Spillover Benefits of Carbon Dioxide Cap and Trade: Evidence from the Toxic Release Inventory

Linh Pham* and Travis Roach†

April 28, 2021

Abstract

Metals and other industrial discharges have been shown to have detrimental cognitive effects in humans as well as bioaccumulate and affect environmental health in other species. The release of these elements in industrial applications is monitored and regulated by many governing bodies, including the United States' Environmental Protection Agency. Here, we show how a regional cap and trade program designed to regulate carbon dioxide emissions has also affected the release of metals and other federally regulated toxins in the Toxic Release Inventory. We find that both metal and non-metal releases and emissions have declined due to the passing and tightening of the cap-and-trade system. Following the introduction of cap-and-trade, toxic releases from electric utility facilities were 72% lower, and by 2019 toxic releases were 91% lower. We further find that there have not been any spillover effects in neighboring regions.

JEL Codes: H23, L94, Q48, Q58
Keywords: Cap and Trade Policy; Toxic Release Inventory; Regional Greenhouse Gas Initiative

---

*University of Central Oklahoma, lpham17@uco.edu
†University of Central Oklahoma, troach2@uco.edu.

1 Introduction

Industrial activity results in numerous downstream products that we interact with daily - from textile production, to medical manufacturing, to the electricity that traveled through the cord that charges or powers the device displaying this sentence. Along with these products, though, are numerous toxic chemical releases that can be harmful to human and environmental health. The Emergency Planning and Community Right-to-Know Act of 1986 is a United States federal law that led to the establishment of the Toxic Release Inventory (TRI) that is compiled by the United States Environmental Protection Agency. As of 2019, a total of 21,393 different facilities reported toxic releases to the Environmental Protection Agency, with total toxic releases of more than 30.7 billion pounds.

Among the industrial activities covered in the TRI, electric utility companies comprised 4% of all releases in 2019.[1,2] This sector has witnessed monumental changes since the creation and implementation of the TRI, for example, a push for more renewable energy sources, historically low natural gas prices, and coal plant retirements due to age and market forces. Additionally, this sector is being shaped by policies put in place to limit the further accumulation of greenhouse gases. In this paper, we document how toxic releases have changed as a direct result of a regional cap-and-trade permit system that regulates carbon dioxide emissions in the Northeastern United States, the Regional Greenhouse Initiative (RGGI). These unintended (or at least, not directly priced and regulated) toxic release reductions are important to consider in *ex post* analyses of cap-and-trade policies, as legislation is considered and discussed in other states, other countries, and even at the Federal level in the United States. Using the introduction and eventual tightening of the carbon dioxide cap as separate treatment periods, we find that total releases and total emissions for pollutants

---

[1] Approximately 1.2 Billion pounds.

[2] The electric utilities sector is the seventh most-emitting sector. The top three sectors: Chemical Manufacturing, Primary Metals and Petroleum Products, account for 55%, 8% and 7% of all toxic releases respectively.

listed in the Toxic Release Inventory have fallen due to carbon dioxide pricing. This remains true when we estimate models at a finer resolution to determine if toxic releases that are classified as metals or non-metals respond differently to carbon dioxide pricing.[3] Using standard difference-in-differences methodology and event-studies models, we find that toxic releases from electric utilities fell by nearly 72% following the introduction of the permit system, and fell an additional 67% after the policy became more stringent. The combined reduction is 90.5% fewer toxic releases (relative to the treatment-free comparison group). For toxic releases categorized as metals (e.g. lead compounds and arsenic compounds), we find that toxic releases fell by 59% initially, and fell by an additional 89.9% after the policy became more binding.[4] Importantly, we also measure any 'leakage' that could occur in states that are not part of the regional cap-and-trade system. Contrary to much of the received literature on how carbon dioxide emissions have changed outside of the regulated region, we find no evidence that toxic releases have increased or 'leaked' into neighboring areas. For chemicals classified as metals, in spillover states we see that the RGGI-policy is associated with nearly no change during the original implementation period and about a 24% increase once the policy became more stringent, though this latter effect is not statistically different from zero.

Prior research indicates that the benefits of these spillover toxic release reductions are far reaching. These benefits include not only obvious health benefits like reduced carcinogen exposure, but also lower crime which is linked to deteriorating cognitive and behavioral change from toxic exposure. Reyes (2007) shows that removing lead from gasoline drastically reduced childhood lead exposure, which in turn fueled the large declines in violent crime in the 1990s. This result is especially concerning given the continued use of leaded aviation gasoline which Zahran et al. (2017) show increased blood levels in children that live near one

---

[3] For example, the metal content of bituminous coal is different than that of natural gas, both of which have vastly different carbon factors.

[4] This is equivalent to a total reduction of 95.8% relative to facilities that are not in RGGI-adopting states.

of the many smaller airports in Michigan. Persico et al. (2019) find that prenatal exposure to Superfund toxic waste sites results in worse cognitive and behavioral outcomes for neonatal-exposed children, worse than their siblings that were not neonatal-exposed. Rau et al. (2015) show that toxic releases containing large amounts of lead, arsenic, and mercury had the downstream effect of reduced math and language scores. Moreover, they find that the magnitude of this effect decreases when a school is located further from the polluted area. We also must consider that the majority of emissions and releases from electric utilities are strictly airborne. Recent work has shown that air pollution has myriad detrimental impacts. Increased air pollution has been linked to infant health and mortality (Simeonova et al. (2019)) and to deaths in general (Samet et al. (2000); Schwartz Joel et al. (2017); Clay et al. (2021)). Jans et al. (2018) uses episodes of air inversions[5] as exogenous variation to show that increases in particulate matter levels result in a 5.5% increase in children's respiratory health problems. Deryugina et al. (2019) make use of wind direction changes to show how particulate matter changes affect mortality among the elderly. These authors find that additional PM 2.5 pollution increases elderly mortality by 0.69 per million, and also leads to more emergency room visits and hospitalizations. Importantly, Persico and Johnson (2021) show that when the EPA stopped enforcing many environmental regulations during the COVID-19 pandemic, there was an 11.8% increase in pollution in counties with more TRI facilities. This rollback caused a 53% increase in the amount of COVID-19 cases and a 10.6% increase in deaths from COVID-19. Other impacts from heightened air pollution include increased school absences (Currie et al. (2009)), lower academic achievement (Heissel et al. (2020)), and increased crime rates (Reyes (2007); Bondy et al. (2019). Considering this prior work, we expect that the decreases in toxic releases due to the passing and tightening of the carbon dioxide cap-and-trade system that we find will have beneficial effects over the following years and decades.

---

[5] Climate phenomena in which warmer air at higher levels in the atmosphere 'traps' pollution instead of the natural process that allows pollution to disperse.

