Prices and Quantities: Implementation of Corporate Voluntary Climate Targets

Joseph E. Aldy and Alison Ong[1]

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Abstract

An increasing number of corporations have voluntarily implemented climate targets. Some firms announce quantitative climate targets, including net-zero goals; some adopt internal carbon pricing to inform strategy and investment risk; some use both approaches. We study how emissions and financial performance evolve after a firm adopts a quantitative target, compared to performance after a firm adopts a hybrid approach of both a quantitative target and internal carbon price. Using a novel, comprehensive dataset that encompasses all major climate targets for the Russell 3000, we document trends in internal carbon price adoption and resulting implications for firm-level emissions. We find that emissions-intensive firms tend to benefit most from hybrid approaches, and that hybrid approaches yield larger amounts of emissions reductions compared to quantity-goal-only approaches.

JEL Codes: Q54, Q58, M48

[1] Aldy: Harvard Kennedy School, Resources for the Future, National Bureau of Economic Research, and Center for Strategic and International Studies; joseph aldy@hks.harvard.edu. Ong: Harvard University; aong@law.harvard.edu. The authors gratefully acknowledge funding support through the Salata Institute cluster project on Corporate Climate Targets, and invaluable feedback from Mike Toffel and Srimayi Tenali. Carissa Hanjani and Ariane Bretl provided excellent research assistance.

I. Introduction

Corporations have increasingly adopted voluntary climate targets, and many of these targets are focused on greenhouse gas emissions reductions. The goal of this study is to assess how a firm's choice of greenhouse gas reduction *instrument* affects both emissions outcomes and corporate financial metrics. Many firms have made voluntary pledges to quantitatively reduce emissions, but only a subset of those firms have also adopted an internal carbon pricing (ICP) mechanism. We compare outcomes for the firms who have only set a quantitative goal, to those where the firm adopts a hybrid approach that pairs a quantitative target with an internal carbon price.

Announcing the intent to achieve a quantitative carbon reduction target does not necessarily translate to substantive or lasting declines in real emissions. However, the presence of an ICP, particularly if it takes the form of an internal carbon fee and/or is broadly applied to firm decision-making, may indicate that the firm is engaging in real financial commitments towards sustainability goals rather than mere "cheap talk." Using a novel dataset of quantitative carbon targets and internal carbon price adoption for the Russell 3000 (Aldy et al. 2026), we characterize patterns in ICP and quantitative target adoption over time, describe heterogeneity in instrument selection across industry types, and conduct event study analyses to examine the association between ICP adoption and declines in firm-level Scope 1 greenhouse gas emissions.

Our work advances knowledge about the types of firms that tend to adopt internal carbon prices and the circumstances under which ICPs may be most effective for emissions reduction. We document steady increases in the uptake of both ICPs and quantitative targets over time: as of 2023, approximately one-third of the Russell 3000 had at least a quantitative goal, and 164 firms had implemented ICPs. Although this means that only around 5% of firms (by count) have an ICP, we show that this set accounts for around half of the Russell 3000's total emissions, and over a quarter of its overall market valuation. In interrogating different modes of ICP implementation, we find that the form of the ICP matters. If the firm treats the ICP as an internal carbon tax, then there is a positive correlation between the ICP $/tonne value and the ambition of its quantitative target. However, there is no such correlation for firms that treat their ICPs as shadow prices or implicit prices. We also compare a matched sample of firms that have implemented both an ICP and a quantitative target (the "hybrid" approach) to firms that have a quantitative target but no ICP (the "Q Only" approach). Our model estimates that firms pairing a quantitative goal with an ICP reduce their annual emissions intensity by approximately 200 tonnes/$M more than firms that only announce quantitative goals; however, there is notable variation across industry types and policy environment. We show that the decline in emissions associated with adopting an ICP tends to be largest for high emissions-intensity firms, implying that ICPs may be particularly well-suited to delivering large emissions reductions for industries such as the utility sector or aviation. Taken together, our results suggest that using price and quantity instruments together can be a compelling approach for firms to achieve meaningful steps towards sustainability.

A longstanding challenge of policy design under uncertainty is the choice of price-based versus quantity-based modes of control (or some hybrid approach of both). The standard prices and quantities framework (Weitzman 1974, 1978) has been applied to a variety of environmental problems including pollution control (Roberts and Spence 1976), the design of carbon emissions policy (Newell and Pizer 2008; Aldy and Armitage 2022; Stavins 2022), and the potential advantages or drawbacks of hybrid approaches (Pizer 2002). Separately, the literature concerning the informational structure of the firm has studied how firms choose between prices and quantities to guide operational decisions under uncertainty (Aoki 1986; Arrow 1985; Lim 1980; Williamson 2005). This line of research has yielded insights into how firms allocate and manage effort in settings like safety-related standards, innovation, and investment-related commitment under uncertainty. The same principles may also fit to the application of a firm-wide sustainability objective.

This study bridges these two sets of research. When choosing between price and quantity approaches for environmental policy, a policymaker weighs the relative costs and benefits to society. When a firm voluntarily adopts a quantitative carbon reduction goal and/or an internal carbon price, it similarly weighs its internalized costs against its benefits, in line with the literature on operational decisions within the firm. As a result, the objective function in question changes from a regulator trying to select the appropriate instrument to maximize social welfare, to a corporation selecting an ICP and/or a quantitative target to maximize its own profit. Here, "profit" should be thought of broadly to include harder-to-quantify benefits, such as reputational gains or ability to hire higher-quality workers.

There are also many recent studies that have begun to explore firm-level voluntary carbon reduction measures. Research on ICPs has mainly concerned factors influencing firm adoption of ICPs and determinants of the pricing level (Bento and Gianfrate 2020, Bento et al. 2021). Our study presents updated and more comprehensive evidence about the variation in ICP adoption and implementation strategies across different industry types, contextualizes the extent of ICP adoption within the American economy, and provides novel evidence assessing emissions performance among firms with ICPs. Recent studies have also examined firms' adoption of quantitative targets, and assessments of progress in fulfilling their pledges (Aldy et al. 2023, Bolton and Kacperczyk 2025, Dietz and Hastreiter 2026). However, knowledge about the tools corporations use to achieve their goals, and how they implement them, remains an underexplored topic. Our study brings together these two strands of work, assessing the relative merits of ICPs and quantitative targets for corporate sustainability.

The paper proceeds as follows. Section II details background information on the various forms of voluntary corporate climate reduction, including internal carbon prices and quantitative goals. Section III introduces the data and empirical approach. Section IV presents results, and Section V discusses takeaways and future work.

II. Instruments Used for Corporate Climate Governance

A. Internal Carbon Pricing

Internal carbon pricing (ICP) provides firms with a framework to account for the cost of their emissions, regardless of the presence or absence of an external carbon pricing regime. Firms may design ICPs to serve a variety of aims. Firms may design ICPs as risk management tools, so investors can measure the financial risk associated with the potential implementation a of carbon pricing policy. In other cases, firms use ICPs for strategic planning purposes, such as identifying climate-related strategic opportunities. Firms can also use ICPs as an input for scenario analyses that guide future investment decisions (Bento et al. 2020).

Just as firms have diverse motivations for potentially implementing an ICP, there are likewise various forms that an ICP can take on to guide firm operations and decision-making (Aldy and Gianfrate 2019, CDP 2021). In many cases, firms treat the ICP as a shadow price, meaning a hypothetical price is assigned to emissions but there is no direct financial impact. The industries that adopt shadow pricing tend to be those with long-lived, capital intensive assets like oil and gas or mining. Shell, BP, and BHP all use shadow carbon prices at values that are informed by current government carbon pricing schemes. Thus, the shadow price operates in an analogous way to a carbon tax policy in terms of informing investment decisions, but without the actual tax payment implications for the firm. A shadow price is often considered the first stage of ICP implementation, as it helps to build awareness about the cost of emissions among decision-makers in the firm. A second form of ICP is the implicit carbon price. It is distinct from a shadow price in the sense that it is derived from the cost of undertaking emission reduction projects such as energy efficiency or renewable energy investments. Thus, it represents a proxy for the average abatement costs of a particular firm instead of a proxy for a potential regulatory carbon pricing scheme or future marginal cost of abatement. For example, Unilever has used an implicit carbon price since 2016, which it calculates as the cost of renewable energy purchases divided by the tonnes of avoided emissions.

