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Firm behaviour and emissions under emission intensity  
regulation: Evidence from Alberta's Specified Gas  
Emitters Regulation

Deepak Rajagopal

October 17, 2014

# Firm behaviour and emissions under emission intensity regulation: Evidence from Alberta's Specified Gas Emitters Regulation

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October 17, 2014

## Abstract

We analyze firm-level data from one of the first economy-wide greenhouse gas (GHG) emission intensity (EI) regulations, the Specified Gas Emitters Regulation (SGER) adopted in 2006 by Alberta, a Canadian province that contains the world's second largest reserves of crude oil in the form of oilsands. After developing a theoretical model of firm behavior under a generic EI regulation, we test hypotheses concerning the impact of an SGER-like EI regulation on firm-level emissions and emission intensity and the cost-effectiveness of GHG reduction from industrial operations. We find that, not in contradiction to theory, the regulation had no significant impact on annual emissions or the emission intensity of the average regulated facility across any of the sectors except the pulp and paper industry. Facilities achieved partial compliance predominantly through the purchase of offset credits from unregulated sectors and made penalty payments to a carbon fund in lieu of remaining "owed" emissions. We discuss the implications of these findings for some prominently cited estimates of marginal cost of GHG abatement and more broadly for the design of emission intensity standards.

*Keywords:* environment, pollution, tax, regulation, permits, offset, oilsand

*JEL codes:* Q52, Q54, Q58

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# 1 Introduction

In the context of greenhouse gases (GHG) and climate change, targets for emissions intensity (EI) of output (physical or economic), or, equivalently, targets for reduction in emission intensity, appear a politically more palatable alternative to the economists' prescription to price emissions either directly, through an emission fee or indirectly through tradable emission permits. A political impediment to enactment of emission taxes is that they take too much revenue away from polluters who tend to have considerable political power (Farrow, 1995; Felder and Schleiniger, 2002; Pezzey, 2003). One approach to limiting revenue loss to polluters so as to improve the political feasibility of taxes while maintaining the incentives for long-run economic efficiency is to grant 'rebates'<sup>1</sup> on taxes on infra-marginal emissions. The Swedish program to reduce Nitrogen oxides from large stationary sources that began in 1992 is an example of one such approach (Stern and Höglund Isaksson, 2006). The equivalent strategy for a system of tradable emission permits (TEP) is to freely distribute emission allowances (a portion or the entire amount) as opposed to a pure auction of all the allowances.

Rebates on infra-marginal emissions or grand-fathering of historical emissions notwithstanding, polluters may yet oppose policies aimed at reducing total emissions if such policies are likely to restrain growth in production even if they adopt the most environment friendly method of production and lead to higher foregone profits. It is well known that emissions policies lead to less output, higher prices and less employment relative to an emission intensity standard (Hochman and Zilberman, 1978). These concerns are amplified when regulated firms compete in an international market and firms outside the jurisdiction are exempt from similar levels of regulation and, which are more justifiable in the context of global pollution to which regulated firms contribute a small share. With incomplete regulation, pollution

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<sup>1</sup>Referred to variously in the literature as 'subsidies', 'exemptions', 'thresholds', or 'allowances'

reduction by regulated facilities could be accompanied by a counter-acting increase in pollution from unregulated facilities, a phenomenon often referred to as leakage, which is a source of inefficiency, one that is especially relevant to global externalities. Under these conditions, it has been shown that an EI standard can dominate the optimal emission tax (or the equivalent tradable emission permit system), because the implicit subsidy for output avoids leakage (Holland, 2012).

Emission intensity regulations are effectively a combination of an implicit tax on emission and an implicit subsidy to output (Fischer, 2001). In addition to the fact that emissions can absolutely increase under EI regulations like under an emission tax but unlike under an emission cap, the implicit output subsidy ensures higher level of output for any given level of emissions relative to emission pricing. This could be one rationale for the greater global support for reducing the rate of growth in GHG emissions as opposed reducing them absolutely (Pizer, 2005; Newell and Pizer, 2008). EI regulation is also less costly both relative to a pure subsidy for cleaner production, be it explicit or implicit as with clean energy mandates, and energy efficiency regulations, for achieving a given environmental outcome. For instance, under EI regulation it would be feasible, up to a limit depending on the stringency of the target, to switch from coal to natural gas or simply use coal more efficiently both of which can reduce emissions and might be less costly than switching to zero carbon fuels under some conditions.

While there is a large theoretical literature on EI regulation as an alternative to emission pricing and renewable energy policies and on designing EI regulation to be as cost-effective as possible through means such as choosing the proper index for measuring the emissions rate (say physical output or input, economic output) (Helfand, 1991), and incorporating features such as trading and banking of emission credits (Tietenberg, 1985), the empirical evidence on GHG standards is relatively scarce, partially attributable to the limited number

of real instances of this approach.<sup>2</sup> In this paper, we first develop a theoretical model of firm behavior under an EI regulation and then econometrically test the predictions of the model using evidence from one of the first province-wide GHG emission intensity regulation in North America (described in the next paragraph). Specifically, we focus on the impact of this regulation on emissions and emission intensity of facilities in different producing sectors. We also analyze the compliance behavior of regulated facilities, which, provides some indirect evidence about the marginal cost of GHG abatement (we lack data necessary to estimate the true cost) in industrial operations.

## 1.1 Alberta's Specified Gas Emitters Regulation (SGER)

At an estimated 168 billion barrels, the Canadian province of Alberta's reserves of oilsands are the second-largest proven reserves of crude oil in the world, the largest being Saudi Arabian reserves (Timilsina et al., 2005).<sup>3</sup> Oilsand extraction and related activities in Alberta have witnessed a cumulative investment of over CAD<sup>4</sup> 140 billion between 2000 and 2011 with a further investment of CAD 350 billion (in 2010 CAD) expected between 2012 and 2035. Annual production of synthetic crude oil from oilsand is currently about 1.8 million barrels per day and comprises over half of Canada's oil production. Production of synthetic crude oil from oilsands is estimated to be about 10% to 20% more GHG-intensive relative to production of conventional crude oil (Charpentier et al., 2009) and oilsands extraction accounts for 7.8% of Canada's GHG emissions. It is on account of its vast oilsand reserves and the rapid expansion this sector is experiencing that Alberta's GHG policies merit a rigorous assessment.

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<sup>2</sup>As the final draft of this paper was being written the US Environmental Protection Agency on June 2<sup>nd</sup> 2014 proposed a Clean Power Plan Rule which sets state-specific targets for CO<sub>2</sub> per MegaWattHour of electricity from fossil fueled power plants in the US <http://www2.epa.gov/carbon-pollution-standards/clean-power-plan-proposed-rule>