In this paper, we find that the introduction of carbon dioxide pricing reduces toxic releases as a direct effect of the policy, but the exact mechanisms of this reduction are not entirely clear since toxic releases are not directly targeted. Instead, one may think of the cap-and-trade policy as internalizing (at least some) of the negative external costs that result in an unfair competitive advantage of highly-polluting plants relative to less-polluting plants. In this way, our results are similar to that of Simon and Prince (2016) who find that increased competition, as measured by the familiar Herfindahl-Hirschman Index, reduces toxic releases. Competition alone cannot account for why toxic releases fall at certain plants, though. Campa (2018) finds plants listed in the TRI that are located near more newspaper headquarters produce lower amounts of toxic emissions. Campa (2018) further shows that when a story is published concerning toxic emissions, a plant reduces emissions by 29% relative to plants that were not covered. While we cannot directly account for newspaper coverage effects of specific plants in our model, we are able to indirectly control for this by including county fixed effects. Moreover, we estimate a triple-difference model that accounts for differences in toxic releases at electric utility plants in the RGGI region relative to non-electric sector toxic releases in the same region (relative to similar differences outside of the RGGI area).

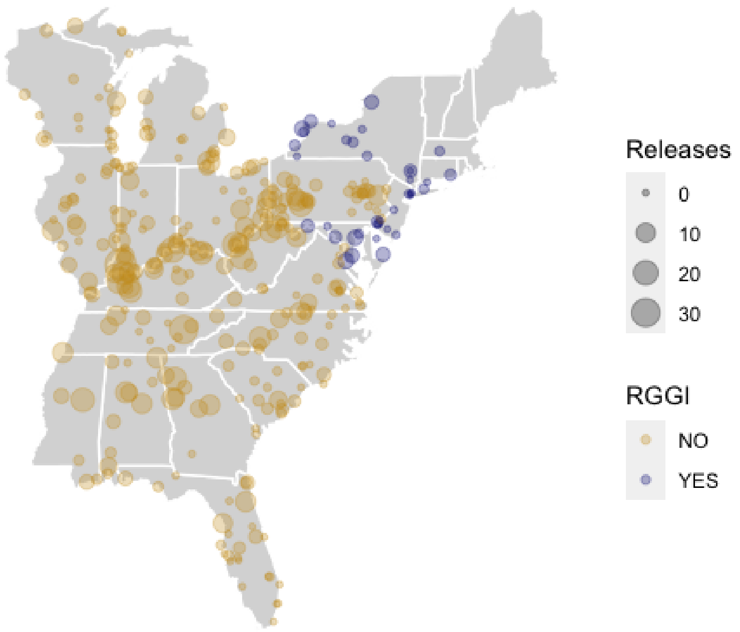
1.1 Background

The RGGI was the first cap and trade system for carbon dioxide emissions put in place in the United States, and this carbon dioxide trading system has existed since 2009. When the policy began, the RGGI implemented a carbon cap of 188 million allowances for the 10-state region which tightened incrementally annually. The original coalition of 10 states included Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. In 2012, New Jersey left the coalition but has now rejoined the RGGI. Virginia is the latest state to join the coalition, and Pennsylvania has passed a policy to join the cap-and-trade system.

In the time since the policy's original implementation, the consortium of states within the RGGI voted to lower their emissions cap effective beginning in 2014. This was done because the original emissions cap was effectively non-binding due to an unanticipated abundance of natural gas that flooded the market after hydraulic fracturing became commonly used in oil and gas production. For example, prices collapsed from more than \$13 per million BTU in July 2008 to just over \$3 per million BTU one year later in July 2009 (right as the policy was implemented). Natural gas prices continued to decline and stayed low, motivating market driven substitution away from coal. Indeed, the dual impact of cheap natural gas and increasing generation capacity from renewable sources (particularly wind) drove many coal-powered units out of their historical role as baseload capacity (Fell and Kaffine (2018)). This organic transition occurred in markets outside of the RGGI, too, but the end result was lower emissions within the RGGI than expected – thus rendering the original carbon cap too high. The newly enacted emission cap reductions from 2014 were more strict. For example, the original 2020 cap was 78,175,215 allowances which equated to 41% of the emissions allowances in 2009. The new, adjusted RGGI cap for 2020 was 56,283,807 allowances or 29.9% of the 2009 level.

While it is true that carbon dioxide emissions have been falling across the United States due to the cost-competitiveness of natural gas since the price collapse, coal plant retirements, and increased renewable energy capacity, early research on the RGGI cap-and-trade system finds that over half of the observed decline in emissions in the RGGI-adopting area are due to the policy (Murray and Maniloff (2015)). However, because the RGGI is a regional policy that takes place within a larger body of electricity flow between adopting and non-adopting states, the potential spillover effect or 'leakage' of carbon dioxide emissions into non-adopting areas is great. Indeed, research published just as the policy was implemented expected carbon-intensive power generation to flow from non-adopting states into RGGI

Figure 1: Electric Utilities Metal Releases (100,000s) in 2008



adopting states (Chen 2009). Empirical research *ex post* has confirmed this expectation. The consensus of this early literature is that the RGGI policy has reduced carbon dioxide emissions in the RGGI-region, but that carbon dioxide leakage is occurring. This latter finding mostly occurs through increased power production at natural gas-fired plants in neighboring (non-adopting) states. Kim and Kim (2016) show that leakage has occurred by using synthetic control methods and yearly state-level data on the share of natural gas used to generate electricity. Lee and Melstrom (2018) agree using state-level electricity flows at a quarterly interval. Fell and Maniloff (2018) and Chan and Morrow (2019) use plant-level data to show that leakage has occurred outside of RGGI-adopting states. Fell and Maniloff (2018) use the proximity of Ohio and Pennsylvania and designate them ‘leaker’ states.[6] They find that the capacity factor of natural gas-fired plants has increased in these ‘leaker’ states – an indication that generation at natural gas facilities has increased since the

---

[6] Nomenclature we adopt in an appendix table.

policy's passing. Chan and Morrow (2019) show that leakage has occurred for both carbon dioxide emissions and associated emissions (sulphur dioxide and nitrous oxide) using plant-level emissions data (not just generation amounts). Of particular concern is that SO_2 has shifted from the RGGI region to areas with higher marginal damages from SO_2 (Chan and Morrow (2019)). Roach and Gittings (2020) have cast doubt on this prior work using a longer time horizon of emissions data and a modeling framework that accounts for the changing stringency of the carbon cap. This is due to a failure of the parallel trends assumption. Roach and Gittings (2020) show that within the RGGI, CO_2 emissions fall at coal plants in both policy periods, but there is no meaningful change at natural gas-fueled plants. For associated emissions, these authors find that NO_x emissions fall at natural gas-units after the policy's implementation, but do not decrease further in the tightening period; SO_2 emissions fall during both policy periods.[7] Unlike much of the prior research, in this paper we find no evidence of toxic release leakage into neighboring areas.[8]

Our paper makes several contributions to the existing literature. First, we are the first to analyze how emissions of known carcinogens and metal substances that the EPA monitors as part of the Toxic Release Inventory change due to the implementation of carbon dioxide pricing. The detrimental downstream health effects of these chemicals are widely studied, and our findings suggest that these toxic releases have greatly diminished due to the passing and tightening of the carbon permit trading system. Second, we make use of a more dynamic treatment effects model than some prior work which captures important policy differences over time. Failure to include these dynamics would lead to an under-estimation of the policy's full effect. Taken together, we conservatively estimate that the unintended reductions in toxic releases documented here are worth up to $586,115 per plant in foregone remediation expenses and health benefits (about $71 Million RGGI-wide).

