Carbon Pricing and Investment Efficiency: Global Evidence

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Abstract

We examine the effects of carbon pricing, in the form of carbon taxes (CTs) and Emissions Trading Systems (ETSs), on firms' capital and labor investment decisions and the efficiency with which these productive inputs are allocated. Using a novel catalogue of 56 carbon pricing interventions and firm-level data from 93 countries over 1996–2022, we find that carbon pricing increases capital investment but reduces capital investment efficiency, whereas firms reduce labor investment without a corresponding deterioration in labor investment efficiency. The timing of these adjustments also differs: capital investment responds primarily after policy implementation, while labor investment exhibits anticipatory adjustment, particularly following carbon-tax announcements. The sequence of policy adoption also matters, with labor adjustments intensifying when an ETS is introduced after an existing CT and carbon taxes playing a particularly important role in capital investment and efficiency. Overall, carbon pricing induces distinct adjustments across firms' productive inputs, with different implications for their allocation efficiency.

Keywords: Carbon pricing, Carbon tax, ETS, Investment efficiency.

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1. Introduction

We examine the effects of carbon pricing, in the form of carbon taxes (CTs) and Emissions Trading Systems (ETSs), on firms' capital and labor investment decisions. By increasing the cost of carbon-intensive production, carbon pricing creates incentives for firms to adjust their production processes, invest in cleaner technologies, and alter their demand for productive inputs (e.g., Acemoglu et al., 2012; Brown et al., 2022). However, it is unclear whether these policies stimulate or constrain firms' capital and labor investment, or whether the resulting adjustments are efficient. Carbon pricing may encourage firms to undertake new capital investment aimed at reducing emissions and improving energy efficiency, while also altering their demand for labor. At the same time, it may increase compliance costs, regulatory uncertainty, and financing needs, thereby delaying or distorting firms' capital and labor investment decisions. Consistent with these competing forces, prior research provides mixed and somewhat conflicting evidence on how carbon pricing affects firms' investment decisions. This may partly reflect the empirical settings examined in prior studies, which often focus on individual countries (e.g., Jacob and Zerwer, 2024; Colmer et al., 2025) or on a single carbon pricing instrument (either a CT or an ETS, e.g., Brown et al., 2022; Jacob and Zerwer, 2024; Colmer et al., 2025). We extend this literature by providing comprehensive international evidence based on 56 new carbon pricing regulations adopted in 45 countries. Our setting allows us to compare firms' responses to the primary carbon pricing instruments (CTs and ETSs) within a common empirical framework and examine whether carbon pricing also affects firms' capital and labor investment decisions.

Beyond the level of investment, it is equally important to understand how carbon pricing affects the efficiency with which firms allocate productive resources. Carbon pricing regulation is intended not only to encourage firms to invest in cleaner technologies but also to facilitate the transition toward lower-carbon production. This transition may require firms to adjust both capital and labor, including the scale and composition of their workforce. Whether firms efficiently undertake these capital and labor adjustments has important implications for policymakers designing environmental regulation, managers allocating capital and labor, and investors evaluating firms' performance. More broadly, the efficient allocation of productive resources is central to productivity growth and economic development. Reflecting this importance, the International Monetary Fund (2024) emphasizes that improving the allocation of capital and labor is essential for raising productivity and mitigating economic slowdowns. Similarly, a joint report by the WTO, IMF, OECD, UNCTAD, and the World Bank (2024) highlights the need for policies that facilitate the efficient reallocation of productive resources during the transition to a low-carbon economy, while cautioning that financing frictions, imperfect information, and the high costs of adopting new technologies may hinder this process.

The limited and often difficult-to-reconcile evidence on how carbon pricing affects firms' investment decisions motivates our study. Jacob and Zerwer (2024) document declines in capital investment following emission-tax adoption in Spain, France, and Ireland, whereas Colmer et al. (2025) find that firms regulated under the EU ETS invest in cleaner production processes without corresponding declines in output or employment. Related studies further document that emissions taxes can increase R&D investment among highly polluting firms (Brown, Martinsson, and Thomann, 2022) and generate cross-border innovation spillovers outside the regulating jurisdiction (Beuselinck, Jacob, and Valle Ruiz, 2026). Evidence on whether carbon pricing improves or impairs firms' investment efficiency is even more limited and is concentrated in a small number of single-country settings (Chen et al., 2022; Wang and Zhang, 2024; Ma, Xiang, and Bai, 2023). Together, the findings from prior studies are setting-specific and may depend on the policy instrument, regulatory incidence, firms' financial capacity, and the country and period examined. Accordingly, little is known regarding the generalizability across countries and policy instruments or whether carbon pricing has different implications for capital and labor investment efficiency. This question is particularly important because carbon pricing can simultaneously affect firms' investment incentives, financing needs, technology adoption, and workforce decisions. Our study addresses this gap by leveraging the adoption of CTs and ETSs globally over the past three decades to jointly examine their effects on both the level and efficiency of firms' capital and labor investment.

Capital and labor investment decisions are interdependent because both draw on firms' limited financial and organizational resources, and adjustments to one input may alter demand for the other. They may function as substitutes through at least two channels. First, investments in automation or cleaner equipment may directly reduce demand for workers whose tasks can be performed by new technologies (Acemoglu and Restrepo, 2020; Acemoglu, Lelarge, and Restrepo, 2020). Second, even without direct technological substitution, the up-front cash outlays required for new equipment and technologies may constrain firms' short-term liquidity and leave fewer resources available for hiring, training, or retaining employees, particularly among financially constrained firms (Caggese, 2008; Campello, Graham, and Harvey, 2010). At the same time, the two inputs may be complementary when new technologies increase demand for employees with the skills needed to implement, operate, and maintain them, consistent with the capital-skill complementarity literature (Griliches, 1969; Krusell et al., 2000; Wang, Wang, and Song, 2023). Carbon pricing may therefore induce firms to rebalance capital and labor rather than adjust either input in isolation. Examining only one input consequently provides an incomplete view of firms' responses to carbon regulation. Our integrated analysis allows us to assess whether carbon pricing reallocates firms' productive inputs and, importantly, whether these adjustments differ not only in magnitude and timing, but also in the efficiency with which capital and labor are allocated.

To examine how carbon pricing affects corporate investment and investment efficiency, we construct an international dataset covering 93 countries and compile a novel catalogue of

56 country-industry-level carbon pricing regulations adopted in 45 countries between 1996 and 2022. To the best of our knowledge, this catalogue constitutes the most comprehensive panel of carbon pricing interventions to date. Combining these data with firm-level information allows us to identify regulated firms across countries, industries, and years, examine the effects of carbon pricing on both capital and labor investment, and distinguish between CTs and ETSs. We estimate these effects using both two-way fixed effects (TWFE) and stacked difference-in-differences estimators (Bertrand, Duflo, and Mullainathan, 2004; Baker, Larcker, and Wang, 2022).

Our findings indicate that carbon pricing regulations have markedly different effects on firms' capital and labor investment decisions. Across both specifications, regulated firms increase capital investment following carbon pricing adoption. The baseline estimate indicates an increase in capital investment of 0.5 percentage points of lagged assets, equivalent to approximately 5.4% of the sample mean. This effect is driven primarily by CTs rather than ETSs and is more pronounced when both instruments coexist, particularly among CT-regulated firms in the power and industrial sectors. A sequence analysis further documents that introducing a CT as the first carbon pricing instrument increases capital investment, whereas introducing an ETS first does not. We find no evidence that adding a second instrument generates an incremental increase in capital investment.

Jointly examining capital and labor reveals a distinct pattern of adjustment following CT adoption. Labor investment declines during the anticipation period immediately following a CT announcement, whereas capital investment does not change significantly before implementation. Once CTs become effective, capital investment increases significantly, while the post-implementation effect on labor investment is no longer statistically significant. This sequencing is consistent with firms beginning to reallocate resources from labor toward capital in response to announced CTs. Because labor is relatively flexible, firms can reduce or pause hiring shortly after a CT is announced. In contrast, capital investment requires more planning and implementation time and therefore increases only after the tax becomes effective. The greater price certainty provided by CTs also allows firms to better evaluate investments in cleaner equipment and production technologies. Together, these timing differences are consistent with firms reallocating resources from labor toward capital in response to CT adoption.

We do not observe the same paired adjustment pattern under an ETS. Capital investment does not increase significantly either during the anticipation period or following implementation. Labor investment instead declines primarily after the ETS becomes operational, although the anticipation estimate provides some weaker evidence of a pre-implementation decline. This pattern is consistent with firms facing greater uncertainty before ETS implementation regarding allowance prices, permit allocations, market liquidity, and ultimately the cost of compliance. Such uncertainty may limit firms' ability to plan capital expenditures in advance and may lead them to rely more heavily on labor adjustments once actual compliance costs become observable. Thus, whereas the CT results are consistent with a sequential reallocation from labor toward capital, the ETS results indicate a reduction in labor investment without a corresponding increase in capital investment.

Overall, the average increase in capital investment is accompanied by a deterioration in capital investment efficiency. Regulated firms exhibit investment efficiency that is approximately 0.4 percentage points lower than that of non-regulated firms, and the findings are qualitatively similar across the TWFE and stacked difference-in-differences specifications. Although both CTs and ETSs are associated with lower capital investment efficiency in the baseline analyses, the sequence and sectoral analyses indicate that the decline is particularly pronounced for CTs. Capital investment efficiency decreases when a CT is introduced as the first carbon pricing instrument and when a CT is added to an existing ETS. In contrast, adding an ETS where a CT is already in place has no significant incremental effect. We also find little evidence that capital investment efficiency changes during the anticipation period, suggesting that the deterioration occurs primarily after policy implementation. Taken together, these findings indicate that the additional capital investment induced by carbon pricing does not necessarily translate into more efficient capital allocation.

Despite the decline in labor investment, we find no consistent evidence that carbon pricing affects labor investment efficiency on average. The sequence analyses further show that firms reduce labor investment regardless of whether a CT or an ETS is introduced first and that the decline intensifies when an ETS is subsequently introduced after an existing CT. We find no corresponding incremental decline when a CT is introduced after an ETS. Finally, our cross-sectional analyses show that financially constrained regulated firms are more likely to underinvest in capital following carbon pricing adoption, which may partially explain the deterioration in capital investment efficiency. We find no corresponding evidence that financial constraints increase labor underinvestment, consistent with the absence of a deterioration in labor investment efficiency.

We further examine whether financial constraints moderate the effect of carbon pricing on firms' capital and labor underinvestment. Financially constrained firms are more likely to experience capital underinvestment following carbon pricing, particularly under ETSs, but we find no corresponding effect on labor underinvestment. These findings suggest that financing frictions contribute to lower capital investment efficiency, particularly when compliance costs are more uncertain (e.g., Metcalf, 2009), but do not appear to affect labor investment efficiency.

Our study contributes to the literature in several ways. First, it contributes to the growing literature on the real effects of carbon pricing regulation (e.g., Brown et al., 2022; Jacob and Zerwer, 2024; Colmer et al., 2025) by providing the first comprehensive international evidence on how carbon pricing affects firms' capital and labor investment decisions. By jointly examining CTs and ETSs, exploiting announcement and implementation dates, and considering the sequence of policy adoption, our analysis helps reconcile the mixed findings in the existing literature. Our study extends the literature beyond investment levels by providing the first international evidence on how carbon pricing affects the efficiency with which firms allocate both capital and labor. We show that environmental regulation has markedly different implications for the efficiency of different production factors, highlighting the importance of examining both the quantity and quality of firms' investment decisions.

Second, our study provides new evidence on how different production factors adjust to the same environmental regulatory shock. Whereas prior studies typically examine capital investment or employment in isolation, we jointly analyse firms' capital and labor investment decisions. We show that labor adjusts more rapidly than capital, with hiring responding during the anticipation period following carbon-tax announcements, whereas capital investment responds primarily after policy implementation. This difference likely reflects the longer planning horizons, financing requirements, and greater irreversibility associated with capital investment, which may lead firms to delay investment until regulatory uncertainty is resolved (Dixit and Pindyck,1994). These findings provide new insights into the heterogeneous timing of production-factor adjustments following carbon pricing regulation.

Finally, our findings have important implications for policymakers, corporate managers, investors, and researchers. For policymakers, the results suggest that carbon pricing can encourage firms to increase capital investment, although complementary policies that reduce financing frictions and improve policy predictability may be needed to mitigate the associated decline in capital investment efficiency. The documented anticipation effects further highlight the importance of clear policy communication and appropriate workforce transition measures, while the stronger labor response when an ETS is introduced after an existing CT suggests that policymakers should consider the cumulative effects of overlapping carbon pricing policies.

For corporate managers and investors, our findings underscore the importance of financial flexibility, strategic planning, and workforce management in responding effectively to carbon pricing regulation.