Firms can also implement an ICP as an internal carbon fee, which imposes a carbon tax within the firm. The proceeds from this tax can then be reinvested towards sustainability measures. For example, in 2012 Microsoft implemented an internal carbon fee of around $7/tonne CO2e, which applied to Scope 1, Scope 2, and business air travel. It has revised both its stringency and scope over time. Today, Microsoft's internal carbon fee is $15/tonne CO2e, and applies to Scopes 1, 2, and 3; it has raised the fee for business air travel from $15 to $100/tonne CO2e. The revenue from the internal carbon fee is put towards a fund that subsidizes investments in sustainability-related projects such as renewable energy resources, carbon offsets, and emerging technologies like direct air capture.

Table 1 below compiles several examples of firm motivations for ICP formation, types of ICPs implemented, and intended usage applications within the firm.

Table 1: Select firms and corresponding ICP types, values, and applications

Firm Name	**ICP Type**	**ICP Value**	**Rationale and Uses**
Microsoft	Internal Fee	\$15/tCO2e for all Scopes, except \$100/tCO2e for air travel.	Provides incentive and justification for investment in climate-related innovation, including purchases of renewable electricity and carbon removal.
Alphabet	Implicit Price	\$50–\$160/tCO2e	Cites \$50–\$160/tCO2 by 2030 as amounts needed for Paris-aligned goals. Applied to operations and procurement.
Pfizer	Shadow Price	\$200/tCO2e	Aligned with current and projected schemes applicable to operating locations including facilities facing EU ETS and carbon taxes. Used for capital expenditure, risk management, and opportunity management.
Procter and Gamble	Shadow Price	\$8–\$200/tCO2e	References alignment with carbon allowance price under an Emissions Trading Scheme.
Capital One	Internal Fee	\$15/tCO2e	Establishes dedicated revenue stream for carbon reduction and sustainability initiatives.
Pinnacle West Capital Co	Internal Fee	\$25/tCO2e	Based on California cap-and-trade 2020 CO2 cost and escalated at 2.5% beginning in 2028; used in integrated resource planning
PPL Corporation	Implicit Price	\$15–\$25/tCO2e	Implied cost of potential future CO2 regulations in resource planning; used in capital expenditure, risk management, and integrated resource planning.
Duke Energy	Shadow Price	\$16.53/tCO2e (\$15/short ton) starting in 2028, increase of \$5/short ton/year	Designed to account for potential future CO2 regulation in non-North Carolina jurisdictions. NC planning reflects mandatory state emissions-reduction legislation directly. Applied in capital expenditure and operations.
Southern Co	Shadow Price	\$0–\$50/tCO2e, escalating annually above inflation	Scenario analysis representing a range of potential policies affecting carbon-emitting resources rather than a specific current compliance price. Applied to capital expenditure, opportunity management, and public policy engagement.
ConocoPhillips	Shadow Price	\$60/tCO2e	Company states it uses carbon price assumptions to navigate GHG regulations. Applied to capital expenditure decisions.
Keurig Dr Pepper Inc	Implicit Price	\$0–\$2000/tCO2e.	Used to determine cost-effective emissions reductions through capital investments.
American Airlines Group	Shadow Price	\$4–\$25/tCO2e	Aligned with estimated CORSIA offset prices and used to assess regulatory obligations for international aviation emissions. Applied to capital expenditure and procurement.

Our main empirical specification classifies the presence of any form of ICP as having the "pricing" approach in place. We also descriptively demonstrate how the use of an internal fee, versus a shadow price or implicit price, tends to be differentially applied across sectors of the economy.

B. Quantitative Climate Targets

We establish clear conditions that a firm's statements need to satisfy in order to be considered a credible emissions target. First, the statement must be forward looking; second, it must explicitly identify the target type; third, it must specify a target amount (which may be either an absolute number or emissions intensity, of either greenhouse gases or carbon dioxide); and fourth, it must include a target year. Where available, we also collect information on the base year, base year quantity, the year in which the firm made its commitment public, and the target's scope of coverage. In addition, we separately track and code qualitative statements about firms' intentions to adopt quantitative targets in the future. Targets may cover Scope 1 (direct emissions), Scope 2 (emissions associated with electricity purchases), and/or Scope 3 (indirect emissions). Our analysis in this paper is focused only on Scope 1 emissions.

Firms could implement ICPs only, quantitative targets only, both, or neither. In our current dataset, we observe that all firms who set ICPs also have quantitative targets (or adopt them in subsequent years).

III. Data and Empirical Strategy

A. Data Sources

Our study seeks to provide a comprehensive picture of internal carbon prices and quantitative targets across the entire American economy. As such, we consider all firms that are part of the Russell 3000 Index, which represents ~98% of the American public equity market. We source information for quantitative targets from the Salata Institute Corporate Climate

Targets Database (Aldy et al. 2026). This is a novel dataset that compiles qualitative carbon commitments, energy efficiency targets, and quantitative carbon targets for Scopes 1, 2, and 3 emissions (if applicable) going back to the year 2000, for each firm in the Russell 3000. The database is comprised of information that is publicly available through sources such as companies' sustainability reports, SEC 10-K filings, and corporate social responsibility reports.

Within the set of firms in the Russell 3000 with quantitative targets, we then identify the firms that have also adopted ICPs. Our initial approach is to source this information from the CDP (formerly Carbon Disclosure Project) annual questionnaire. CDP is a global firm that runs an independent environmental disclosure system. We use responses to CDP Question C11.3, which asks firms, "Does your organization use an internal price on carbon?" CDP also documents detail about the type of ICP (e.g., shadow price, internal fee) and scope of emissions that the ICP applies to. Possible answers are, "No, but we anticipate doing so in the next two years," "No, and we do not currently anticipate doing so in the next two years," "Yes," "Question not applicable," or (blank). We code only "Yes" responses as having an ICP in our analyses.

CDP is a valuable resource, but because it is a voluntary registry, the set of available data only encompasses firms that have opted in to disclose their information. The key advantage of our data approach is that we are able to describe the performance of firms across the US economy more broadly: using our Corporate Climate Targets Database, we record nearly 1,100 firms with quantitative targets as of 2023, whereas just 640 of these firms voluntarily disclosed quantitative targets in CDP. Because this Database does not explicitly code information about ICPs, we are in the process of developing a large language model tool to extract the relevant information from the same corpus of documents used to construct the Corporate Climate Targets Database. Thus, our eventual analysis will be based on all publicly-available information regarding both ICPs and quantitative targets across the Russell 3000.

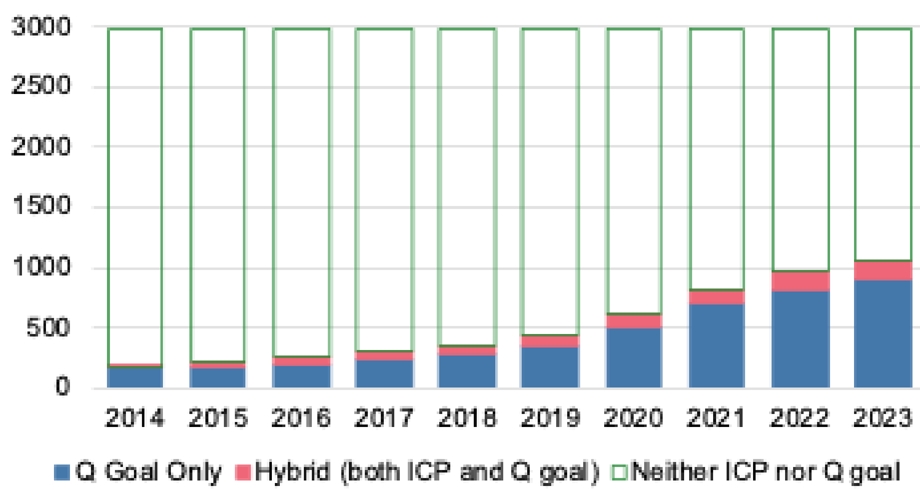
We employ S&P Global Trucost data on annual Scope 1 emissions (both absolute and intensity values). Trucost sources their data from firm-disclosed measures through the CDP survey, as well as from other disclosed sources. Trucost also produces estimates of emissions when disclosed data are not available.