---

[7] Among coal plants, each policy period is associated with lower emissions for both pollutants, and there are larger declines in the cap-tightening period than in the initial period.

[8] Moreover, the failure of the parallel trends assumption in the spillover regions that was a concern in Roach and Gittings (2020) is not found to be an issue in our setting.

2 Empirical Strategy

Our analysis begins with an event-study style model of toxic releases and emissions in RGGI adopting states for all chemicals, and then separately by metal classification at all electricity generating facilities in the Toxic Release Inventory. The RGGI is sharply defined along state lines, so electricity generating sources outside of the RGGI are used as a 'treatment-free' comparison group subject to the same global factors that both treated and untreated units face.[9] Here, we see that the Stable Unit Treatment Value Assumption (SUTVA) is valid, and further notice that the dynamic treatment effect is dependent on the policy stringency. The event-study models motivate the use of the two-treatment period difference-in-differences model we use to calculate average treatment effects by policy period. There is a clear start date to the carbon dioxide trading policy which began in 2009 which we use as the first 'treatment' period.[10] There is variation in the intensity of treatment because the cap on emissions was lowered in 2014, and this subsequent policy intervention serves as our second treatment period. Fortunately for our case, though not for reducing emissions or toxic releases, there is not staggered adoption of the policy across other states which would bias our difference-in-differences estimates (Goodman-Bacon (2018); Callaway and Sant'Anna (2020)).[11] We next extend the difference-in-differences analysis to measure changes outside of the RGGI-region to see if there are policy spillovers. Much of the received literature finds that some emissions have been 'relocated' to states just outside RGGI or in the same electricity balancing region. Finally, while the difference-in-differences analysis based solely on toxic releases from electricity producing facilities is illustrative, we also measure the impact of the RGGI on plant-level emissions using a triple difference-in-differences framework

---

[9] E.g. commodity price changes or the Coal Combustion Residuals rule we reference in the conclusion.

[10] The first auction took place on September 25, 2008 but the permits are for future emissions so we begin our treatment policy in 2009.

[11] California has instituted carbon dioxide pricing through cap-and-trade as well, and the policy began in 2013. The amount of facilities in this state is low relative to the entire treatment-free comparison group, so these facilities are included in the sample used throughout all tables. When we exclude these facilities from our sample (not shown) our point estimates are nearly identical.

Table 1: Electric utilities' toxic pollution – Summary statistics

	RGGI		Non-RGGI	
	Before 2009 (1)	After 2009 (2)	Before 2009 (3)	After 2009 (4)
Emissions				
Total	1023.83	588.97	3130.57	3556.84
	(2011.00)	(1661.99)	(5708.77)	(7189.48)
Metal	121.18	69.05	349.34	325.27
	(232.00)	(150.68)	(630.50)	(567.32)
Non-metal	952.88	567.27	2882.44	3327.61
	(1905.08)	(1612.23)	(5355.60)	(6883.93)
Releases				
Total	725.91	193.58	1809.68	1110.11
	(1719.55)	(657.33)	(3029.38)	(1898.64)
Metal	118.23	66.79	335.07	315.00
	(230.77)	(148.16)	(611.98)	(558.05)
Non-metal	656.20	167.30	1560.57	849.58
	(1641.93)	(609.82)	(2728.46)	(1487.19)
Observations	1143	1009	4741	4768

Note: Emission and releases are measured in thousands of pounds.
Numbers in parentheses are standard deviations.

which compares electricity producing entities with other plants in the TRI that are subject to the same state and local restrictions.[12] Although highly unlikely because of the large fixed costs and long planning horizons to adhere to Federal Energy Regulatory Commission standards, this particular robustness check is helpful in addressing concerns that firms may strategically change location (Gray and Shimshack (2011); Bui and Kapon (2012); Wang et al. (2020)). Our results from this triple difference robustness test are consistent with the prior difference-in-differences estimate.

2.1 Data Description

We collect facility-level annual toxic pollution from the Environmental Protection Agency (EPA)'s Toxic Release Invetory (TRI) from 2000 to 2019. The TRI requires facilities who produce or process more than 25,000 pounds or otherwise uses more than 10,000 pounds of toxic chemicals to report to the EPA on their management of these chemicals through disposal, recycling, energy recovery and treatment. As an illustrative example, Figure 1 shows the location of electricity generating facilities that are listed in the Toxic Release Inventory, whether not these facilities are in RGGI adopting states (blue indicates facilities in the RGGI). The amount of metals released in 2008, just prior to the adoption of carbon dioxide pricing, is also shown by the size of each bubble.

Since the RGGI targets electric utilities, our analysis will focus on toxic pollution in this sector, though we make use of the full Toxic Release Inventory (TRI) in our triple difference specification for robustness. The TRI data measures pollution discharge in aggregate as 'emissions' which is the sum of all releases, recycled materials, and treated emissions. That is to say, emissions are a gross number of toxic pollution generated by each facility. For our analyses, our dependent variables include total emissions, but we also limit our dependent variable to only net releases which includes only the untreated toxic pollution that is released or disposed into the environment. We further separate facility-level toxic emissions and releases in aggregate ('total emissions' and 'total releases') by their classification as a metal or non-metal ('metal emissions' and 'metal releases'). Table 1 provides summary statistics. Columns (1) and (2) summarize toxic emissions and releases by facilities located in the RGGI states before and after 2009. Columns (3) and (4) provides the same information for facilities located in the non-RGGI states. The table shows a decline in toxic releases and emission in the RGGI states after 2009.

---

[12] Or proximity to newspaper headquarters (Campa (2018))

2.2 Econometric Specification

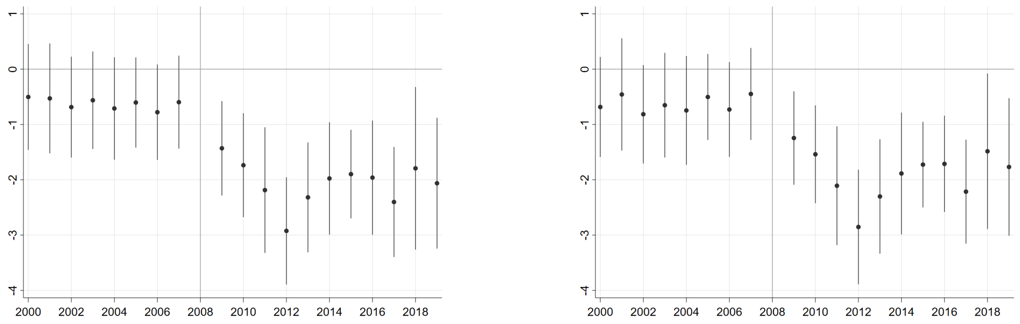
To investigate the impact of the RGGI on toxic emissions and releases, we first employ the following event-study model:

$$log(y_{ist}) = \beta_0 + \sum_{\substack{t=2000 \\ t\neq 2008}}^{2019} \Big[\beta_t RGGI_{is} * I(Year = t)\Big] + \zeta RPS_{st} + \mu_c + \eta_t + \nu_{ist} \qquad (1)$$