2. Theoretical background and development of testable hypotheses

2.1 Carbon pricing policy background

Two common market-based policy instruments aimed at reducing harmful emissions are CTs and ETSs (e.g., the European Union Emissions Trading System). Both seek to lower greenhouse gas emissions by imposing costs on carbon-intensive activities, but they operate through different mechanisms. A CT is a non-income tax levied directly on carbon emissions from production and operates as a price-based instrument. In contrast, an ETS establishes a cap on total emissions across regulated entities, with the market determining the price of emissions permits. Firms that exceed their allocated quotas must purchase additional permits from firms with lower emissions.

Two important differences between these policy instruments are the certainty they provide regarding future compliance costs and the way they allocate regulatory risk. A CT specifies the carbon price in advance, allowing firms to anticipate the direct cost of emissions with relatively greater certainty; whereas an ETS fixes the quantity of allowable emissions while leaving the carbon price to be determined in the permit market. Consequently, firms regulated under an ETS face greater uncertainty regarding future compliance costs because allowance prices may fluctuate over time in response to market conditions, policy design, and permit supply (Weitzman, 1974; Pizer, 2002; Metcalf, 2009; Ellerman et al., 2010). These differences may influence both the timing and magnitude of firms' investment responses to carbon pricing regulation. The economic incidence of carbon pricing may also depend on firms' ability to pass higher energy costs through to customers rather than absorb them internally (Ganapati, Shapiro, and Walker, 2020).

Firms can respond to carbon pricing through several channels, including: reducing emissions; investing in cleaner technologies; and managing or trading emissions permits under an ETS. These responses can range from short-term abatement activities that reduce firms' net emissions more immediately to longer-term investments in cleaner technologies and green innovation that reduce the emissions intensity of production (Bustamante and Zucchi, 2024). While green innovation offers more persistent environmental benefits, it is typically more costly, involves longer implementation periods, and is subject to greater uncertainty. The choice among these adjustment channels ultimately determines how carbon pricing influences firms' capital and labor investment decisions, which we examine next.

2.2 Hypothesis development

2.2.1 Carbon pricing regulation and capital investment

The adoption of carbon pricing regulation, either through a CT or an ETS, is intended to induce firms to internalize the social cost of carbon emissions and is therefore expected to influence both the level and timing of corporate investment (Hall and Jorgenson, 1967). By increasing the cost of carbon-intensive production (Jacob and Zerwer, 2024), carbon pricing may discourage investment when cleaner technologies are costly or their benefits are uncertain (Jacob and Zerwer, 2024; Bustamante and Zucchi, 2024). Conversely, it may encourage firms to invest in cleaner technologies and innovation (Aghion et al., 2016). The net effect on corporate investment is therefore ambiguous.

Recent studies examining the effects of carbon pricing on corporate investment typically employ rigorous research designs aimed at strengthening causal identification. However, by focusing on single-country or single-carbon pricing setting, they address the relatively narrow question of how firms respond when a specific jurisdiction adopts a particular carbon pricing instrument and consequently report mixed findings. As a result, several important questions remain regarding whether investment responses generalize across institutional settings, whether CTs and ETSs exert differential effects, and whether the coexistence of multiple carbon pricing regimes shapes firms' investment incentives. Brown et al. (2022) show that the adoption of a CT can increase R&D investment. In contrast, Jacob and Zerwer (2024) find that the 2013 introduction of a local emission tax in Spain's Valencian Community reduced private firms' investment. Finally, Colmer et al. (2025) examine the EU ETS and document that it reduced global emissions while encouraging targeted investment in cleaner production processes.

Taken together, prior studies provide important evidence that carbon pricing regulation can affect corporate investment, but the existing evidence remains difficult to generalize. This limitation is particularly important because CT and ETS programs may coexist and differ in their salience, price certainty, compliance structure, and implementation across countries; all of which may shape firms' investment responses. We revisit this question using a comprehensive international setting that jointly examines CTs and ETSs and exploits substantial variation across countries, industries, and time. Our setting further allows us to investigate the effects of policy sequencing by examining the incremental impact of introducing one carbon pricing instrument when the other is already in place. Based on the above discussion, we formulate the following null hypothesis:

Hypothesis 1*: The adoption of carbon pricing is not associated with the level of corporate capital investment.*

2.2.2 Carbon pricing regulation and investment efficiency

In frictionless markets, firms invest until the marginal benefit of capital equals its marginal cost (Modigliani and Miller, 1958; Tobin, 1969; Yoshikawa, 1980; Hayashi, 1982). Investment efficiency is achieved when firms undertake all positive net present value (NPV) projects and reject those with negative NPVs (Biddle and Hilary 2006; Biddle et al., 2009; Chen et al., 2011; Guariglia and Yang, 2016; Amberger et al., 2021; Chay et al., 2023). However, in practice agency conflicts and information asymmetries can cause firms to overinvest or underinvest relative to this optimum (Jensen and Meckling 1976; Biddle et al., 2009; and Baik et al., 2024).

Managers seeking to maximize their own welfare may make investment decisions that are inconsistent with shareholder value maximization. In such cases, managers pursuing private benefits may overinvest by financing value-destroying projects (Jensen, 1986; Chetty and Saez, 2010); whereas managers preferring a "quiet life" may underinvest (Bertrand and Mullainathan, 2003). Both forms of inefficient investment are more likely when agency conflicts are severe, such as in environments characterized by weak internal or external monitoring (Biddle and Hilary 2006; McNichols and Stubben 2008; Lu and Sapra 2009; Jian and Lee 2011; Cheng et al., 2013; Goodman et al., 2014; Bae et al., 2017; Chen et al., 2019; Heitzman and Huang 2019; Amberger et al., 2021; Chan and Liu 2022).

The effect of carbon pricing regulation on investment efficiency is ambiguous ex ante. On the one hand, by increasing the cost of polluting activities (Porter and Van der Linde, 1995), strengthening environmental monitoring (Lin et al., 2024), and encouraging cleaner technologies and innovation (Acemoglu et al., 2012; Aghion et al., 2016; Brown et al., 2022), carbon pricing may discourage inefficient investments, reduce managerial discretion, and improve capital allocation (Jensen, 1986; Biddle et al., 2009).

On the other hand, carbon pricing may reduce investment efficiency by increasing compliance costs (Joshi et al., 2001), raising barriers to entry (Ryan, 2012), increasing regulatory uncertainty, and weakening firms' ability to finance productive investments. The resulting adjustment costs may delay or distort investment decisions (Walker, 2013), contributing to suboptimal investment timing and lower investment efficiency (Känzig, 2026). Based on the above discussion, we formulate the following null hypothesis:

Hypothesis 2*: The adoption of a carbon pricing regulation is not associated with capital investment efficiency.*

2.2.3 Carbon pricing regulation and labor investment

Carbon pricing regulation can incentivize firms to invest in cleaner technologies and innovation (Acemoglu et al., 2012; Aghion et al., 2016; Brown et al., 2022). Such technological investments may affect both the quantity of labor demanded (Harrison et al., 2014) and the composition of employment by changing the relative demand for skilled and unskilled workers (Brynjolfsson and Hitt, 2000; Lindner et al., 2022).

The broader technology literature suggests that the employment consequences of technological investment are theoretically ambiguous. Technology may substitute for some categories of labor and reduce employment in directly exposed occupations (Acemoglu et al., 2020; Acemoglu and Restrepo, 2020), but it may also increase productivity, expand output, and ultimately raise labor demand (Aghion et al., 2020). Consequently, carbon pricing may alter firms' labor investment through capital deepening and changes in workforce composition, making the overall effect on labor investment ambiguous ex ante.

Despite extensive evidence on technology, employment, and workforce composition, little is known about how carbon pricing affects firms' labor investment. Existing evidence is limited and mixed. Lariau and Shi (2023) show that labor market outcomes depend on the design of green policies, while Matzner and Steininger (2024) and Trinks and Hille (2026) document employment declines following carbon pricing. In contrast, Colmer et al. (2025) find that EU ETS regulated firms invested in cleaner production without detectable reductions in labor demand. Accordingly, we formulate the following null hypothesis:

Hypothesis 3*: The adoption of carbon pricing regulation is not associated with firms' labor investment.*

2.2.4 Carbon pricing regulation and labor investment efficiency

Labor adjustments following carbon pricing-induced technological investments may not occur efficiently. Firms may overreact by undertaking excessive layoffs or underreact by delaying necessary hiring and workforce reallocation. Moreover, changes in production technologies and skill requirements may increase adjustment costs, making it more difficult for firms to align labor decisions with underlying economic fundamentals. These considerations raise the largely unexplored question of whether carbon pricing affects labor investment efficiency. To our knowledge, no prior study has directly examined this relation.

On the one hand, carbon pricing-induced technological and organisational adjustments may improve labor investment efficiency by encouraging firms to better align workforce decisions with changing production needs and skill requirements. On the other hand, carbon pricing may reduce labor investment efficiency by increasing adjustment costs, regulatory uncertainty, and coordination frictions. These forces may lead firms either to retain workers whose skills are no longer well matched to production needs or to reduce employment more aggressively than warranted by economic fundamentals. Consequently, the overall effect of carbon pricing regulation on labor investment efficiency is ambiguous ex ante. We therefore formulate the following null hypothesis:

Hypothesis 4: *The adoption of carbon pricing regulation is not associated with firms' labor investment efficiency.*

3. Data and Research Design

3.1 Data Sources

Our data are drawn from multiple sources. We first collect information on the global adoption of CTs and ETSs during 1990–2022 from the Carbon Tax Center, International Carbon Action Partnership (ICAP), and World Bank (Marten and van Dender, 2019; World Bank Group, 2019; 2022; Yunis and Aliakbari, 2020; ICAP, 2022). For each policy event, we then collect information on the regions and sectors covered, the implementation year, and manually identify the affected industries and announcement year. This process begins with government sources, uses Large Language Models (ChatGPT) solely for heuristic screening, and concludes with evidence-based manual verification for every policy event. To the best of our knowledge, this is the most comprehensive global catalogue of market-based carbon pricing instruments in terms of temporal, geographic, and industry coverage.[1] Between 1990 and 2022, 25 countries adopted CTs (30 policy introductions) and 39 countries adopted ETSs (31 program introductions). We begin the sample period in 1996 because firm-level data are unavailable for countries that adopted carbon pricing regulations before that year. Our final sample comprises 56 carbon pricing regulations adopted by 45 countries between 1996 and 2022. Figure 1 traces the evolution of carbon pricing policies globally from 1990 to 2022.

We collect firm-level data from Compustat North America and Compustat Global for 1996–2022. We then merge these data with our environmental policy dataset to identify whether each firm is subject to a CT and/or an ETS at the national or regional level in each sample year. An additional advantage of our dataset is that it allows us to examine the effects of CTs and ETSs separately, jointly, and at the margin by assessing the incremental impact of introducing one carbon pricing instrument when the other is already in place. Table 1 reports the definitions and sources of all variables used in the analysis.

3.2 Sample and summary statistics

Table 2 presents summary statistics for the main variables used in our analysis. The sample consists of 449,914 firm-year observations from 1996 to 2022. To mitigate the influence of outliers, all continuous variables are winsorized at the 1st and 99th percentiles.

Across the sample, firms deviate from their estimated optimal level of investment by an average of 7.2% of prior-year total assets, while actual investment equals 9.3% of prior-year total assets. These magnitudes are broadly consistent with recent international evidence. For

[1]To ensure accuracy, we cross-validate all information across the Carbon Tax Center, ICAP, and the World Bank. Our dataset shares some similarities with Laeven and Popov (2023), who classify countries using a binary indicator for the adoption of a CT or an ETS. However, our dataset substantially extends theirs by identifying regulated firms at the firm–country–sector–year level, providing broader geographical coverage, incorporating subnational carbon pricing regimes (e.g., Canada and China), and recording policy announcement dates. These additional features improve the precision of treatment assignment and strengthen our identification strategy.

example, Baik et al. (2024) report investment inefficiency of 6.1% and investment of 9.1%. Regarding the treatment variables, 16.4% of firm-year observations are subject to a carbon pricing system. Separately, 7.0% are subject to a CT and 13.5% to an ETS, while 4.1% are subject to both policies simultaneously.

By construction, carbon pricing targets firms operating in specific industries, sectors, countries, and years. To further characterize our sample, Tables 3 and 4 provide country- and industry-level breakdowns. Table 3 reports the country composition of the sample. Consistent with prior international studies, most firm-year observations originate from Japan, China, the United States, India, and the United Kingdom (see also Baik et al., 2024). Overall, 45 of the 93 countries in the sample have at least one carbon pricing regulation, and firms from these countries account for 303,697 firm-year observations, or 67.5% of the sample.

Table 4 reports the industry composition of the sample. Industries such as Chemicals and Allied Products, Business Services, Electronic & Other Electrical Equipment, Food & Kindred Products, and Industrial Machinery and Equipment are among the most represented.