We source annual financial data from Compustat. Compustat provides metrics such as total assets and total market valuation (in units of millions of dollars, nominal) for each firm.

B. Patterns of ICP and Quantitative Target Adoption

Figure 1 below shows the distribution of the firms in our study by "instrument type," meaning the presence of an ICP and/or quantitative goal. The possible states are having a quantitative goal and no ICP ("Q Goal Only"), having both a quantitative goal and ICP ("Hybrid"), or having neither instrument in place. As of 2023, there is no firm that had an ICP without an accompanying quantitative goal. We note that there do exist some instances where a firm initially adopted an ICP only, but those firms all eventually added quantitative goals.

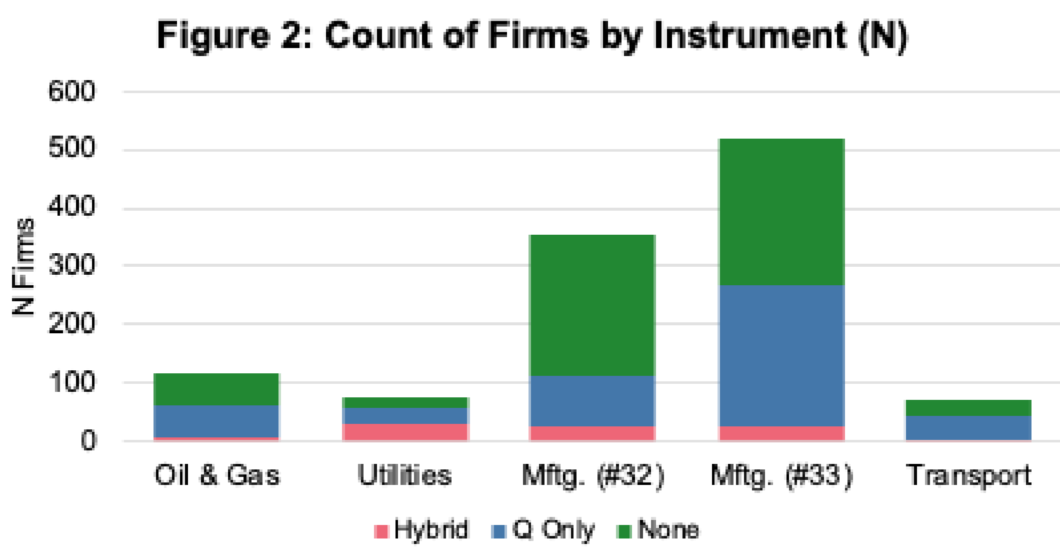
Figure 1: Count by Instrument Type



Notes: Our firm list is based on the 2023 edition of the Russell 3000, as reflected in the Salata Institute Corporate Climate Targets Database. The table tallies the number of firms out of this set of 2,986 that employ a quantitative goal, both an ICP and quantitative goal, or neither approach, as of that year.

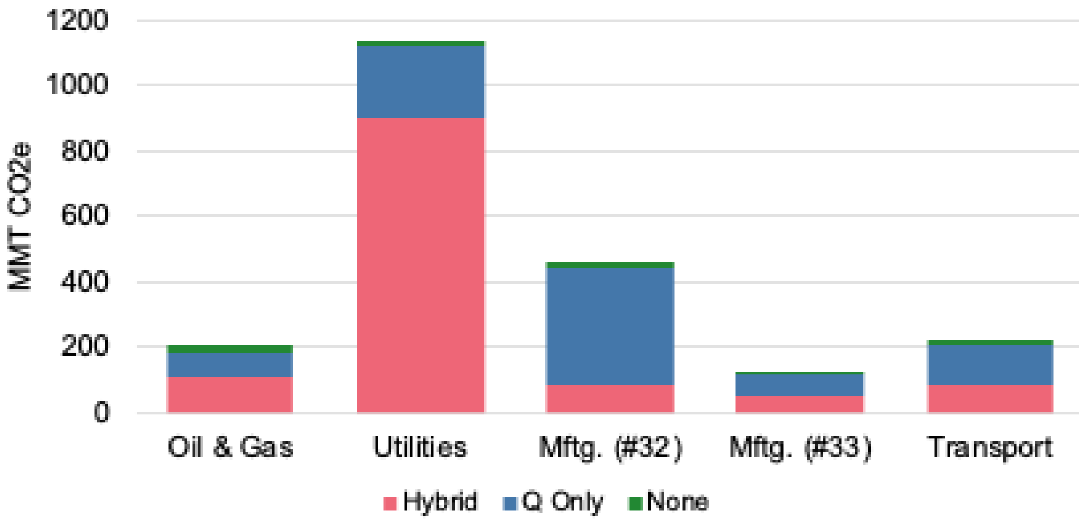
Industries vary greatly in terms of their contribution to overall emissions, as well as in their propensity to adopt quantitative goals and/or ICPs. We find that the relatively emissions-intensive industries tend to adopt hybrid approaches. In addition, the relatively more emissions-intensive firms within a given industry also tend to adopt hybrid approaches. Below, we present descriptive charts that focus on the four highest-emitting industry types. Based on two-digit North American Industry Classification System (NAICS) codes, these are mining (NAICS code

#21), utilities (#22), manufacturing (#32 and #33), and transportation/aviation (#48). Together, they comprise nearly 90% of all emissions (and around 25% of total market valuation). If we consider the adoption rate of ICPs and quantitative targets in terms of firm count, this rate is high in the utilities and transportation sectors, and modest in mining and manufacturing (Figure 2). However, if we instead consider adoption in terms of the share of emissions, it appears that nearly all major emitters are covered by at least a quantitative target, with ICPs being especially prevalent for utility sector emissions (Figure 3).



Notes: The total height of the bar indicates the number of firms in the Russell 3000 belonging to that NAICS code. Each shaded portion of the bar indicates the share of firms that adopt a quantitative goal, hybrid approach, or neither, at some point during our sample period. For example, as of 2023, there were 73 firms in the utilities sector, 29 (40%) of which adopted hybrid approaches, 27 (37%) of which adopted quantitative targets only, and 17 (23%) of which adopted neither.

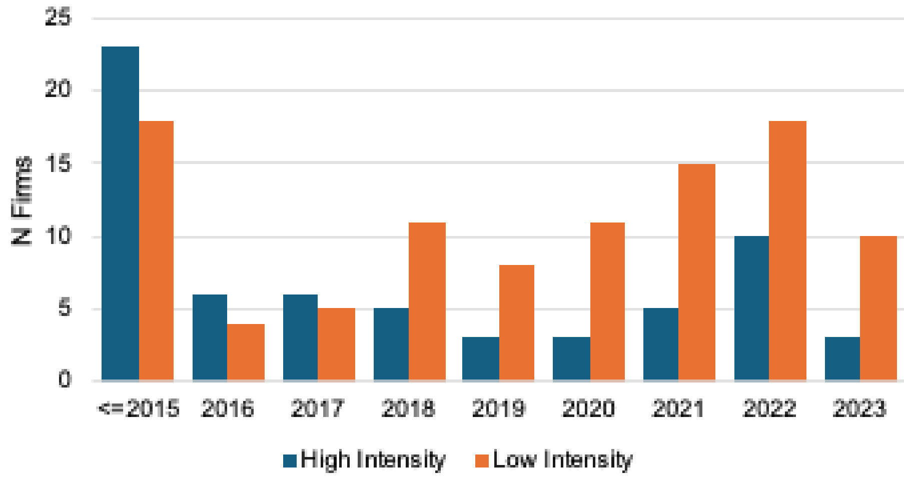
Figure 3: Total Emissions by Instrument (MMT)



Notes: The total height of the bar indicates the annual average emissions, in millions of metric tonnes CO2e, emitted by that sector in total. Each shaded portion of the bar indicates the emissions of firms that adopt a quantitative goal, hybrid approach, or neither, at some point during our sample period. For example, as of 2023, the utilities sector emitted about 1,130 MMT CO2e annually, 990 MMT (87%) of which came from firms that adopted hybrid approaches, 133 MMT (12%) of which came from firms that adopted quantitative targets only, and 12 MMT (1%) of which came from firms that adopted neither.