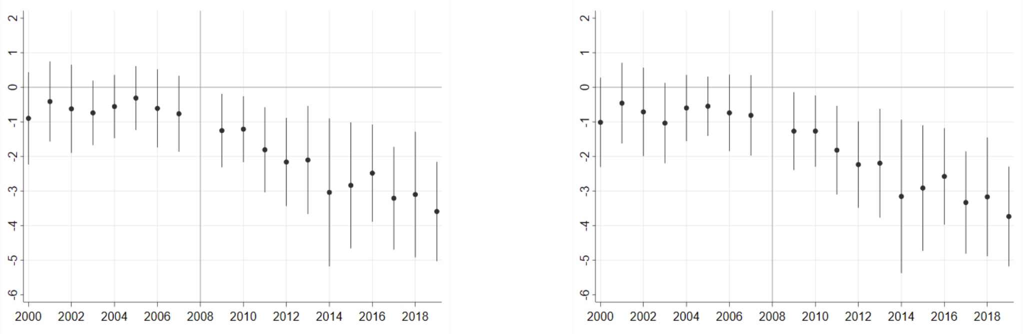
Where i, c, s, t denote facility, county, state and year. y_{ist} denotes the toxic pollution by facility i in state s in year t. $RGGI_s$ is an indicator variable that equals 1 if the facility is located in a RGGI adopting state and $I(Year = t)$ is a dummy variable for year t. We normalize $\beta_{2008} = 0$, thus, $\beta_t (t \neq 2008)$ captures the average annual effect of being in a RGGI adopting state both before and after the policy implementation, with reference to emissions in 2008. RPS_{st} denotes the percentage of renewable energy required by a state's Renewable Portfolio Standards (RPS), where $RPS_{st} = 0$ if a state does not implement RPS during a year. μ_c and η_t denote the county and year fixed effects. Finally, the standard errors ν_{ist} are clustered at the state level.

Figure 2 graphs the estimated parameters β_t and their standard errors, which are obtained from the event study model in equation (1). First, β_t is close to 0 and not statistically significant before 2008, which indicates a lack of pre-RGGI trends in toxic pollution that were specific to the RGGI adopting states. In 2009, when the RGGI cap-and-trade program began, both metal and non-metal emissions and releases immediately fell by approximately 75%, relative to the year before the policy implementation. Following this, we see that both metal and non-metal emissions and releases fall at an increasing rate for every year between 2009 and 2013. Beginning in 2014, new (lower) standards were set for the amount of carbon dioxide that could be released by electric utilities in RGGI states. After the cap tightening in 2014, we see that the reduction rate in metal emissions and releases continue to increase, while the reduction rate in non-metal emissions and releases slows down or even slightly

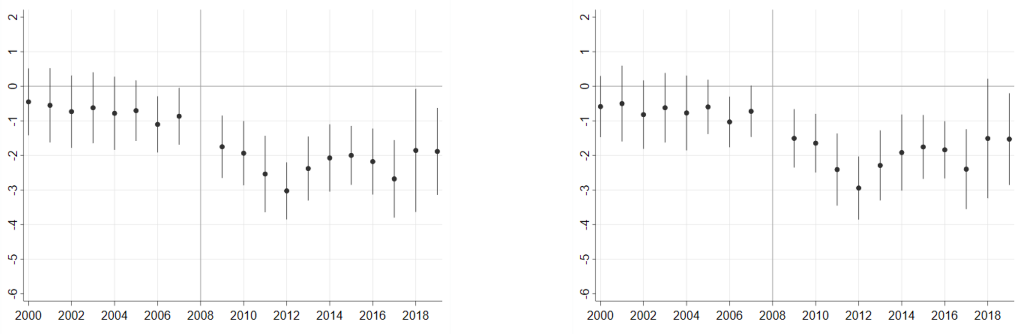
Figure 2: Event study


(a) Total emissions

(b) Total releases


(c) Metal emissions

(d) Metal releases


(e) Non-metal emissions

(f) Non-metal releases

increases. Overall, the event study results indicate a reduction in toxic emission and releases after the implementation of the RGGI, and motivates the need for at least two 'treatment' periods in our analyses below.

Our primary analytical model makes use of standard difference-in-difference (DD) methodology to assess the impact of the RGGI on toxic pollution. The prior event-study analysis showed that policy dynamics over time are important to consider. To capture these dynamics, we use two 'treatment' periods that capture (i) the first implementation of the cap-and-trade system, and (ii) the lowering of the carbon cap. Specifically, we estimate the following model:

$$\begin{aligned} log(y_{ist}) &= \beta_0 + \beta_1 Begin_t + \beta_2 Lower_t + \beta_3 RGGI_s \\ &+ \gamma_1 Begin_t * RGGI_s + \gamma_2 Lower_t * RGGI_s \\ &+ \zeta RPS_{st} + \mu_c + \eta_t + \nu_{ist} \end{aligned} \tag{2}$$

where $Begin_t$ is an indicator variable that equals 1 for the years when the RGGI was first introduced (2009-2013). $Lower_t$ is an indicator variable that equal 1 for the years when the RGGI carbon dioxide emissions cap was reduced (2014-Present). The main coefficients of interest are γ_1 and γ_2, which capture the treatment effect of the RGGI and its subsequent emissions cap reductions on facility-level toxic pollution, relative to emissions at facilities that are not in the RGGI-adopting region.

3 Empirical results

Table 2 reports the estimation results of the difference-in-difference model in equation (2). The top panel shows each estimated coefficient, and the bottom panel translates these coefficient estimates into percentage change form for ease of discussion. We also calculate the combined effect of each policy period by adding each coefficient. Note, that the combined effect in percentage change form will not directly add like the results in the top panel.[13] Columns (1)-(3) present the results for total, metal and non-metal emissions, and columns (4)-(6) present the results for total, metal and non-metal releases. The results show that the RGGI decreases emissions and releases of toxic materials by electric utilities. Indeed, this is true of both policy treatment periods. Specifically, we find that metal emissions and releases decrease by 61.95% and 59% during the beginning years of the RGGI (2009–2013) and by 90% and 89.9% during the cap-tightening years (2014–2019)[14] By the end of the policy, the total reduction in facility-level metal emissions and releases is 3.21 log points ($\gamma_1 + \gamma_2$). This change equates to a 95.96% decrease in metal emissions in the electricity sector in the RGGI region. Non-metal emission and releases also decline after the implementation of RGGI. It is of interest to note that these results are robust to changes in the composition of the treatment free comparison group.[15] The next section discusses policy spillovers into neighboring regions which implies the possibility that our 'control' group might be comprised of tainted controls. After all, the crux of difference-in-differences methodology assumes that non-treated units are stable and not affected by the policy in question. Our estimates are nearly identical when we only include power generating facilities that are located outside of the Eastern Interconnection in our control group.[16]

3.1 Policy Spillovers

Prior work has shown that carbon dioxide emissions have spilled-over into neighboring non-adopting states that are part of the same electricity transmission network (Chan and Morrow

---

[13] For example, assume we begin at 100 units. If there is a 75% reduction this would result in 25 units. If there is an additional 75% reduction this would result in 6.25 units – a combined 93.75% reduction from the original 100.

