Available Online at https://www.nepjol.info/index.php/IJOSH
International Journal of Occupational Safety and Health, Vol. 7 No. 2 (2017) 3 – 16

Optimizing Health and Safety Inspections in Canada

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Abstract

Background: Each year, the Canadian government assigns inspectors to visit firms and ensure compliance to the occupational health and safety provisions of the Canada Labour Code. This paper presents evidence supporting the hypothesis that assignments reduce the number of disabling injuries. It also presents a mathematical technique improving the performance of how firms are chosen for inspection.

Methods: By combining two administrative databases covering worksites under federal jurisdiction, the impact of assignments on injuries is estimated using instrumental variables. The instruments are the exogenous part of the government's assignment rule for inspectors.

Results: The impact of one assignment on injuries is estimated to be -0.33 in the year following the assignment. Furthermore, by introducing a measure of diminishing marginal returns of assignments by sector, a more efficient assignment rule to help further minimize the number of injuries resulting from non-compliance with the Labour Code is suggested. This improved rule includes a reallocation of assignments across industries compared to the current allocation. In particular, assignments are transferred from the sectors of Air Transport and Road Transport to the sectors of Banking, Postal Contractors and Crown Corporations.

Conclusions: A counterfactual experiment with the new allocation of assignments suggests an 18% decrease in the number of injuries for the same yearly average number of assignments. Based on available estimates of the cost of injuries, the suggested change in the targeting tool would lead to annual savings of 72 million dollars in workers' compensation claims.

Key words: Inspections Management, Occupational Health Safety, Optimization.

DOI: https://doi.org/10.3126/ijosh.v7i2.22890

Introduction

Each year, the Labour Program of the Canadian government sends inspectors to firms in the federal jurisdiction to ensure compliance with the Canada Labour Code (Labour Code). Some of these inspections relate to Occupational Health and Safety (OHS) provisions, which aim to guarantee safe working conditions in workplaces. Those inspections include *proactive inspections*, namely, inspections that are the initiative of the department. The targeting rule employed to choose inspected firms is a policy set by the Labour Program of Employment and Social Development in Canada.

In part, the current targeting rule assigns inspections based on previously observed injuries and national and regional priorities in some economic sectors.* Targeting inspections based on past injuries implicitly assumes that the injuries are caused by a lack of compliance with the Labour Code. The logic is that if firms have a history of numerous injuries, they are somewhat out of compliance with the Labour Code. Hence, firms that have a high rate of injuries are inspected more frequently.

However, some injuries occur on worksites regardless of the compliance of businesses to the Labour Code. For an efficient use of assignments, the targeting

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* Worksites under the purview of the Labour Program are grouped into seventeen sectors (or business lines), ranging from the aerial transportation sector to the water transportation sector. SeeAppendix A for a completelist of sectors and regions.

tool must account for the impact of inspections on reducing injuries. This paper proposes a targeting tool. It presents a new allocation rule based on both a combined statistical estimation of firms' responses to inspections and the effectiveness of the department in reducing injuries. Based on Canadian data from businesses under federal jurisdiction, the estimation of this new allocation rule suggests an 18% improvement in terms of reduced injuries, while the same average number of inspections is still performed. Based on the average cost of compensation in Canada, this reduction of injuries translates into a savings of 72 million dollars annually.[1]

From a statistical perspective, this paper uses an estimation strategy that accounts for the endogeneity of the outcomes induced by the current targeting tool. Since the targeting tool is based on past injuries, a simple estimation of the relationship between current inspections and injuries might reflect reverse causality. Exogenous shifts in the targeting tool (changes in national and regional priorities) are used as instruments for inspections to circumvent this problem. As the national and regional priorities changed at known dates, they provide a good source of identification. This approach can thus disentangle the impact of the targeting tool from the impact of inspections on injuries. Access to the administrative database and the details of the current targeting technique provide a good basis to estimate the impact of the targeting tool. This instrumental variable technique is implemented in the estimation model reported by Gray and Scholz, which eliminates any potential fixed effects or time effects at the site level.[2-5]

A critical review of the literature was published by Tompa, Trevithick and McLeod[6], but an overview of the papers reporting the impact of inspections on injuries is still useful. Gray and Scholz lay some groundwork by studying the period from 1978–1985 and find that a 10% increase in the number of inspections leads to a 1% decrease in the number of injuries.[2] In a subsequent study performed during the same period, the same authors assessed the possible endogeneity biases arising from the OSHA targeting tool.[5] Using the Chamberlain technique to remove those biases, the authors find that a 10% increase in the number of inspections leads to a cumulative 2.2% decrease in the number of injuries.

The same analysis was then conducted by Mendelhoff and Grayfor various periods from 1979 to 1998. The authors observed a decreasing effect of inspections over time.[4] Moreover, inspections without penalties were less effective than inspections with penalties. A subsequent paper by Haviland et al. performed a similar analysis from 1998–2005 and observed a similar impact of inspections with penalties to the original study.[3]

Some other papers have used different identification techniques and have also explored the relationship between OSHA inspections and observed injuries. Smith used the timing of inspections in the business year to distinguish inspections that would have an impact on the current year reports from inspections that would not have an effect.[7] Early inspections are more likely to have an impact during the current year than late inspections. Comparing similar firms, he found that inspections decrease injuries by 16% for one period of study, but no impact was observed for another period. The paper does not assess the impact of the OSHA targeting tool. Using time series data, Viscusi also explored the impact of OSHA inspections.[8] He did not observe an effect of inspections whatsoever and concluded that penalties imposed by OSHA are too low. Barteland and Thomas provided evidence that inspections (combined with a fining system) decrease the number of injuries.[9] Their identification strategy relies on structural equations identifying the "supply and demand" for injuries. The small impact of inspections on injuries raises questions about the very existence of OSHA.

The remaining sections of the paper are organized as described below. Section two presents the datasets used and the methodology. Section three focuses on the results and presents the new targeting tool and its assessed impact. A brief description of the conclusions follows in section four. The objective of this study is to provide an estimate of the impact of inspections on reducing injury.

Methodology

The statistical analysis was performed on a dataset generated by matching two administrative databases, namely the Federal Jurisdiction Injury Database (FJID) and the Labour Application 2000 Administrative Database (LA2000).