3.3 Research design

3.3.1 Capital investment inefficiency

Following prior literature (e.g., Biddle et al., 2009, Chay et al., 2023; Baik et al., 2024), we measure capital investment inefficiency as the deviation of a firm's actual investment from its optimal level, where optimal investment is a function of growth opportunities proxied by sales growth. In the first stage, we estimate capital investment efficiency by cross-sectionally regressing investment in year t on sales growth in year $t - 1$ for each country–industry–year group in our sample. To avoid generating spurious estimates arising from small peer groups, we estimate eq. (1) only for country–industry–year clusters with at least 10 observations.[2]

[2] Our results are qualitatively similar when requiring either a minimum of five observations per country–industry–year, consistent with Baik et al. (2024), or a minimum of 20 observations, consistent with Biddle et al. (2009).

$$Capital\ Investment_{i,t} = B_0 + B_1 Sales\ Growth_{i,t-1} + \varepsilon_{i,t} \tag{1}$$

$Capital\ Investment$ is the sum of capital expenditures, acquisitions, and research and development (R&D) expenses minus the sale of property plant and equipment (PPE), scaled by lagged total assets of firm i in time t (see e.g., Biddle et al., 2009, Chay et al., 2023; Baik et al., 2024). $Sales\ Growth$ is the annual sales growth rate for firm i in year $t-1$. The predicted values from the estimation of eq. (1) represent the expected level of investment, which we use as a proxy for optimal investment. The residual from the estimation of eq. (1), $\hat{\varepsilon}_{i,t}$, captures the deviation of a firm's actual investment from its optimal level, and reflects the portion of investment not explained by the firm's growth opportunities. Positive residuals indicate overinvestment, whereas negative residuals indicate underinvestment. Because both positive and negative residuals represent deviations from optimal investment, we construct our measure of capital investment efficiency ($Capital\ Investment\ Efficiency$), as the absolute value of these residuals, $|\hat{\varepsilon}_{i,t}|$ multiplied with -1. Thus, higher values indicate a greater degree of investment efficiency. In other words, larger deviations from the optimal level (i.e., more negative values of $Capital\ Investment\ Efficiency$) correspond to lower capital investment efficiency, and vice versa.

3.3.2 Labor investment inefficiency

Following Pinnuck and Lillis (2007) and Jung et al. (2014), we use firms' net hiring as a proxy for labor investment. We then measure abnormal net hiring as the difference between actual net hiring and the level of net hiring predicted by firms' underlying economic fundamentals:

$$Abnormal\ Net\ Hiring_{i,t} = Net\ Hiring_{i,t} - \widehat{Net\ Hiring}_{i,t}.$$

To estimate expected net hiring, we estimate the following model:

$$Net\ Hiring_{\ i,t} = a_0 + a_1 Sales\ Growth_{i,t} + a_2 Lagged\ Sales\ Growth_{i,t-1} + a_3 ROA_{i,t} + a_4 \Delta ROA_{i,t} + a_5 \Delta ROA_{i,t-1} + a_5 Return_{i,t} + a_6 \mathrm{Size}_{i,t-1} +$$

$$a_7 Quick\ Ratio_{i,t-1} + a_8 \Delta Quick\ Ratio_{i,t} + a_9 \Delta Quick\ Ratio_{i,t-1} + a_{10} Leverage_{i,t-1} + \sum_{i=0}^{5} \theta_j Loss\ Dummy_{i,t-j} + h_{i,t} + v_{i,t} \quad (2)$$

Consistent with prior studies (e.g., Pinnuck and Lillis, 2007; Jung et al., 2014 and Ben-Nasr and Alshwer, 2016), we expect net hiring to be positively associated with firms' growth opportunities and profitability, as reflected in sales growth and ROA. After estimating Equation (2), we apply the estimated coefficients to each firm-year observation to obtain expected net hiring, $\widehat{Net\ Hiring}_{i,t}$. The absolute difference between actual and expected net hiring captures the extent of labor investment inefficiency. Consistent with our capital investment efficiency measure, we multiply this absolute deviation by -1 so that higher values indicate greater labor investment efficiency.

$$Labour\ Investment\ Efficiency_{i,t} = -|Net\ Hiring_{i,t} - \widehat{Net\ Hiring}_{i,t}|.$$

3.3.3 Carbon pricing regimes and inefficiency

Finally, to identify the effect of carbon pricing adoption on capital and labor investment and investment efficiency, we employ a staggered difference-in-differences (DiD) research design. This approach exploits the fact that different carbon pricing policies regulate firms across different countries sectors and industries at different points in time (e.g., Bertrand et al. 2004). We formally estimate the following two-way fixed effects (TWFE) DiD specification:

$$\begin{Bmatrix} Capital\ Investment_{i,t} \\ Capital\ Investment\ Efficiency_{i,t} \\ Labour\ Investment_{i,t} \\ Labour\ Investment\ Efficiency_{i,t} \end{Bmatrix} = \beta_0 + \beta_1 Carbon\ Pricing\ Policy_{i,j,c,t-1} + \gamma Controls_{i,t} + \varphi_{i,t} + u_{i,t}. \quad (3)$$

Where $Capital\ Investment$, $Labour\ Investment$, $Capital\ Investment\ Efficiency$ and $Labour\ Efficiency$ are as defined above. The variable of interest is $Carbon\ Pricing\ Policy$, an indicator variable equal to 1 for years following the adoption of a carbon pricing policy (i.e., a CT or an ETS) in a given country, and 0 otherwise. $Carbon\ Pricing\ Policy$ is specific to firm i operates in country c, industry j, and year t. Throughout our empirical analysis, we employ three alternative indicator variables to capture carbon pricing policy exposure. Specifically, we use $Regulated\ Firm$, which does not distinguish between policy regimes, as well as $Carbon\ Tax\ Regulated\ Firm$, and $ETS\ Regulated\ Firm$ which allow us to examine each regime separately. Accordingly, our treatment variable, $Carbon\ Pricing\ Policy$, is implicitly the interaction of a country and industry environmental regulation indicator (equal to 1 for treated industries within a given country) and a $Post$ indicator (equal to 1 for all post-adoption years t). Our DiD estimator, β_1, is statistically significant only if the average change in investment and/or investment efficiency for regulated firms differs significantly from that of non-regulated firms within the same year.

$Controls$ is a vector of variables included to account for time-varying firm-, industry-, and country-level characteristics known to influence investment efficiency. Specifically, we control for financial leverage ($Leverage$), a dividend payer indicator ($Dividends$), $Return\ on\ Asset$, an indicator for loss-making firms ($Loss\ Indicator$), prior-year investment ($Lagged\ Capital\ Investment$), $Asset\ Growth$, $Sales\ Growth$, assets tangibility ($Tangibility$), $Inventory$, cash flows from operations scaled by total sales ($CFOSale$), the ratio of cash to PPE ($Slack$), and the volatility of cash flows ($\sigma Cash\ Flows$), return on asset (σROA), total sales ($\sigma Sales$), and investment ($\sigma Investment$). We also include prior-year sales growth ($Lagged\ Sales\ Growth$), $Debt\ Issuance$, $Equity\ Issuance$ $Financial\ Reporting\ Quality$, $Statutory\ Tax\ Rate$, $GDP\ Growth$, $GDP\ per\ Capita$, $Inflation$ and $Unemployment\ Rate$. Controlling for these variables, which are identified in prior literature as determinants of investment and investment efficiency, along with the inclusion of firm and industry-year fixed effects, allows us to better isolate the effect of our DiD estimator. Accordingly, our DiD estimator, β_1, captures the average change in investment and investment efficiency for regulated firms relative to the contemporaneous change for non-regulated firms (Callaway and Sant'Anna, 2021; Goodman-Bacon, 2021).

A potential concern with our research design is that carbon pricing policies are not randomly assigned across firms. Countries may adopt these policies in settings where regulated firms differ systematically from non-regulated firms in ways that are also related to subsequent capital or labor investment outcomes. To improve comparability between the treated and control groups on observable characteristics, we conduct our analyses using entropy-balanced samples.[3]

We also examine the dynamics surrounding policy adoption. The results support parallel trends for capital investment, whereas labor investment exhibits an anticipatory decline following CT announcements. We therefore distinguish the announcement-to-implementation period from the post-implementation period in our labor analyses, allowing firms' early workforce adjustments to be estimated separately from responses after the policy becomes effective.

4. Results

4.1 Carbon Pricing Regulations and Capital Investment

4.1.1 Carbon Pricing and Capital investment: TWFE DiD

We test Hypothesis 1 by estimating Equation (3) with corporate investment as the dependent variable. Table 5 reports the results. Columns 1–3 present the TWFE DiD estimates. All estimations are based on an entropy-balanced sample, ensuring greater comparability between treated and control firms while addressing concerns regarding covariate imbalance. In Column 1, where we examine firms subject to any carbon pricing regulation ($Regulated\ Firm$), the

[3] This balancing strengthens the credibility of non-regulated firms as a counterfactual for firms subject to carbon pricing interventions (McMullin and Schonberger 2020, 2022). Furthermore, we implement stacked cohort difference-in-differences specifications to mitigate concerns arising from treatment-effect heterogeneity across cohorts and over time (see Baker et al., 2022; Baik et al., 2024).

DiD estimate is positive and statistically significant at the 1% level. The coefficient 0.005 indicates that carbon pricing regulated firms increase investment by 0.5 percentage points of lagged assets, equivalent to approximately 5.38% of the sample mean relative to non-regulated firms (i.e., 0.005/0.093). Columns (2) and (3) indicate that this positive effect is associated primarily with CT adoption. The coefficient on *CT Regulated Firm* is positive and statistically significant, whereas the coefficient on *ETS Regulated Firm* is small and statistically insignificant.[4]

4.1.2 Carbon Pricing and Capital Investment: Stacked DiD

Our TWFE DiD design exploits variation in investment between firms subject to a carbon pricing policy and firms that are not concurrently subject to such a policy. Consequently, the control group includes firms in never-treated countries, as well as firms in countries that are not yet treated or were treated in earlier periods. Because previously treated firms may provide contaminated controls and bias TWFE estimates when treatment effects vary across cohorts, we also estimate a stacked cohort DiD specification (Baker et al., 2022; Baik et al., 2024; Ghosh et al., 2026). Specifically, we construct event-specific datasets around each carbon pricing adoption, exclude firms treated in earlier periods, and compare firms in the treated country with firms in never-treated countries over the same event window. We then stack these datasets and re-estimate Equation (3) using the resulting sample.

Table 5, Columns 4–6, report the stacked DiD results. Column 4 shows that carbon pricing regulation is associated with a statistically significant increase in corporate investment. When the instruments are examined separately, the coefficient on $CT\ Regulated\ Firm$ is

[4] In untabulated tests we re-estimate the TWFE DiD results without entropy balancing. The results are economically and statistically similar to those reported in Table 5, indicating that our findings are not driven by the entropy-balancing procedure. We nevertheless report entropy-balanced specifications throughout the paper because entropy balancing improves the comparability of treated and control firms by balancing the distribution of observed covariates, thereby strengthening the credibility of the estimated treatment effects. Additional untabulated analyses indicate that the increase in capital investment is more pronounced when CTs and ETSs coexist and is primarily driven by CT-regulated firms operating in the power and industrial sectors

positive and statistically significant, whereas the coefficient on $ETS\ Regulated\ Firm$ is also positive but not statistically significant at conventional levels. Overall, these findings are consistent with the TWFE estimates reported in Columns 1–3 and indicate that carbon pricing, particularly CTs, increases corporate investment. The similarity between the stacked and TWFE estimates further alleviates concerns that our main findings are driven by treatment-effect heterogeneity across adoption cohorts.

4.1.3 Carbon Pricing and Capital Investment: Accounting for Anticipation Effects

Governments typically announce carbon pricing policies before they become legally binding. Our carbon pricing policy catalogue, includes regulations with official announcement dates occurring between zero and, in a few cases, four years before implementation. Estimating treatment effects solely from the implementation date could therefore underestimate the overall policy impact by attributing pre-implementation adjustments to the post-treatment period. To examine whether firms respond following policy announcements, we augment our baseline specification with $CT\ Anticipation$ and $ETS\ Anticipation$, which capture investment responses between the announcement and implementation of each policy. Columns 7–9 of Table 5 report the results. We find no evidence of an anticipatory increase in capital investment, suggesting that firms do not systematically raise investment immediately following policy announcements. Instead, capital investment responds primarily after carbon pricing becomes effective.[5]

Overall, our results indicate that firms increase capital investment following the adoption of carbon pricing regulations, with the effect driven primarily by CTs rather than ETSs. A plausible explanation relates to differences in policy certainty. CTs are typically announced

[5] As an additional robustness test, we re-estimate our treatment variables using the official announcement date of each carbon pricing regulation rather than its implementation date (untabulated). The findings are qualitatively similar to those reported in Table 5, indicating that firms increase capital investment following the announcement of a carbon pricing regulation, with the effect being more pronounced for carbon taxes (CTs).

together with a predefined tax schedule or clearly specified tax rate, providing firms with relatively precise information about future compliance costs. This greater predictability facilitates long-term capital investment planning, particularly for investments aimed at improving energy efficiency or reducing emissions (Weitzman, 1974; Pizer, 2002). In contrast, firms subject to an ETS face greater uncertainty regarding allowance prices, allocation rules, market liquidity, and compliance costs (Weitzman, 1974; Ellerman et al., 2010). Given that capital investments are costly and partially irreversible, firms may delay investment until this uncertainty is resolved (Dixit and Pindyck, 1994). Consequently, CTs are more likely than ETSs to stimulate capital investment following implementation.

