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Robbing Peter to Pay Paul: The Impact of California's Cap-and-Trade Program on Toxic Emissions

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Abstract. We empirically examine the consequences of the introduction of a cap-and-trade program in California, showing that although the program helped reduce greenhouse gas (GHG) emissions, it had the unintended consequence of increasing toxic emissions from treated facilities, as facilities cut back on their waste-treatment efforts to reduce GHG emissions. We further show that this effect was weaker for more harmful toxins, for facilities that had invested in reducing toxic waste at source, and for those that were subject to close scrutiny from regulators, consistent with it being the result of strategic firm actions.

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Keywords: environmental sustainability • toxic emissions • regulation • multiple objectives • social impact • climate change

1. Introduction

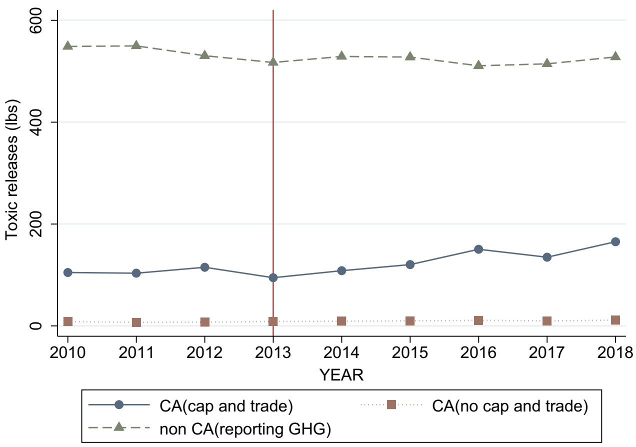
Faced with the growing threat of climate change, regulators and policy makers have increasingly sought ways to reduce greenhouse gas (GHG) emissions. One popular policy initiative to do so has been the introduction of cap-and-trade regimes—programs that set a limit on overall emission levels but allow firms to trade allowances, thus creating market incentives for firms to reduce GHG emissions—with such programs being implemented in California, the northeastern United States, Europe, and China, among others (Bang et al. 2017). Such programs have been shown to be effective: for instance, recent evidence suggests that facilities subject to cap-and-trade in California reduced their GHG emissions by 3%–9% (Hernandez-Cortes and Meng 2023).

What has received less attention is the impact of such policies on other environmental outcomes, such as emissions of toxic chemicals (King and Shaver 2001, Lenox and King 2004, Berchicci et al. 2017). This may be a critical oversight. As shown in Figure 1, average toxic emissions from California facilities subject to cap-and-trade increased by 75% in the five years after the introduction of the policy, while there were no comparable increases in emissions from facilities not subject to cap-and-trade, either within California or in other states.[1] This is a substantial and worrying increase in overall pollution levels, and a startling one, given that California has historically had some of the lowest levels of toxic emissions in the United States. Could it be that the cap-and-trade program has caused firms to reprioritize their efforts away from toxic emission reduction and toward GHG reduction, making one environmental outcome worse, even as it improves the other?

In this paper, we investigate that possibility. Adopting an empirically driven approach, we ask three questions: (1) Did the cap-and-trade program in California increase toxic emissions from treated facilities? (2) If so, what were the mechanisms driving this increase? (3) Was this effect strategic—that is, was it the result of specific firms choosing to reprioritize their environmental efforts to allow for higher toxic emissions?

Using detailed emissions data on 1,100 large U.S. manufacturing facilities from 2010 to 2018 and a difference-in-difference design that matches facilities subject to cap-and-trade in California to similar facilities elsewhere, we show that cap-and-trade did indeed have a positive effect on toxic emissions, causing such emissions to increase by 26%–42% relative to control facilities. We posit that this increase occurred because

Figure 1. (Color online) Toxic Emissions from Treated California Facilities, Nontreated California Facilities, and Non-California Facilities



Source. Author calculations based on EPA data.
Notes. We compare the average toxic emissions from treated California facilities (subject to cap-and-trade), nontreated California facilities, and non-California facilities that report their GHGs emissions to the EPA—that is, facilities of similar size as those subject to cap-and-trade.

cap-and-trade made waste-treatment activities more expensive, inadvertently raising the costs of emission reduction and prompting firms to strategically reduce their emission reduction efforts. Consistent with this, we show that the increase in toxic emissions following cap-and-trade was stronger the greater a facility's reduction in GHG emissions from waste treatment and that facilities subject to cap-and-trade reduced their waste-treatment activities, especially those conducted in-state.

To explore the strategic nature of this effect, we show that this effect was not uniform across all facilities. Building on the logic for our proposed mechanisms, we predict that the effect of cap-and-trade will depend on its impact on the costs of reducing toxic emissions, as well as the potential benefits to firms of doing so. Consistent with this, we find that our main effect is weaker for facilities that have implemented source reduction technologies, for facilities that are subject to regulatory scrutiny, and for comparatively more harmful chemicals. We also document a significant increase in toxic emissions from facilities not subject to cap-and-trade but owned by firms impacted by the regime change, consistent with the increase in toxic emissions being a strategic decision made at the corporate level.