[14] Note, emissions are in logarithm form, so to measure the treatment effect change in percentage change terms we compute $(e^{\hat{\gamma}} - 1) * 100$ and display this in the bottom panel of each table.

[15] These estimates are available on request.

[16] Plants located in the Western Interconnection and ERCOT which cannot exchange electricity into the Eastern Interconnection because the three major interconnections operate at a different phase.

Table 2: The impact of the RGGI on electric utilities' toxic pollution

	Emissions			Releases		
	Total (1)	Metal (2)	Non-metal (3)	Total (4)	Metal (5)	Non-metal (6)
RGGI × Begin	-1.37***	-0.96***	-1.48***	-1.26***	-0.89***	-1.33***
	(0.40)	(0.34)	(0.44)	(0.41)	(0.32)	(0.44)
RGGI × Lower	-1.30***	-2.31***	-1.31***	-1.10***	-2.29***	-1.05**
	(0.36)	(0.63)	(0.45)	(0.37)	(0.61)	(0.45)
Combined effect	-2.68***	-3.28***	-2.81***	-2.36***	-3.18***	-2.39***
	(0.64)	(0.90)	(0.72)	(0.66)	(0.86)	(0.72)
% change in pollution						
Begin	-74.66***	-61.95***	-77.43***	-71.55***	-59.00***	-73.65***
	(10.12)	(12.76)	(9.90)	(11.54)	(12.92)	(11.49)
Lower	-73.02***	-90.06***	-73.28***	-66.80***	-89.86***	-65.37***
	(9.56)	(6.23)	(11.86)	(12.23)	(6.20)	(15.52)
Total	-93.16***	-96.22***	-93.97***	-90.55***	-95.84***	-90.88***
	(4.36)	(3.40)	(4.36)	(6.20)	(3.57)	(6.54)
Observations	11172	9120	10926	11152	9118	10902
Adjusted R^2	0.55	0.60	0.55	0.53	0.60	0.53
County FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
RPS	Y	Y	Y	Y	Y	Y

Numbers in parentheses are standard errors. *, **, *** denote 10, 5, 1% significance levels.

(2019); though Roach and Gittings (2020) cast doubt on this finding). Here, we seek to see if the same leakage into non-adopting states is occurring with toxic releases from electric utility firms, too. To identify whether or not leakage has occurred, we depend on the fact that electricity supply and demand is subject to the physical limitations of transmission networks and exploit variation in the overlapping network of 'balancing authorities' whose job it is to dispatch (or curtail) electricity transmission depending on the load demand profile of an area. Load demand does not necessarily fall evenly across RGGI-adopting state lines, and although the RGGI coalition is defined along state boundaries, electricity generation and balancing is dependent on supply and demand conditions across these invisible geopolitical barriers. Moreover, larger balancing regions or 'pools' vary in their state-to-state makeup. For example, the New York ISO balances supply and demand within New York (an RGGI member), and the PJM balancing authority balances generation and demand across West Virginia, Pennsylvania, Ohio (and smaller portions of other states) *in addition to* many of the RGGI states. Additionally, these balancing authorities coordinate with one another to help electricity flow unimpeded within the entire Eastern Interconnection that covers states east of Colorado and north of Texas. For example, generation in the PJM territory was drastically increased to service heightened load demand due to the severe winter storm of February 2021 that greatly affected states in the Southwest Power Pool (Oklahoma north to North Dakota).[17]

To determine if toxic releases have changed in facilities located in nearby non-adopting states, we include an additional 'treatment' group of facilities in non-RGGI adopting states that are part of the PJM balancing authority (which includes some RGGI-adopting states). The average treatment effect is thus the change in toxic emissions and releases before and

---

[17] Throughout most of February 15th, the coldest day during the winter storm, there were upwards of 15,000MWh of outflow (interchange) from PJM into the neighboring Midcontinent Independent System Operator (MISO), and more than 3,000 MWh were transported from MISO into the Southwest Power Pool. Texas, which is mostly covered by the ERCOT balancing authority, is not connected to a larger interconnection and did not receive inflow from neighboring areas. Millions of homes were without power for multiple days during this time because generation was not enough to cover load demand.

after the implementation and tightening of the cap-and-trade system relative to facilities in other non-adopting states that are not part of the same balancing pool.[18]. The estimating equation is essentially equation (2) with an additional treatment group indicator that is equal to one for facilities located in the PJM territory (but that are not part of the RGGI). This additional indicator variable is also interacted with the two policy treatment periods as before.

Table 3 presents the results with the additional PJM treatment group indicator. First, the effects of the cap implementation and tightening within the RGGI system are consistent with our prior results. Specifically, total emissions and total releases from electric utility facilities still decrease by about 94%. Regarding spillovers, we do not find any evidence that total emissions or releases of metals have changed in non-RGGI areas. The point estimate is positive in the more stringent policy period, but it is not statistically significant. If anything, there is some evidence that total releases for non-metals have decreased in the second policy period outside of the RGGI-region, though this is marginally significant with wider standard errors than those associated with estimates for facilities in RGGI-adopting states.

3.2 Robustness

Finally, we investigate the change in toxic pollution between targeted and non-targeted industries before and after the RGGI. Evidence from the prior event-study models indicate that the parallel trends assumption is likely valid in our setting, though we are unable to determine whether changes in the electric utilities industry are distinct relative to changes in non-targeted sectors within the state. For instance, the local occurrence of negative effects from toxic releases of metals from all facilities may motivate local authorities to reduce *all* releases – regardless of the industry releasing these metals. To this end, we expand our data set to include both utilities and non-utilities and estimate a difference-in-difference-in differ-

---

[18] Other authors have looked into spillover into Pennsylvania and Ohio alone. We also examine this and find consistent results to our PJM specification. This specification is shown in appendix table 5