<sup>3</sup><http://www.energy.alberta.ca/oilsands/791.asp>

<sup>4</sup>Canadian Dollar

In 2006, Alberta adopted the Specified Gas Emitters Regulation (SGER)<sup>5</sup>. This regulation requires that facilities, which emit more than 100,000 tonnes CO<sub>2</sub> equivalent greenhouse gases per year, and which were in operation prior to the year 2000, reduce their emissions intensity by 12%, as of July 1, 2007. Facilities that became operational after 2000 are provided a gradually increasing annual target for emission intensity reduction of their output that eventually amount to a 12% reduction. Facilities that began operations after 2007, are exempted from requiring to reduce emission intensity for their first three years of operation. Each regulated facility can comply with the regulation in four different ways – i) it could improve its own performance say by becoming more energy efficient, switching to cleaner fuels and processes or end of pipe treatment; ii) acquire emission credits generated by other regulated facilities that have exceeded their compliance target; iii) acquire emission credits generated by unregulated facilities within Alberta, and these are called as offset credits; or iv) pay a penalty of \$15 per tonne of carbon dioxide emissions they failed to abate. The quantity of emissions “owed” to which the penalty applies is computed as product of the difference between the actual emission intensity during a given year and the target emission intensity for that year and the output in the given year (see Equation (2) in Section 2). The penalty payments are deposited in to the Climate Change and Emissions Management fund that is used to support R&D and demonstration projects aimed at developing new GHG mitigation technologies. SGER is considered to be the first phase of a longer run commitment by Alberta to reducing GHG emissions, which is set to expire in 2014. The targets and rules for the second phase are currently under deliberation. A salient aspect of SGER is that by dictating a uniform target for emission intensity reduction for each regulated facility, it allows for different levels of emission performance for different facilities even within a given sector. In other words, it does not strive to achieve a uniform level of of emissions performance within each sector, let alone a uniform level of emissions performance per unit

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<sup>5</sup><http://environment.alberta.ca/0915.html>

of economic output economy-wide.<sup>6</sup>

A motivation of this paper is to understand the behavior of firms under environmental regulation and test how well the empirical evidence accords with the theoretical insight on the impact on different variables of interest. Another goal is to see whether there exists some evidence for the abundance of low or negative cost CO<sub>2</sub> abatement in industrial settings as predicted by some prominent studies. For instance, Enkvist et al. (2007) of McKinsey & Company, state that there is potential for about of 0.6 to 0.8 gigatonne of CO<sub>2</sub>e abatement at negative “lifecycle” cost through improvements to industrial processes, combined heat and power generation and efficiency improvements in electric power plants. They do however note that despite being negative lifecycle cost, these projects might be capital intensive and so compete with projects with higher internal rate of return, a point we return to later. A US National Academies (2010) report titled *Real Prospects for Energy Efficiency in the United States* (NAS, 2010), which relies on Enkvist et al. (2007) as one of the sources of data, also concludes that there is potential to save 3.9 quads in annual energy-usage using investments with an internal rate of return of 10% or higher (NAS, 2010). In the SGER, given that a firm could pay a penalty of \$15 per tonne of emissions “owed” due to non-compliance, this represents an upper limit on the marginal abatement cost incurred by firms. Thus, if a major mode of compliance is via actual onsite emission intensity reduction or through the purchase of emissions performance credits from other regulated facilities, then this provides some indirect support to the claims made by the studies cited above. If, however, this is not the case, it calls for caution towards engineering-based cost estimates, the reasons for which several economists have already laid out (see Gillingham et al. (2009) for a comprehensive review of this literature).

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<sup>6</sup>Personal communications the author had with Mr. Bob Savage, the former Director of the Climate Change Secretariat at Alberta Environment, the agency implementing the SGER, revealed that a rationale for selection of a uniform target for facility-level emission intensity reduction, as opposed to a uniform target for sector-wide performance, which from an economic standpoint appears more intuitive, is to encourage all facilities to improve and not concentrate improvement in narrow set of facilities



Although there exist but a few real world examples of EI regulation for GHGs, indexed regulations, the broad class of regulations with which EI regulation can be associated, are more frequently encountered. These regulations take the form of limits on pollution per unit of input or output, regulation of use of polluting inputs (e.g. pesticides), minimum energy or fuel efficiency standards (e.g. automobile fuel economy standards) etc. See (Helfand, 1991) for a detailed theoretical comparison of firm behavior under different types of standards. In the United States, prominent examples of intensity-based regulations include, New Source Performance Standards (NSPS) that dictate the level of pollutant per unit of discharge from new industrial facilities<sup>7</sup>, minimum energy efficiency standards for appliances and automobiles (first established under the Energy Policy and Conservation Act of 1975)<sup>8</sup>, the approach used in the phase-down of lead in gasoline<sup>9</sup> and Renewable Portfolio Standards that dictate the share of electricity to be derived from renewable sources. A recent and prominent example of a GHG intensity standard is the California Low Carbon Fuel Standard, which mandates reduction in greenhouse gas (GHG) intensity of transportation fuels consumed in California. GHG EI regulation has received serious consideration at the US federal level for both electricity and transportation fuels (Holland et al., 2009; Burtraw et al., 2012; Huang et al., 2013). The SGER is unique in that it is amongst first economy-wide (agricultural and forestry emissions excluded) GHG performance standard.

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<sup>7</sup>See <http://www.epa.gov/compliance/monitoring/programs/caa/newsources.html>

<sup>8</sup>See [http://www1.eere.energy.gov/buildings/appliance\\_standards/](http://www1.eere.energy.gov/buildings/appliance_standards/)

<sup>9</sup>See <http://www.epa.gov/history/topics/lead/02.html>

## 2 Model of firm behavior under emission intensity regulation

We present a model of a competitive profit-maximizing firm<sup>10</sup> under emission intensity regulation with an option to default and simply pay a tax as a penalty for non-compliance, and develop some hypotheses concerning the impact on emissions, output and emission intensity. The default option of paying a tax penalty is similar to the safety-valve under a tradable emission permit system, which represents an upper-limit on the permit price at which the regulator issues an unlimited number of permits. It is an upper-bound on the marginal expenditure on emission abatement incurred by a regulated facility. Let  $p$  denote the output price,  $q$  the quantity produced,  $Z$  and  $z$  represent the firm's total emissions and emission intensity of output.  $C(q, z)$  is a cost function with the following usual properties: increasing marginal cost i.e.,  $C_q > 0, C_{qq} > 0$ ; decreasing in average emission intensity,  $C_z < 0$  but at a declining rate i.e.,  $C_{zz} > 0$ . Finally, for the cost function to be convex, we will assume  $C_{qq}C_{zz} - [C_{qz}]^2 > 0$ . The firm has  $K$  different means to offset a portion of its own emissions, say through the purchase of emission performance credits or offset credits. Let the cost of the  $k^{th}$  option,  $k \in K$ , be  $C^a(Z_k^a)$ , where  $Z_k^a$  is the emissions offset. Let  $\bar{\gamma}$  denote the emission intensity target<sup>11</sup> and let  $\tau$  represent the carbon tax per unit of emissions owed by the facility when it fails to ensure that its effective emission intensity is below the target, where effective emission intensity is computed as follows

$$z_{eff} = \frac{zq - \sum_{k=1}^K Z_k^a}{q} = z - \frac{\sum_{k=1}^K Z_k^a}{q} \quad (1)$$

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<sup>10</sup>Note that even though the regulation is at the facility level, the intuition extends to the firm-level since, with the opportunity to purchase (and sell) emission credits a firm faces the same opportunity costs of investment in onsite abatement as it would if the regulation applied to each individual firm as opposed to each individual facility