Our study not only sheds new light on an important policy initiative to combat climate change by showing that it may have the unintended consequence of increasing toxic emissions, but it also links that unintended consequence to the strategic choice of some firms to respond to the new policy by cutting back on voluntary environmental efforts elsewhere. It thus joins an existing literature highlighting how firm strategies can undermine policy initiatives—for instance, work on pollution havens which shows that firms strategically relocate their activities to avoid more stringent regulation (Madsen 2009, Berry et al. 2021)—showing that, in some cases, firms may respond to new regulation at the expense of their voluntary prosocial efforts. In doing so, we also highlight the need to think about trade-offs among social objectives (Wang et al. 2016, Luo et al. 2018, Leslie 2019).

2. Empirical Context, Measures, and Methods

2.1. California's Cap-and-Trade Program

California's cap-and-trade program is a regulatory regime implemented by the California Air Resources Board (CARB), pursuant to California Assembly Bill 32, a legislative action aimed at reducing greenhouse gas emissions from facilities in California.[2] Under the cap-and-trade system, all facilities producing emissions of over 25,000 metric tons of CO_2 per year (such facilities make up over 80% of industrial GHG emissions in the state) are allocated a fixed allowance of CO_2 emissions every year, starting in 2013. These allowances are adjusted annually for each facility, with the allocation being based on the facility's production levels and benchmark GHG emissions for its products, as well as an annual cap adjustment factor (that reduces total allowances in the system by 4% every year) and an industry-level assistance factor, which places the burden of GHG reduction disproportionately on certain industries, based on the likely economic impact of GHG reduction on the industry. Facilities are allowed to trade their allowances through auctions organized by the state, so facilities whose emissions exceed their allowed cap can purchase allowances, while those whose emissions are below their cap can sell their excess allowances.[3] The purpose of the program is to create a market for GHG emissions and, thus, to incentivize firms to reduce their GHG emissions.

Although the impact of this program has been widely studied, the focus has, unsurprisingly, been on its effectiveness in reducing GHG emissions, with early work raising concerns about the program's efficacy and equity (Cushing et al. 2018), but more recent studies finding strong support for a systematic reduction in GHG emissions (Hernandez-Cortes and Meng 2023). Our focus in this study, however, is on the effect of the cap-and-trade system on a different type of pollution: emissions of toxic chemicals. Such emissions were not the target of the cap-and-trade system, nor was the implementation of the system expected to impact such emissions; in fact, the CARB site clearly states: "All covered entities in the Cap-and-Trade program are still subject to existing air quality permit limits for toxic air pollutants." Moreover, it seems very unlikely that California lawmakers intended to pass a law that would increase the exposure of their constituents to poisonous chemicals. If the cap-and-trade program caused an increase in such emissions, therefore, it seems reasonable to conclude that such a consequence was unintended.

2.2. Data

A key advantage of studying toxic emissions is that releases of toxic chemicals are closely tracked by the U.S. Environmental Protection Agency (EPA) at a facility level, and reporting of such releases is mandatory. For our analysis, we combine panel data on these releases—collected in the EPA's Toxic Release Inventory (TRI)—with three other databases from the EPA: the Greenhouse Gas Reporting Program (GHGRP) for greenhouse gas releases; Pollution Prevention data for clean technologies installation; and the Enforcement and Compliance History Online data for compliance and enforcement. All of these data sets have been used extensively in prior research on corporate environmental sustainability (King and Shaver 2001, Kalnins and Dowell 2017, Sampson and Zhou 2018, Kim et al. 2019). Combining these data gives us a facility-level panel of environmental data from 2010 (the year in which the EPA launched the GHGRP) to 2018 (the latest year available from the EPA at the time of data collection), which we restrict to facilities in manufacturing industries (two-digit Standard Industrial Classification codes 20–39) and to facilities reporting over 25,000 metric tons of GHG emissions.[4] We then match each facility to the Dun and Bradstreet (D&B) Historical Data File using hand-collected D&B numbers, in order to collect ownership and financial data on each facility. Because we want to isolate the impact of the cap-and-trade program from the effect of changes in ownership (Sampson and Zhou 2018), we drop 2,002 facilities that went through ownership changes during our study period. This leaves us with a full sample of 12,566 observations across 1,570 facilities from 2010 to 2018.

2.3. Measures

Our main outcome variable is a facility's toxic chemical emissions in a given year. We construct this measure by summing emissions of all toxic chemicals reported to the EPA at the facility level. Following prior work, we take the natural logarithm of this sum, both because the raw emission numbers are highly skewed and because we are interested in the proportional changes in toxic emissions within a facility over time (King and Shaver 2001, King and Lenox 2002). Unlike prior work, we do not weight the individual chemicals by their toxicity (though our results are robust to doing so), but instead undertake supplementary analyses to look at how our main effect varies for less versus more toxic chemicals.