The relatively emissions-intensive industries also tended to adopt ICPs earlier than the less emissions-intensive industries did. Figure 4 shows the number of firms that adopted ICPs in a given year. High intensity industries tended to adopt ICPs in 2015 or earlier, while low intensity industries adopted ICPs in later years.

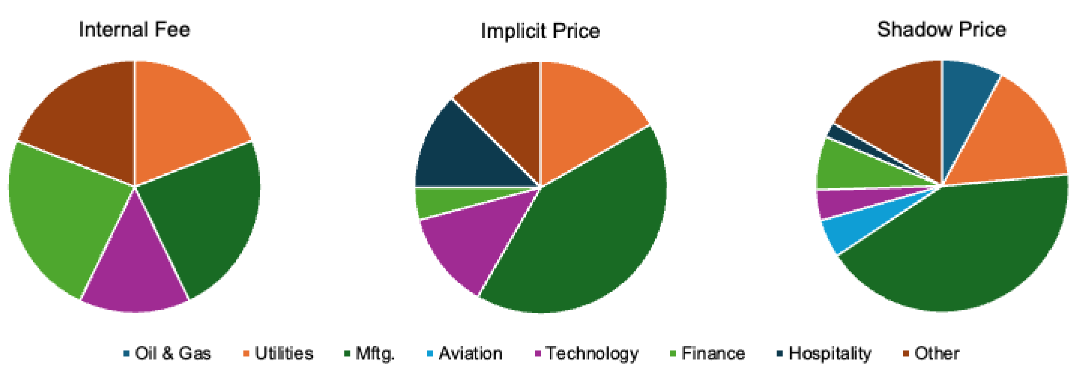
Figure 4: Firm Count by ICP Adoption Year



Notes: Each pair of columns shows the number of firms from high-intensity industries and low-intensity industries respectively, that adopted an ICP in a given year. The left-most pair aggregates ICP adoption in 2015 and earlier. High-intensity is defined as specific industries within the NAICS sectors shown in Figures 2 and 3: oil & gas, mining, utilities, lumber, paper manufacturing, petroleum & coal products, chemical manufacturing, cement, steel, and aluminum.

We also observe patterns in the form of ICP by industry. Internal carbon fees are only found in a few sectors, while the variety of sectors adopting shadow pricing ICPs is larger. Figure 5 below illustrates the composition of firms that adopt internal carbon fees, implicit carbon prices, and shadow prices respectively. We note that certain sectors, such as oil & gas and aviation, only use shadow pricing, whereas other sectors such as utilities and technology, have adopted varied approaches in ICP implementation.

Figure 5: Makeup of Each ICP Type by Sector



Notes: Each pie chart shows the breakdown of firms adopting that type of ICP, by sector, as defined by that firm's NAICS code.

Finally, we implement a logistic regression model that tests a broader set of financial and firm-specific covariates, and includes both industry and year fixed effects:

$$\Pr(ICP_{it} = 1) = F(\alpha_j + \alpha_t + \beta' Z_{i,t-1})$$

where F() is the logistic CDF; α_j and α_t are industry-specific (NAICS2) and year-specific fixed effects, respectively; $ICP_{it} = 1$ in the year firm *i* first adopts an ICP; and $Z_{i,t-1}$ represents the set of covariates tested, which are all lagged by one year. As shown in Table 2 below, we find that firm size (as measured by the log of total firm assets) is consistently the only strong predictor of ICP adoption. This finding is similar to the result reported in Tenali and Toffel (forthcoming) which examines selection into having a quantitative carbon target (meaning net-zero, carbon-neutrality, or carbon-reduction).

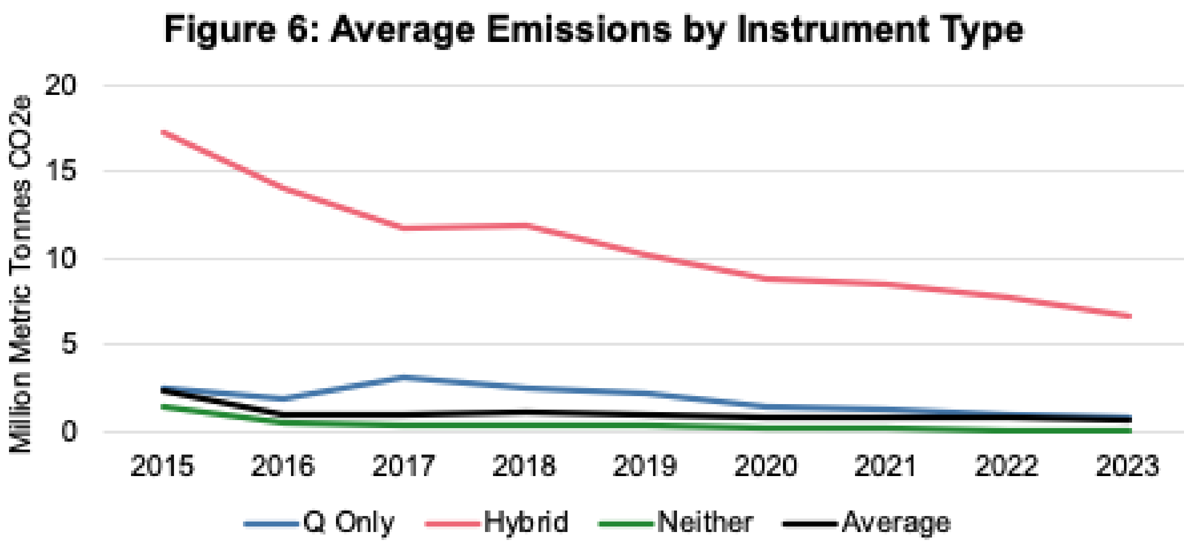
Table 2: Logit of first adoption of an internal carbon price

VARIABLES	(1) Pre-baseline	(2) Baseline	(3) Alt: NAICS3 + State FE	(4) All controls
Log total assets, t-1	0.902***	0.834***	1.190***	0.879***
	(0.076)	(0.160)	(0.254)	(0.166)
Tangibility (w99), t-1		0.911	0.908	0.485
		(1.288)	(2.513)	(1.417)
Log Scope 1 emissions, t-1		-0.062	-0.132	-0.113
		(0.160)	(0.258)	(0.172)
Share of peers in NAICS2 industry with target, t-1		-2.919	-2.839	-1.981
		(2.949)	(3.284)	(3.364)
State RPS/RGGI target, t-1	0.470	0.008	1.251	-0.134
	(0.463)	(0.486)	(0.945)	(0.590)
Log industrial electricity price (state annual avg, $/MMBtu), t-1		0.757	0.725	0.666
		(0.538)	(2.522)	(0.765)
Stock volatility (w99), t-1				-0.015
				(0.021)
Operating profitability, EBITDA/assets (w99), t-1				-2.437**
				(0.985)
LCV state environmental score (0-100), t-1				0.007
				(0.012)
Recent disaster damage, HQ county, (prior 2yr, log $)				0.033
				(0.057)
Rolling 10-yr disaster damage, HQ county (trailing 10yr, log $), t-1				0.006
				(0.092)
Num.Obs.	16889	9001	4006	5850
R^2	0.259	0.224	0.321	0.212
AIC	443.6	397.2	374.2	327.2
Industry FE	NAICS2	NAICS2	NAICS3	NAICS2
State FE	No	No	Yes	No
Year FE	Yes	Yes	Yes	Yes

Notes: Standard errors clustered at the firm level in parentheses. *** p<0.01, ** p<0.05, * p<0.10. Discrete-time logit of first adoption of a quantitative carbon target (net-zero, carbon-neutrality, or carbon-reduction); firm-years are dropped from the risk set after first adoption. All right-hand-side variables are lagged one year (t−1).