<sup>11</sup>The SGER although it only specifies an emission intensity reduction target, it effectively nevertheless implies an emission intensity target for each facility. Say the regulation requires an  $\alpha\%$  reduction in emission intensity with respect to a base value of emission intensity  $\gamma_0$ . Then we can write  $\bar{\gamma} = (1 - \alpha)\gamma_0$

where,  $zq$  is the emissions from production and  $\sum_{k=1}^K Z_k^a$  denotes the total emissions abated by the various means. If  $z_{eff} > \bar{\gamma}$ , then the firm owes emissions, then

$$Z_{owed} = [z_{eff} - \bar{\gamma}]q \quad (2)$$

The firm pays emission taxes equal to  $\tau[z_{eff} - \bar{\gamma}]q$ . A profit maximizing firm would perform the following calculus with respect to output, emission intensity and abatement:

$$\begin{aligned} \max_{q, z, Z_k^a} \Pi &= pq - C(q, z) - \sum_{k=1}^K C^a(Z_k^a) - \tau Z_{owed} \\ &= pq - C(q, z) - \sum_{k=1}^K C^a(Z_k^a) - \tau [z_{eff} - \bar{\gamma}]q \\ &= pq - C(q, z) - \sum_{k=1}^K C^a(Z_k^a) - \tau \left[ zq - \sum_{k=1}^K Z_k^a - \bar{\gamma}q \right] \end{aligned} \quad (3)$$

Equation (3) is similar to the familiar profit maximization in the presence of a pigouvian tax  $\tau$  on emissions but with modification that a portion of the tax collected is rebated back to the firm. The rebated amount in this case is equal to the tax multiplied by the target emission intensity. In other words, the taxes are owed only on the portion of total emissions and that too when the firm fails to meet a target performance. This also has similarities to a system of tradable permits with partial free allocation. So long as the rebated (or exempted or subsidized) portion is independent of firm's behavior this approach remains cost-effective. However, since in case of the EI regulation, the rebated amount,  $\tau\bar{\gamma}q$ , is in proportion to the quantity produced, which is the firm's decision, this approach is not cost-effective. Differentiating Equation (3) with the respect to  $q, z, Z_k^a$ , we get the following first

order conditions (FOC) respectively:

$$p - \frac{\partial C}{\partial q} - \tau[z - \bar{\gamma}] = 0 \quad (4)$$

$$-\frac{\partial C}{\partial z} - \tau q = 0 \quad (5)$$

$$-\frac{\partial C^a}{\partial Z_k^a} + \tau = 0 \text{ for each } k \in K \quad (6)$$

*Proposition 1:* When compared to any given level of a pure emission tax, an emission intensity regulation which provides an option to pay a tax on “emissions owed” instead of achieving compliance, would lead to higher output, higher profits and either a higher or lower emission intensity and emissions

*Proof:* The profit maximization calculus in the presence of a pure tax of the same level,  $\tau$ , as the penalty per unit of emissions owed for non-compliance with the EI regulation is

$$\begin{aligned} \max_{q, z, Z_k^a} \Pi &= pq - C(q, z) - \sum_{k=1}^K C^a(Z_k^a) - \tau Z \\ &= pq - C(q, z) - \sum_{k=1}^K C^a(Z_k^a) - \tau zq \end{aligned} \quad (7)$$

Comparing Equation (3), to Equation (7), we can see why an emission intensity standard is effectively a combination of an emission tax and output subsidy. The profit under the emission standard is higher by the amount  $\tau\bar{\gamma}q$ . For a pure tax, we would have  $p - \frac{\partial C}{\partial q} - \tau z = 0$  or  $p - \tau z = \frac{\partial C}{\partial q}$ . However, for the EI regulation, we have  $p - \tau[z - \bar{\gamma}] = \frac{\partial C}{\partial q}$ . The left hand side expression under the EI regulation,  $p - \tau[z - \bar{\gamma}]$  is greater compared to that under a pure tax,  $p - \tau z$ . Now since the right hand side in both cases is the marginal cost of production, the marginal cost of production is higher under the EI regulation in equilibrium. Under our assumption that  $\frac{\partial C}{\partial q} > 0$ , a higher marginal cost implies higher output in equilibrium under an emission intensity standard.

With respect to profits, again comparing Equation (3), to Equation (7), we can see that  $\Pi^{EIS} = \Pi^{Puretax} + \tau\bar{\gamma}q$  which implies that  $\Pi^{EIS} > \Pi^{Puretax}$ .

The proof for the impact on emissions intensity and emissions is shown together with the proof for Proposition 2, which follows.

*Proposition 2:* Under an SGER-like policy, i.e., emission intensity regulation with an option to pay a tax in lieu of compliance, for any given firm, all else constant, emission intensity, emissions and output, would each either decline or be unaffected.

*Proof:* See the appendix for a detailed mathematical proof. In the following discussion, it is assumed that all else except the policy parameters are fixed. To see the intuition behind the proposition, let us analyze the effect of each of the two policy parameters – the emission intensity limit for a firm and the tax rate for emission owed under non-compliance with the intensity limit in isolation. Imposing an emission intensity limit when none existed before cannot by itself cause a firm to increase its average emission intensity further. However, a firm may choose not to reduce its own emission intensity reduction if the total cost of compliance exceeds the tax liability for non-compliance. For this reason, the emission intensity may not decline. However, the additional cost due the regulation should cause a competitive firm to reduce its output. Since both the average emission intensity and output cannot increase, a firm's emissions also cannot increase with the imposition a constraint that a firm's emission intensity has to decline.

Similarly, imposing a tax on excess emissions i.e., emissions owed, we can see that this cannot cause a firm to increase output or emissions by itself. With neither emissions nor output increasing, average emission intensity cannot increase either.

### 3 Empirical analysis

To test the theoretical propositions stated above, we analyze facility-level data from regulated firms within Alberta and unregulated firms both within Alberta and the rest of Canada.

#### 3.1 Data

The data for the empirical analysis is derived from two different sources combined together. One source is that reported under the Specified Gas Reporting Regulation (SGRR), a program adopted by Alberta in 2003 requiring all facilities emitting over 100,000 tonnes of carbon dioxide equivalent (CO<sub>2</sub>e) annually to report their emissions. This contains data that includes annual facility level emissions for various types of GHGs, the NAICS industry code and location, for all reporting facilities within Alberta.<sup>12</sup> A second related source is reporting under the SGER, which contains data on various compliance modes (discussed earlier) and the emission intensity of production for each regulated facility with Alberta.<sup>13</sup> Given the emissions and the emission intensity for a facility within Alberta, we impute the output for each reporting facility as the ratio of emissions to emission intensity. The third source of data is the Environment Canada's Greenhouse Gas Emissions Reporting Program, which also contains facility level data on annual emissions for facilities on Canada that required to report under this program.<sup>14</sup> The Canada GHG reporting program requires that facilities emitting 50,000 metric tonnes or more of GHGs per year in carbon dioxide equivalent units (CO<sub>2</sub>eq) per year report their emissions. This third source provides the controls for identifying the effect of the SGER. For facilities within Alberta we reconciled any differences between the data reported to the two different programs. The data reported to

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<sup>12</sup>This data can be accessed at <http://esrd.alberta.ca/focus/alberta-and-climate-change/regulating-greenhouse-gas-emissions/greenhouse-gas-reporting-program.aspx>

<sup>13</sup>This data can be accessed at <http://esrd.alberta.ca/focus/alberta-and-climate-change/regulating-greenhouse-gas-emissions/greenhouse-gas-reduction-program/default.aspx>

<sup>14</sup>This dataset can be accessed at <http://www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=8044859A-1>

Environment Canada does not include the emission intensity and therefore for regressions in which the dependent variable is the emission intensity, our controls for identifying the effect of the regulation are only those facilities within Alberta that are not required to comply, and these tend to be small emitters compared to the treatment group.