Because we are running a difference-in-difference analysis, a simple treatment variable would be the interaction of *CA_post2013*, capturing the effect of facilities being exposed to the cap-and-trade system, which went into effect for all of our treated facilities in the year 2013. However, such a variable might reflect any other change (regulatory or otherwise) impacting facilities in California after 2013. To deal with this issue, we instead use as our main treatment variable *Stringency*, which is calculated as the inverse of the average number of free allowances given to a facility in that industry in that year. We base our stringency measure on the aggregate allocation to each sector in that year rather than facility-level allocations because the latter may be influenced by firm strategies and because we do not have data on facility-level allowances in any case. Our stringency measure thus leverages the variance in allowances across industries and years, as determined by the combination of CARB's industry assistance factor and its cap adjustment factor (Online Appendix B documents this variation).

Intuitively, this measure captures the "strength" of the cap-and-trade treatment, with higher values reflecting a more stringent GHG emissions cap.[5] It also has the advantage of being specific to cap-and-trade, making it less likely that we are capturing the effect of other regulatory changes or economic trends in California. Note that *Stringency* is zero for all facilities not subject to cap-and-trade—that is, all facilities outside California and California facilities before 2013.

In addition to these main measures, we include a number of control variables (King and Shaver 2001, Kim et al. 2019), including the size of the facility, the number of toxic chemicals it processes, and whether it was subject to EPA inspection or corrective action in the past five years, as well as firm-level controls for number of subsidiaries and states in which the firm operates. Online Appendix C lists all controls, as well as a set of moderating variables used in supplementary analyses. In addition to these controls, all analyses include year and facility fixed effects. Table 1 reports the summary statistics and correlations of variables for our main sample. Although we see a few high correlations, the average variance inflation factor for variables included in our main regressions is just 2.30.

2.4. Method

As mentioned, we use a difference-in-difference analysis to identify the causal effect of the cap-and-trade program. Our main specification is:

$$Toxic\ emissions_{it} = \alpha + \beta Treatment_{it} + \chi_{it} + \phi_i + \phi_t + \varepsilon_{it},$$

for facility i in year t, where $Treatment_{it}$ is measured as $Stringency_{it}$ in our main analysis. All models include facility- and year-fixed effects, as well as the full set of

Table 1. Summary Statistics and Correlations

Variable	Mean	SD	Min	Max	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1) *GHG*	10.64	3.08	0.00	15.98																	
(2) *Toxic*	9.77	3.44	0.00	17.05	0.23																
(3) *Stringency*	0.45	2.98	0.00	35.63	−0.02	−0.08															
(4) *Employees*	4.43	1.78	0.00	8.16	−0.02	0.06	0.02														
(5) *# of chemicals*	5.70	5.69	1.00	41.00	0.27	0.38	−0.07	0.02													
(6) *Same owner*	22.41	30.99	1.00	181.00	0.00	0.04	−0.05	0.10	−0.06												
(7) *# of states*	8.90	8.21	1.00	34.00	−0.02	0.01	−0.03	0.12	−0.05	0.82											
(8) *Inspection 1*	0.44	0.50	0.00	1.00	0.01	−0.02	0.02	0.03	−0.03	0.07	0.04										
(9) *EPA action 1*	0.39	0.49	0.00	1.00	0.04	0.03	0.00	0.02	0.02	0.07	0.02	0.89									
(10) *Energy*	9.74	3.42	0.00	15.39	0.70	0.22	0.00	0.05	0.27	−0.06	0.01	−0.01	0.02								
(11) *Waste*	0.74	2.50	0.00	12.56	0.09	0.20	−0.04	0.03	0.05	0.13	0.09	0.02	0.03	0.10							
(12) *Production*	3.96	5.50	0.00	15.58	0.41	0.13	−0.04	−0.02	0.13	−0.02	−0.06	0.01	0.04	−0.04	−0.05						
(13) *Generated*	11.36	3.96	−11.73	19.12	0.14	0.79	−0.04	0.09	0.41	0.00	−0.02	−0.03	0.01	0.19	0.15	0.07					
(14) *Treated*	7.11	6.45	0.00	19.90	0.03	0.38	−0.03	0.06	0.37	0.05	0.02	−0.03	−0.01	0.11	0.16	−0.13	0.58				
(15) *In-state*	7.48	6.33	0.00	19.90	0.02	0.37	−0.03	0.09	0.38	0.04	0.02	−0.01	0.01	0.11	0.15	−0.11	0.62	0.93			
(16) *Out-state*	0.69	2.18	0.00	18.08	0.04	0.14	−0.04	0.06	0.17	−0.03	0.02	−0.05	−0.03	0.05	−0.04	0.07	0.24	0.09	0.11		
(17) *Inspection 2*	0.07	0.25	0.00	1.00	0.04	0.06	−0.01	−0.03	0.15	−0.02	−0.02	0.02	0.03	0.04	−0.00	0.01	0.06	0.05	0.05	0.02	
(18) *EPA action 2*	0.09	0.29	0.00	1.00	0.02	0.01	0.03	0.04	−0.00	0.03	0.00	0.36	0.34	0.01	0.02	0.02	0.00	−0.01	0.00	−0.04	−0.00