FJID has recorded all information contained in the Employer's Annual Hazardous Occurrence Report (EAHO report, since 1982.[10] These reports contain information on the number of fatal injuries, minor injuries and (nonfatal) disabling injuries at worksites under federal jurisdiction. They also contain information about the number of hours worked, full-time equivalent employees (FTEs), front-line employees, and desk-assigned employees. Information about each worksite, such as its address and its economic sector (Table A2), is also maintained in the records.

The LA2000 database records all actions related to inspections instigated under the Labour Code since 2000. It contains records of proactive inspections, recorded violations and the number of complaints for each worksite. It also contains information about worksites such as a working address, the economic sector and the presence of a union at the worksite.

Some worksites that are under federal jurisdiction, such as Canadian embassies or military bases, are included in FJID, but are not subject to inspections and thus are not included in LA2000 databases. As a general rule, these omitted sites are located abroad. Furthermore, some inspections related to the Labour Code are not performed by the Labour Program. For instance, onboard inspections within planes owned by Canadian companies are performed by Transport Canada. Those inspections are excluded from the dataset and the analysis. The remaining worksites under federal jurisdiction are then considered for matching purposes.

As no common identifier exists in the two databases, the matching between records is performed based on the most reliable information. Each worksite is sorted according to its postal code and economic sector. Worksites are then matched based on the similarity between company names and addresses using a simple Levenhstein metric. The resulting matches are then sampled by province and corrected until the rate of matching error was less than 6%, a rate considered acceptable. In general, this matching technique is likely to aggregate worksites with similar names that are located within the same postal code. This aggregation is likely to occur for Air Transportation worksites, which are usually all located in the same building of an airport.

At its inception, the LA2000 database programmers transferred records of inspections prior to 2000 in such a way that the inspection year is indistinguishable from the year 2000. Thus, all observations prior to and including the year 2000 are useless for matching purposes. Hence, the useful time span of the matched databases ranges from 2001 to 2014 inclusively. The final dataset is an unbalanced panel of roughly 38,000 worksites per year; some of these worksites are active solely during a subset of the time span.

I use the following two definitions throughout this paper:

1. A **"disabling** injury" is "any employment injury or an occupational disease that results in either time loss, or modified duties".[10] It encompasses both fatalities and nonfatal disabling injuries. Unless mentioned otherwise in the text, disabling injuries and injuries are used interchangeably.
2. The "disabling injury incidence rate" (DIIR) is the ratio of the disabling injuries divided by the number of FTE multiplied by 100.

Table 1 presents summary statistics drawn from the FJID. The first panel presents statistics about the sites recorded, which is defined as the number of sites recorded since 2000, the number of active sites in 2014 and the number of EAHO reports received in 2014. The second panel presents 2014 statistics related to the average number of FTEs by type of worker. It also presents the mean average hours of work per FTE worker in each sector.

The last panel of the table presents summary statistics on the average number of injuries per site for each type of injury. The sectors of Longshoring, Rail Transport, Road Transport, Air Transport and Energy and Mining yield the highest number of disabling injuries. In the targeting tool, those sectors, with the exception of the Energy and Mining sector, are identified as national and regional priorities, meaning that they are currently inspected more frequently.[Ψ]

Figure 1 presents the evolution of disabling injuries in each economic sector over time. The left panel shows sectors with a smaller number of disabling injuries, while the right panel shows sectors with a higher rate of disabling injuries. Air Transport, Road Transport, Public Services and Postal Contractors have higher rates of injuries. This finding is largely due to the size of those sectors, as they have more employees.

Ψ Inspections in the Energy and Mining sector are under the purview of the National EnergyBoard and are therefore not included in the policyanalysis presented in thispaper.

Table 1: FJID Statistics by Sector, Canada, 2014

	Sites			FTE Employees (mean per site)				Injuries (mean per site)			
	Total*	**Active**	**EAHO**	**Total**	**Non-office**	**Office**	**Hours/FTE**	**Minor**	**Disab**	**Fatal (x100)**	**Other**
Water Transport	927	844	980	23.91	14.60	8.75	567.74	0.92	0.33	0.00	0.60
Longshoring	160	149	24	43.96	31.13	12.75	1325.02	2.63	1.63	0.00	1.00
Rail Transport	872	283	390	117.92	111.95	5.61	1133.31	1.82	1.46	0.51	1.01
Communications	2778	1989	1336	112.55	60.44	52.07	1220.73	0.34	0.38	0.00	0.20
Pipelines	307	289	43	132.93	83.30	49.60	1601.81	0.74	0.35	0.00	0.05
Bridges and Tunnels	5	5	Und	Und	Und	Und	Und	Und	Und	Und	Und
Road Transport	11813	10985	1562	59.43	47.75	11.63	1590.09	2.35	2.25	0.06	0.49
Air Transport	3330	3118	1394	57.36	45.05	11.89	962.59	3.28	1.37	0.07	0.50
Broadcasting	2643	1791	1191	43.16	26.81	15.87	737.64	0.58	0.34	0.08	0.04
Banking	15330	11604	7064	59.70	30.02	29.64	931.86	0.14	0.13	0.00	0.05
Grain Elevators	346	310	115	46.30	31.58	14.72	1438.33	0.82	0.16	0.87	0.07
Feed, Flour, and Seed	654	567	164	30.82	23.48	7.29	1478.88	0.84	0.51	0.00	0.08
Energy and Mining	31	31	1	434.00	346.00	88.00	1697.19	78.00	6.00	0.00	3.00
Public Service	7639	6742	3791	127.43	72.52	54.81	1048.27	1.86	0.63	0.24	0.75
Postal Contractors	5108	4207	4743	10.50	9.46	0.75	1415.67	0.41	0.82	0.00	0.00
Crown Corporations	593	533	380	139.49	77.69	61.76	988.05	0.90	0.40	0.00	0.06
Aboriginal	561	555	161	72.81	45.59	27.21	1151.29	1.40	0.17	0.62	0.12
Total	**53097**	**44002**	**23339**	**63.45**	**38.09**	**25.19**	**1100.12**	**0.94**	**0.63**	**0.07**	**0.26**

Source: FJID, 2015. Notes: EAHO: Number of sites that submitted an "Employer's Annual Hazardous Occurrence Investigation Report", FTE: "full-time equivalent", Und: "undisclosed". *Total sites covered in the 1985–2015 period.