C. Descriptive Trends

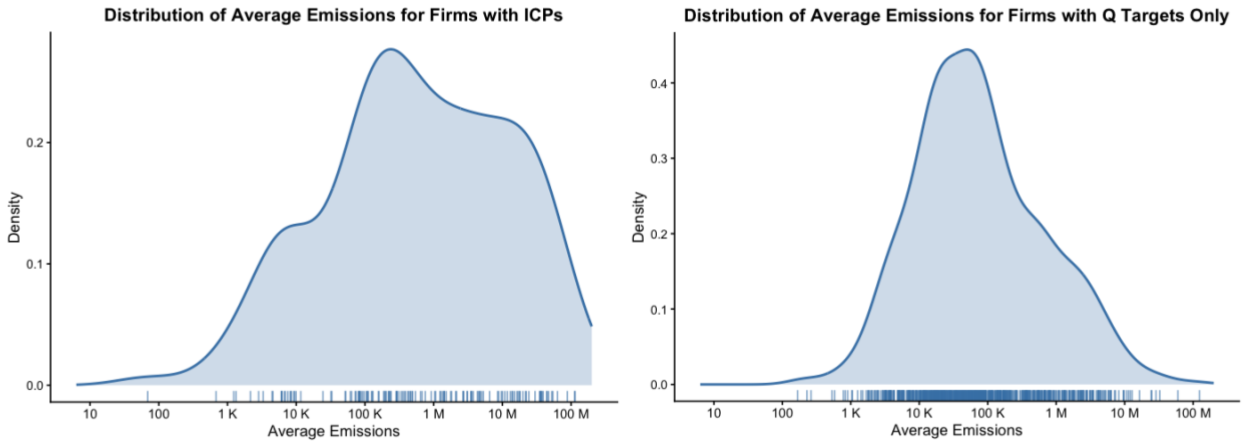
We compute the average annual emissions by instrument type (Figure 6) for the set of firms in the R3000. The "quantitative goal only" and "neither instrument" groups exhibit far lower average emissions than the "hybrid" group; these lower values are approximately flat, while the hybrid group's average emissions fall steadily over time, such that the 2023 average is about 40% of the 2015 average.



Notes: As in Figure 1, the input data for this figure correspond to averages across the set of firms in the Russell 3000, conditional on the firm disclosing the presence of a quantitative target, hybrid approach, or neither, by that particular year. The vertical axis measures average Scope 1 emissions in units of million metric tonnes of CO2e. Emissions data are sourced from Trucost.

It is important to note that because Figure 6 plots group averages, it obscures the large variability in firm-level emissions. The distribution of firm emissions spans eight orders of magnitude. Figure 7 shows density plots of average emissions for the set of firms with hybrid price-quantity approaches and quantitative targets only, respectively. While both figures show very high heterogeneity in firm-level emissions among the Russell 3000, a relatively larger proportion of "hybrid" firms are high emitters.

Figure 7: Distribution of average emissions for firms that adopt ICPs during our sample period, and for firms that adopt quantitative targets only

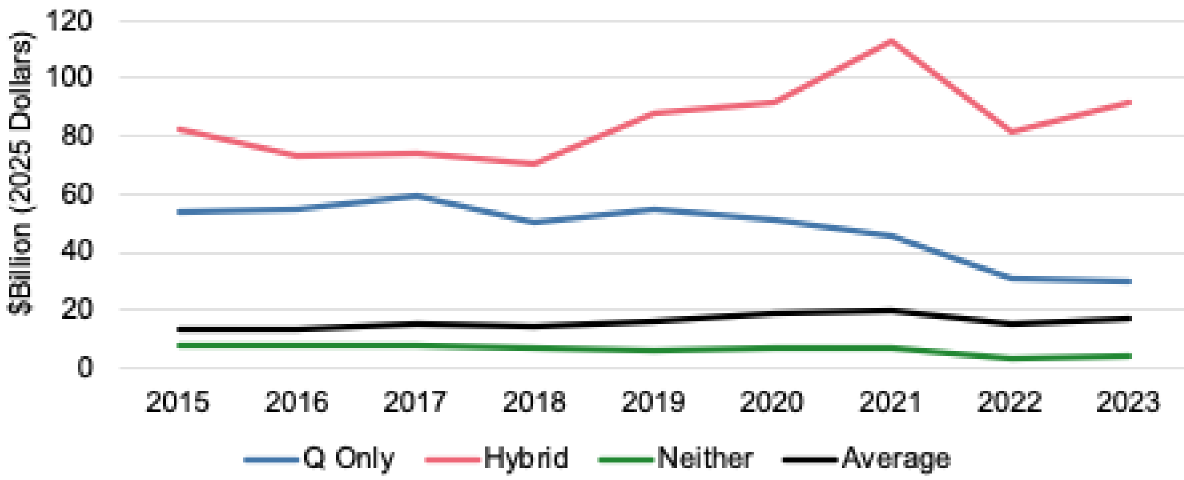


Notes: The input data for these plots correspond to reported values across the set of firms that have been verified to have adopted an internal carbon price plus quantitative target, or a quantitative target only. Data reflect the average Scope 1 emissions over all the years of data available.

Besides examining descriptive trends in emissions, we also compute the average annual market valuation by instrument type (Figure 8). On average, "hybrid" firms have higher market valuation than "Q only" firms, and both groups have higher average market valuation than the set of firms without either quantitative goals or ICPs.

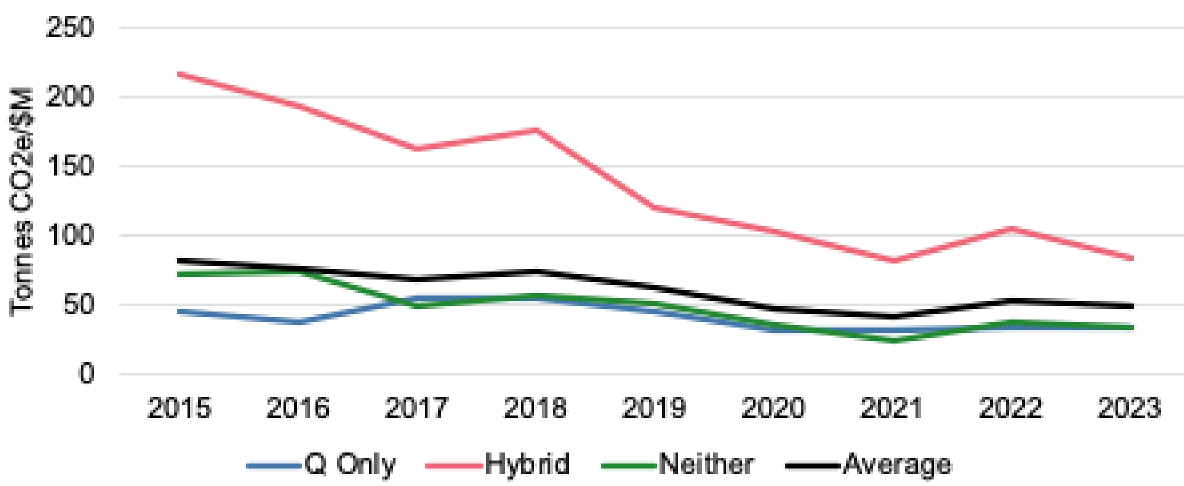
Finally, we combine the data in Figures 6 and 8 to produce a graph of emissions intensity (Figure 9). Figure 9 emphasizes that the firms adopting hybrid approaches tend to be relatively more emissions-intensive firms, and that emissions intensity has generally trended downward over time.

Figure 8: Market Valuation by Instrument Type



Notes: As in Figure 1, the input data for this figure correspond to averages across the set of firms in the Russell 3000, conditional on the firm disclosing the presence of a quantitative target, hybrid approach, or neither, by that particular year. The vertical axis measures average annual market valuation in units of billion dollars, adjusted to 2025$ using the GDP implicit price deflator. Implicit price deflator values are sourced from FRED, and market valuation data are sourced from Compustat.

Figure 9: Emissions Intensity by Instrument Type



Notes: As in Figure 1, the input data for this figure correspond to averages across the set of firms in the Russell 3000, conditional on the firm disclosing the presence of a quantitative target, hybrid approach, or neither, by that particular year. The vertical axis measures emissions intensity in units of tonnes CO_2e/$million, in $2025. Emissions data are sourced from Trucost.