4.1.4 Assessing the Parallel Trends Assumption

A potential concern with our previous results is that countries may systematically select into adopting carbon pricing policies. To assess the validity of the parallel trends assumption, we examine whether investment evolved similarly for regulated and non-regulated firms prior to policy implementation. Specifically, we estimate the TWFE DiD specification from Table 5 using the entropy-balanced sample and replace the treatment indicator with a series of event-time indicators spanning the year of implementation and the five years before and after policy adoption (i.e., $Regulated\ Firm_{t-5}$, $Regulated\ Firm_{t-4}, \ldots\ Regulated\ Firm_{t+4}$, $Regulated\ Firm_{t+5}$).

If the parallel trends assumption holds, the coefficients on the pre-treatment indicators should be statistically indistinguishable from zero. Figure 2 reports the results using observations within five years of each regulatory event. The estimated pre-treatment coefficients are generally not statistically significant, indicating no systematic differences in investment trends between regulated and non-regulated firms before policy adoption. In contrast, the post-treatment coefficients become positive and statistically significant, consistent with regulated firms increasing investment following the adoption of carbon pricing regulation.

4.1.5 Carbon Pricing Regime Sequence and Corporate Investment

Existing studies typically examine the effects of a single carbon pricing instrument within a particular institutional setting to strengthen causal identification (e.g., Jacob and Zerwer, 2024; Colmer et al., 2025). As a result, little is known about how firms respond when multiple carbon pricing instruments coexist or are introduced sequentially. Our international dataset allows us to address this question by examining the sequence in which CTs and ETSs are adopted within a country.

Table 6 reports the results. We find that, in countries without prior carbon pricing regulation, introducing a CT as the first instrument significantly stimulates firms' capital investment, whereas introducing an ETS first does not. A test of coefficient equality confirms that the investment response is significantly greater for CT-first than for ETS-first adoption (difference = 0.0065, p = 0.002). Introducing a CT after an ETS does not significantly increase investment relative to the ETS-only state, whereas introducing an ETS after an existing CT carries a negative but statistically insignificant coefficient (ETS After CT = −0.005, t = −1.23). Comparing the two dual-regime sequences, the investment response is statistically greater when a CT follows an ETS than when an ETS follows a CT (difference = 0.0082, p = 0.055). Overall, these findings suggest that the positive investment response is driven primarily by the initial adoption of a CT rather than by subsequent introduction of a second carbon pricing instrument.

4.2 Carbon Pricing Regulations and Capital Investment Efficiency

4.2.1 Baseline analysis on capital investment efficiency

Our analysis thus far shows that firms increase investment following the adoption of carbon pricing regulation. However, greater investment does not necessarily imply more efficient capital allocation. Carbon pricing may induce firms to invest to comply with policy requirements, reduce emissions, or adopt cleaner technologies, while regulatory pressure, uncertainty, and financing constraints may reduce investment efficiency. We therefore examine whether carbon pricing affects the efficiency of firms' investment decisions.

Table 7 reports the results. Columns 1–3 present the TWFE DiD estimates, while Columns 4–6 report the stacked DiD estimates that account for potential treatment-effect heterogeneity. The findings are qualitatively similar across both specifications. In both the TWFE (Column 1) and stacked DiD (Column 4), the coefficient on $Regulated\ Firm$ is negative and statistically significant, indicating that firms subject to either a CT or an ETS exhibit investment efficiency that is approximately 0.4 percentage points lower than that of non-regulated firms. Examining each policy separately, we find that both CTs and ETSs are associated with lower investment efficiency, with coefficients ranging from −0.002 to −0.003. Additional untabulated analyses indicate that this decline is primarily driven by CT-regulated firms operating in the power sector as well as by firms operating in industrial sector.

Next, we examine whether firms adjust investment efficiency during the anticipation period between the announcement and implementation of a carbon pricing regulation. Columns 7–9 of Table 7 provide little evidence of meaningful anticipation effects. The results are consistent with both the TWFE and stacked DiD estimates, suggesting that policy announcements have, at most, a negligible effect on investment efficiency before implementation.[6]

Overall, the evidence indicates that although carbon pricing regulations increase investment, the additional investment does not translate into more efficient capital allocation. Instead, regulated firms deviate further from their estimated optimal level of investment following policy implementation, indicating a deterioration in capital investment efficiency.

[6] As an additional untabulated robustness test, we examine whether dating the treatment using the announcement, rather than the implementation, of a carbon pricing regulation affects firms' investment efficiency. Consistent with Table 7, we find little evidence that regulatory announcements have a meaningful effect on investment efficiency.

This deterioration is particularly pronounced when a CT is introduced in the presence of an existing ETS, as we will explain in more details in subsection 4.2.3 regarding sequence.

4.2.2 Assessing the Parallel Trends Assumption

Similarly to the capital investment analysis, a potential concern is that countries may systematically select into the adoption of carbon pricing policies. To assess the validity of the parallel trends assumption, we examine whether investment efficiency evolved similarly for regulated and non-regulated firms prior to policy implementation. Specifically, we estimate the specification from Table 7, Column 1, using the entropy-balanced sample and replace the treatment indicator with a series of event-time indicators spanning the year of implementation and the five years before and after policy adoption (i.e., $Regulated\ Firm_{t-5}$, $Regulated\ Firm_{t-4},\ \ldots Regulated\ Firm_{t+4}, Regulated\ Firm_{t+5}$).

Figure 3 reports the results. The estimated pre-treatment coefficients are generally statistically indistinguishable from zero, providing support for the parallel trends assumption. Following the adoption of carbon pricing regulation the estimated coefficients become negative and statistically significant, indicating that capital investment efficiency declines for regulated firms after policy implementation.

4.2.3 Carbon Pricing Regime Sequence and Capital Investment Efficiency

We next examine whether the sequence of carbon pricing regulations provides additional insights into how carbon pricing affects corporate investment efficiency. Table 8 reports the results. Capital investment efficiency declines when either a CT or an ETS is introduced as the first carbon pricing instrument, although the decline is significantly larger for CT-first adoption than for ETS-first adoption (difference = −0.0039, p = 0.045). Introducing a CT after an existing ETS is associated with an additional decline in investment efficiency relative to the ETS-only state (difference = −0.0032, p = 0.068). In contrast, introducing an ETS after an existing CT does not significantly change investment efficiency relative to the CT-only state (difference =

0.0005, p = 0.939). The effects of the two dual-regime sequences are statistically indistinguishable, providing no evidence that adoption order matters once both instruments are in place. Overall, the findings indicate that the results suggest that CT adoption is associated with a more pronounced decline in capital investment efficiency, particularly when introduced as the initial carbon pricing instrument.

4.3 Carbon Pricing Regulations and Labor Investment

4.3.1 Baseline analysis on labor investment

Carbon pricing regulation can encourage firms to invest in cleaner technologies and innovation (Acemoglu et al., 2012; Aghion et al., 2016; Brown et al., 2022). Such technological investments may affect both labor demand (Harrison et al., 2014) and workforce composition by changing the relative demand for skilled and unskilled workers (Brynjolfsson and Hitt, 2000; Lindner et al., 2022).

We next examine whether carbon pricing affects labor investment, measured by $Net\ Hiring$. Table 9 reports the results. Columns 1–3 present the TWFE DiD estimates, while Columns 4–6 report the stacked DiD estimates. In both specifications, the coefficient on $Regulated\ Firm$ is negative and statistically significant at the 1% level, indicating that labor investment declines following the adoption of carbon pricing regulation (Columns 1 and 4). These findings are consistent with recent evidence (Matzner and Steininger, 2024; Trinks and Hille, 2026).[7]

The dynamic treatment effects reported in Figure 4 show a downward trajectory in the estimated coefficients during the pre-implementation period, suggesting that labor investment begins to decline in advance of policy implementation. Because carbon pricing policies are

[7] Our dataset also allows us to replicate findings from prior studies that examine a single country and/or a single carbon pricing instrument. For example, restricting the sample to French firms and examining the effect of the EU ETS on labor investment yields no significant effect (untabulated), consistent with the findings of Colmer et al. (2025).

often announced in advance, this pattern may reflect firms' anticipatory responses to policy announcements. We investigate this possibility in later tests by separately identifying the period between policy announcement and implementation.

Although both the TWFE and stacked DiD estimators consistently indicate that carbon pricing reduces labor investment, the attribution of this effect across CT and ETS differs (Columns 2–3 versus Columns 5–6). The anticipation tests (Columns 7–9) suggest that these differences are at least partly driven by heterogeneous adjustment timing across the two policy instruments. Specifically, labor investment declines during the anticipation period following CT announcements (Column 8), whereas the post-implementation CT effect is not significant, indicating that firms begin adjusting labor investment before the tax becomes effective. In contrast, labor adjustments associated with ETS occur primarily after implementation (Column 9), consistent with greater uncertainty regarding future allowance prices and compliance costs before the market becomes operational. In additional untabulated tests, we redefine treatment using official policy announcement dates and continue to document declines in labor investment following carbon pricing announcements. The decline is more pronounced for CTs, corroborating the evidence in Table 9 that firms begin adjusting labor investment before a CT becomes effective.[8]

Comparing the labor and capital results provides further insight into firms' adjustment decisions. For capital investment, the TWFE and stacked DiD estimators produce nearly identical estimates and no evidence of anticipation effects, indicating that firms adjust capital expenditure primarily after carbon pricing becomes effective. In contrast, labor investment exhibits significant anticipatory adjustments, particularly following CT announcements. Given the greater flexibility of labor relative to capital, firms appear able to adjust hiring before

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[8] Because the stacked DiD estimator identifies treatment effects around individual policy adoptions, whereas the TWFE estimator averages effects across staggered adoption cohorts, these differences in adjustment timing affect how the overall decline in labor investment is attributed to each policy instrument.

implementation. Consequently, the estimated post-implementation labor effects are more sensitive to the treatment timing underlying alternative DiD estimators. The differing regime-specific estimates therefore are consistent with heterogeneous adjustment dynamics rather than inconsistency across estimation methods.

4.3.2 Carbon Pricing Regime Sequence and Labor Investment

Consistent with our analysis of capital investment, we next examine whether the sequence of carbon pricing regulations provides additional insights into how carbon pricing affects labor investment. Table 10 reports the results. Two findings emerge. First, both CT-first and ETS-first adoption are associated with significant declines in labor investment, and the magnitudes of these declines are statistically indistinguishable (difference = 0.0057, $p = 0.211$). Second, introducing an ETS after an existing CT further reduces labor investment relative to the CT-only state (difference = −0.0181, $p = 0.050$). In contrast, introducing a CT after an existing ETS does not significantly alter labor investment relative to the ETS-only state (difference = −0.0021, $p = 0.594$). Overall, these findings suggest that introducing a second instrument intensifies labor adjustments when an ETS follows a CT, but not when a CT follows an ETS.

4.4 Carbon Pricing Regulations and Labor Investment Efficiency

Adjustments in labor demand following carbon pricing-induced technological investments may not necessarily occur efficiently. Firms may overreact through excessive layoffs or underreact by delaying necessary hiring and workforce reallocation. Moreover, changes in production technologies and skill requirements may increase adjustment costs, making it more difficult to align labor decisions with underlying economic fundamentals. These considerations raise an important and largely unexplored question of whether carbon pricing affects firms' labor investment efficiency. We report these tests in Table 11. Regardless of whether we employ the conventional TWFE DiD or the stacked DiD estimator, we find no evidence that carbon pricing significantly affects labor investment efficiency.