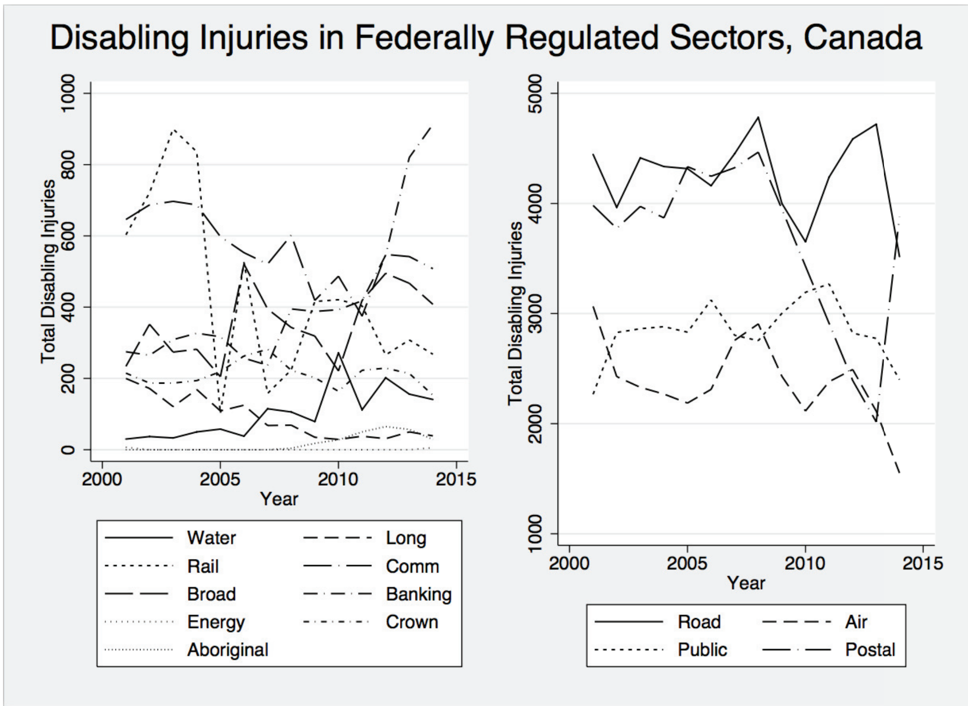

Figure 1: Disabling Injuries in Federally Regulated Jurisdictions in Canada.
Source: FJID, 2015.

Estimation Technique

The responses of firms to proactive inspections are modeled using the established framework developed by Gray and Scholz.[2,4,5‡] This framework estimates the change in the number of disabling injuries based on the number of inspections one year earlier and a set of controls; see equation (1). The dependent variable is modeled as the change in the number of disabling injuries from one year to another. The first explanatory variable is a constant. Because the equation measures differences, it is expected to be zero. The coefficient measures the impact of inspections ($insp_{it}$) on the change in the number of disabling injuries ($\Delta disab_{it}$), which is expected to be negative.

$$\Delta disab_{it}=\beta_0+\beta_1\, insp_{it}+\beta_2\, hours_{it}+\beta_3\, \Delta vio_{it}+\beta_5\, react_{it}+\varepsilon_{it}\forall it \quad (1)$$

The controls that are included account for other possible factors that may influence disabling injuries. First, the change in the size of the firm, which is measured in total number of hours ($hours_{it}$), is assumed to have a level effect on injuries. The two remaining variables are proxies for the "safety culture" within firms. The variable Δvio_{it} is a measure of the change in the number of citations at the worksite. The last variable ($react_{it}$) is a measure of the change in the number of reactive inspections, namely, inspections initiated by complaints from workers (or, to a lesser extent, from employees). These coefficients are expected to be positive, as delays and reactive complaints are indications of indifference towards safety. Finally, the last term (ε_{it}) accounts for the unexplained factors that a linear model is unable to capture.

The Current Targeting Tool

In addition to developing Canadian estimates, this paper differs from previous published studies by instrumenting inspections through exogenous changes in the targeting tool. Since the targeting tool assigns inspections based in part on past injuries, a simple regression analysis of the effect of inspections on injuries would bias estimates downwards or even reverse the sign of the estimate. Using proper instruments, the reversed causation is removed and the impact of inspections is able to be properly identified.

The current targeting tool assigns inspections according to five dimensions.[12]These dimensions are national priorities, regional priorities, the sector average DIIR and the raw number of disabling injuries per site. As explained in the introduction, national and regional priorities are established by the department as sectors that should be inspected more frequently, and the only difference between these priorities is whether they are applied to a region or the whole country. The last three dimensions are used together as a composite priority index: the five-year average number of disabling injuries is multiplied by a worksite's DIIR and divided by the DIIR average of the sector over the past five years. This index provides an estimate of the importance of the number of injuries occurring at a worksite compared to the sector average. The sector average DIIR is also used to account for the relative differences in the number of injuries persect or, while the deviations from the mean are used to position a specific firm in terms of severity with respect to the sector.

From a statistical standpoint, these indicators suggest a simple estimation strategy to model the number of inspections at a particular worksite during a specific year. The following reduced form is the model employed to reflect the government's targeting tool:

$$\begin{aligned} insp_{it} &= \phi_{atl}atl_i + \phi_{qc}qc_i + \phi_{cen}cen_i + \phi_{nw}nw_i + \cdots \\ \ldots &+ \sum_{T=t-1}^{t-5} \phi_{1T}disab_{iT} + \phi_2 DIIRsite_{it-1} + \cdots \\ \ldots &+ \sum_{T=t-1}^{t-5} \phi_{3T}DIIRsector_{iT} + \cdots \\ \ldots &+ \sum_s \phi_{4s}nat_{siT} + \sum_s \phi_{5s}reg_{siT} + \varepsilon_{it}\forall it \qquad (2) \end{aligned}$$

Where, s is an index covering economic sectors. Equation (2) states that the number of inspections at site i at year t is a function of a regional constant, the number of disabling injuries at that worksite in the last five years, the site DIIR in the last year, the last five-year DIIR of the sector, and a set of dummy variables that indicate whether a particular sector is either a national priority (nat_{siT}) or a regional priority (reg_{siT}).