D. Empirical Approach

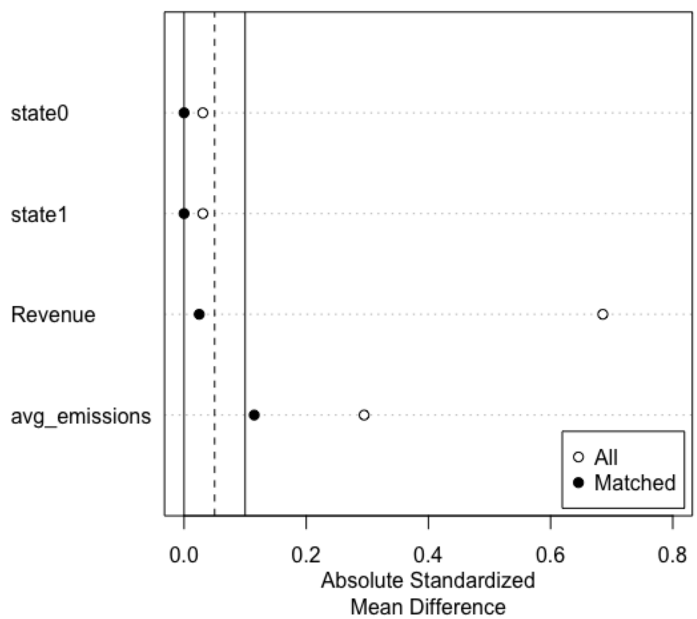
The default state for a firm is to have neither a quantitative goal nor an ICP. A firm can opt to select into one of two other approaches: a quantitative goal only (the "Q only" approach), or a quantitative goal paired with an ICP (the "hybrid" approach). In our empirical models, we will use indicator variables, which will vary by year and firm, for whether a given firm's status is "Q only" or "hybrid." Firm-years characterized by the default state will be the omitted indicator variable, given our specifications include year and firm fixed effects. Because our study is primarily concerned with the implications of ICP adoption, our main specification involves comparing the "Q only" group to the "hybrid" group. Since the timing of when a firm moves from "Q only" to "hybrid" is staggered across our sample, we estimate our panel fixed effects models based on Callaway and Sant'Anna (2021). For firms that adopt the hybrid approach, the event time is the year in which a given firm first reported having a price instrument (meaning a price alone, or a price-and-quantity hybrid). In this setting, the outcome of interest is firm-level emissions for companies adopting a hybrid approach, as compared to emissions for firms with only quantitative goals and no ICP. Formally, for each firm *i* that adopted an ICP in cohort year *c*, emissions in year *t* are given by:

$$E_{i,t,c} = \beta_{(t-c),c} * ICP_{i,t} + \lambda_i + \omega_t + \varepsilon_{i,t,c}$$

where E is emissions, ICP is an indicator variable for the presence of an ICP, λ is a vector of firm fixed effects, ω is a vector of time fixed effects, and ε represents an idiosyncratic error term.

We obtain a balanced panel of data by first removing firms with missing emissions data pre-2016. This yields 839 firms with quantitative targets, of which 145 also have ICPs. We then conducted a 1:1 coarsened exact matching approach without replacement between these "hybrid" and "Q only" groups. We matched on three sets of characteristics: lagged average market valuation (quintiles), whether the state (based on headquarters location) has a carbon pricing policy (binary), and lagged average emissions intensity (terciles). In the US, the states with carbon pricing schemes are the Northeastern states participating in the Regional Greenhouse Gas Initiative, and California. We diagnose the quality of the matching procedure by checking for covariate balance between the "hybrid" and "Q only" groups. Figure 10 shows a plot of the absolute standardized mean differences before and after performing coarsened exact matching. We chose terciles for the lagged average emissions intensity to compromise between matching precision and statistical power. Requiring closer matches on lagged emissions intensity (i.e., by increasing the number of tranches) would bring the absolute standardized mean difference for this variable below the 0.1 threshold, but it would result in a larger number of unmatched firms.

Figure 10: Love Plot of Absolute Standardized Mean Differences



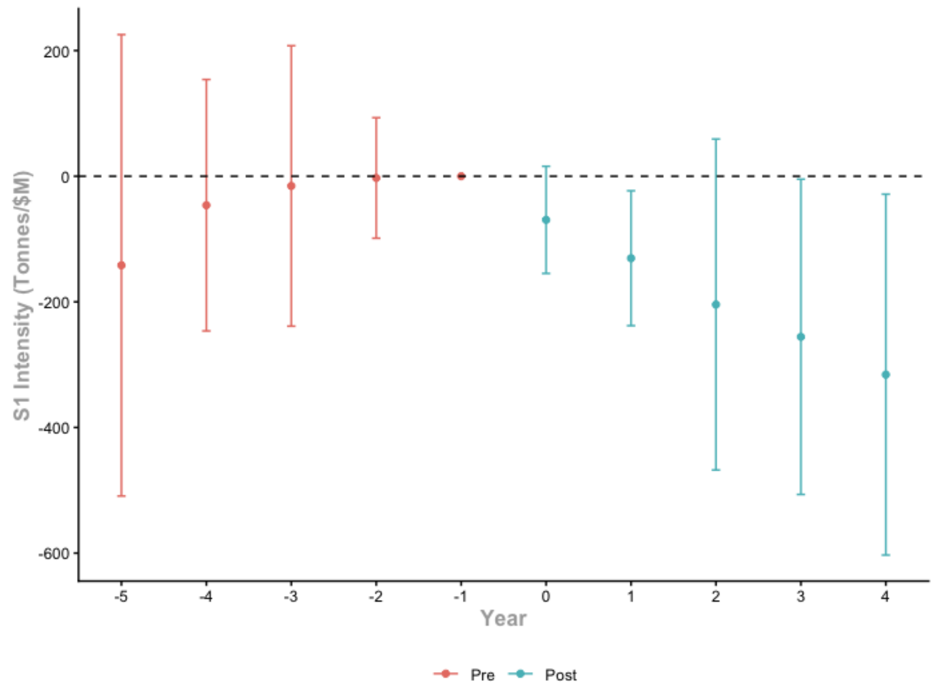
Notes: The matching method used was 1:1 coarsened exact matching without replacement. After restricting the sample to nonmissing data across all parameters for matching, there were 358 “Q Only” observations and 89 “Hybrid” observations. Of these, 84 received a match and 5 were unmatched.

IV. Results

A. Event Study Models

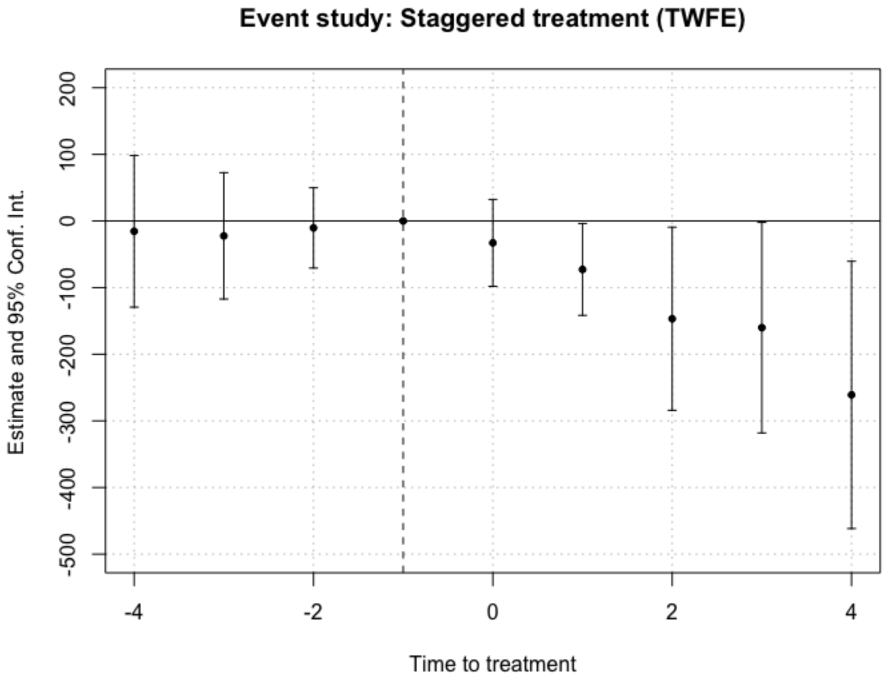
Our initial event study model compares the emissions reduction performance of hybrid instruments to quantity-only instruments, for all applicable firms in the Russell 3000. Figure 11 shows aggregated group-time average effects for firms that move from having quantitative targets only, to having both a quantitative target and an ICP (Tables corresponding to each figure can be found in the Appendix). Emissions intensity appears to fall in the years after ICP adoption. We also implement a standard TWFE model in place of the Callaway Sant'Anna approach, and find similar results: a statistically significant decline in emissions intensity occurs post-ICP adoption (Figure 12).