These findings suggest that although carbon pricing reduces labor investment, the associated adjustments do not become systematically more or less efficient. A possible explanation is that labor is inherently more flexible than capital, allowing firms to adjust hiring decisions relatively quickly and align workforce changes with evolving production needs. Consequently, while carbon pricing affects the level of labor investment, it does not appear to distort the efficiency with which firms allocate labor. This interpretation is further supported by untabulated analyses that redefine the policy event using the official announcement date rather than the implementation date. These analyses continue to show no significant average effect of carbon pricing on labor investment efficiency, consistent with the absence of a systematic post-implementation pattern in Figure 5.[9]

4.4.1 Carbon Pricing Regime Sequence and Labor Investment Efficiency

Consistent with our analysis of labor investment, we next examine whether the sequence of carbon pricing regulations provides additional insights into how carbon pricing affects labor investment efficiency. Table 12 reports the results. Neither the adoption of a CT or an ETS as the first carbon pricing instrument nor the subsequent introduction of a second instrument is significantly associated with labor investment efficiency. Moreover, none of the coefficient differences across adoption sequences is statistically significant. Thus, although firms reduce labor investment following carbon pricing adoption, we find no evidence that either the sequence of policy adoption or the introduction of a second instrument affects labor investment efficiency.

4.5 Cross-sectional Analysis

Carbon pricing regulation imposes additional compliance and adjustment costs on regulated firms (Jacob and Zerwer, 2024). These costs may increase firms' financing needs and

[9] The anticipation specifications in Table 11 show a positive and statistically significant coefficient on *ETS Anticipation*, suggesting that labor investment efficiency improves during the period between ETS announcement and implementation.

cost of capital, particularly among financially constrained firms with limited access to internal funds and greater reliance on external financing. Consequently, such firms may forgo positive net present value investments (Chetty and Saez, 2010; Guariglia and Yang, 2016; Chay et al., 2023), including investments needed to adapt production processes and reduce emissions. Carbon pricing may therefore exacerbate capital and labor underinvestment by reducing resources available for necessary investments.

In untabulated analyses we examine whether financially constrained firms are more likely to underinvest following carbon pricing adoption. We find that financially constrained regulated firms are more likely to exhibit capital underinvestment following carbon pricing adoption. Because underinvestment is defined relative to the level of capital investment predicted by firms' underlying economic fundamentals, this finding is not inconsistent with the average increase in capital investment documented in Table 5. Firms can increase capital investment on average, as shown in Table 5, while still investing less than their economic fundamentals would imply. Together, the findings suggest that underinvestment among financially constrained firms may partially contribute to the documented decline in capital investment efficiency. This interpretation is consistent with these firms having less flexibility to finance timely capital adjustments and absorb additional compliance costs, particularly under ETS regimes, where future costs depend on allowance prices, allocation rules, and permit-market conditions (Metcalf, 2009).

We repeat our analyses for labor underinvestment (untabulated). We find no evidence that financial constraints increase the likelihood of labor underinvestment following carbon pricing adoption. This result is consistent with our earlier finding that labor investment efficiency does not systematically deteriorate. Taken together, the evidence suggests that financial constraints are more consequential for firms' ability to adjust capital efficiently than for their labor adjustments, likely because capital investment requires larger and more immediate financial commitments.

5. Conclusions

This study examines how carbon pricing regulation affects firms' capital and labor investment decisions and the efficiency with which these productive inputs are allocated. We construct a novel international catalogue of 56 CTs and ETSs interventions adopted across national and subnational jurisdictions in 45 countries and combine it with firm-level data from 93 countries over 1996–2022. Exploiting variation in the timing and sectoral coverage of these interventions, we employ entropy-balanced TWFE and stacked difference-in-differences estimators to examine the overall effects of carbon pricing, distinguish between alternative policy instruments, and assess the consequences of sequential policy adoption.

Our findings reveal markedly different responses across capital and labor. Carbon pricing increases capital investment, with the effect particularly evident for CTs. However, this increase is accompanied by a decline in capital investment efficiency, indicating that additional investment following carbon pricing does not necessarily translate into more efficient capital allocation. In contrast, carbon pricing reduces labor investment without significantly affecting labor investment efficiency. The timing of these responses also differs. Capital investment adjusts primarily after carbon pricing becomes effective, whereas labor investment exhibits anticipatory adjustment, particularly following CT announcements. Moreover, the sequence of policy adoption matters. Capital investment increases primarily when a CT is introduced as the first carbon pricing instrument, while capital investment efficiency declines both when a CT is introduced first and when it is added to an existing ETS. The corresponding ETS effects are generally weaker. For labor investment, initial adoption of either a CT or an ETS reduces hiring, and hiring declines further when an ETS is subsequently introduced after an existing CT.

Our cross-sectional analysis provides further insight into the different efficiency effects across productive inputs. Financially constrained regulated firms are more likely to experience capital underinvestment following carbon pricing adoption, which may partially contribute to the documented deterioration in capital investment efficiency. By contrast, we find no systematic evidence that financial constraints increase the likelihood of labor underinvestment, consistent with the absence of a significant overall change in labour investment efficiency. These results suggest that financing frictions are more consequential for firms' ability to adjust capital efficiently than for their labour adjustments.

Taken together, our findings show that examining capital or labor in isolation provides only a partial view of firms' responses to environmental regulation. Carbon pricing induces firms to increase capital investment while reducing labor investment, with these adjustments differing in their direction, timing and efficiency consequences. Our findings therefore extend the literature beyond the effects of carbon pricing on investment or employment levels by documenting how firms jointly adjust productive inputs and the efficiency with which those inputs are allocated. For policymakers, the results suggest that carbon pricing can stimulate capital investment, but complementary measures that alleviate financing frictions may help mitigate capital underinvestment and associated efficiency losses. The anticipatory and cumulative effects on labor investment further highlight the importance of credible policy timing, communication and consideration of workforce adjustments when designing and combining carbon pricing instruments.

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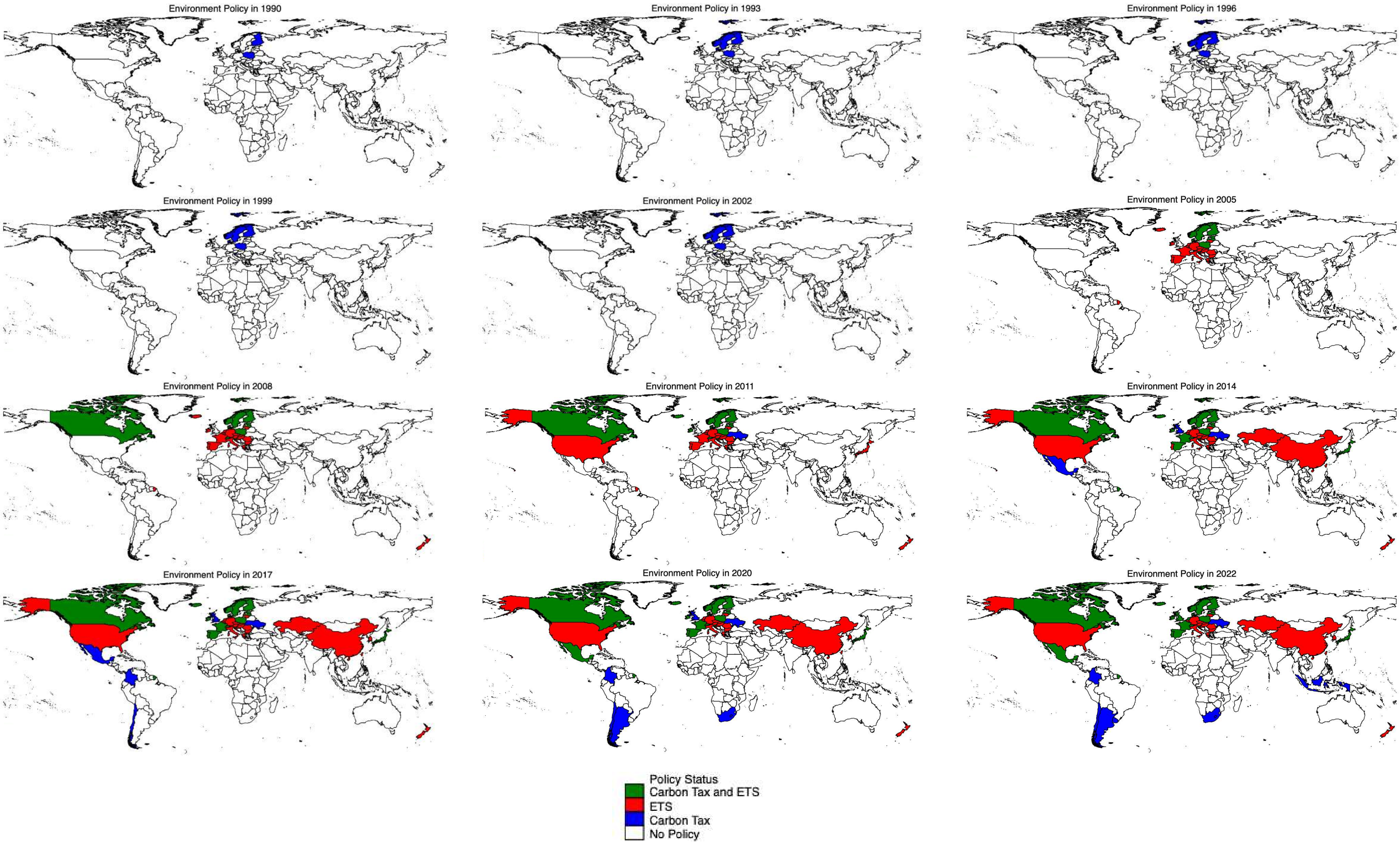
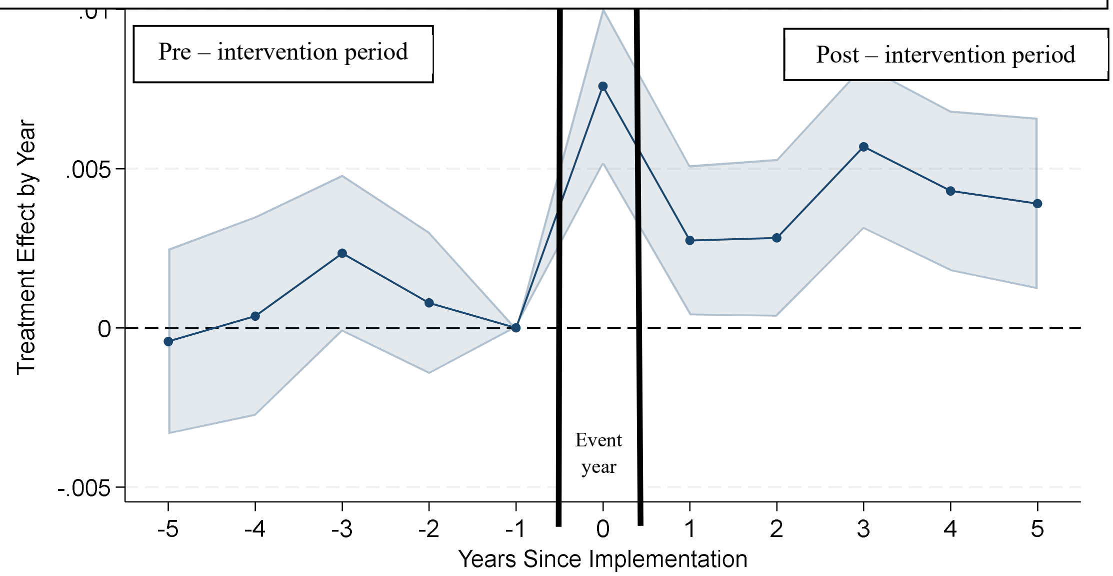
Figure 1. Carbon Pricing Policy Development From 1990 - 2022



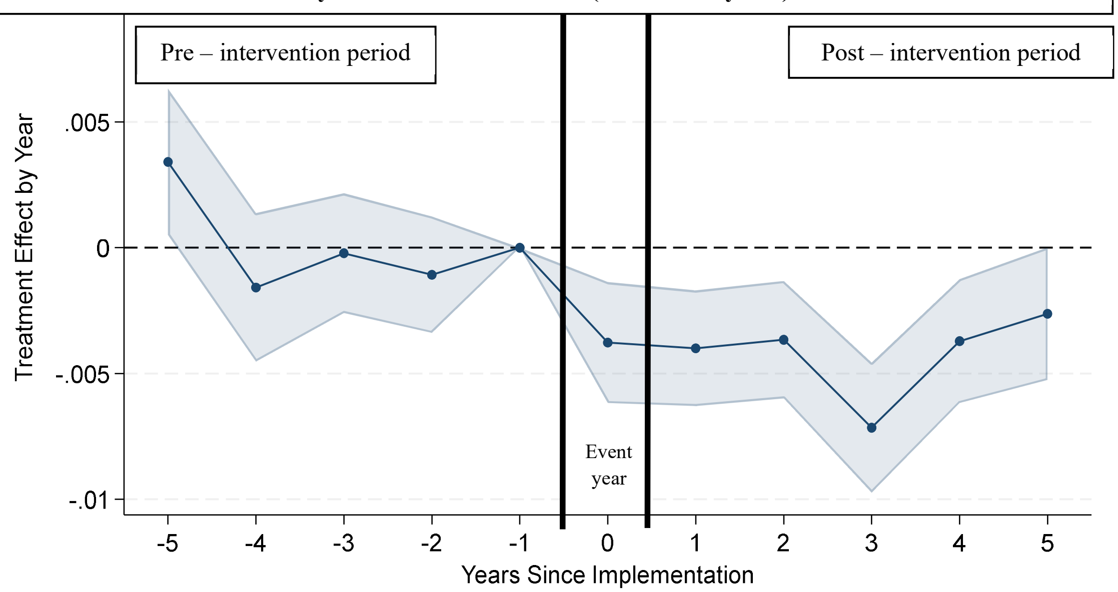
Notes. Global carbon pricing policy (carbon tax, ETS or both) implementation. This figure illustrates the dynamics of the carbon pricing policy implementation globally between 1990 – 2022. (Source: Carbon Tax Center, International Carbon Action Partnership (ICAP), and World Bank Group Carbon Pricing Dashboard.)