The sign of the site DIIR coefficient is expected to be positive, reflecting the current allocation rule: firms at which more injuries occurred in the past should be inspected more frequently. The signs of the sector DIIRs are expected to be negative because they are part of the denominator in the priority index. The

‡ All analyses are performed with the software Stata (College Station, Texas, USA).

tiering coefficients should also be positive, and they should increase with the tiering category. Likewise, if a sector is a regional or a national priority, the number of inspections should increase.

For instrumentation, a functional form that includes only the variables that are not related to the number of injuries on the site is used. Thus, the following equation is used to define the instrumental variable:

$$\widehat{insp}_{it} = \phi_{atl} atl_i + \phi_{qc} qc_i + \phi_{cen} cen_i + \phi_{nw} nw_i + \cdots$$

$$\ldots + \sum_s \phi_{4s} nat_{siT} + \sum_s \phi_{5s} reg_{siT} + \varepsilon_{it} \forall it \quad (3)$$

Equations Estimated and the Proposed Policy Reform

Section 3.2 presents equation (4), instead of those described in the previous sections. In essence, this equation has two differences. First, the logarithm of the number of inspections is used as the instrument to include some diminishing marginal returns. It also provides an easily interpretable and efficient policy.§ Secondly, the impact of inspections on the economic sector is estimated, because the equation estimates the sector-specific marginal impacts of inspections.

$$\Delta disab_{it} = \beta_0 + \sum_s \beta_{1s} \log(\widehat{insp}_{it}) + \beta_2 hours_{it} + \beta_3 \Delta vio_{it} + \beta_5 react_{it} + \varepsilon_{it} \forall it \ (4)$$

This equation analyses efficiency by comparing the relative effectiveness of inspections per sector. The suggested policy reform is then based on the following principle: given a fixed number of inspections *m*, what is the best way to minimize the total number of disabling injuries? Because of diminishing marginal returns, one additional inspector does not yield the same reduction in the number of injuries across sectors. Hence, by choosing which sector is inspected more frequently based on the responsiveness of firms, policymakers can increase the efficiency of the department's inspection activities.

Mathematically, the solution to the following program is sought:

$$\{insp_s^*\} \equiv \arg\max \sum_s disab_s \ s.t.$$

$$disab_s = \omega_s \widehat{\beta}_s \log(\widehat{insp}_{sit}) + c_s$$

$$m = \sum_s insp_s \ (5)$$

where, $disab_s$ is the number of injuries in a particular sector, w_s is the number of sites in sector *s*, $\widehat{\beta}_s$ is the sector-relevant estimated coefficients from equation (4) c_s and is a constant that is not influenced by the choice of inspections, the remainder of equation (4), summed by sector. The last equation states that the sum of the number of inspections in all sectors must equal the total number of inspections that can be performed (*m*). The efficiency of inspections by sector (the solution to equation 5) satisfies the following equation:

$$insp_s = \frac{\omega_s \widehat{\beta}_s}{\sum_{s'} \omega_{s'} \widehat{\beta}_{s'}} m \forall s \ (6)$$

Equation (6) is interpreted as follows: the number of inspections in sector *s* is proportional to the fraction of the relative impact of inspections on injuries in that sector. The ratio measures the efficiency of inspections in sector *s* at reducing injuries, which is measured as a percentage. The ratio is a number between zero and one. By multiplying this fraction by *m*, the total number of inspections, the efficient allocation of inspections per sector is obtained. Hence, if a sector reduces injuries to a greater extent than another sector after a specific number of inspections (if the coefficient has a higher magnitude), it should receive a greater number of inspections.

Results and Discussion

Impact of the Current Targeting Tool

As shown in Table 2, sectors with the highest disabling injury rates were inspected most frequently in 2014. The sole exception to this trend is the Feed, Flour and Seed sector, which has a notable share of inspections but fewer injuries than other sectors (it is set as a national priority by the department).

Although the Public Service sector has a relatively high number of injuries, the yearly number of proactive inspections is somewhat lower than in other sectors with high injury rates, as shown in Figure 2. The number of proactive inspections conducted in that sector is of the same order as in sectors with lower injury levels because the DIIR in the Public Services sector is somewhat smaller than the first three sectors and the Longshoring sector (Figure 3). Longshoring inspections are set as a regional priority in coastal regions (Atlantic Provinces, Québec and the Northwest Pacific region).

§ An easy to understand targetingtool is crucial for discussions of implementationwithin the department.

Table 2: LA2000 Statistics, 2014, Canada

	Sites		Inspections			Violations
	Total*	Active	Total	Reactive	Proactive	Total
Water Transport	945	624	30	13	17	20
Longshoring	423	157	111	90	21	74
Rail Transport	1943	933	210	67	143	114
Communications	6070	2130	626	239	387	350
Pipelines	207	49	68	8	60	48
Bridges and Tunnels	35	8	12	6	6	6
Road Transport	26600	13686	4302	1274	3028	2991
Air Transport	5704	2628	807	422	385	464
Broadcasting	1042	305	164	71	93	91
Banking	9308	1979	370	30	340	113
Grain Elevators	2841	2352	68	37	31	47
Feed, Flour, and Seed	1595	710	177	103	74	120
Energy and Mining	88	49	13	6	7	10
Public Service	15884	7297	398	224	174	260
Postal Contractors	5889	1256	123	48	75	94
Crown Corporations	1139	598	71	34	37	41
Aboriginal	5241	1944	468	92	376	247
Total	**84954**	**36705**	**8018**	**2764**	**5254**	**5090**

Source: LA2000, 2015. *Notes*: Und: “undisclosed”. *Total sites covered in the 1985–2015 period.

Table 3 presents the estimates obtained from equations (2) and (3). These estimates are instructive as they capture the current behaviors of operations. The results from these regression analyses can be interpreted as a reduced form of the current rule to assign inspections. The coefficients presented are thus viewed as a marginal increase in the number of inspections based on an increase in the variable studied.

The results of the regression analyses shown in Table 3 also illustrate the reverse causality observed after simply attempting to regress injuries on inspections. Because the current targeting tool is based on past injuries, regressing injuries on inspections would show a positive relationship, suggesting (wrongly) that inspections increase injuries.