Figure 11: ATT estimators for hybrid P-Q firms, versus those with quantitative targets only (Callaway and Sant'Anna method)



Notes: The overall ATT is -195 tonnes/$M (SE 88.7). Model uses data for the Russell 3000 for years 2015–2024. The reference year is the first year where a firm announced an ICP. The horizontal axis is in units of years relative to the reference year. The vertical axis is in units of tonnes of CO2e per million dollars in revenue. Standard errors are clustered at the firm level.

Figure 12: ATT estimators for hybrid P-Q firms, versus those with quantitative targets only (Standard TWFE implementation)



Notes: Model uses data for the Russell 3000 for years 2015–2024. The reference year is the first year where a firm announced an ICP. The horizontal axis is in units of years relative to the reference year. The vertical axis is in units of tonnes of CO2e per million dollars in revenue. Standard errors are clustered at the firm level.

As noted above, there is substantial heterogeneity across firms with respect to emissions. We examine differences in the impact of ICPs on high emissions intensity firms versus low emissions intensity firms. We define the cutoff point as the median value of lagged emissions intensity across all firms in our sample. The results of these model specifications are shown in Figures 13a and 13b. Firms with high emissions intensity exhibit a statistically significant and persistent reduction post-ICP adoption. In contrast, firms with low emissions intensity show virtually no change in behavior.

Figure 13a: ATT estimators for firms with high emissions intensities

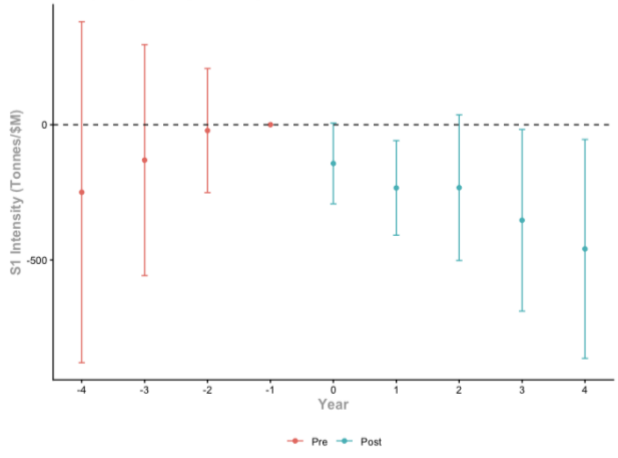
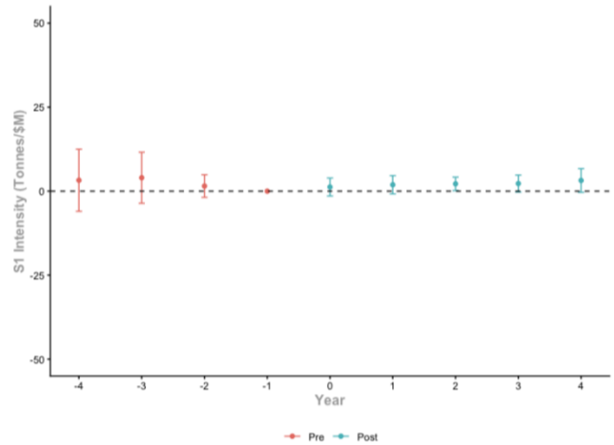


Figure 13b: ATT estimators for firms with low emissions intensities



Notes: Model uses data for the Russell 3000 for years 2015–2024. The reference year is the first year where a firm announced an ICP. The horizontal axis is in units of years relative to the reference year. The vertical axis is in units of tonnes of CO2e per million dollars in revenue. Standard errors are clustered at the firm level.

B. Marginal Abatement Costs and Abatement Quantities

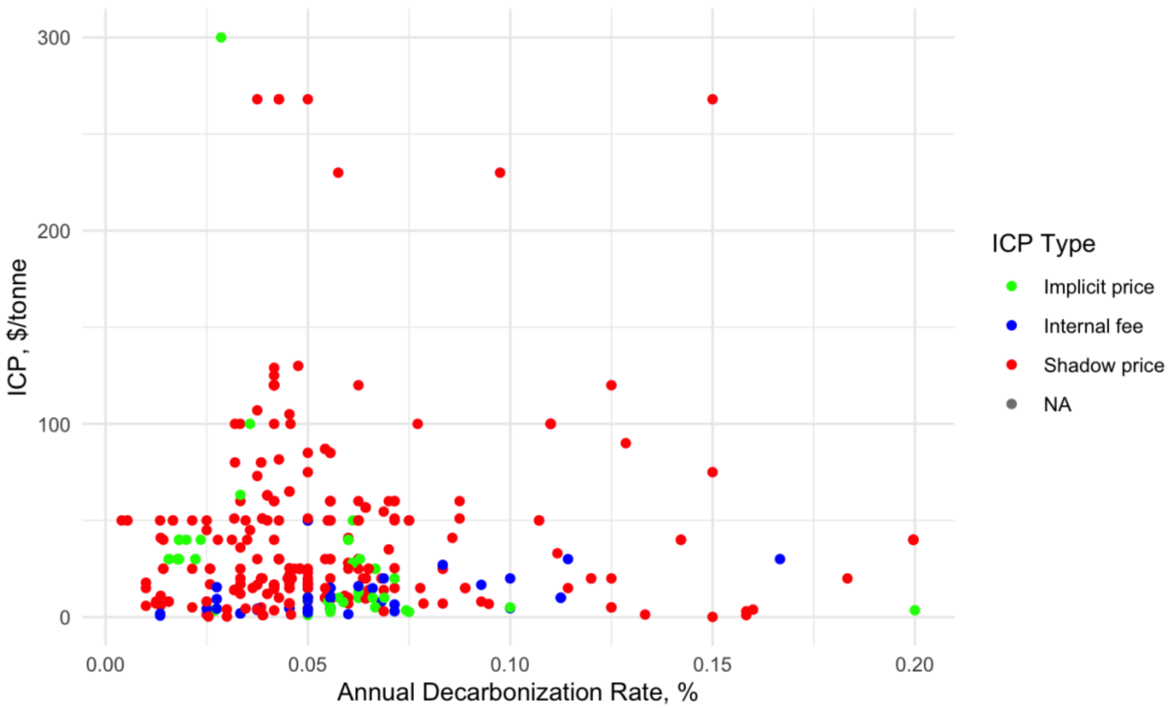
The value of a firm's ICP may reveal information about how the firm perceives its costs of emissions abatement. Each firm with an ICP also has an associated quantitative target; with some modest assumptions about a firm's counterfactual emissions and emissions reduction trajectory, we can produce a point on the marginal abatement cost function (i.e., the price that is associated with a given quantity of emissions abatement) for each firm.