Figure 2. Carbon Pricing regulation and Investment
Dynamic Treatment Effect ($t-5, t+5$ years).



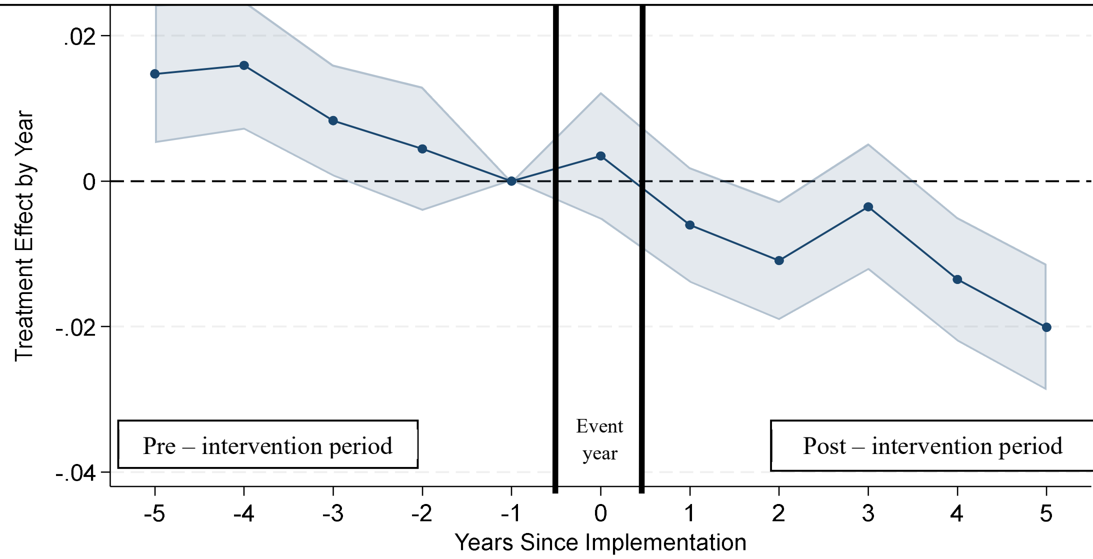
Note: This figure presents lead-lag estimates of the dynamic treatment effects of environmental regulation five years around the adoption of a carbon tax or an emissions trading system. Treated firms are firms subject to either a carbon tax or an emissions trading system, while control firms are firms not subject to these regulations. The coefficients capture the difference in outcomes between treated and control firms in each year relative to the intervention year, with the shaded area representing confidence intervals. Figure presents results for investment.

Figure 3. Carbon Pricing regulation and Investment Efficiency
Dynamic Treatment Effect ($t-5, t+5$ years).



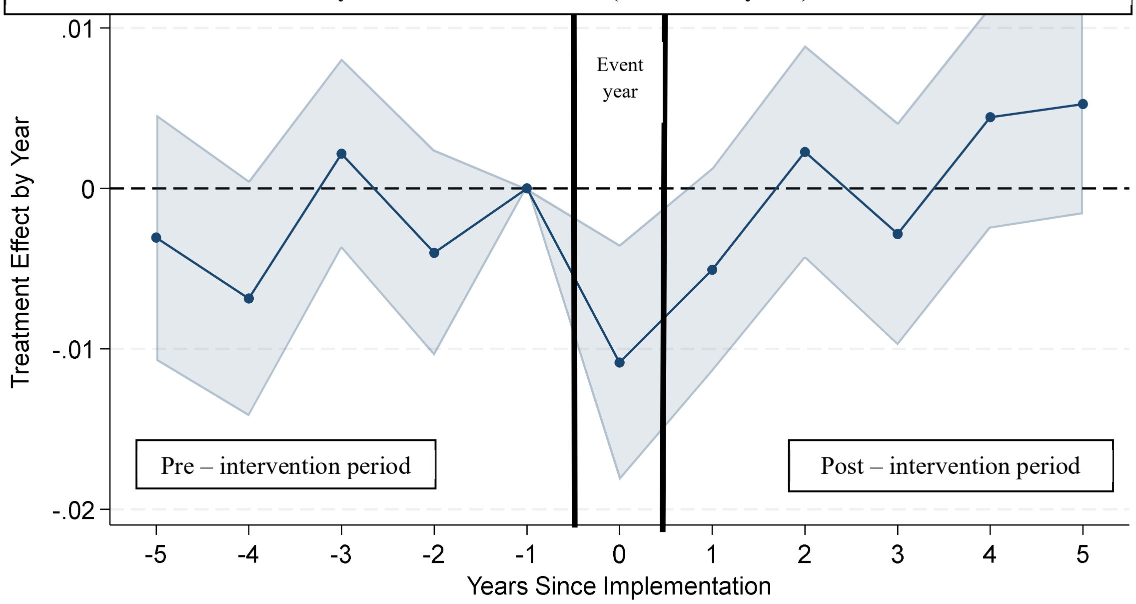
Note: This figure presents lead-lag estimates of the dynamic treatment effects of environmental regulation five years around the adoption of a carbon tax or an emissions trading system. Treated firms are firms subject to either a carbon tax or an emissions trading system, while control firms are firms not subject to these regulations. The coefficients capture the difference in outcomes between treated and control firms in each year relative to the intervention year, with the shaded area representing confidence intervals. Figure 3 presents results for investment efficiency using the full sample period

Figure 4. Carbon Pricing regulation and Labor Investment
Dynamic Treatment Effect ($t-5, t+5$ years).



Note: This figure presents lead-lag estimates of the dynamic treatment effects of environmental regulation five years around the adoption of a carbon tax or an emissions trading system. Treated firms are firms subject to either a carbon tax or an emissions trading system, while control firms are firms not subject to these regulations. The coefficients capture the difference in outcomes between treated and control firms in each year relative to the intervention year, with the shaded area representing confidence intervals. This figure presents results for labor investment.

Figure 5. Carbon Pricing Regulation and Labor Investment Efficiency
Dynamic Treatment Effect ($t-5, t+5$ years).



Note: This figure presents lead-lag estimates of the dynamic treatment effects of environmental regulation five years around the adoption of a carbon tax or an emissions trading system. Treated firms are firms subject to either a carbon tax or an emissions trading system, while control firms are firms not subject to these regulations. The coefficients capture the difference in outcomes between treated and control firms in each year relative to the intervention year, with the shaded area representing confidence intervals. This figure presents results for labor investment efficiency using the full sample period.

Table 1. Variable Definition

Variable	Definition	Sources
Investment-related variables		
Capital Investment	Capital expenditures (capx) plus R&D expenditures (rxrd) plus acquisitions (aqc) minus the sale of property, plant, and equipment (sppe) in year t, divided by lagged total assets. Following prior literature, missing values of R&D expenditures and acquisitions are set to zero; missing values of the sale of property, plant, and equipment are replaced with sppiv where available and set to zero otherwise.	Compustat
Capital Investment Efficiency	The negative absolute value of residual obtained from Equation (1). Higher values indicate greater capital investment efficiency.	Compustat
Net Hiring (Labor Investment)	Number of employees in year t minus number of employees in year $t-1$, divided by number of employees in year $t-1$.	Compustat
Labor Investment Efficiency	The negative absolute value of the residual from the expected-hiring model of Jung, Lee, and Weber (2014). Higher values indicate greater labor investment efficiency.	Compustat
Carbon Pricing Variables		
Regulated Firm	An indicator variable that equals one if firm i, in industry j, is covered by a CT or an ETS that is in effect in jurisdiction c during year t, and zero otherwise.	Carbon Tax Center, ICAP, & World Bank
CT Regulated Firm	An indicator variable that equals one if firm i, in industry j, is covered by a CT that is in effect in jurisdiction c during year t, and zero otherwise.	Carbon Tax Center, ICAP, & World Bank
ETS Regulated Firm	An indicator variable that equals one if firm i, in industry j, is covered by an ETS that is in effect in jurisdiction c during year t, and zero otherwise.	Carbon Tax Center, ICAP, & World Bank
CT Anticipation	An indicator variable equal to one for firm i operating in a carbon-tax-covered sector from the official announcement year through the year immediately preceding implementation, and zero otherwise.	Hand – collected data from official websites
ETS Anticipation	An indicator variable equal to one for firm $i$operating in a ETS-covered sector from the official announcement year through the year immediately preceding implementation, and zero otherwise.	Hand – collected data from official websites
CT First	An indicator equal to 1 beginning in the implementation year of a CT for covered firm-years in jurisdictions that adopt a CT before adopting an ETS. For jurisdictions that subsequently adopt an ETS, the indicator equals one only through the year preceding ETS implementation.	Carbon Tax Center, ICAP, & World Bank
ETS First	An indicator equal to 1 beginning in the implementation year of a ETS for covered firm-years in jurisdictions that adopt an ETS before adopting a CT. For jurisdictions that subsequently adopt a CT, the indicator equals one only through the year preceding CT implementation.	Carbon Tax Center, ICAP, & World Bank
CT After ETS	An indicator equal to 1 beginning in the implementation year of a CT for covered firm-years in jurisdictions where an ETS was already in effect, and 0 otherwise.	Carbon Tax Center, ICAP, & World Bank
ETS After CT	An indicator equal to 1 beginning in the implementation year of an ETS for covered firm-years in jurisdictions where a CT was already in effect, and 0 otherwise.	Carbon Tax Center, ICAP, & World Bank

Table 1. Variable Definition

Variable	Definition	Sources
Firm-Level Control variables		
Asset Growth	Annual change in total assets from year $t-1$ to year t, scaled by total assets in year $t-1$.	Compustat
σCash Flows	The standard deviation of cash flows from operating activities from $t-5$ to $t-1$, ignoring missing values.	Compustat
CFOSale	Cash flow from operating activities divided by sales.	Compustat
Debt Issuance	An indicator variable equal to one if total debt, measured as long-term debt plus debt in current liabilities, increases by more than 5% relative to the prior year, and zero otherwise.	Compustat
Dividends	An indicator variable equal to one if firm i at time t pays a cash dividend, and zero otherwise.	Compustat
Equity Issuance	An indicator variable equal to one if total shareholders' equity increases by more than 5% relative to the prior year, and zero otherwise.	Compustat
Financial Reporting Quality	The negative absolute value of the residual from the performance-adjusted discretionary-accrual model of Kothari, Leone, and Wasley (2005). Higher values indicate higher financial reporting quality.	Compustat
Inventory	Inventory (total) divided by lagged total assets.	Compustat
σInvestment	The standard deviation of Investment from $t-5$ to $t-1$, ignoring missing values.	Compustat
Lagged Capital Investment	Capital Investment measured in the previous year, $t-1$.	Compustat
Lagged Sales Growth	Sales Growth measured in the previous year, $t-1$.	Compustat
Leverage	Long-term debt divided by lagged total assets.	Compustat
Loss Indicator	An indicator variable equal to one if firm earnings before extraordinary items (IB) are below zero, and zero otherwise.	Compustat
Negative Lagged Sales Growth Indicator	An indicator variable equal to one if Lagged Sales Growth is negative, and zero otherwise.	Compustat
Return on Asset	Operating income after depreciation divided by lagged total assets.	Compustat
σROA	The standard deviation of ROA from $t-5$ to $t-1$, ignoring missing values.	Compustat
σSales	The standard deviation of sales from $t-5$ to $t-1$, ignoring missing values.	Compustat
Sales Growth	Annual change in sales from year $t-1$ to year t, scaled by sales in year $t-1$.	Compustat
Slack	Cash divided by Property, Plant, and Equipment (net).	Compustat
Tangibility	Property, Plant, and Equipment (net) divided by lagged total assets.	Compustat
Country-Level Control variables		
Inflation	Annual percentage change in consumer prices (inflation rate) for country c in year t.	World Bank
GDP Growth	Annual percentage growth rate of gross domestic product for country c in year t.	World Bank
GDP per Capita	Natural logarithm of gross domestic product per capita for country c in year t.	World Bank
Statutory Tax Rate	Statutory corporate income tax rate for country c in year t.	Tax Foundation
Unemployment Rate	Unemployment as a percentage of the total labor force (ILO-modelled estimate) for country c in year t.	World Bank

Notes: CT denotes carbon tax, and ETS denotes emissions trading system. All continuous variables are winsorized at the 1st and 99th percentiles.