I first discuss the results presented in the first column, which uses variables related to the site and sector disabling injuries, as well as regional constants. Based on these constants, not all regions of operations are equal in terms of inspections. Atlantic and Québec sites are inspected more frequently on average than their counterparts in other provinces. In Atlantic Provinces, the average number of inspections per site is 0.0556, while the value is seven times smaller in Northwest Pacific provinces (and territories). In terms of disabling injuries, the estimates suggest that the cumulative impact, based on the past five years and the variable of the site DIIR, is to increase inspections by 0.013 on average. In other words, an average increase of roughly 75 disabling injuries is required to observe an increase of one inspection (each year) atone specific site.

The cumulative effect of the sector DIIR has roughly the same impact (0.011) as the site DIIR. Its pattern is interesting and suggests that the department assigns inspections to a sector if a sudden increase in the number of injuries occurs, but the number of inspections decreases afterwards (-0.124 inspections per site in the second year, and additional small corrections afterwards). The increase in the number of sector inspections in the fifth year suggests a cyclical pattern of five years.

Column two presents the same estimates; in this case, national and regional priorities are added. All disabling injuries and DIIR-related coefficients maintained the same magnitude, although some become statistically insignificant. As a general rule, if a sector is designed as a national or regional priority, the number of inspections increases in those sectors. For instance, the estimate of the Air Transportation coefficient shows an associated increase of 0.246 inspection per site on average. Three notable exceptions are identified, the Communications sector, Crown Corporations and the Public Service sectors, which do not seem to have increased activity.

The third column presents the impact of national and regional priorities alone, which is the equation used to implement inspections (equation (3)). The coefficient associated with the Road Transport sector is 0.0742, as opposed to 0.0576 in the previous estimation. Likewise, worksites in the Rail sector receive an increase of 0.218 inspection on average. Two noticeable exceptions in these coefficients are identified: the Broadcasting sector, and the Crown Corporations sector. The negative coefficients for these sectors are explained by the small number of sites for these sectors overall.

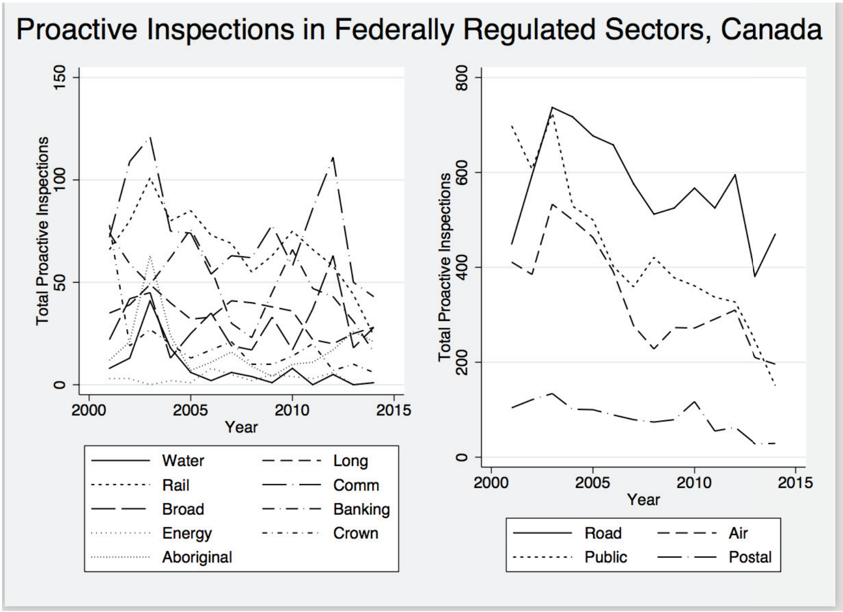

Figure 2: Proactive Inspections in Federally Regulated Jurisdictions in Canada. **(***Source*: LA2000, 2015).

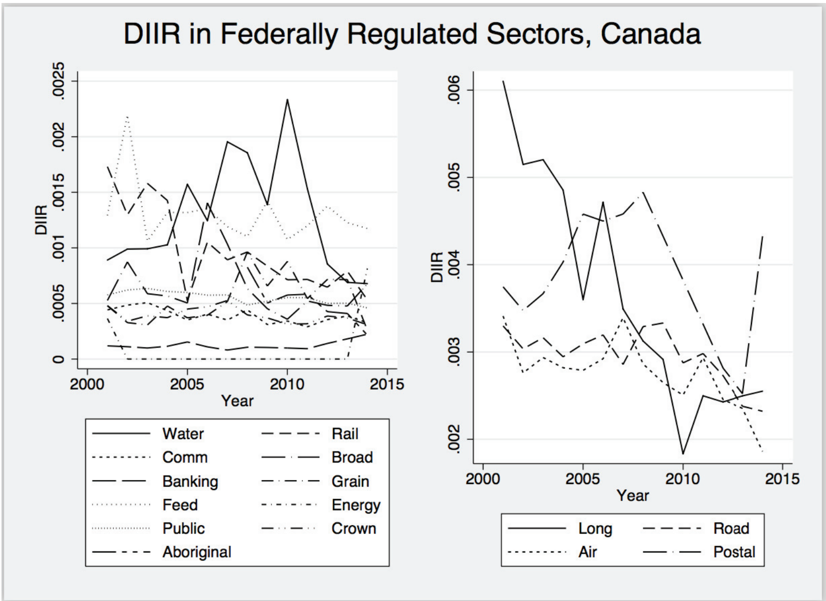

Figure 3: DIIR in Federally Regulated Jurisdictions in Canada. (*Source*: FJID, 2015. *Note:* The DIIR variation in the Postal Contractors Sector from 2008 to 2014 is due to a lack of data reported by Canada Post from 2008 to 2010).