Note. See Online Appendix C for variable definitions and sources.

controls. For our main models, we cluster standard errors at the state level to account for the potential interdependence between facilities in the same state. We choose to cluster standard errors by state because that is the level at which our treatment—the introduction of a cap-and-trade regime—is implemented, so errors within the same state may be correlated, biasing ordinary least squares (OLS) estimates (Bertrand et al. 2004, Cameron and Miller 2015). For full transparency, we report the results of alternative clustering approaches in Online Appendix D, which confirms that our main results are supported when clustering standard errors by facility or parent firm, as well as by EPA regions (to account for correlations between facilities subject to the same regulatory jurisdiction).[6]

We run this analysis on a sample of facilities that meet the threshold to be subject to cap-and-trade (CO_2 emissions exceeding 25,000 metric tons a year) both within California and outside. As such, our empirical design compares California facilities subject to cap-and-trade to similar facilities outside California. We prefer this design to the alternative design of comparing treated California facilities (i.e., those subject to cap-and-trade) to untreated California facilities (cf. Hernandez-Cortes and Meng 2023) for two reasons. First, by definition, untreated California facilities are generally smaller in scale than treated California facilities, making the two groups not strictly comparable. Second, although the cap-and-trade regime was directly targeted at facilities of a certain size, it seems likely that it would have substantial spillovers to other California facilities (Simcoe and Toffel 2014). Indeed, in later analysis, we show evidence of such a spillover effect of cap-and-trade on untreated California facilities. Thus, California facilities not strictly subject to cap-and-trade may still be partly "treated," making them less appropriate as controls. That said, our main findings are robust to comparing treated California facilities to untreated California facilities, as well as to comparing treated California facilities with high stringency to those with low stringency (with standard errors clustered by facility), as shown in Online Appendix E.

In using non-California facilities as our control group, a key identifying assumption for our analysis is that facilities in California are otherwise identical to facilities elsewhere in terms of toxic emissions, except for the effect of the treatment (the introduction of cap-and-trade). This assumption would be violated if California facilities differed from facilities in other states on other dimensions: their size, the kind of products they manufactured, the types of chemicals used, etc. To adjust for this, we use coarsened exact matching (CEM) to create a subsample of treated and control facilities that look more similar on observables prior to 2013. Specifically, we match each of our treated facilities to facilities in the same (four-digit North American Industry Classification

System) industry that were similar in facility size (measured by number of employees), toxic emission levels, and number of toxic chemicals processed, because these are all factors that are likely to directly impact facility emission levels. In addition, we also match on the number of other facilities owned by the same firm as well as on two key location characteristics—the presence of an environmental nongovernmental organization (NGO) in the same county, and the county's political orientation (i.e., whether it voted Republican or Democrat in the presidential election)—because these may also impact the extent to which a facility engages in voluntary emissions reduction, though (as shown in Online Appendix F) our results are robust to not matching on these additional variables. As a result of this matching, our final sample reduces to 8,801 observations across 1,100 facilities. For further robustness, we also undertake analyses using synthetic controls, rather than CEM, at both state and facility level, the results of which are shown in Online Appendix G.

3. Did Cap-and-Trade Raise Toxic Emissions in California?

Table 2 shows the results of our main analysis. Specifically, Model (1) shows a regression predicting toxic emissions as a function of all our control variables (including year and facility fixed effects), and Model (2) then adds our main treatment measure *Stringency*.

Table 2. Main Result

Variable	M1	M2	M3	M4
Stringency		0.03***		
		(0.00)		
Auction			0.03***	
			(0.01)	
CA_post2013				0.28***
				(0.09)
Employees	0.03	0.03	0.03	0.03
	(0.05)	(0.05)	(0.05)	(0.05)
# of chemicals	0.29***	0.29***	0.29***	0.29***
	(0.05)	(0.05)	(0.05)	(0.05)
Same owner	0.01	0.01	0.01	0.01
	(0.01)	(0.01)	(0.01)	(0.01)
# of states	−0.05	−0.05	−0.05	−0.05
	(0.06)	(0.06)	(0.06)	(0.06)
Inspection 1	−7.27***	−7.30***	−7.30***	−7.29***
	(1.51)	(1.51)	(1.51)	(1.51)
EPA action 1	0.10	0.11	0.11	0.11
	(0.33)	(0.33)	(0.33)	(0.33)
Observations	8,801	8,801	8,801	8,801
R^2	0.10	0.10	0.10	0.10
Number of facilities	1,100	1,100	1,100	1,100
Year FE	Y	Y	Y	Y
Facility FE	Y	Y	Y	Y