As a starting point, we calculate the "implied ambition" of each quantitative target as the annual emissions reduction necessary to put the firm on a linear trajectory from its emissions in year t_0, when it announced its commitment, to the emissions necessary in target year T:

$$Ambition = \frac{target\ reduction\ \%}{T - t_0}$$

This value is then plotted against the firm's ICP, to produce an illustrative scatterplot. Because firms may update their ICPs and quantitative goals each year, we plot all firm-years for which there are both ICP data and implied ambition data available. If taken as a whole, there is no apparent correlation between the two variables (Figure 14); however, the scatterplot does reveal some notable patterns in the type and spread of ICP values. Internal carbon fees, shown in blue, generally take on lower values relative to implicit prices/shadow prices. Here, there is indeed a meaningful correlation between the value of the internal fee and the implied ambition (cor = 0.37, p = 0.015). This does not hold for the other types of ICPs. Further, both quantitative goals and shadow prices frequently take on the same, round values—particularly 5% carbon reduction per year and $50/tonne, respectively—this suggests that, for many firms, there is still a high degree of speculation in implementing future carbon reduction goals. Filtering the scatterplot to specific industry types provides suggestive evidence of sector-specific trends. For example, there is an overall positive correlation between ICP value and target ambition among technology firms (Figure 15a), consistent with the fact that such firms tend to adopt internal carbon fees. The oil and gas industry only uses shadow carbon pricing and not implicit pricing or internal fees, and there is actually a *negative* relationship between ICP level and quantitative target ambition (cor = -0.35, p = 0.07) (Figure 16b). Among high emissions intensity sectors overall, there appears to be no relationship (Figure 16c).

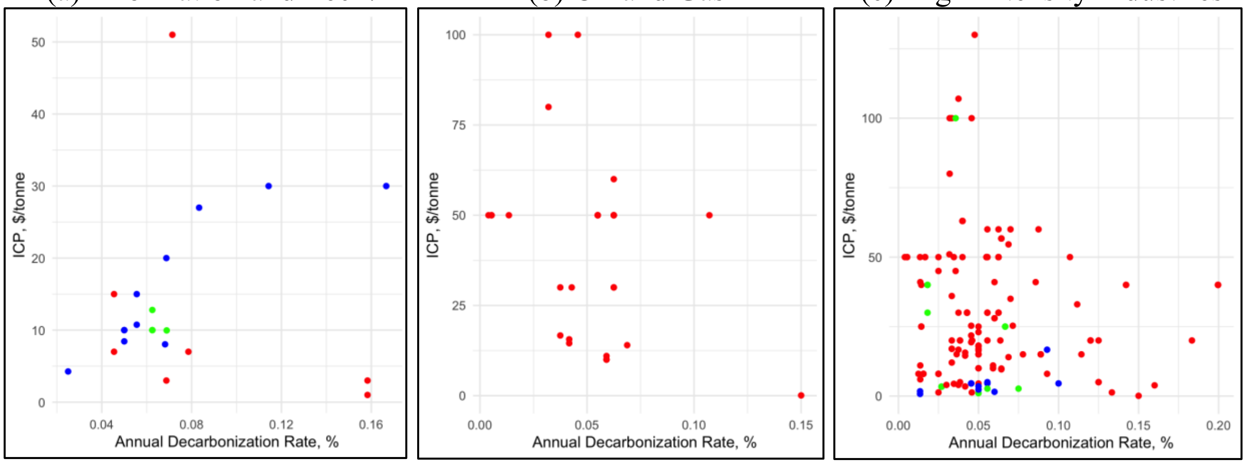
Figure 14: Scatter of ICP values versus annualized emissions reductions



Notes: Emissions reduction calculations assume a linear trajectory between documented emissions level in that year and the target emissions level in the firm's target year. Each dot represents a firm-year, and the colors denote the type of ICP.

Figure 15: Sector-Specific Scatters of ICP values versus annualized emissions reductions

(a) Information and Tech. (b) Oil and Gas (c) High-Intensity Industries



Notes: Emissions reduction calculations assume a linear trajectory between documented emissions level in that year and the target emissions level in the firm's target year. Figure 15a defines "Information and Technology" as firms with NAICS codes 51 (Information) and 54 (Professional, Scientific, and Technical Services). Figure 15b defines "Oil and Gas" as firms with NAICS code 21. Figure 15c defines "High-Intensity Industries" as specific industries that have especially high emissions intensity: oil & gas, mining, utilities, lumber, paper manufacturing, petroleum & coal products, chemical manufacturing, cement, steel, and aluminum.

V. Conclusion and Next Steps

We analyze corporate adoption of internal carbon prices and quantitative targets for decarbonization, as well as the emission trajectories associated with various approaches. The prior literature reports mixed findings about the efficacy of quantitative target adoption, and knowledge around how corporations can successfully implement sustainability plans is still emerging. Our work demonstrates that firms who pair their quantitative targets with an internal carbon price appear to substantially and persistently reduce their emissions over time, shedding light on an important pathway for firms to achieve their sustainability goals.

Future work could expand the analyses in two ways. The first would involve additional specifications that focus on the transitional years when a firm moves from no price/quantity instrument to a hybrid approach. This includes studying the impact of adopting a quantitative goal in the years immediately before an ICP, and possible anticipatory behavior when the firm announces it plans to implement an ICP within the next two years. Second, our work to-date uses binary indicators for the presence of ICPs and/or quantitative targets; a useful extension would be to conduct additional statistical tests to understand the impact of ICP/quantitative target *stringency* on outcomes.

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Appendix

Table A1: Summary of Dynamic Effects, Adoption of Hybrid Approach

Event Time	Estimate	Standard Error	[95% Pointwise	Conf. Band]
-4	-131.2	180.8	-511.3	248.9
-3	-48.9	101.2	-261.7	164.0
-2	2.5	60.6	-125.0	130.0
-1	0.0	NA	NA	NA
0	-72.5	44.3	-165.6	20.7
1	-135.0	56.6	-254.1	-15.9 *
2	-118.2	85.3	-297.6	61.2
3	-176.6	107.0	-401.5	48.3
4	-238.3	125.7	-502.5	25.9

Notes: Estimates are ATT's based on number of years with quantitative goal in place, using the method described in Callaway and Sant'Anna (2021). "*" indicates confidence band does not cover 0. Table corresponds to Figure 11.

Table A2: TWFE Event Study Results: Emissions Intensity

Event Time	**value**
t – 4	5.27
	(61.46)
t – 3	−39.41
	(37.62)
t – 2	7.15
	(23.36)
t = 0	−20.78
	(34.75)
t + 1	−50.95
	(40.41)
t + 2	-122.05^{**}
	(58.32)
t + 3	-134.34^{*}
	(70.46)
t + 4	-232.70^{**}
	(92.13)
Cusip6 FE	Yes
Year FE	Yes
Observations	1,512
R^2	0.920
Adjusted R^2	0.909
Notes:	Standard errors clustered at the firm level; Table corresponds to Figure 12. *p<0.1; **p<0.05; ***p<0.01

Table A3: Summary of Dynamic Effects, Adoption of Hybrid Approach

Event Time	Estimate	Standard Error	[95% Pointwise	Conf. Band]
-4	-249.6	309.5	-879.7	380.5
-3	-131.0	209.7	-557.9	295.9
-2	-21.7	112.6	-251.1	207.6
-1	0.0	NA	NA	NA
0	-143.2	73.4	-292.6	6.1
1	-233.7	85.8	-408.4	-58.9 *
2	-232.7	132.3	-502.0	36.6
3	-353.3	165.0	-689.1	-17.4 *
4	-459.1	198.7	-863.7	-54.6 *

Notes: Estimates are ATT's based on number of years with quantitative goal in place, using the method described in Callaway and Sant'Anna (2021). In this specification, since the sample is already split into high emissions intensity and low emissions intensity, the coarsened exact matching procedure used only the lagged market valuation and presence of state carbon pricing policy variables. "*" indicates confidence band does not cover 0. Table corresponds to Figure 13a.

Table A4: Summary of Dynamic Effects, Adoption of Hybrid Approach

Event Time	Estimate	Standard Error	[95% Pointwise	Conf. Band]
-4	3.25	4.04	-5.98	12.49
-3	4.00	3.33	-3.60	11.60
-2	1.53	1.47	-1.84	4.89
-1	0.00	NA	NA	NA
0	1.24	1.17	-1.43	3.90
1	1.91	1.19	-0.80	4.63
2	2.18	0.87	0.19	4.18 *
3	2.26	1.10	-0.26	4.79
4	3.19	1.54	-0.34	6.72

Notes: Estimates are ATT's based on number of years with quantitative goal in place, using the method described in Callaway and Sant'Anna (2021). In this specification, since the sample is already split into high emissions intensity and low emissions intensity, the coarsened exact matching procedure used only the lagged market valuation and presence of state carbon pricing policy variables. "*" indicates confidence band does not cover 0. Table corresponds to Figure 13b.