Table 3: Impact of the Current Targeting Tool on Proactive Inspections (Canada)

	$insp_{it}$		
	(1)	**(2)**	**(3)**
$disab_{it-1}$	0.00513***	0.00488***	
	(0.000478)	(0.000476)	
$disab_{it-2}$	0.000691	0.000518	
	(0.000469)	(0.000467)	
$disab_{it-3}$	0.00224***	0.00214***	
	(0.000357)	(0.000355)	
$disab_{it-4}$	0.00168***	0.00162***	
	(0.000363)	(0.000361)	
$disab_{it-5}$	0.000123	0.000209	
	(0.000297)	(0.000296)	
$DIIRsite_{it-1}$	0.00287***	0.00278***	
	(0.000412)	(0.000412)	
$DIIRsector_{it-1}$	0.0243***	0.0153***	
	(0.00510)	(0.00532)	
$DIIRsector_{it-2}$	-0.124***	-0.0129	
	(0.0166)	(0.0174)	
$DIIRsector_{it-3}$	-0.0125	-0.0617**	
	(0.0237)	(0.0243)	
$DIIRsector_{it-4}$	-0.0623***	-0.0484**	
	(0.0220)	(0.0221)	
$DIIRsector_{it-5}$	0.183***	0.108***	
	(0.0156)	(0.0167)	
	(1)	(2)	(3)
Nat. Com		0.00836	-0.000567
		(0.00594)	(0.00430)
Nat. Road		0.0576***	0.0742***
		(0.00481)	(0.00227)
Nat. Air		0.246***	0.354***
		(0.00857)	(0.00493)
Nat. Broad		-0.00391	-0.0208***
		(0.00668)	(0.00480)
Reg. Long		0.315***	0.451***
		(0.0637)	(0.0471)
Reg. Rail		0.153***	0.218***
		(0.0254)	(0.0191)
Reg. Grain		0.0910***	0.0995***
		(0.0257)	(0.0193)
Reg. Feed		0.0442***	0.0701***
		(0.0158)	(0.0118)
Reg. Public		-0.00189	0.0483***
		(0.0107)	(0.00778)
Reg. Crown		-0.0337	-0.0796***
		(0.0267)	(0.0202)
Atlantic	0.0556***	0.0575***	0.101***
	(0.00444)	(0.00504)	(0.00268)
Québec	0.0515***	0.0531***	0.0489***

Notes: The table continues on the next page. Standard errors are shown in parentheses: *** p<0.01, ** p<0.05, and * p<0.1.

Table 3 (continued): Impact of the Current Targeting Tool on Proactive Inspections (Canada)

	(0.00379)	(0.00393)	(0.00212)
Ontario	0.0373***	0.0362***	0.0365***
	(0.00281)	(0.00297)	(0.00164)
Central	0.0178***	0.0137***	0.0524***
	(0.00458)	(0.00482)	(0.00269)
Northwest	0.00836***	-0.00392	0.0173***
	(0.00318)	(0.00343)	(0.00188)
Observations	104,24	104,24	364,84
R-squared	0.035	0.043	0.035

Standard errors are shown in parentheses: *** p<0.01, ** p<0.05, and * p<0.1.
Source: LA2000, 2015, FJID, 2015 and calculations.

Responsiveness of Firms

Table 4 presents the estimates obtained from equation (1).

Table 4: Impact of Inspections on Injuries in Canada

		Δinj_{it}	
$insp_{it}$	-0.0155		
	(0.0164)		
$\widehat{insp}_{it}$		-0.383***	-0.326***
		(0.113)	(0.108)
ΔFTE_{it}			4.21e-06***
			(3.29e-08)
Δvio_{it}			0.0996*
			(0.0598)
$\Delta Complaints_{it}$			0.0902***
			(0.00639)
Constant	-0.00533	0.0203*	0.0281
	(0.00864)	(0.0116)	(0.0199)
Observations	338 780	338 780	167 206
R-squared	0.000	n/a	0.088

Notes: Standard errors are shown in parentheses. *** p<0.01, ** p<0.05, and * p<0.1.
Source: LA2000, 2015, FJID, 2015 and calculations.

The first column presents a naive estimation strategy, which regresses injuries on the number of proactive inspections without any instrumentation. As the column shows, the coefficient is not significantly different from zero. This finding is caused by two effects. As explained in the previous section, current inspections are allocated based on past injuries, and since past injuries are correlated with current injuries, this approach drives a positive correlation between inspections and injuries. The second effect, which is the effect of interest, is the impact of inspections on reducing injuries. As shown in the first column, when the inspection variable is not instrumented, the estimated coefficient is negative, but not statistically different from no effect.

Column 2 shows the findings obtained when inspections are implemented based on national and regional priorities. Because these variables are not influenced by yearly changes in the number of injuries, the positive bias is eliminated. When using instrumental variables, the marginal impact of inspections shifts to a negative value and becomes significantly different from zero. The estimate suggests that an average of 2.6 inspections (1/0.383≈2.6) is required to reduce the number of disabling injuries by one.

The third column adds a set of covariates to the regression equation, namely the change in the size of the worksite measured in the number of hours worked, the change in the number of violations and the change in the number of reactive complaints.

The size of the workforce (measured in hours) has a leveling effect, meaning that an increase in the number of worked hours is more likely to increase injuries. The effect is quite small, however. An increase of an order of 250,000 hours is required to increase the number of injuries by one, because some small sites have high DIIRs (the Transport sector, for instance), decreasing the average size effect. The coefficient for violations is positive, suggesting that an increase in the number of violations increases the number of injuries. Thus, a reduction in the number of violations likely reduces the number of injuries. Finally, the number of reactive complaints increases the likelihood of having injuries. The last two variables combined may represent a good proxy for the extent to which worksites care for safety or regulations.

A New Allocation Rule

Table 5 presents the values of the estimated coefficients from equation (3) for each economic sector. Coefficients are estimated and are all negative, suggesting that inspections decrease the number of injuries in each sector. With the exception of the Energy and Mining sector, all coefficients are significantly different from zero at least at the 90% level.

The reader should notice the important differences in the magnitude of the coefficients. For instance, the Banking sector has an estimated impact of -14.57, which is approximately twice the magnitude of the second highest coefficient in the Postal Contractors sector. The interpretation of each coefficient is that an increase in the number of inspections by 1% at a particular site will decrease the number of injuries by an average of 14.57 at a site in that sector. The sector with the smallest responsiveness is the Energy and Mining sector, where a 1% increase in the number of inspections only decreases the number of injuries by 0.25.

The second column shows the inferred efficient-policy allocation based on the calculated coefficients. The second column measures the percentage of inspections that should be allocated to each sector under an efficient policy (the solution to equation (6)).