Notes. Dependent variable is (log) toxic emissions. OLS panel regressions with year and facility fixed effects. Robust standard errors clustered by state are in parentheses.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

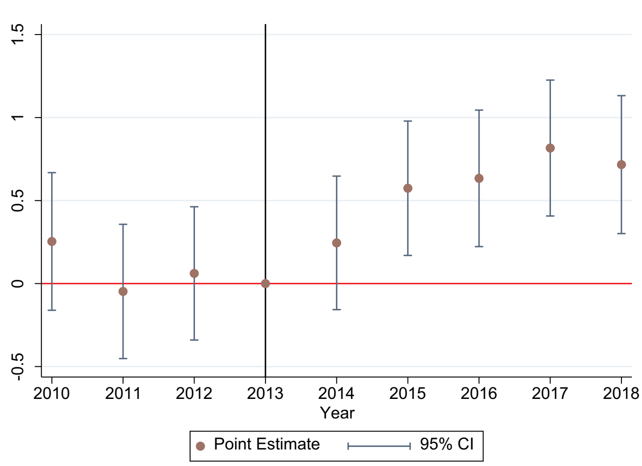
This treatment measure enters the regression with a positive and significant coefficient, confirming that the cap-and-trade regime did lead to a relative increase in toxic emissions from treated facilities compared with matched facilities elsewhere. In terms of economic magnitude, the point estimate in Model (2) implies that moving from a regime without cap-and-trade to one with average stringency[7] is associated with a 33.6% increase in toxic emissions from treated facilities relative to controls (the 95% confidence intervals for this estimate imply an increase of between 25.5% and 41.7%). Models (3) and (4) further confirm the robustness of this main result using alternative treatment measures carbon auction price and a binary indicator of treatment respectively. Online Appendix F presents epistemic maps (King et al. 2021), showing that this relationship holds across 135 different specifications, using a range of alternative measures and sampling choices.

Figure 2 shows our main results graphically, plotting the year-by-year coefficients of the treatment from a two-way fixed-effects (TWFE) model. As expected, the coefficients for the lead period are not significantly different from zero (a joint significance test yields an F-statistic of 0.77 and a p-value of 0.51), whereas the coefficients for the lag period are generally positive and significant (F-statistic of 4.37 and a p-value of 0.00).

4. Exploring the Causal Mechanism

Having established a causal relationship between the introduction of cap-and-trade in California and an increase in the toxic emissions from treated facilities, we next attempt to better understand the mechanism underlying this effect. Our basic intuition is that firms engage in voluntary toxic emission reduction in order to avoid censure from environmental activists and

Figure 2. (Color online) Event-Study Plot



Note. Based on TWFE, we create the plot with the point estimate and confidence interval (CI) of the difference between the treated (California facilities in cap-and-trade program) and the control (matched non-California facilities) groups.

local communities or to be rewarded for their responsible behavior by key stakeholders, such as investors, employees, or customers (Hiatt et al. 2015, Kim et al. 2019, Luo and Kaul 2019). Cap-and-trade increases the costs of such voluntary efforts because the treatment of toxic waste is a substantial source of GHG emissions (in our sample, GHG emissions attributable to waste treatment accounted for an average of 15% of overall GHG emissions), and an increase in the cost of GHG emissions (coupled with incentives to cut back on such emissions) makes toxic waste treatment more expensive. Firms may thus respond to cap-and-trade by strategically cutting back on their toxic emission reduction efforts in light of their higher cost.

Although there are, of course, other ways for firms to reduce GHG emissions or compensate for the higher costs of waste treatment, three factors make cutting back on waste treatment an especially expedient way of reducing GHG emissions. First, end-of-pipe waste treatment processes (Dutt and King 2014) are often relatively independent of the main manufacturing process itself, so firms can choose to cut back on those without risking impact to their primary production process. Second, the amount of waste generated in making a product is not directly related to the quality of the product itself. End consumers of a firm's products may not be exposed to the toxic emissions produced by a firm's facilities, given that such emissions are largely local in nature, and without detailed monitoring and transparency of reporting consumers may not even know the amount of waste associated with the products they purchase. Cutting back on waste treatment may thus have a relatively limited impact on firm competitiveness, compared with the alternative of passing on the higher cost of GHG emissions to their customers. Third, both toxic emissions and GHG emissions represent forms of environmental impact—albeit with distinct effects—so firms might reasonably expect that environmental stakeholders' concern with increasing toxic emissions may be partly offset by their appreciation of lower GHG emissions. In sum, we think a plausible response to the introduction of cap-and-trade—and the resulting increase in costs of waste treatment—is for firms to cut back on voluntary reductions of their toxic emissions.