Table 3: PJM Results

	Emissions			Releases		
	Total (1)	Metal (2)	Non-metal (3)	Total (4)	Metal (5)	Non-metal (6)
RGGI × Begin	-1.42***	-0.99**	-1.49***	-1.36***	-0.89**	-1.41***
	(0.43)	(0.38)	(0.47)	(0.42)	(0.36)	(0.45)
RGGI × Lower	-1.37***	-2.22***	-1.34***	-1.29***	-2.17***	-1.26**
	(0.39)	(0.64)	(0.50)	(0.39)	(0.63)	(0.47)
Combined effect, RGGI	-2.77***	-3.21***	-2.81***	-2.64***	-3.05***	-2.66***
	(0.71)	(0.96)	(0.82)	(0.69)	(0.92)	(0.75)
PJM × Begin	-0.12	-0.08	-0.02	-0.24	-0.02	-0.19
	(0.26)	(0.26)	(0.27)	(0.24)	(0.25)	(0.24)
PJM × Lower	-0.20	0.14	-0.13	-0.45*	0.21	-0.48
	(0.27)	(0.25)	(0.31)	(0.27)	(0.26)	(0.29)
Combined effect, PJM	-0.30	0.07	-0.13	-0.68	0.20	-0.66
	(0.50)	(0.49)	(0.55)	(0.46)	(0.49)	(0.49)
% change in pollution						
Begin, RGGI	-75.67***	-62.72***	-77.31***	-74.34***	-58.77***	-75.64***
	(10.45)	(14.36)	(10.77)	(10.72)	(15.02)	(10.87)
Lower, RGGI	-74.24***	-89.15***	-73.40***	-72.32***	-88.57***	-71.37***
	(10.16)	(6.99)	(13.36)	(10.84)	(7.21)	(13.65)
Total, RGGI	-93.73***	-95.96***	-93.97***	-92.90***	-95.29***	-93.02***
	(4.42)	(3.87)	(4.94)	(4.87)	(4.34)	(5.24)
Begin, PJM	-10.79	-7.17	-1.40	-21.37	-1.47	-16.87
	(23.03)	(23.80)	(26.98)	(18.74)	(25.16)	(20.04)
Lower, PJM	-17.16	15.18	-11.30	-35.49**	23.94	-37.61**
	(22.71)	(29.47)	(27.53)	(17.09)	(32.20)	(18.20)
Total, PJM	-26.10	6.92	-12.54	-49.27**	22.12	-48.13*
	(36.67)	(51.91)	(47.94)	(23.30)	(59.97)	(25.42)
Observations	11172	9128	10926	11152	9126	10902
Adjusted R^2	0.55	0.60	0.55	0.53	0.60	0.53
County FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
RPS	Y	Y	Y	Y	Y	Y

Numbers in parentheses are standard errors. *, **, *** denote 10, 5, 1% significance levels.

ence (DDD) model. The DDD model allows us to compare differences in pollution between utilities and non-utilities in RGGI states while holding constant differences in pollution between utilities and non-utilities in non-RGGI states. Specifically, the estimation equation is as follows:

$$\begin{aligned} log(y_{ist}) &= \beta_0 + \beta_1 Begin_t + \beta_2 Lower_t + \beta_3 RGGI_s + \beta_3 Utilities_i \\ &+ \gamma_1 Begin_t * RGGI_s + \gamma_2 Lower_t * RGGI_s + \gamma_3 Utilities_i * RGGI_s \\ &+ \gamma_4 Begin_t * Utilities_i + \gamma_5 Lower_t * Utilities_i \\ &+ \theta_1 Begin_t * RGGI_s * Utilities_i + \theta_2 Lower_t * RGGI_s * Utilities_i \\ &+ \zeta RPS_{st} + \mu_c + \eta_t + \nu_{ist} \end{aligned} \tag{3}$$

Where $Utilities_i$ is an indicator variable that equals 1 if facility i belongs to the electric utilities sector. θ_1 and θ_2 are the parameters of interest, which capture the treatment effects of the RGGI phases on utilities while holding constant changes in non-targeted facilities within RGGI states over the same period and holding constant similar comparisons in non-RGGI states.

Table 4 reports the results of the DDD model in equation (3). We find that the cap-and-trade implementation and eventual tightening leads to a larger reduction in toxic pollution in the electric utility sector than other sectors within the same state that are not directly targeted by the RGGI carbon dioxide pricing policy. Interestingly, we now find that emissions and releases of metals are not statistically different from zero through the first phase of the RGGI, though the point estimate is negative. We do find a statistically discernible decrease in the period when the carbon cap is lowered, and the combined effect is 89.8% and 97.3% fewer emissions and releases, respectively. We further find that non-metal emissions and releases fall in both policy periods. Taken together, these results indicate that the average

Table 4: The triple-difference results

	Emissions			Releases		
	Total (1)	Metal (2)	Non-metal (3)	Total (4)	Metal (5)	Non-metal (6)
RGGI× Begin×Utilities	-1.31**	-0.52	-1.36***	-1.29***	-0.43	-1.28***
	(0.52)	(0.45)	(0.48)	(0.47)	(0.41)	(0.42)
RGGI× Lower×Utilities	-1.76***	-1.78**	-1.31**	-1.68***	-1.65**	-1.17***
	(0.59)	(0.79)	(0.52)	(0.49)	(0.74)	(0.44)
Combined effect	-3.08***	-2.28**	-2.67***	-2.97***	-2.06**	-2.45***
	(1.05)	(1.13)	(0.91)	(0.89)	(1.04)	(0.76)
% change in pollution						
Begin	-73.18***	-40.38	-74.38***	-72.49***	-34.59	-72.26***
	(13.89)	(26.82)	(12.28)	(12.94)	(26.77)	(11.64)
Lower	-82.83***	-82.92***	-73.07***	-81.30***	-80.55***	-68.89***
	(10.14)	(13.46)	(13.96)	(9.08)	(14.47)	(13.60)
Total	-95.40***	-89.81***	-93.10***	-94.86***	-87.27***	-91.37***
	(4.82)	(11.54)	(6.30)	(4.58)	(13.20)	(6.52)
Observations	395438	239686	257799	363541	213025	244369
Adjusted R^2	0.11	0.13	0.13	0.15	0.19	0.16
County FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
RPS	Y	Y	Y	Y	Y	Y

Numbers in parentheses are standard errors. *, **, *** denote 10, 5, 1% significance levels.

treatment effect of the RGGI on toxic emissions and releases in the electricity sector is distinct from changes both outside the RGGI-area and in non-targeted sectors within the RGGI-area.

4 Conclusions and Policy Discussion

The regulation of carbon dioxide emissions using market-based mechanisms like a cap-and-trade system is popular among economists, though actual implementation of these policies have been scarce. Here, we observe how the first (and for many years only) carbon dioxide pricing scheme has affected the release of toxic chemicals that are not directly priced and regulated in the market. These 'spillover' benefits are important to consider in *ex post* analyses of carbon dioxide pricing schemes because, for the most part, the policies are judged on the value of emissions reductions through reduced impact on further greenhouse gas accumulation and climatic change. Moreover, these spillover benefits are important to consider given the ample literature on the detrimental effects of toxic releases that affect mortality, health expenditures, cognitive function, and even crime levels.

Using data from the Toxic Release Inventory, we find that the implementation of carbon dioxide pricing caused significant declines in the amount of total emissions and net releases of toxic chemicals at electricity producing facilities. These reductions are substantial, and in many cases are more than 90% lower as a direct result of the policy. Moreover, we do not find that there has been an increase in toxic releases in neighboring states that have not joined into the cap-and-trade market. Given prior findings that carbon dioxide emissions have risen in these neighboring areas, it may seem strange that we do not find similar results for toxic releases. However, because the majority of these emissions have been replaced using natural gas-fired facilities, the net effect of reducing coal-fired generation seems to be that toxic releases fall without partial offset in the outside (non-adopting) area like we see with carbon dioxide emissions.