An intuitive approach to understanding the efficient allocation of resources is to consider the following example. A 1% increase in the number of inspections in the Banking sector amounts to one additional inspection every nine years. This additional inspection can easily be shifted from the Road Transport sector, which undergoes roughly 1,800 inspections annually. The reader should intuitively understand that this displacement of inspections decreases the overall number of injuries: these additional inspections reduce the number of injuries by 15 in the Banking sector, while the diminution of inspections in the Road Transport sector increases injuries by less than .1%. Repeating this displacement of inspections between sectors as often as there is a net gain in injuries will provide the efficient solution. An efficient solution is obtained when equation (6) is satisfied for all sectors.

Table 5: Estimation of Equation 3(Instrumented) and Efficient Policy Weights

	$\Delta disab_{it}$	
	Log of the number of inspections in...	**Efficient allocation (%)**
Water transport	-7.080*	0,0229
	(4.211)	
Longshoring	-1.401*	0,0023
	(0.761)	
Rail Transport	-1.923***	0,0079
	(0.633)	
Communications	-3.632***	0,0558
	(1.020)	
Road Transport	-1.843***	0,1472
	(0.305)	
Air Transport	-1.638***	0,0173
	(0.256)	
Broadcasting	-6.748***	0,1208
	(2.312)	
Banking	-14.57***	0,4150
	(3.014)	
Grain Elevators	-1.215	0,0027
	(0.954)	
Feed, Flour, and Seed	-1.380*	0,0071
	(0.756)	
Energy and Mining	-0.247	0,0000
	(2.237)	
Public Service	-1.572***	0,0276
	(0.326)	
Postal Contractors	-8.313***	0,1547
	(1.718)	
Crown Corporations	-4.956*	0,0106
	(2.539)	
Aboriginals	-3.272*	0,0083
	(1.970)	
Observations	167,206	

Source: FJID, 2015, LA2000, 2015 and calculations. *Note*: Sectors marked with an asterisk (*) are constrained.

Only one exception to this rule is identified: when the marginal decrease in the number of injuries exceeds the actual number of injuries occurring in a sector. In that case, the increase in the number of inspections should decrease the average number of injuries to zero. A good example is the Water Transport sector. An allocation of 2.29% of inspections, as the unconstrained efficient rule would suggest, would decrease the number of injuries by an average of 3,000 injuries, which is clearly excessive because only an average of 176.6 injuries have been recorded in the past five years. Doubling inspections (precisely, a 102.9% increase) is sufficient to decrease the average number of injuries to zero. When this situation occurs, these sectors are said to be *constrained*. When a sufficient number of injuries are recorded in the sector, the allocation should then follow the efficient allocation rule provided by equation (6).

The proposed policy is described in detail in Table 6. Sectors marked with an asterisk are constrained. The first panel (6a) describes three counterfactual policies in terms of injuries (results), while the second panel describes the same policies in terms of inspections (means). The first column presents the current average number of injuries in each sector over the last five years. It describes the state of injuries within firms based on the current targeting tool. The next column presents the number of injuries that would occur if no inspections were performed. Because inspections reduce the number of disabling injuries, this counterfactual condition represents an overall increase in injuries.

The third and fourth columns present the impact of the efficient allocation in terms of both injuries and percentages. The "takeaway" is that the new efficient allocation approach reduces injuries by 18.17% on average. The last two columns also show an efficient allocation of resources, with a 10% increase in the number of proactive inspections. This increase in the number of inspections would translate to a 23.33% reduction in the number of injuries compared to the current allocation.

The columns of the second panel (6b, below) refer to the same counterfactual policies as the first panel, but now focus on inspections rather than injuries. The third and fourth columns show a significant departure from the current allocation of inspections. For instance, 59% and 18% decreases in the numbers of inspections are observed in the Air and Road Transport sectors, respectively. Freeing inspections from these sectors provides resources that can be redistributed to sectors where inspections have a greater impact. In particular, inspections in the Postal Contractor, Crown Corporations and Banking sectors increase by 362%, 180% and 77%, respectively. To a lesser extent, an increase is also observed in the Public Service, Grain Elevators and Communications sectors. Longshoring, Rail Transport, and Flour and Seed sectors also achieve a modest increase in the number of inspections.

Table 6a: Efficient Allocation of Inspections

	Inspections					
	Current	None	Efficient	Change (%)	Efficient (+10% insp.)	Change (%)
Water Transport (*)	26	0	52.25	102.91	52.25	102.91
Longshoring	100	0	10.00	-90.00	11.28	-88.72
Rail Transport	102	0	81.55	-20.05	92.03	-9.78
Communications	273	0	351.64	29.04	396.82	45.62
Road Transport	1412	0	1146.49	-18.80	1293.80	-8.37
Air Transport	479	0	195.66	-59.11	220.80	-53.86
Broadcasting	95	0	93.55	-1.53	105.57	11.13
Banking (*)	57	0	100.81	77.64	100.81	77.64
Grain Elevators (*)	49	0	113.45	130.36	113.45	130.36
Feed, Flour, and Seed	128	0	44.54	-65.21	50.26	-60.74
Energy and Mining	9	0	0.55	-94.05	0.62	-93.29
Public Service	312	0	521.40	67.38	588.39	88.89
Postal Contractors (*)	63	0	289.32	362.92	289.32	362.92
Crown Corporations	48	0	134.71	180.65	152.02	216.71
Aboriginal (*)	162	0	176.58	9.34	176.58	9.34
Total	**3313**	**0**	**3313**	**0.00**	**3644**	**10.01**

Source: FJID, 2015, LA2000, 2015 and calculations. *Note*: Sectors marked with an asterisk (*) are constrained.