Table 1: Data distribution across sectors and by facility location and regulatory state. Table shows the number of observations under each category

Sector	Regulated	Non-regulated	Total	AB	ROC	Total
Conv. Oil and Gas	123	346	469	338	131	469
Oilsand	107	62	169	136	33	169
Coal	5	55	60	9	51	60
Electricity	104	505	609	189	420	609
Paper and pulp	17	143	160	36	124	160
Oil Refining	12	114	126	21	105	126
Chemicals	22	47	69	32	37	69
Organic Chemicals	15	69	84	31	53	84
Fertilizer	24	45	69	36	33	69
Cement	12	115	127	18	109	127
Pipelines	18	89	107	27	80	107
Landfill	0	161	161	13	148	161
Total	459	1,751	2,210	886	1,324	2,210

Note: AB - Alberta, ROC - Rest of Canada

The different data sources combined provide data on 675 facilities of which 190 were located within the province of Alberta and the dataset spans the period 2004 to 2012. The raw dataset spanned facilities belonging to 83 different sectors based on the NAICS codes. Focussing only on the sectors that span the SGER dataset and excluding problematic observations such as those with missing information for key variables and those containing seemingly erroneous data, our final dataset comprises of 405 facilities of which 152 are located within Alberta and span 12 major industrial sectors. Table 1 shows the distribution of the observations in the dataset across the different sectors by their location and by their

regulatory status.

Table 2: Descriptive statistics

Sector	# of operating facilities				Avg. annual sector total emissions			
	Before 2007		Post 2007		Before 2007		Post 2007	
	AB	ROC	AB	ROC	AB	ROC	AB	ROC
Conv. Oil and Gas	32	12	69	29	7%	4%	7%	6%
Oilsand	9	4	24	5	19%	1%	29%	2%
Coal	0	6	2	10	0%	1%	0%	2%
Electricity	23	50	27	83	54%	56%	48%	53%
Paper and pulp	4	18	4	21	1%	2%	1%	2%
Oil Refining	2	14	3	13	3%	13%	3%	14%
Chemicals	4	5	4	5	4%	2%	3%	2%
Organic Chemicals	4	5	4	12	3%	3%	2%	2%
Fertilizer	4	5	4	4	4%	2%	4%	2%
Cement	2	14	2	14	2%	9%	2%	8%
Pipelines	3	10	3	11	3%	6%	2%	4%
Landfill	1	15	3	34	0%	1%	0%	3%
Total	88	158	149	241	100%	100%	100%	100%

Note: AB - Alberta, ROC - Rest of Canada

Table 2 shows for each sector the number of facilities and average annual sector total emissions as a share of total emissions from a region for each of the two regions, Alberta (AB) and Rest of Canada (ROC) both before and after the regulation. It is worth pointing out that for oil and gas sector and oilsand sector, the number of facilities within Alberta exceed that in ROC. Secondly, with regard to emissions, electricity sector contributes about 50% or more of the total emissions from each region from all the sectors considered here. Thirdly, the share of oilsands sector in total average annual emissions from Alberta appears to have doubled in the post-regulation years, i.e., since 2007, a fact that we account for in the econometric estimations of the impact of regulation that follow.

Figure 1 shows the total annual emissions from all reporting facilities in Alberta and rest of Canada. Emissions from Alberta are increasing during the observed period of 2004 to 2011 while that for the rest of Canada combined is declining. Interestingly, it appears that emissions in rest of Canada started to decline from 2007, the SGER went into effect in Alberta



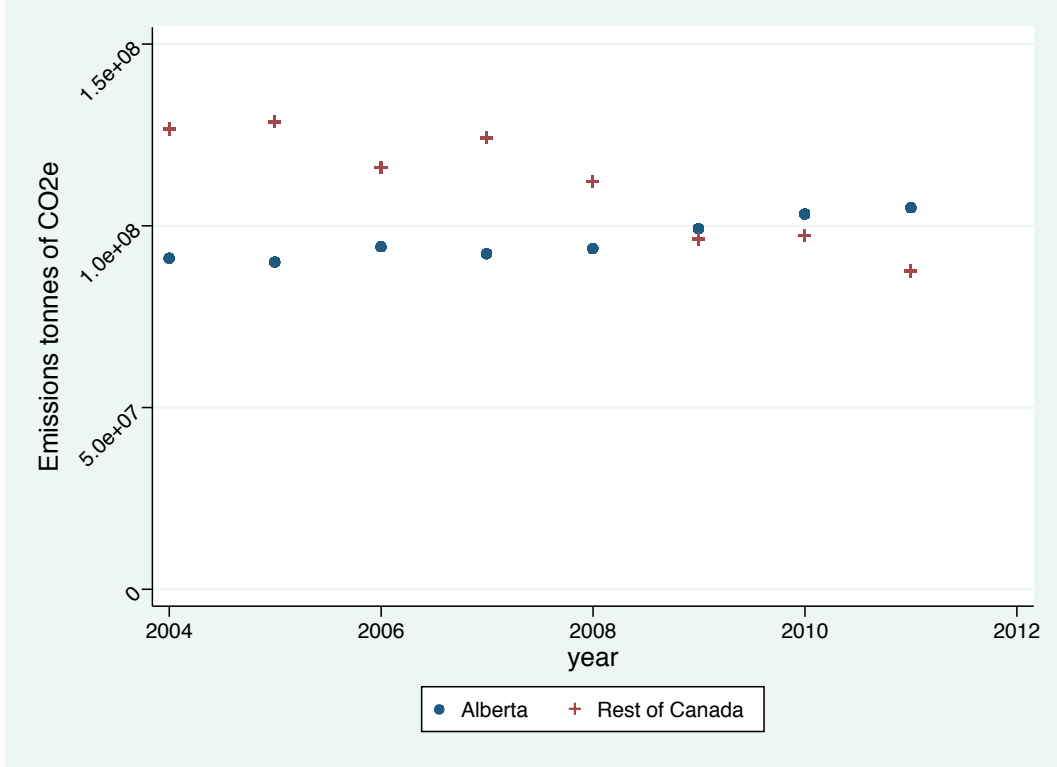


Figure 1: Total annual emissions in tonnes of CO<sub>2</sub> equivalent from all facilities in Alberta and in Rest of Canada.

where as there is such no discernible effect on Alberta’s emissions itself. Figure 2 shows total annual emissions from all reporting facilities in Alberta and rest of Canada for each sector. It shows that for Conventional oil and gas, Oilsands, Fertilizers and Chemicals sectors, annual emissions from Alberta exceed annual emissions from rest of Canada combined. There appears to be a discernible decrease in annual emissions for Electricity, Pipelines and Organic chemicals sectors but not for the other sectors. Oilsands sector in Alberta shows a consistent increasing trend in emissions beginning 2005.