We undertake two sets of analyses to test this potential mechanism.[8] First, in Table 3, Panel A, we look at the effect of cap-and-trade on GHG emissions, broken out by the source of the emissions (energy generation, production, or waste treatment). The analysis in this table uses the same difference-in-difference specification as that in Table 2, except that our outcome variable is now (logged) GHG emissions. Consistent with prior work (Hernandez-Cortes and Meng 2023), we do see a reduction in GHG emissions as a result of cap-and-trade, but this reduction is limited to GHG emissions from waste treatment and production. This confirms that firms responded to cap-and-trade by cutting back on GHG emissions from waste treatment. Table 3, Panel B then looks at how these GHG reductions moderate the main effect of *Stringency* in Table 2. We see a negative coefficient of the interaction between *Stringency* and GHG emissions from waste treatment when predicting toxic emissions, meaning that the positive effect of cap-and-trade on a facility's toxic emissions is stronger the greater the facility's reduction of GHG

Table 3. Mechanism Analysis: GHG Reduction by Source

	Panel A			Panel B		
Variables	*Energy*	*WasteGHG*	*ProdGHG*	*Toxic emissions*		
Stringency	−0.00	−0.01***	−0.02***	0.03***	0.04***	0.04***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
WasteGHG				−0.03		−0.03
				(0.04)		(0.04)
Stringency × *WasteGHG*				−0.00***		−0.00***
				(0.00)		(0.00)
ProdGHG					0.07***	0.07***
					(0.02)	(0.02)
Stringency × *ProdGHG*					−0.00***	−0.00***
					(0.00)	(0.00)
Controls included	Y	Y	Y	Y	Y	Y
Observations	8,801	8,801	8,801	8,801	8,801	8,801
R^2	0.02	0.03	0.04	0.10	0.11	0.11
Number of facilities	1,100	1,100	1,100	1,100	1,100	1,100
Year FE	Y	Y	Y	Y	Y	Y
Facility FE	Y	Y	Y	Y	Y	Y

Notes. Dependent variable is (log) GHGs based on source of emissions, as defined by the EPA, for Panel A and (log) toxic emissions in Panel B. OLS panel regressions with year and facility fixed effects. All models include full set of control variables. Robust standard errors clustered by state are in parentheses.

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

emissions from waste treatment. This is in line with our proposed mechanism.

Next, in Table 4, we look directly at the effect of cap-and-trade on waste generation, release, and treatment, again using the same difference-in-difference specification, but now focusing on toxic waste outcomes as our dependent variables. The first two columns of Table 4 show that although the amount of toxic waste generated by treated facilities saw a small relative decline following cap-and-trade, the waste released increased following cap-and-trade, even after controlling for the waste generated. This is consistent with firms treating less of their waste after cap-and-trade was introduced. The next three columns of Table 4 test this directly, looking at the effect of cap-and-trade on the amount of waste treated by the facility, while controlling for waste generated. Moreover, the last two columns distinguish between waste treatment from California facilities within the state versus out-of-state treatment of waste from California facilities. Consistent with our theory, we see that negative effect on waste treatment is limited to in-state waste treatment; out-of-state waste treatment from California facilities is not impacted by cap-and-trade.

5. Is This Effect Strategic?

Our argument thus far has been that the increase in toxic emissions following cap-and-trade is the result of firms strategically cutting back on voluntary efforts to reduce toxic emissions as the higher cost of GHG emissions makes such efforts more costly. If that is true, we would expect our main effect to vary across facilities and firms, being stronger (a) the weaker the potential benefits to the firm from voluntary reduction in toxic emissions and (b) the stronger the effect of cap-and-trade on the cost of treating toxic emissions. We explore these potential sources of heterogeneity through three sets of analyses, using a split sample approach (Shaver 2019).

5.1. Facility Inducements and Constraints

We start by considering how the effect of cap-and-trade on the benefits and costs of toxic emission reduction may vary across facilities. First, we would expect the effect of cap-and-trade to be weaker the less a facility's efforts to reduce toxic emissions result in increased GHG emissions. In particular, we expect them to be weaker for facilities that have installed source reduction technologies—that is, have modified their manufacturing process to generate less toxic waste—compared with facilities that simply rely on end-of-pipe treatment of the waste they generate (Dutt and King 2014). The costs of reducing toxic emissions for facilities that rely on source reduction are less connected to GHG emissions and therefore less impacted by cap-and-trade, and such facilities may also be reluctant to make significant changes to their operations to reduce GHG emissions at the cost of higher toxic emissions. Table 5, Panel A shows support for this prediction, with facilities without source reduction technologies being significantly more likely to increase their toxic emissions after the introduction of cap-and-trade. In fact, the entire increase in toxic emissions comes from such facilities. Facilities that had source reduction technologies reduced their toxic emissions even after cap-and-trade was put in place.

