10
Drywall	0.0074 (0.0128)	0.0132 (0.02)	6.13*	0.56
Concrete	0.0031 (0.0056)	-0.00005 (0.0124)	0.87	0.48
Precast Concrete	-0.0016 (0.0021)	0.0007 (0.0031)	0.77	0.19
Plumbing	0.0072 (0.011)	0.0066 (0.0157)	0.07	0.44
Painting	0.0222 (0.043)	0.0055 (0.026)	2.39	0.72
Electrical	0.0399 (0.039)	0.0264 (0.0327)	3.28	2.32
Bricklaying	0.0017 (0.0029)	0.0024 (0.0052)	0.56	0.14
Drilling	-0.0037 (0.001)	0.0067 (0.007)	407.73*	0.59
Structural Steel	0.0072 (0.0082)	0.008 (0.0119)	0.26	2.82
Heavy Machinery	0.0075 (0.0157)	0.0058 (0.0206)	0.18	1.01
Carpet & Lino	0.1341 (0.1635)	0.0218 (0.0319)	2.27	1.43
Acoustical Material	0.008 (0094)	0.0176 (0.0311)	1.95	1.62
Sprinkler	0.0063 (0.01)	0.0039 (0.0181)	0.37	1.39
Metal Siding	0.0028 (0.0021)	-0.0006 (0.0044)	28.05*	0.05
Moving Buildings	0.0153 (0.045)	0.0136 (0.0464)	0.0056	0.61
Demolition	-0.0065 (0.0079)	-0.0006 (0.0118)	1.38	3.51
Pilings/Caisson	0.0036 (0.0047)	0.0036 (0.0064)	0.000006	0.00003
Plastic Film & Heat.	0.0053 (0.0179)	0.0779 (0.062)	0.86	0.49
Insulation (Mechanical)	-0.0238 (0.0152)	-0.0019 (0.0156)	10.14*	1.14

TABLE 4 - SUB-INDUSTRY INSPECTIONS EQUATIONS FOR THE ALBERTA CONSTRUCTION INDUSTRY, 1987 - 1992 (cont'd.)

Estimated Coefficients	Generalized Least Squares Estimates[a)]	Instrumental Variables Estimates[b)]	Hausman[c)]	Wald[d)]
CONV	-0.0579 (0.033)	-0.036 (0.027)	61.10*	2.47
COMP	0.028 (0.003)*	0.022 (0.004)*	1.46	0.85
ΔMP	-0.0247 (0.0097)*	-0.017 (0.011)	9.78*	0.21
UNEMP	-0.0023 (0.0004)*	-0.002 (0.0004)*	4.45*	0.03
YEAR	-0.098 (0.014)*	-0.081 (0.018)*		
Log of Likelihood	31.76	-43.26		

[a)]Corrected for sub-industry heteroskedasticity.
[b)]Tobit predicted instrumental variable for I.
[c)]Hausman test results for exogenous inspections variable.
[d)]Wald test results for a continued inspection effort after 1989.
[e)]I is number of inspections per thousand man years, CONV is number of convictions for safety violations, ΔMY is percentage change in man years of employment, COMP is yearly average workers compensation payment per day, UNEMP is yearly average unemployment rate in the Alberta construction industry and YEAR is a dummy year variable.
[f)]Standard error in parenthesis, *statistically significant at the 95% level.

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