We estimate the average facility-level effect of the regulation on three variables – annual emissions (denoted  $Z^{act}$ ), annual emissions net of abatement via the various modes of compliance, henceforth referred to simply as *effective* emissions (denoted  $Z^{eff}$ ), and the emission intensity of output (denoted  $EI$ ), which is the target of the regulation. Subsequently, we

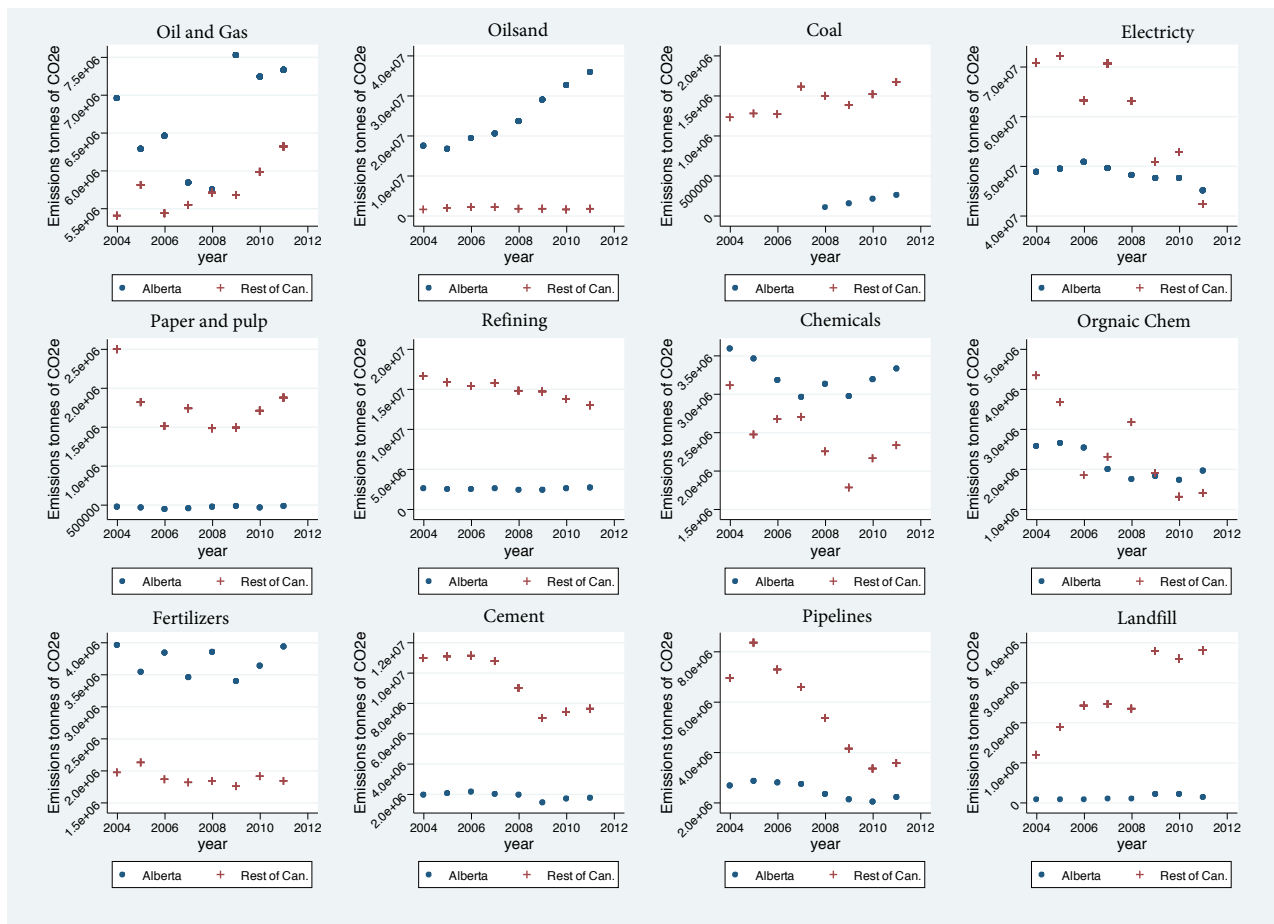


Figure 2: Sector annual emissions in tonnes of CO<sub>2</sub> equivalent from all facilities in Alberta and in Rest of Canada.

analyze, using descriptive statistics, the compliance choices of the regulated firms.

### 3.2 Econometric approach

Identification of the causal effect of SGER on regulated facilities requires that we control for what would have occurred in the absence of the SGER. For this we rely on the difference-in-difference (DiD) technique. One assumption of this technique is that in the absence of the SGER, trends in the dependent variable of interest would have been the same for both regulated and unregulated facilities so that observed differences in trends subsequent to the implementation of SGER are a consequence of the SGER. Regulated facilities within Alberta

are the “treatment” group while unregulated facilities within Alberta and rest of Canada are the controls.

The DiD technique controls for unobserved facility-specific variables that may confound the effect of the SGER. However, this technique cannot control for any exogenous shocks to the treatment group that are temporally coincident with the primary treatment. For instance, in our case, Alberta is unique because of its oilsands resource. Any exogenous shock to the oilsand sector, say due to the global economic boom and the consequent increase in global oil demand in the half-a-decade or more prior to 2007, is likely to make the oilsands sector and other sectors of Alberta’s and Canada’s that are closely linked to oilsands extraction, would cause the DiD technique to mistakenly attribute the observed changes in the affected facilities to the SGER. It is therefore important to ensure that any such coincidental shocks are controlled for. We accomplish this in two ways.

Recall from our earlier discussion that an activity that is salient to Alberta is the mining and extraction of oilsands, a sector that experienced a major increase in the rate of annual investment between 2004 and 2008, and after a temporary decline in 2009, an increase again since 2010 (see Figure 3 that shows the time path of annual investment in oilsand extraction). The figure also shows that the annual rate of investments in conventional oil and gas also increased together with oilsands. We therefore test whether controlling for this additional shock specific to the oilsands and conventional oil and gas sectors in Alberta affects our estimate of the average effect on emissions. We will also test the robustness of the oil sectors’ specific shock by modifying the year from which this shock begins to take effect. We then also conduct several placebo tests by making this additional sector-specific dummy to each of the other sectors in Alberta, one at a time, and show its effects. These tests are discussed in more detailed later.

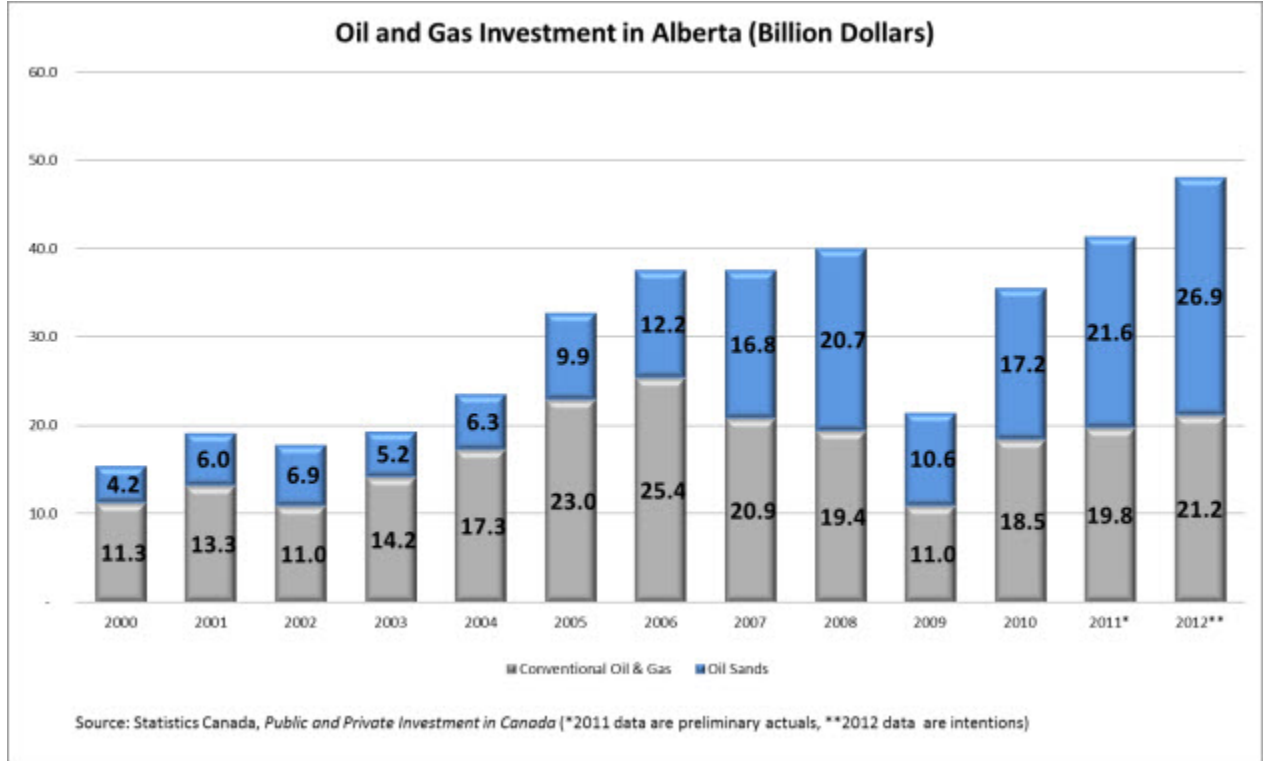


Figure 3: The figure shows the annual investment in new capacity of conventional oil and gas and oilsands in Alberta.