Table 2: Descriptive Statistics

	Obs.	Mean	SD	p5	p25	Median	p75	p95
Capital Investment	449,914	0.093	0.139	0.001	0.021	0.053	0.109	0.311
Capital Investment Efficiency	364,530	-0.072	0.106	-0.221	-0.083	-0.044	-0.020	-0.004
Net Hiring	260,186	0.053	0.270	-0.229	-0.038	0.013	0.090	0.418
Labor Investment Efficiency	234,751	-0.129	0.209	-0.460	-0.140	-0.066	-0.029	-0.006
Regulated Firm	449,914	0.164	0.370	0.000	0.000	0.000	0.000	1.000
CT Regulated Firm	449,914	0.070	0.255	0.000	0.000	0.000	0.000	1.000
ETS Regulated Firm	449,914	0.135	0.341	0.000	0.000	0.000	0.000	1.000
Leverage	449,914	0.142	0.191	0.000	0.003	0.072	0.212	0.504
Dividends	449,914	0.469	0.499	0.000	0.000	0.000	1.000	1.000
Return on Asset	449,914	0.039	0.200	-0.188	0.010	0.054	0.107	0.239
Loss Indicator	449,914	0.249	0.433	0.000	0.000	0.000	0.000	1.000
Asset Growth	449,914	0.131	0.465	-0.227	-0.027	0.051	0.165	0.664
Sales Growth	449,914	0.152	0.634	-0.349	-0.043	0.063	0.203	0.739
Tangibility	449,914	0.342	0.266	0.020	0.129	0.290	0.496	0.840
Inventory	449,914	0.137	0.144	0.000	0.021	0.101	0.202	0.415
CFOSale	449,914	-0.173	2.121	-0.377	0.011	0.070	0.147	0.366
Slack	449,914	3.349	14.229	0.012	0.112	0.400	1.388	12.131
σCash Flows	449,914	0.118	0.345	0.012	0.030	0.053	0.097	0.301
σROA	449,914	0.101	0.348	0.007	0.018	0.036	0.072	0.270
σSales	449,914	0.295	0.517	0.024	0.074	0.149	0.301	0.956
σInvestment	449,914	0.073	0.108	0.004	0.016	0.035	0.079	0.299
Lagged Sales Growth	449,914	0.174	0.695	-0.337	-0.040	0.066	0.210	0.802
Debt Issuance	449,914	0.437	0.496	0.000	0.000	0.000	1.000	1.000
Equity Issuance	449,914	0.462	0.499	0.000	0.000	0.000	1.000	1.000
Financial Reporting Quality	449,914	-0.070	0.091	-0.229	-0.085	-0.042	-0.019	-0.004
Statutory Tax Rate	449,914	0.292	0.068	0.190	0.250	0.297	0.340	0.395
GDP Growth	449,914	3.458	3.579	-2.577	1.564	3.053	6.055	9.191
GDP per Capita	449,914	9.668	1.268	7.195	8.813	10.373	10.682	10.989
Inflation	449,914	3.047	6.658	-0.283	1.064	2.142	3.779	8.912
Unemployment Rate	449,914	5.731	3.327	2.467	3.896	4.822	7.432	10.354

Table 3: Sample Distribution

Panel A: Sample Distribution by Country

Country	Obs.	%	Carbon Pricing	Country	Obs.	%	Carbon Pricing
Japan	56,640	12.59	Yes	Kuwait	974	0.22	No
China	55,859	12.42	Yes	Jordan	856	0.19	No
United States	49,226	10.94	Yes	Portugal	853	0.19	Yes
India	47,531	10.56	No	Cyprus	838	0.19	Yes
United Kingdom	23,630	5.25	Yes	Romania	797	0.18	Yes
Australia	18,439	4.10	No	Bulgaria	667	0.15	Yes
Korea	17,675	3.93	Yes	Arab Emirates	639	0.14	No
Malaysia	16,223	3.61	No	Luxembourg	617	0.14	Yes
Germany	10,321	2.29	Yes	Tunisia	613	0.14	No
France	10,175	2.26	Yes	Jamaica	549	0.12	No
Singapore	10,146	2.26	Yes	Colombia	540	0.12	Yes
Thailand	9,851	2.19	No	Morocco	527	0.12	No
Canada	8,513	1.89	Yes	Lithuania	525	0.12	Yes
Sweden	7,554	1.68	Yes	Slovenia	468	0.10	Yes
Indonesia	6,962	1.55	No	Kenya	454	0.10	No
Poland	6,746	1.50	Yes	Zimbabwe	389	0.09	No
Pakistan	4,723	1.05	No	Latvia	381	0.08	Yes
Italy	4,350	0.97	Yes	Mauritius	346	0.08	No
Brazil	4,128	0.92	No	Estonia	319	0.07	Yes
Switzerland	4,125	0.92	Yes	Kazakhstan	302	0.07	Yes
Israel	3,905	0.87	No	Hungary	300	0.07	Yes
South Africa	3,701	0.82	Yes	Qatar	298	0.07	No
Viet Nam	3,694	0.82	No	Czech Republic	278	0.06	Yes
Turkey	3,643	0.81	No	Bahrain	257	0.06	No
Norway	2,980	0.66	Yes	Iceland	237	0.05	Yes
Greece	2,972	0.66	Yes	Argentina	232	0.05	Yes
Russia	2,810	0.62	No	Malta	228	0.05	Yes
Netherlands	2,766	0.61	Yes	Palestine	199	0.04	No
Sri Lanka	2,720	0.60	No	Trinidad & Tobago	193	0.04	No
Philippines	2,698	0.60	No	Ukraine	179	0.04	Yes
Finland	2,594	0.58	Yes	Serbia	167	0.04	No
Chile	2,588	0.58	Yes	Zambia	156	0.03	No
Hong Kong	2,535	0.56	No	Ghana	152	0.03	No
Denmark	2,349	0.52	Yes	Botswana	146	0.03	No
New Zealand	2,096	0.47	Yes	Tanzania	126	0.03	No
Saudi Arabia	1,877	0.42	No	Slovakia	122	0.03	Yes
Spain	1,855	0.41	Yes	Papua New Guinea	95	0.02	No
Bangladesh	1,696	0.38	No	Côte d'Ivoire	88	0.02	No
Mexico	1,659	0.37	Yes	Uganda	67	0.01	No
Belgium	1,619	0.36	Yes	Malawi	66	0.01	No
Peru	1,557	0.35	No	Panama	44	0.01	No
Egypt	1,362	0.30	No	Venezuela	40	0.01	No
Ireland	1,317	0.29	Yes	Lebanon	22	0.00	No
Oman	1,260	0.28	No	Bahamas	18	0.00	No
Austria	1,235	0.27	Yes	Ecuador	16	0.00	No
Croatia	1,123	0.25	Yes	Senegal	4	0.00	No
Nigeria	1,102	0.24	No	**Total Obs**	**449,914**		

Panel B: Country and Observation Coverage by Carbon Pricing Status

Carbon pricing status	# Countries	Countries (%)	# Obs.	Obs. (%)
Total	93	100.0	449,914	100.0
With carbon pricing	45	48.4	303,697	67.5
Without carbon pricing	48	51.6	146,217	32.5

Table 4: Sample Distribution by Industry

SIC2	Industry	Obs.	%	SIC2	Industry	Obs.	%
28	Chemicals & Allied Products	42,853	9.52	58	Eating & Drinking Places	3,912	0.87
73	Business Services	42,105	9.36	53	General Merchandise Stores	3,684	0.82
36	Electronic & Other Electrical Equipment	31,233	6.94	24	Lumber & Wood Products	3,126	0.69
20	Food & Kindred Products	26,543	5.90	54	Food Stores	2,909	0.65
35	Industrial Machinery & Equipment	26,364	5.86	29	Petroleum & Coal Products	2,906	0.65
49	Electric, Gas & Sanitary Services	18,742	4.17	45	Transportation by Air	2,835	0.63
33	Primary Metal Industries	15,907	3.54	78	Motion Pictures	2,762	0.61
37	Transportation Equipment	14,768	3.28	42	Trucking & Warehousing	2,547	0.57
38	Instruments & Related Products	13,829	3.07	1	Agricultural Production - Crops	2,452	0.54
50	Wholesale Trade - Durable Goods	13,540	3.01	17	Special Trade Contractors	2,390	0.53
32	Stone, Clay, Glass & Concrete Products	11,373	2.53	55	Automotive Dealers & Service Stations	2,348	0.52
22	Textile Mill Products	9,914	2.20	25	Furniture & Fixtures	2,336	0.52
10	Metal Mining	9,289	2.06	56	Apparel & Accessory Stores	2,302	0.51
34	Fabricated Metal Products	9,073	2.02	82	Educational Services	2,158	0.48
48	Communications	8,935	1.99	12	Coal Mining	1,899	0.42
30	Rubber & Miscellaneous Plastics Products	8,721	1.94	57	Furniture & Home Furnishings Stores	1,836	0.41
51	Wholesale Trade - Nondurable Goods	8,609	1.91	31	Leather & Leather Products	1,516	0.34
13	Oil & Gas Extraction	8,200	1.82	14	Nonmetallic Minerals, Except Fuels	1,381	0.31
87	Engineering & Management Services	7,858	1.75	41	Local & Interurban Passenger Transit	986	0.22
16	Heavy Construction, Except Building	7,640	1.70	52	Building Materials & Garden Supplies	859	0.19
26	Paper & Allied Products	6,868	1.53	21	Tobacco Products	841	0.19
59	Miscellaneous Retail	5,649	1.26	40	Railroad Transportation	802	0.18
23	Apparel & Other Textile Products	5,536	1.23	2	Agricultural Production - Livestock	752	0.17
70	Hotels & Other Lodging Places	5,424	1.21	75	Auto Repair, Services & Parking	715	0.16
44	Water Transportation	5,402	1.20	72	Personal Services	646	0.14
27	Printing & Publishing	5,151	1.14	7	Agricultural Services	534	0.12
47	Transportation Services	5,132	1.14	9	Fishing, Hunting & Trapping	390	0.09
15	General Construction	5,131	1.14	8	Forestry	309	0.07
99	Nonclassifiable Establishments	4,786	1.06	46	Pipelines, Except Natural Gas	143	0.03
80	Health Services	4,429	0.98	83	Social Services	103	0.02
79	Amusement & Recreation Services	4,284	0.95	89	Services, NEC	92	0.02
39	Miscellaneous Manufacturing Industries	4,069	0.90	81	Legal Services	86	0.02

Table 5: Carbon Pricing and Capital Investment (DiD estimation)