The full extent of these spillover benefits will likely accrue for many years, and may even not be present in outcome variables of interest until affected young people age (Persico et al. (2019); Deryugina et al. (2019); Persico and Johnson (2021)). However, we are able to calculate a very conservative 'back-of-the-envelope' estimate of the value of these benefits by evaluating cost savings from avoided cleanup and other environmental benefits. A 2014 regulatory impact analysis of the EPA's final "Coal Combustion Residuals[19] rule" estimated the benefits of avoiding future disposal failures as the sum of avoided costs of cleanup and ecosystem restoration.[20] Within this analysis, the EPA considered avoided cleanup costs in addition to benefits in the form of: reduced incidence of cancer, mitigated IQ loss from mercury and lead, reduced need for special education, protection of endangered and threatened species, reduced groundwater withdrawals, and improved air quality around power plants. We use the EPA's lower-bound annualized benefit estimate[21] from this report and connect it to the reduction in total emissions found here. We note that our estimated effects are from all electric facilities which includes electricity produced by natural gas or even landfill methane, not just coal-fired units. Thus, the benefits of this rule are specific to coal ash which are only a portion of the toxic releases included in our estimates. Over the prior 11 years, we conservatively estimate that these spillover benefits in toxic release emissions are worth up to at least $586,115 per plant in avoided costs, avoided IQ loss, and other environmental services (about $53 thousand dollars per plant, per year). Using their higher annualized benefit assumption value, our spillover benefits estimates amount to over $730,117 per plant ($66.3 thousand dollars per plant, per year). Summing over the 121 electric utility facilities in the RGGI region, these benefits are conservatively valued at $70.9 - $88.3 million dollars over the 11 years of the carbon dioxide pricing program.

---

[19] Coal ash

[20] *EPA's 2015 RCRA Final Rule Regulating Coal Combustion Residual (CCR) Landfills and Surface Impoundments At Coal-Fired Electric Utility Power Plants* (2014)

[21] Higher discount rate

References

Bondy, M., Roth, S. and Sager, L. (2019). Crime Is in the Air: The Contemporaneous Relationship between Air Pollution and Crime, *Journal of the Association of Environmental and Resource Economists* **7**(3): 555–585. Publisher: The University of Chicago Press.
URL: *https://www.journals.uchicago.edu/doi/10.1086/707127*

Bui, L. T. M. and Kapon, S. (2012). The impact of voluntary programs on polluting behavior: Evidence from pollution prevention programs and toxic releases, *Journal of Environmental Economics and Management* **64**(1): 31–44.
URL: *https://www.sciencedirect.com/science/article/pii/S0095069612000034*

Callaway, B. and Sant'Anna, P. H. C. (2020). Difference-in-Differences with multiple time periods, *Journal of Econometrics* .
URL: *https://www.sciencedirect.com/science/article/pii/S0304407620303948*

Campa, P. (2018). Press and leaks: Do newspapers reduce toxic emissions?, *Journal of Environmental Economics and Management* **91**: 184–202.
URL: *https://www.sciencedirect.com/science/article/pii/S0095069616301371*

Chan, N. W. and Morrow, J. W. (2019). Unintended consequences of cap-and-trade? Evidence from the Regional Greenhouse Gas Initiative, *Energy Economics* **80**: 411–422.
URL: *http://www.sciencedirect.com/science/article/pii/S0140988319300222*

Chen, Y. (2009). Does a regional greenhouse gas policy make sense? A case study of carbon leakage and emissions spillover, *Energy Economics* **31**(5): 667–675.
URL: *http://www.sciencedirect.com/science/article/pii/S0140988309000309*

Clay, K., Muller, N. Z. and Wang, X. (2021). Recent Increases in Air Pollution: Evidence and Implications for Mortality, *Review of Environmental Economics and Policy* pp. 000–

000. Publisher: The University of Chicago Press.
URL: *https://www.journals.uchicago.edu/doi/full/10.1086/712983*

Currie, J., Hanushek, E. A., Kahn, E. M., Neidell, M. and Rivkin, S. G. (2009). DOES POLLUTION INCREASE SCHOOL ABSENCES?, *The Review of Economics and Statistics* **91**(4): 682–694. Publisher: The MIT Press.
URL: *https://www.jstor.org/stable/25651370*

Deryugina, T., Heutel, G., Miller, N. H., Molitor, D. and Reif, J. (2019). The Mortality and Medical Costs of Air Pollution: Evidence from Changes in Wind Direction, *American Economic Review* **109**(12): 4178–4219.
URL: *https://www.aeaweb.org/articles?id=10.1257/aer.20180279*

EPA's 2015 RCRA Final Rule Regulating Coal Combustion Residual (CCR) Landfills and Surface Impoundments At Coal-Fired Electric Utility Power Plants (2014). *Technical report*, Environmental Protection Agency.
URL: *https://www.regulations.gov/document/EPA-HQ-RCRA-2009-0640-12034*

Fell, H. and Kaffine, D. T. (2018). The Fall of Coal: Joint Impacts of Fuel Prices and Renewables on Generation and Emissions, *American Economic Journal: Economic Policy* **10**(2): 90–116.
URL: *https://www.aeaweb.org/articles?id=10.1257/pol.20150321*

Fell, H. and Maniloff, P. (2018). Leakage in regional environmental policy: The case of the regional greenhouse gas initiative, *Journal of Environmental Economics and Management* **87**: 1–23.
URL: *http://www.sciencedirect.com/science/article/pii/S0095069616302984*

Goodman-Bacon, A. (2018). Difference-in-Differences with Variation in Treatment Timing,

Technical Report w25018, National Bureau of Economic Research.
URL: *https://www.nber.org/papers/w25018*

Gray, W. B. and Shimshack, J. P. (2011). The Effectiveness of Environmental Monitoring and Enforcement: A Review of the Empirical Evidence, *Review of Environmental Economics and Policy* **5**(1): 3–24. Publisher: The University of Chicago Press.
URL: *https://www.journals.uchicago.edu/doi/10.1093/reep/req017*

Heissel, J. A., Persico, C. and Simon, D. (2020). Does Pollution Drive Achievement? The Effect of Traffic Pollution on Academic Performance, *Journal of Human Resources* p. 1218. Publisher: University of Wisconsin Press.
URL: *http://jhr.uwpress.org/content/early/2020/04/03/jhr.57.3.1218-9903R2*

Jans, J., Johansson, P. and Nilsson, J. P. (2018). Economic status, air quality, and child health: Evidence from inversion episodes, *Journal of Health Economics* **61**: 220–232.
URL: *https://www.sciencedirect.com/science/article/pii/S0167629616300704*

Kim, M.-K. and Kim, T. (2016). Estimating impact of regional greenhouse gas initiative on coal to gas switching using synthetic control methods, *Energy Economics* **59**: 328–335.
URL: *http://www.sciencedirect.com/science/article/pii/S0140988316302316*