We estimate the following basic model:

$$V_{i,t} = \alpha + \delta I_{i,t}^{SGER} + \phi I_{i,t}^{OS,t > \bar{T}} + \mu_i + \lambda_t + \epsilon_{i,t} \quad (8)$$

where,  $V$  is the dependent variable and we run the basic model for the three variables discussed above,  $i$  represents a facility,  $t$  represents a given year.  $\mu_i$  is a facility fixed effect which controls for differences across facilities such as technology, managerial capacity etc. and  $\lambda_t$  is a year fixed effect that controls for shocks common to all facilities.  $I_{i,t}^{SGER}$  is a binary variable that denotes whether the facility is required to comply. It is assigned the value 1 for facilities within Alberta whose annual emissions exceed 100,000 tones of CO<sub>2</sub> equivalent in the years beginning 2006 and is assigned 0 otherwise. The coefficient  $\delta$  denotes the effect of the regulation on the dependent variable  $V$ .  $I_{i,t}^{OS,t > \bar{T}}$  is another binary variable

that denotes whether the facility is an oilsands extraction facility within Alberta and whether the year of observation is past the threshold year,  $\bar{T}$ , after which the oilsand sector-specific shock is acting.  $\epsilon_{i,t}$  is an idiosyncratic error term that is assumed to be iid. In the following econometric analysis we focus only on sites with a minimum of four years of observations. Since we do not have any other information at the facility level that varies with time, we are therefore only able to explain a small portion of the variation in the dependent variable.

### 3.3 Average effect

Table 3: Impact of SGER - Facility Fixed Effect estimation of Equation (8)

	(1)	(2)	(3)	(4)
	ztot	ztot	zeff	ei
$I_{i,t}^{SGER}$	128444** (52,897)	79,037 (56,419)	-25,004 (57,817)	-.0064 (.0093)
$I_{i,t}^{OS,t>2006}$ (Binary)		200173** (80,438)	251099*** (82,430)	-.0043 (.0076)
N	1,831	1,831	1,831	661
r2	.03	.034	.042	.049

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

We estimate the model in Equation (8) using the fixed effect estimator. Table 3 shows the average effect on the three dependent variables,  $Z^{act}$ ,  $Z^{eff}$  and  $EI$  estimated using the specification in Equation (8). From column (1) it appears that the *ceteris paribus* effect of the regulation was actually an increase in emissions for the average regulated facility. While theory leads us to hypothesize either a negative effect or no effect on emissions as a consequence of an environmental regulation, *ceteris paribus*, a positive effect is harder to reconcile with economic intuition. One possible reason for the result in column (1) might be the omission of any additional shocks that might have overlapped with the time period in question and which served to have a large positive effect on emissions.

With the inclusion of an additional dummy variable for the two oil related sectors in Alberta beginning 2006, the coefficient on the SGER variable is no longer significant (see Column 2). Thus, omission of this sector-specific shock appears to have biased our estimates of the average effect of the regulation shown in Column (1). Column (3) of Table 3 shows that the regulation also had no significant impact on effective emissions, i.e., emissions net of abatement via purchase of emission credits, offsets and fund payments. Finally, facility level emission intensity (Column (4) of Table 3), the actual target of the regulation, too, did not decrease as a result of the regulation. This suggests that the principle modes of compliance with the regulation might have been via the purchase of offsets and fund payments and that emission intensity reduction via actual improvements in performance at the regulated facilities was not a major mode of compliance. Note the relatively smaller sample size since data on emission intensity is reported only for the regulated facilities within Alberta.

To test the robustness of the oil sectors' specific shock we modify the year from which this shock begins to take effect as 2007, 2008, 2009 and 2010. The results are shown in Table 4. The result that the average effect on emissions is one of no significant impact, holds. We then also tested the robustness of the sector-specific shock by arbitrarily making this shock specific to each of the other sectors, one at a time and found that it had no significant impact. In other words the placebo shocks did not absorb away the significance of the coefficient on SGER dummy reported in column (1), which indicates the salience of the shock to the two oil related sectors.

We also repeated the analysis by focussing on sites with both fewer and greater number of observations and confirmed that the inferences hold.

Table 4: Robustness of SGER's effect on actual facility-level emissions to including shock specific to Alberta's oil sectors - Facility Fixed Effect estimation of Equation (8)

	(1)	(2)	(3)	(4)	(5)	(6)
SGER (Binary)	128444** (52,897)	79,037 (56,419)	55,526 (60,174)	56,294 (55,623)	68,446 (53,997)	87,525 (53,317)
$I_{t \geq 2006}$ *AB*Oils (Binary)		200173** (80,438)				
$I_{t \geq 2007}$ *AB*Oils (Binary)			191599** (75,804)			
$I_{t \geq 2008}$ *AB*Oils (Binary)				265148*** (65,981)		
$I_{t \geq 2009}$ *AB*Oils (Binary)					305945*** (63,691)	
$I_{t \geq 2010}$ *AB*Oils (Binary)						306504*** (66,811)
N	1,831	1,831	1,831	1,831	1,831	1,831
r2	.03	.034	.034	.04	.044	.043

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

### 3.4 Sector-specific effects

To disaggregate the effect on the different sectors, we estimate the following modified specification of Equation (8):

$$V_{i,t} = \alpha + \beta X + \sum_{j=1}^J \delta_j I_j I_{i,t} + \mu_i + \lambda_t + \epsilon_{i,t} \quad (9)$$

Where,  $J$  is the number of different sectors,  $I_j$  is a binary variable that takes the value 1 if facility  $i$  belongs to sector  $j$  and 0 otherwise. The co-efficient on the regulation dummy is  $\delta_j$ .

Table 5 shows the sector-specific effects of the SGER on actual emissions, effective emissions and emission intensity, all at the facility-level. With respect to actual facility emissions, we see that the regulation had no significant effect on any sector. For effective emissions, again there is no significant on any sector with the exception of the electricity sector. With respect to emission intensity, there is no significant impact with the exception of paper and pulp sector, which is the only sector to have reduced its emission intensity onsite (see Table 6).