Table 6b: Impact of the Efficient Allocation of Inspections

	Injuries					
	Current	No insp.	Efficient	Change (%)	Efficient (+10% insp.)	Change (%)
Water Transport (*)	176.60	355.25	0.00	-100.00	0.00	-100.00
Longshoring	37.00	145.40	131.82	256.28	130.14	251.72
Rail Transport	332.80	518.95	368.60	10.76	350.17	5.22
Communications	491.00	1422.34	240.28	-51.06	100.70	-79.49
Road Transport	4131.00	6607.65	4578.51	10.83	4329.24	4.80
Air Transport	2130.20	2850.26	2541.13	19.29	2502.97	17.50
Broadcasting	401.60	959.67	409.07	1.86	347.92	-13.37
Banking (*)	617.40	1432.61	0.00	-100.00	0.00	-100.00
Grain Elevators (*)	75.40	134.62	0.00	-100.00	0.00	-100.00
Feed. Flour. and Seed	65.40	227.80	168.20	157.18	160.79	145.86
Energy and Mining	1.20	3.29	3.16	163.15	3.14	161.71
Public Service	2886.00	3365.51	2573.84	-10.82	2475.97	-14.21
Postal Contractors (*)	1657.40	2164.45	0.00	-100.00	0.00	-100.00
Crown Corporations	196.60	425.42	-176.68	-189.87	-245.88	-225.06
Aboriginal (*)	45.40	553.02	0.00	-100.00	0.00	-100.00
Total	**13245.00**	**21166.25**	**10837.93**	**-18.17**	**10155.18**	**-23.33**

Source: FJID, 2015, LA2000, 2015 and calculations. *Note*: Sections marked with an asterisk (*) are constrained.

Conclusions

This paper provides evidence supporting the hypothesis that organizational health and safety proactive inspections performed at worksites under federal jurisdiction reduce the number of disabling injuries in the workplace. With the allocation rule used by the government as an instrument for inspections, one inspection reduces the number of disabling injuries by 0.33 in the year following the inspection compared to the year of the inspection. In other words, approximately three inspections are required to decrease the number of disabling injuries by one.

When estimates are desegregated by economic sector, a wide range of differences in the responsiveness of firms to inspections is identified, suggesting that an efficient allocation of inspections should consider these differences. Based on these estimates, an alternative approach to allocating inspections across industries that increases the efficiency by which inspections reduce injuries is suggested. This approach leads to the displacement of inspections from the Air and Road Transport sectors to other sectors, such as Banking, Postal Contractors and Crown Corporations sectors. The estimates presented in this paper suggest that this reallocation of inspections would reduce the number of disabling injuries by an additional 18%. The new allocation is robust to changes in the estimated coefficient.

Acknowledgments

I am thankful to Maxime Champagne, Craig Eschuk, Tristan Harrisson, Brian LaGroix, Rodney Noseworthy, Maria Spielauer, Tammy Salomon, David Wilkinson, participants of the Labour Program seminars and participants to the session of the Canadian Economics Association for their comments, suggestions and edits. All errors remain my own.

References

1. Association of Workers Compensation Boards of Canada. Detailed Key Statistical Measures Report. [Internet]. Canada: Association of Wroker Compensation Boards of Canada; 2017[Accessed: 02-Oct-2017]. Available: http://awcbc.org/?page_id=9759.
2. Scholz JT, Gray WB. OSHA enforcement and workplace injuries: A behavioral approach to risk assessment. J Risk Uncertain. 1990;3(3):283–305.
3. Haviland AM, Burns RM, Gray WB, Ruder T, Mendeloff J. A new estimate of the impact of OSHA inspections on manufacturing injury rates, 1998-2005. Am J Ind Med. 2012;55(11):964–75.

4. Mendel Off J, Gray WB. Inside the Black Box: How do OSHA Inspections Lead to Reductions in Workplace Injuries?. Law & Policy. 2005;27(2): 219–37.
5. Gray WB, Scholz JT. Does Regulatory Enforcement Work? A Panel Analysis of OSHA Enforcement. Law Soc Rev. 1993;27(1):177.
6. Tompa E, Trevithick S, McLeod C. Systematic review of the prevention incentives of insurance and regulatory mechanisms for occupational health and safety. Scand J Work Environ Health. 2007;33(2):85–95.
7. Smith RS. The impact of OSHA inspections on manufacturing injury rates. J Hum Resour. 1979;14(2):145–70.
8. Viscusi WK. The Impact of Occupational Safety and Health Regulation. Bell J. Econ. 1979;10(1):117.
9. Bartel AP, Thomas LG. Direct and indirect effects of regulation: a new look at OSHA's impact. J. Law Econ. 1985;28(1):1–25.
10. Employment and Social Development Canada. Hazardous occurrence investigation recording and reporting. Canada: Government of Canada[Internet]. 2017[Accessed: 02-Oct-2017]. Available: https://www.canada.ca/en/employment-social-development/services/health-safety/reports/hazardous-occurrence.html.
11. Employment and Social Development Canada-Labour. Occupational health and safety - Priority sectors. Canada: Government of Canada[Internet]; 2017[Accessed: 02-Oct-2017].. Available: https://www.canada.ca/en/employment-social-development/services/health-safety/priority-industries.html.
12. Solomon T. Occupational Health and Safety (OHS): Planned Interventions and the Targeting Tool. ESDC internal document; 2009.

Appendix A. Economic Sectors and Regions of Operations

This appendix presents the economic sectors and regions of operations in which some sectors are targeted.

Table A1: Regions of Operations for Labour-related Inspections

Region	Provinces/Territories
Atlantic Provinces	New Brunswick, Newfoundland, Nova Scotia and Prince Edward Island
Québec	Québec
Ontario	Ontario
Central Provinces	Manitoba and Saskatchewan
Northwest Pacific	Alberta, British Columbia, Northwest Territories, Nunavut and Yukon

Source: [11]

Table A2: Sectors under Federal Jurisdiction and OHS Priorities

Sector (*s*)	National Priority (2015–2017)	Regional Priority (2015–2017)
Aboriginal Reserves	No	No
Air transport	Yes	No
Banks	No	No
Crown Corporations	No	No
Federal Public Services	No	Ont
Feed, Flour and Seed Mills	Yes	No
Grain Elevators	No	Central
Interprovincial Canals and Pipelines	No	No
Interprovincial Ferries, Tunnels, Bridges and Causeways	No	No
Interprovincial Road Transport	Yes	No
Mining and Mineral Processing	No	No
Postal Services	No	No
Radio and Television	No	No
Rail transport	No	Ont, Qc and Central
Shipping: Water Transport	No	
Shipping: Harbour Activities and Longshoring	No	Atl, Qc and NW Pacific
Telephone, Telegraph and Communications Systems	No	No

Source: [12]