Second, we expect the effect of cap-and-trade to be weaker the greater the potential benefit to the facility from reducing toxic emissions (or, equivalently, the greater the potential cost to it of increasing toxic emissions). Specifically, we expect this benefit to be greater for facilities that are collocated with environmental nonprofits because such nonprofits are likely to closely monitor the emissions of facilities in their backyard and are capable of imposing penalties on facilities that

Table 4. Mechanism Analysis: Waste Generation, Release, and Treatment

			Waste_treat		
Variables	*Waste_gen*	*Waste_release*	Total	Instate	Outstate
Stringency	−0.01***	0.04***	−0.01**	−0.01*	−0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Waste_gen		0.67***	0.45***	0.44***	0.00
		(0.00)	(0.08)	(0.08)	(0.01)
Controls included	Y	Y	Y	Y	Y
Observations	8,801	8,801	8,801	8,801	8,801
R^2	0.09	0.43	0.14	0.13	0.04
Number of facilities	1,100	1,100	1,100	1,100	1,100
Year FE	Y	Y	Y	Y	Y
Facility FE	Y	Y	Y	Y	Y

Notes. Dependent variable is (log) toxic waste. All models include full set of control variables. OLS panel regressions with year and facility fixed effects. Robust standard errors clustered by state are in parentheses.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Table 5. Strategic Moderators: Facility Inducement and Constraints

	Panel A: Reduction technology		Panel B: Stakeholder monitoring			
			County NGO		*EPA Penalties*	
Measure	Yes	No	Yes	No	Yes	No
Stringency	−0.07***	0.05***	0.03***	0.04***	0.02**	0.05***
	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
Difference	*0.12****		*0.01*		*0.03****	

Notes. Dependent variable is (log) toxic emissions. Coefficients shown are from OLS panel regressions with full set of controls and year and facility fixed effects. Definitions of moderators used to split samples can be found in Online Appendix C. Robust standard errors clustered by state are in parentheses. Numbers in italics show the difference between the coefficients of interest, with p-values based on Wald test of significance of difference.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

increase their emissions (Hiatt et al. 2015, Luo et al. 2018). We also expect this benefit to be greater for facilities that are being closely monitored by government regulators. To the extent that the toxic emission reduction efforts of such facilities are mandatory, rather than voluntary, they may not have the option of cutting back on them. Table 5, Panel B shows partial support for these predictions, showing that the effect of cap-and-trade on toxic emissions is weaker for facilities that have incurred EPA penalties for their toxic emissions in the recent past, though we do not see a significant difference between facilities subject to NGO scrutiny and those not.

5.2. Chemical Toxicity

The arguments above also suggest that the effect of cap-and-trade may vary across different toxic chemicals. If the increase in toxic emissions reflects firms strategically cutting back on toxic emission reduction in response to higher costs, we would expect this increase to be systematically higher for (relatively) less harmful chemicals. The less harmful the chemical, the lower the potential benefit to the firm from reducing its emissions and, equivalently, the lower the potential cost of allowing such emissions to increase. Table 6 tests this prediction, splitting our overall toxic emissions measure into more versus less toxic emissions, based on five different indicators of toxicity (described in Online Appendix C). Consistent with our expectation, we find that the positive effect of cap-and-trade is stronger for comparatively less toxic chemicals, further confirming that our main findings reflect strategic intent. Note that less toxic chemicals are also those subject to less regulatory scrutiny—as reflected in our reportable quantity and reference concentration measures—so these results are also consistent with firms strategically limiting the increase in emissions to chemicals less subject to regulatory scrutiny.

5.3. Nontreated Facilities Owned by Treated Owners

As a final test of strategic behavior, we consider California facilities not subject to cap-and-trade, distinguishing between those that were owned by firms that had other facilities subject to cap-and-trade and those that were not. The logic here is that the potential benefits of toxic emission reduction are likely to accrue at the firm level, so the decision to increase toxic emissions should be a strategic choice at the firm level, rather than an operational choice by a facility. We would expect a firm cutting back on toxic emission reduction to do so across all its facilities, irrespective of whether they were subject to cap-and-trade. Table 7 shows support for this prediction. It shows that untreated California facilities belonging to treated firms saw a significant increase in their toxic emissions

Table 6. Strategic Moderators: Chemical Toxicity

	(1) Carcinogenic		(2) Bio-accumulative		(3) Reportable quantities		(4) Reference concentration		(5) Inhalation unit risk	
Measure	More	Less	More	Less	More	Less	More	Less	More	Less
Stringency	0.01**	0.03***	0.00	0.04***	0.01*	0.03***	0.01***	0.02***	−0.00	0.04***
	(0.01)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)
Difference	*0.02****		*0.04****		*0.02****		*0.01***		*0.04****	

Notes. Dependent variable is (log) toxic emissions. Coefficients shown are from OLS panel regressions with full set of controls and year and facility fixed effects. Definitions of moderators used to split samples can be found in Online Appendix C. Robust standard errors clustered by state are in parentheses. Numbers in italics show the difference between the coefficients of interest, with p-values based on Wald test of significance of difference.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Table 7. Strategic Moderators: Treated Owner

	Treated owner		
Measure	Yes		No
Stringency	0.06*** (0.00)		0.01*** (0.01)
Difference		*−0.05****	