### 3.5 Analysis of compliance modes

#### 3.5.1 Sector-aggregate and annual-aggregate share of compliance modes

We descriptively analyze the compliance data to glean broad trends across the facilities about compliance behavior. Table 6 depicts the share of different modes of compliance summed across all years for each sector. This is computed as follows. Firstly, Net emission reduction = Emission avoided via onsite intensity reduction + Emission Performance Credits (EPC) + Offset credits + Tax payments. Therefore, Fraction of emissions avoided via onsite intensity reduction =  $\frac{\text{Emission avoided via onsite intensity reduction}}{\text{Net emission reduction}}$ , with emissions avoided onsite =



Table 5: Sector-specific impact of SGER - Facility Fixed Effect estimation of Equation (9)

	(1)	(2)	(3)
	ztot	zeff	ei
Conv. Oil and Gas	136957 (87,272)	98,479 (89,299)	-.0083 (.011)
Oilsand	311392 (193244)	262292 (197731)	.0049 (.018)
Electricity	-1,870 (97,915)	-266346*** (100189)	-.0037 (.012)
Paper and Pulp	184345 (181461)	183344 (185675)	-.027* (.015)
Oil Refining	162869 (262519)	56,825 (268615)	.011 (.021)
Chemicals	97,813 (215282)	50,339 (220281)	.024 (.018)
Organic Chemicals	72,145 (237826)	63,180 (243349)	.0095 (.021)
Fertilizer	116529 (187247)	57,070 (191595)	.022 (.016)
Cement	-44,211 (262519)	-69,820 (268615)	-.01 (.021)
Pipelines	32,547 (215282)	-47,025 (220281)	-.014 (.018)
$I_{t \geq 2006}^{*AB*Oils}$ (Binary)	300077 (217528)	301418 (222579)	.000022 (.018)
N	1,644	1,644	614
r2	.046	.058	.082

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table 6: Shares of different compliance modes for each sector summed across all years

	Onsite reduction	EPC	Offset	Tax
Conv. Oil & Gas	-0.02	0.06	0.27	0.70
Oilsand	0.19	0.19	0.23	0.39
Coal	-0.32	0.00	0.35	0.96
Electricity	-0.02	0.07	0.56	0.39
Paper and Pulp	1.00	0.00	0.00	0.00
Oil Refining	-0.07	0.23	0.35	0.49
Chemicals	-0.40	0.13	1.20	0.06
Organic Chemicals	2.61	-0.55	0.00	-1.06
Fertilizer	-1.07	0.38	0.17	1.52
Cement	0.12	0.00	0.63	0.25
Pipelines	0.06	0.00	0.00	0.94

$[z_{t-1} - z_t]q_t$ , where,  $z_t$  is a facility's own emission intensity of production in year  $t$ , and  $q$  is quantity produced. If  $z_t > z_{t-1}$ , then facility's own emission intensity increases with time and emissions avoided onsite is a negative quantity. In Table 6 a negative entry for a compliance mode for a given sector indicates either that the compliance mode contributed to an increase in effective emissions while effective annual emissions declined or alternatively that a given compliance mode contributed to a decrease in effective emissions while there was a net increase in effective emissions. The former is the case for all sectors with the exception of the Organic Chemicals sector which showed an increase in effective emissions despite a net emission reduction. Therefore, conventional oil and gas, coal, electricity, oil refining, chemicals and fertilizers all experienced an increase in facility emission intensity, which contributed to an increase in onsite emissions. Another interesting observation is that the combined share of onsite reduction and emission performance credits in total reduction is a small share of the total emission reduction for almost sectors. The oilsand and paper and pulp sectors are the only two sectors to have a sizable contribution from onsite emission intensity reduction.

Table 7 depicts the share of different modes summed across all sectors for each year.

Table 7: Shares of different compliance modes for each year summed across all sectors

	Onsite reduction	EPC	Offset	Tax
2007	0.00	0.01	0.27	0.73
2008	-0.15	0.04	0.43	0.69
2009	-0.10	0.14	0.54	0.42
2010	0.01	0.16	0.44	0.39
2011	-0.14	0.10	0.74	0.30
2012	0.24	0.03	0.28	0.45

The signs have a similar interpretation to that discussed above. Similar to the trend across sectors, changes in the emission intensity at a facility contributed to an increase in emissions except during the year 2010. And again, offsets and tax payments are the principal modes of compliance. Given the extent of reliance on offsets in the case of the SGER by facilities across all sectors, the additionality and permanence of offsets, is a topic of further research.

The observed compliance behavior of facilities seems to provide some indirect evidence (in the absence of actual cost of abatement) against prominently cited estimates of the cost-effectiveness of CO<sub>2</sub> abatement via improvements to industrial processes such as the study by Enkvist et al. (2007) and the report by the US National Academies (NAS, 2010). Although these studies estimate costs for investments made in the United States, it is plausible to assume similar range of estimates are applicable for Canada as well given the geographic similarities and the technological advancement in both countries. These studies suggest an enormous potential for CO<sub>2</sub> abatement, on the order of about 1 Giga tonne of CO<sub>2</sub>e at negative marginal cost, which means that those investments generate net positive economic returns over the life of the investment (Enkvist et al., 2007). Since we do not have the necessary firm-specific data to estimate marginal abatement cost, we can only hypothesize the plausible reasons. One explanation for the limited contribution of onsite emission intensity reduction and emission performance credits in facilities achieving compliance, both across sectors and in any given year, could be that the marginal cost of industrial CO<sub>2</sub> abatement

might exceed \$15 per tonne forcing firms to choose to comply with the aid of offsets and tax payments. An alternative explanation is that while the marginal cost of abatement might be less \$15 per tonne, such investments may entail a high fixed cost that are not justified given the low level “owed” emissions. Either a low tax rate or not too stringent emission intensity target or both might conspire to reduce the total taxes owed for non-compliance. Recall that taxes are assessed only on emissions owed which is the difference between the facility’s own emission intensity in a given year and the target level of emission intensity, which could be a small fraction of taxes that would be owed when assessed on actual emissions, in a true pigouvian sense.

## 4 Summary

The SGER has not had a negative impact (i.e., caused a decline) on even the emission intensity of regulated facilities, the target of the regulation, let alone emissions. An exception is the pulp and paper sector for which the emission intensity declined for the average facility. This fits with the theoretical model, which suggested that the *ceteris paribus* effect of an SGER-like regulation would be that a firm’s emission intensity would not increase but that it need not also decline if the total cost of compliance is greater compared to the tax liability for non-compliance. Our analysis suggests that perhaps the latter might be the case, but we lack the data to verify this. We are not able to test our hypothesis about the causal impact of SGER on the output from a regulated facility because data on output is not reported for the non-treatment facilities.

With three different means to achieve compliance (on-site performance improvement, purchase of tradable performance credits and purchase of offset credits), we find that across sectors and for each year since the regulation, the predominant strategy of facilities is to purchase offsets and make penalty payments for non-compliance. Reduction in facility emission

intensity and purchase of emission credits from other regulated facilities contributed a minor share. This suggests either that limited opportunities exist for abatement at a marginal cost less than \$15/tonne or that the fixed cost of onsite improvements is sizable enough that it is uneconomical at the current cost of non-compliance and the quantity of “owed” emissions for the average non-compliant facility. This situation is akin to that under the US Federal Corporate Fuel Economy Standards (CAFE), wherein, it has been observed that the monetary incentive for compliance was too low with the result that several automakers consistently choose to pay penalties in lieu compliance (GAO, 2007). Testing either of these hypotheses requires data on the fixed and variable costs of abatement for different facilities, and is left for future research. If the former (that marginal abatement cost exceeds \$15/tonne) is the case, then this raises some concerns about some prominent studies that identify a large potential for GHG abatement at a negative cost. According to Enkvist et al. (2007) and NAS (2010) this potential exceeds 1 Giga tonne of CO<sub>2</sub> of abatement in the case of US industries. Thus, to induce real changes in facility emission intensity via regulation requires either more stringent emission intensity reduction targets or higher cost of non-compliance.