Lee, K. and Melstrom, R. T. (2018). Evidence of increased electricity influx following the regional greenhouse gas initiative, *Energy Economics* **76**: 127–135.
URL: *http://www.sciencedirect.com/science/article/pii/S0140988318303992*

Murray, B. C. and Maniloff, P. T. (2015). Why have greenhouse emissions in RGGI states declined? An econometric attribution to economic, energy market, and policy factors, *Energy Economics* **51**: 581–589.
URL: *http://www.sciencedirect.com/science/article/pii/S0140988315002273*

Persico, C., Figlio, D. and Roth, J. (2019). The Developmental Consequences of Superfund Sites, *Journal of Labor Economics* **38**(4): 1055–1097. Publisher: The University of Chicago Press.
URL: *https://www.journals.uchicago.edu/doi/full/10.1086/706807*

Persico, C. L. and Johnson, K. R. (2021). The effects of increased pollution on COVID-19 cases and deaths, *Journal of Environmental Economics and Management* p. 102431.
URL: *https://www.sciencedirect.com/science/article/pii/S0095069621000140*

Rau, T., Urzúa, S. and Reyes, L. (2015). Early Exposure to Hazardous Waste and Academic Achievement: Evidence from a Case of Environmental Negligence, *Journal of the Association of Environmental and Resource Economists* **2**(4): 527–563. Publisher: The University of Chicago Press.
URL: *https://www.journals.uchicago.edu/doi/10.1086/683112*

Reyes, J. W. (2007). Environmental Policy as Social Policy? The Impact of Childhood Lead Exposure on Crime, *The B.E. Journal of Economic Analysis & Policy* **7**(1). Publisher: De Gruyter Section: The B.E. Journal of Economic Analysis & Policy.
URL: *https://www.degruyter.com/document/doi/10.2202/1935-1682.1796/html*

Roach, T. and Gittings, R. K. (2020). Power Sector Emissions under Tightening Carbon Dioxide Quotas.

Samet, J. M., Dominici, F., Curriero, F. C., Coursac, I. and Zeger, S. L. (2000). Fine Particulate Air Pollution and Mortality in 20 U.S. Cities, 1987–1994, *New England Journal of Medicine* **343**(24): 1742–1749. Publisher: Massachusetts Medical Society _eprint: https://doi.org/10.1056/NEJM200012143432401.
URL: *https://doi.org/10.1056/NEJM200012143432401*

Schwartz Joel, Bind Marie-Abele and Koutrakis Petros (2017). Estimating Causal Effects

of Local Air Pollution on Daily Deaths: Effect of Low Levels, *Environmental Health Perspectives* **125**(1): 23–29. Publisher: Environmental Health Perspectives.
URL: *https://ehp.niehs.nih.gov/doi/10.1289/EHP232*

Simeonova, E., Currie, J., Nilsson, P. and Walker, R. (2019). Congestion Pricing, Air Pollution, and Children's Health, *Journal of Human Resources* p. 0218. Publisher: University of Wisconsin Press.
URL: *http://jhr.uwpress.org/content/early/2019/10/07/jhr.56.4.0218-9363R2*

Simon, D. H. and Prince, J. T. (2016). The effect of competition on toxic pollution releases, *Journal of Environmental Economics and Management* **79**: 40–54.
URL: *https://www.sciencedirect.com/science/article/pii/S0095069616000139*

Wang, X., Deltas, G., Khanna, M. and Bi, X. (2020). Community Pressure and the Spatial Redistribution of Pollution: The Relocation of Toxic Releasing Facilities, *Journal of the Association of Environmental and Resource Economists* . Publisher: The University of Chicago Press.
URL: *https://www.journals.uchicago.edu/doi/10.1086/711656*

Zahran, S., Iverson, T., McElmurry, S. P. and Weiler, S. (2017). The Effect of Leaded Aviation Gasoline on Blood Lead in Children, *Journal of the Association of Environmental and Resource Economists* **4**(2): 575–610. Publisher: The University of Chicago Press.
URL: *https://www.journals.uchicago.edu/doi/10.1086/691686*

Appendix

Table 5: PA/OH Results

	Emissions			Releases		
	Total (1)	Metal (2)	Non-metal (3)	Total (4)	Metal (5)	Non-metal (6)
RGGI × Begin	-1.42***	-0.97***	-1.53***	-1.35***	-0.89**	-1.41***
	(0.41)	(0.35)	(0.45)	(0.41)	(0.33)	(0.44)
RGGI × Lower	-1.34***	-2.28***	-1.33***	-1.20***	-2.25***	-1.15**
	(0.38)	(0.64)	(0.48)	(0.38)	(0.63)	(0.47)
Combined effect, RGGI	-2.77***	-3.24***	-2.86***	-2.55***	-3.13***	-2.56***
	(0.67)	(0.93)	(0.78)	(0.67)	(0.89)	(0.74)
Leaker × Begin	-0.46	-0.08	-0.36	-0.65**	-0.04	-0.55*
	(0.32)	(0.23)	(0.37)	(0.28)	(0.22)	(0.29)
Leaker × Lower	-0.35	0.14	-0.21	-0.65**	0.19	-0.56**
	(0.34)	(0.25)	(0.44)	(0.25)	(0.24)	(0.27)
Combined effect, Leaker	-0.81	0.06	-0.56	-1.30***	0.15	-1.11**
	(0.65)	(0.46)	(0.80)	(0.47)	(0.44)	(0.51)
% change in pollution						
Begin, RGGI	-75.87***	-61.90***	-78.29***	-73.90***	-58.77***	-75.60***
	(9.93)	(13.49)	(9.86)	(10.65)	(13.81)	(10.72)
Lower, RGGI	-74.01***	-89.72***	-73.67***	-69.99***	-89.41***	-68.31***
	(9.79)	(6.61)	(12.59)	(11.49)	(6.64)	(14.86)
Total, RGGI	-93.73***	-96.08***	-94.28***	-92.17***	-95.63***	-92.27***
	(4.23)	(3.65)	(4.44)	(5.27)	(3.91)	(5.74)
Begin, Leaker	-36.63*	-7.52	-29.89	-47.72***	-3.43	-41.96**
	(20.49)	(21.57)	(26.12)	(14.76)	(21.76)	(16.90)
Lower, Leaker	-29.75	14.69	-18.93	-48.10***	20.87	-43.15***
	(24.09)	(28.71)	(35.47)	(13.06)	(29.19)	(15.54)
Total, Leaker	-55.48*	6.06	-43.16	-72.86***	16.72	-67.00***
	(28.92)	(49.22)	(45.36)	(12.80)	(51.82)	(16.81)
Observations	11172	9120	10926	11152	9118	10902
Adjusted R^2	0.55	0.60	0.55	0.53	0.61	0.53
County FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
RPS	Y	Y	Y	Y	Y	Y

Numbers in parentheses are standard errors. *, **, *** denote 10, 5, 1% significance levels.