Notes. Sample includes 811 nontreated California facilities (i.e., facilities not subject to cap-and-trade) matched to facilities outside California. Dependent variable is (log) toxic emissions. Coefficients shown are from OLS panel regressions with full set of controls and year and facility fixed effects. Definitions of moderators used to split samples can be found in Online Appendix C. Robust standard errors clustered by state are in parentheses. Numbers in italics show the difference between the coefficients of interest, with p-values based on Wald test of significance of difference.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

following the introduction of cap-and-trade compared with matched facilities outside California. When we compare untreated facilities without such ownership ties to matched non-California facilities, the effect is much smaller. Not only does this result suggest strategic action on the part of firms with facilities subject to cap-and-trade, it also documents a (within-firm) spillover of our main effect from treated to untreated facilities.

6. Discussion and Conclusion

Our study sheds new light on a key policy initiative to deal with climate change: the use of cap-and-trade regimes to limit carbon emissions (Bang et al. 2017). We show that although such policies may be successful in reducing GHG emissions (Hernandez-Cortes and Meng 2023), they may have the unintended consequence of making toxic waste treatment more costly, driving firms to strategically increase their emissions of toxic chemicals. We further show that this effect is not uniform across facilities, but is stronger where the effect of cap-and-trade on the cost of toxic emission reduction is likely to be high and the benefits of reducing toxic emissions are low and that it applies across all facilities of a treated firm. In developing policies to deal with climate change, policymakers thus need to consider how higher costs of carbon may impact other (voluntary) environmental efforts by firms, including efforts to reduce other pollutants.

Our findings are also important for strategy scholars. Recent work in this area has sought to move beyond the traditional emphasis on trade-offs between financial and social objectives (Battilana et al. 2022) to examine trade-offs among different social objectives (Wang et al. 2016) and the concern that firms may sometimes contribute to one social issue by cutting back on voluntary efforts on another (Luo et al. 2018, Leslie 2019). Not only do we document firms making such trade-offs across two key environmental objectives, but we also highlight factors that may limit such behavior, such as monitoring by the state (Luo and Kaul 2019) and irreversible resource commitments (Dutt and King 2014, Cuypers et al. 2016). Further, our work contributes to recent literature highlighting how the strategic actions of firms in response to regulation may serve to undermine that regulation by producing unintended consequences (Berry et al. 2021). Finally, our work has important social implications. Increased levels of toxic emissions have been linked to a variety of serious health conditions—including asthma, cancer, and infant mortality—as well as to ecological damage and economic harm. The sharp increase in toxic emissions following the introduction of cap-and-trade that we document thus reflects a substantial increase in social costs for California residents. Of course, our study is limited to examining the impact of a single policy change in a single jurisdiction, so it would be good to have our findings replicated in other contexts.

To conclude, we empirically examine the impact of the introduction of a cap-and-trade regime on emissions of toxic chemicals. Using a difference-in-difference design, we show that treated facilities in California increased their toxic emissions relative to similar facilities in other states, primarily through a reduction in toxic waste treatment. We also find that this effect is concentrated in relatively less toxic chemicals, facilities subject to lower regulatory scrutiny, and facilities without source reduction technologies and that this effect holds for nontreated facilities of treated firms—all suggesting that it reflects firms strategically adjusting their voluntary toxic emission reduction efforts in response to higher costs of waste treatment caused by the policy.

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Endnotes

[1] Online Appendix A provides further evidence for this pattern at the county level, showing that California counties with more facilities subject to cap-and-trade saw a greater increase in toxic emissions after the program began.

[2] For more details on the California cap-and-trade program see: https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program (accessed July 15, 2024).

[3] Facilities are also allowed to offset their emissions by planting trees, etc., but such offsets are allowed at the discretion of the board and are capped at no more than 8% of total emissions. For the purposes of our analyses below, we ignore these offsets.

[4] Although all facilities employing 10 or more people and processing, using, or storing more than a threshold amount of any one of over 600 toxic chemicals are required to report their emissions to the TRI, only facilities emitting more than 25,000 metric tons of CO_2 are required to report to the GHGRP. Because this is also the emissions cut-off for the cap-and-trade regime, limiting our sample in this way allows us to compare treated facilities in California to facilities of comparable size elsewhere.

[5] In robustness checks, we use an alternative treatment measure, the auction price of carbon allowances, which also varies from year to year and captures the extent to which the cap-and-trade regime is constraining GHG emissions, with higher prices implying a more binding constraint.

[6] Online Appendix D does show that some of our moderation results are not robust to some alternative clusterings. We do not see these as negating these findings, which are exploratory in any case, because we think states are the right level at which to cluster our results, but report these alternative clustering approaches in the online appendix for full transparency.

[7] Average value of stringency for treated facilities is 10.18.

[8] Online Appendix H presents analyses examining, and ruling out, two alternative mechanisms.

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