Whereas the current level of the regulation, both in terms of the intensity reduction target and the cost of non-compliance, might not have had the desired impact, the theoretical model clearly shows that either increasing the stringency of the emission intensity (reduction) target or increasing the level of the tax on emissions owed under non-compliance or both increases the likelihood that both emissions and emission intensity decline. Furthermore, if an intention of such regulations is to induce innovation in and adoption of pollution-reducing technologies across all the different sectors and across all different types of facilities within a given sector (which, is a plausible rationale for site-specific performance standards), then one approach the policy makers could consider is to place an upper-bound and lower-bound on the extent to which an individual facility can rely on any given mode of compliance including the extent to which polluters can rely on tax penalties to continue operating under

non-compliance. For instance, the Regional Greenhouse Gas Initiative (RGGI), which is the first mandatory CO<sub>2</sub> emission reduction program in the US, limits the use of offset allowances to 3.3 percent of a power plant's compliance obligation in each control period.<sup>15</sup>

Our analysis also provides some insights into the broader discussion as to what is an appropriate policy for lower-level jurisdictions within a nation or a single nation or a group of nations in a global context to begin to address the problem of global externalities when national (global) agreement is not forthcoming. In several such jurisdictions there clearly is popular support for policy leadership at the local or regional level as evidenced by the growing number of city, state, regional and multi-national climate agreements. There might also be economic justification for some unilateral measures on account of first-mover advantage, learning-by-doing and innovation spillovers, reducing uncertainty, etc. In light of concerns that leakage might undermine unilateral policies, it seems reasonable that policymakers in such jurisdictions might seek to reduce the emissions rate as opposed to emissions absolutely in order to balance environmental concerns against the effects of unilateral environmental regulations on competitiveness and employment of the region's economy. Features such as emission credit trading, offsets and safety-valve on abatement cost limit the cost of the regulation but as we see in the case of SGER, the other policy parameters such as the stringency of the intensity target, the tax rate on non-compliance, and choice of upper and lower-bounds on specific modes of compliance are important considerations that will influence if and at what cost the desired outcomes are achieved.

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# Appendix

## Proof of Proposition 2

Rewriting the system of FOCs for a profit-maximizing firm under an SGER-like policy:

$$p - C_q - \tau[z - \bar{\gamma}] = 0 \quad (10)$$

$$-C_z - \tau q = 0 \quad (11)$$

$$-\frac{\partial C^a}{\partial Z_k^a} + \tau = 0 \text{ for each } k \in K \quad (12)$$

Partially differentiating Equation (11) with respect to output  $q$ , we get that, in equilibrium,

$$-C_{zq} - \tau = 0 \quad (13)$$

To show the effect of changing the exogenous parameters on the equilibrium outcome, we perform comparative static analysis of the FOCs. Let  $C_i, C_{ij}$  denote the first and second order partial derivatives of the cost function with respect to  $i$  and  $i$  followed by  $j$  respectively. Completely differentiating each equation in the system above, we get:

$$dp^* - C_{qq}dq^* - C_{qz}dz^* - d\tau(z - \bar{\gamma}) - \tau(dz^* - d\bar{\gamma}) = 0 \quad (14)$$

$$-C_{zz}dz^* - C_{zq}dq^* - \tau dq^* - d\tau q^* = 0 \quad (15)$$

$$-C_{Z^a Z^a}dZ^{a*} + d\tau = 0 \quad (16)$$

$q, z$  and  $Z^a$  are decision variables, while  $p, \bar{\gamma}$  and  $\tau$  are exogenous parameters. We are mainly interested in the effect of the two policy parameters, the emission intensity target ( $\bar{\gamma}$ ) and the tax penalty rate ( $\tau$ ) and so we will always set  $dp = 0$  and focus only on the former two.

Using Equation (13), the above system reduces to

$$dp^* - C_{qq}dq^* + \tau d\bar{\gamma} - d\tau(z - \bar{\gamma}) = 0 \quad (17)$$

$$-C_{zz}dz^* - d\tau q^* = 0 \quad (18)$$

$$-C_{Z^a Z^a}dZ^{a*} + d\tau = 0 \quad (19)$$

First, let us fix the tax penalty rate i.e.,  $d\tau = 0$  and study the effect varying the emission intensity target by  $d\bar{\gamma}$  on the equilibrium emissions, emission intensity and output. Solving Equations (17) and (18) for  $\frac{dq^*}{d\bar{\gamma}}$  and  $\frac{dz^*}{d\bar{\gamma}}$  :

$$\frac{dq^*}{d\bar{\gamma}} = \frac{\tau}{C_{qq}} > 0 \quad (20)$$

$$\frac{dz^*}{d\bar{\gamma}} = 0 \quad (21)$$

$$\frac{dZ^{a*}}{d\bar{\gamma}} = 0 \quad (22)$$

That is, holding the tax rate fixed, increasing (decreasing) the target level of emission intensity, increases (decreases) the equilibrium output, which is intuitive. However, the equilibrium average emission intensity is unaffected. This is interesting, but not surprising since what determines whether a firm reduces its emission intensity and by how much is the cost of reducing emission intensity and the cost of non-compliance which is determined by the tax rate. Likewise emissions avoided off-site or via the purchase of credits and offsets is unaffected so long as the tax rate is fixed. Holding these fixed, changing the target rate of emission intensity has no real effect on a firm's own emission intensity.

With respect to emissions  $Z$ ,

$$Z^* = z^* q^*$$

$$\text{Differentiating totally : } dZ^* = z^* dq^* + q^* dz^*$$

$$\begin{aligned} \text{Dividing by } d\bar{\gamma} : \frac{dZ^*}{d\bar{\gamma}} &= z^* \frac{dq^*}{d\bar{\gamma}} + q^* \frac{dz^*}{d\bar{\gamma}} \\ &= z^* \frac{dq^*}{d\bar{\gamma}} > 0 \quad (\text{Since } \frac{dz^*}{d\bar{\gamma}} = 0) \end{aligned} \quad (23)$$

Now let us fix the intensity target, i.e.,  $d\bar{\gamma} = 0$ , and study the effect of varying the tax rate for non-compliance by  $d\tau$ . Solving Equations (17) through (19) we get:

$$\frac{dq^*}{d\tau} = \frac{-(z - \bar{\gamma})}{C_{qq}} < 0 \quad (24)$$

$$\frac{dz^*}{d\tau} = -\frac{q}{C_{zz}} < 0 \quad (25)$$

$$\frac{dZ^{a*}}{d\tau} = \frac{1}{C_{Z^a Z^a}} < 0 \quad (26)$$

It follows that  $\frac{dZ^*}{d\tau} = z^* \frac{dq^*}{d\tau} + q^* \frac{dz^*}{d\tau} < 0$

Table 8: Comparative static results

$\frac{dq^*}{d\bar{\gamma}} > 0$	$\frac{dq^*}{d\tau} < 0$
$\frac{dz^*}{d\bar{\gamma}} = 0$	$\frac{dz^*}{d\tau} < 0$
$\frac{dZ^*}{d\bar{\gamma}} > 0$	$\frac{dZ^*}{d\tau} < 0$
$\frac{dZ^{a*}}{d\bar{\gamma}} = 0$	$\frac{dZ^{a*}}{d\tau} > 0$

Combining the effects of the intensity target and tax rate, we can see why under an SGER-like policy, for any given firm, all else constant, emission intensity, emissions and output, would each decline.