	TWFE DID			*Stacked DID*			*TWFE DID with anticipation*		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Regulated Firm	**0.005*** **			**0.007*** **			**0.005*** **		
	(4.34)			**(5.73)**			**(4.24)**		
CT Regulated Firm		**0.008*** **			**0.008*** **			**0.009*** **	
		(5.55)			**(7.27)**			**(5.37)**	
ETS Regulated Firm			**0.001**			**0.002**			**0.001**
			(0.52)			**(1.45)**			**(0.46)**
CT Anticipation							**-0.003* **	**0.003**	
							(-1.91)	**(0.86)**	
ETS Anticipation							**0.002**		**0.000**
							(1.31)		**(0.02)**
Leverage	0.087***	0.076***	0.089***	0.077***	0.067***	0.079***	0.087***	0.076***	0.089***
	(16.00)	(9.65)	(15.11)	(16.26)	(14.46)	(16.76)	(16.01)	(9.64)	(15.11)
Dividends	0.006***	0.006***	0.005***	0.008***	0.008***	0.008***	0.006***	0.006***	0.005***
	(8.85)	(7.42)	(7.82)	(11.99)	(13.52)	(11.80)	(8.86)	(7.41)	(7.82)
Return on Asset	-0.098***	-0.090***	-0.101***	-0.097***	-0.098***	-0.097***	-0.098***	-0.090***	-0.101***
	(-13.23)	(-8.92)	(-12.77)	(-11.51)	(-11.10)	(-11.45)	(-13.23)	(-8.92)	(-12.77)
Loss Indicator	-0.014***	-0.016***	-0.014***	-0.018***	-0.017***	-0.018***	-0.014***	-0.016***	-0.014***
	(-16.16)	(-12.70)	(-14.59)	(-18.50)	(-20.00)	(-18.80)	(-16.17)	(-12.69)	(-14.58)
Asset Growth	0.086***	0.086***	0.085***	0.085***	0.090***	0.085***	0.086***	0.086***	0.085***
	(36.09)	(21.36)	(34.49)	(36.72)	(38.35)	(36.87)	(36.09)	(21.37)	(34.49)
Sales Growth	0.006***	0.004***	0.007***	0.006***	0.005***	0.006***	0.006***	0.004**	0.007***
	(6.27)	(2.58)	(6.45)	(5.52)	(4.18)	(5.83)	(6.27)	(2.58)	(6.45)
Tangibility	0.160***	0.160***	0.165***	0.166***	0.148***	0.171***	0.160***	0.160***	0.165***
	(31.60)	(22.90)	(29.11)	(24.34)	(22.00)	(26.54)	(31.59)	(22.90)	(29.11)
Inventory	-0.016**	-0.028***	-0.016**	-0.019***	-0.022***	-0.018***	-0.016**	-0.028***	-0.016**
	(-2.37)	(-2.77)	(-2.25)	(-3.46)	(-3.83)	(-3.33)	(-2.38)	(-2.77)	(-2.25)
CFOSale	-0.001***	-0.001**	-0.001***	-0.001	-0.001*	-0.001	-0.001***	-0.001**	-0.001***
	(-3.24)	(-2.09)	(-3.44)	(-1.26)	(-1.71)	(-1.42)	(-3.24)	(-2.09)	(-3.44)
Slack	-0.000***	-0.000	-0.000***	-0.000**	-0.000**	-0.000**	-0.000***	-0.000	-0.000***
	(-4.48)	(-1.05)	(-4.63)	(-2.03)	(-2.17)	(-2.48)	(-4.48)	(-1.05)	(-4.63)
σCash Flows	0.009**	0.003	0.010**	0.004	0.003	0.005	0.009**	0.003	0.010**
	(2.32)	(0.48)	(2.45)	(0.75)	(0.54)	(1.14)	(2.31)	(0.48)	(2.45)
σROA	0.007	0.012*	0.005	0.006	0.007	0.004	0.007	0.012*	0.005
	(1.60)	(1.82)	(1.13)	(1.08)	(1.30)	(0.75)	(1.61)	(1.82)	(1.13)
σSales	0.007***	0.007***	0.007***	0.005***	0.004***	0.006***	0.007***	0.007***	0.007***
	(5.16)	(3.32)	(5.25)	(4.63)	(3.51)	(5.31)	(5.15)	(3.32)	(5.25)

Table 5: Carbon Pricing and Capital Investment (DiD estimation) (Cont.)

	TWFE DID			*Stacked DID*			*TWFE DID with anticipation*		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
σInvestment	-0.115***	-0.111***	-0.121***	-0.079***	-0.071***	-0.083***	-0.115***	-0.111***	-0.121***
	(-18.90)	(-12.08)	(-18.76)	(-15.12)	(-13.97)	(-16.04)	(-18.90)	(-12.08)	(-18.76)
Lagged Sales Growth	0.005***	0.004***	0.004***	0.004***	0.004***	0.004***	0.005***	0.004***	0.004***
	(7.25)	(4.08)	(6.68)	(9.05)	(8.85)	(8.98)	(7.25)	(4.08)	(6.68)
Debt Issuance	0.013***	0.012***	0.013***	0.015***	0.014***	0.014***	0.013***	0.012***	0.013***
	(28.55)	(19.59)	(26.01)	(30.35)	(32.01)	(30.63)	(28.52)	(19.60)	(26.01)
Equity Issuance	0.005***	0.003***	0.005***	0.005***	0.005***	0.005***	0.005***	0.003***	0.005***
	(8.69)	(5.06)	(8.24)	(10.64)	(10.39)	(10.35)	(8.68)	(5.06)	(8.24)
Financial Reporting Quality	-0.048***	-0.052***	-0.048***	-0.054***	-0.057***	-0.052***	-0.048***	-0.052***	-0.048***
	(-7.86)	(-5.90)	(-7.31)	(-9.17)	(-10.63)	(-8.82)	(-7.86)	(-5.90)	(-7.31)
Statutory Tax Rate	0.003	-0.048***	0.015	0.011	0.004	0.008	0.005	-0.048***	0.015
	(0.29)	(-4.10)	(1.20)	(0.97)	(0.41)	(0.77)	(0.47)	(-4.14)	(1.20)
GDP Growth	0.000	0.000***	0.000	-0.000	-0.000	-0.000	0.000	0.000***	0.000
	(1.50)	(3.43)	(0.90)	(-1.57)	(-0.61)	(-1.33)	(1.53)	(3.42)	(0.90)
GDP per Capita	0.020***	0.013***	0.022***	0.020***	0.018***	0.019***	0.020***	0.014***	0.022***
	(10.24)	(5.38)	(10.57)	(9.54)	(9.42)	(9.33)	(10.24)	(5.40)	(10.57)
Inflation	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***
	(-5.08)	(-4.41)	(-4.74)	(-5.41)	(-4.35)	(-5.23)	(-5.11)	(-4.41)	(-4.74)
Unemployment Rate	-0.000	0.000*	-0.000	-0.001***	-0.001***	-0.001***	-0.000	0.000*	-0.000
	(-1.58)	(1.74)	(-1.47)	(-7.39)	(-7.14)	(-7.65)	(-1.61)	(1.75)	(-1.47)
Observations	449,914	449,914	449,914	5,647,892	5,477,000	4,669,368	449,914	449,914	449,914
Adjusted R-squared	0.5823	0.5915	0.5845	0.5562	0.5732	0.5595	0.5823	0.5915	0.5845
Firm & Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Entropy Balance	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Table 5 presents analyses of the effect of carbon pricing interventions on corporate capital investment. The dependent variable in all the specifications is *Capital Investment*. The main variables of interest are *Regulated Firm, CT Regulated Firm*, *ETS Regulated Firm*, *CT Anticipation, and ETS Anticipation*. Columns (1)–(3) report results using a two-way fixed effects difference-in-differences research design., Columns (4)–(6) report estimates from a stacked difference-in-differences design, while Columns (7)–(9) two-way fixed effects difference-in-differences estimates that incorporate the anticipation period between the official announcement and implementation of each policy. All specifications use the entropy-balanced sample and include firm and industry-year fixed effects. The table reports coefficient estimates with *t*-statistics in parentheses. Standard errors are clustered at the firm level. ***, **, & * denote significance at the 1%, 5%, and 10% levels, respectively. The constant terms are omitted for brevity. All variables are defined in Table 1.

Table 6: Carbon Pricing Regime Sequence and Capital Investment (DiD estimation)

	Baseline	Regime Sequence
	(1)	(2)
Regulated Firm	**0.004*****	
	(3.56)	
CT First		**0.008*****
		(4.82)
ETS First		**0.001**
		(0.84)
CT After ETS		**0.003**
		(1.63)
ETS After CT		**-0.005**
		(-1.23)
Controls	Yes	Yes
Observations	446,650	446,650
Adjusted R-squared	0.5819	0.5819
Firm & Industry-Year FE	Yes	Yes
Cluster	Firm	Firm
Entropy Balance	Yes	Yes

Notes: Table 6 presents analyses of how the sequence of carbon pricing regimes affects corporate capital investment using a two-way fixed effects difference-in-differences design. The dependent variable is *Capital Investment*. The main variables of interest are *Regulated Firm*, *CT First*, *ETS First*, *CT After ETS*, and *ETS After CT*. All specifications use the entropy-balanced sample and include firm and industry-year fixed effects. The regressions also include the same control variables as the main specifications reported in Table 5, but the corresponding coefficient estimates are omitted from the table for brevity. The table reports coefficient estimates with *t*-statistics in parentheses. Standard errors are clustered at the firm level. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. All variables are defined in Table 1.

Table 7: Carbon pricing and Capital Investment Efficiency

	TWFE DID			*Stacked DiD*			*TWFE DID with anticipation*		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
Regulated Firm	**-0.004***** **(-4.16)**			**-0.004***** **(-4.13)**			**-0.005***** **(-4.16)**		
CT Regulated Firm		**-0.003**** **(-2.49)**			**-0.003***** **(-3.14)**			**-0.003**** **(-2.37)**	
ETS Regulated Firm			**-0.002**** **(-2.02)**			**-0.003***** **(-2.62)**			**-0.003**** **(-1.96)**
CT Anticipation							**0.004*** **(1.85)**	**-0.001** **(-0.33)**	
ETS Anticipation							**-0.002** **(-1.39)**		**-0.001** **(-0.73)**
Leverage	-0.076*** (-13.41)	-0.053*** (-6.67)	-0.083*** (-13.35)	-0.076*** (-15.40)	-0.056*** (-11.40)	-0.080*** (-16.19)	-0.076*** (-13.42)	-0.053*** (-6.67)	-0.083*** (-13.35)
Dividends	0.000 (0.21)	-0.000 (-0.20)	0.000 (0.23)	-0.001** (-2.33)	-0.001* (-1.75)	-0.001** (-2.29)	0.000 (0.19)	-0.000 (-0.20)	0.000 (0.22)
Return on Asset	0.067*** (10.72)	0.059*** (5.98)	0.066*** (10.27)	0.075*** (12.25)	0.072*** (11.82)	0.074*** (12.17)	0.067*** (10.72)	0.059*** (5.98)	0.066*** (10.27)
Loss Indicator	0.000 (0.29)	0.000 (0.27)	0.000 (0.17)	0.004*** (3.69)	0.002** (2.42)	0.003*** (3.67)	0.000 (0.31)	0.000 (0.27)	0.000 (0.17)
Lagged Capital Investment	-0.021*** (-4.78)	-0.025*** (-3.84)	-0.020*** (-4.47)	-0.028*** (-6.78)	-0.030*** (-7.03)	-0.029*** (-7.34)	-0.021*** (-4.78)	-0.024*** (-3.84)	-0.020*** (-4.47)
Asset Growth	-0.057*** (-24.66)	-0.056*** (-12.92)	-0.056*** (-23.87)	-0.059*** (-28.23)	-0.063*** (-24.83)	-0.059*** (-29.56)	-0.057*** (-24.67)	-0.056*** (-12.93)	-0.056*** (-23.87)
Sales Growth	-0.004*** (-4.08)	-0.002 (-1.17)	-0.004*** (-4.30)	-0.003*** (-3.11)	-0.002* (-1.85)	-0.003*** (-3.25)	-0.004*** (-4.08)	-0.002 (-1.17)	-0.004*** (-4.30)
Tangibility	-0.070*** (-13.90)	-0.068*** (-9.35)	-0.074*** (-13.31)	-0.075*** (-13.45)	-0.060*** (-10.64)	-0.079*** (-14.94)	-0.070*** (-13.90)	-0.068*** (-9.35)	-0.074*** (-13.31)
Inventory	0.033*** (5.14)	0.049*** (5.17)	0.032*** (4.80)	0.039*** (7.41)	0.047*** (8.39)	0.038*** (7.27)	0.033*** (5.15)	0.049*** (5.17)	0.032*** (4.80)
CFOSale	0.00 (1.34)	-0.01 (-0.01)	0.001** (2.01)	0.00 (1.27)	0.00 (0.85)	0.00 (1.02)	0.000 (1.34)	-0.000 (-0.01)	0.001** (2.01)
Slack	0.00 (-1.16)	-0.000* (-1.79)	0.00 (-0.61)	0.00 (-1.45)	-0.000*** (-3.89)	0.00 (-0.54)	-0.000 (-1.16)	-0.000* (-1.79)	-0.000 (-0.61)
σCash Flows	-0.000 (-0.01)	0.021*** (2.92)	-0.002 (-0.37)	0.000 (0.07)	0.003 (0.57)	0.000 (0.05)	-0.000 (-0.01)	0.021*** (2.92)	-0.002 (-0.37)
σROA	-0.011** (-2.55)	-0.034*** (-4.80)	-0.009** (-2.12)	-0.007 (-1.43)	-0.011* (-1.91)	-0.006 (-1.43)	-0.011** (-2.55)	-0.034*** (-4.79)	-0.009** (-2.12)

Table 7: Carbon pricing and Capital Investment Efficiency (Cont.)

		TWFE DID			*Stacked DiD*			*TWFE DID with anticipation*	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
σSales	-0.005***	-0.003	-0.006***	-0.005***	-0.004***	-0.006***	-0.005***	-0.003	-0.006***
	(-4.06)	(-1.28)	(-4.17)	(-4.33)	(-2.99)	(-4.99)	(-4.06)	(-1.28)	(-4.17)
σInvestment	0.110***	0.106***	0.114***	0.088***	0.072***	0.094***	0.110***	0.106***	0.114***
	(17.06)	(10.85)	(16.47)	(15.29)	(13.47)	(16.59)	(17.06)	(10.85)	(16.47)
Lagged Sales Growth	0.001	0.002*	0.000	0.000	0.000	0.000	0.001	0.002*	0.000
	(1.04)	(1.85)	(0.72)	(0.16)	(-0.43)	(0.74)	(1.04)	(1.85)	(0.72)
Debt Issuance	0.001**	0.00	0.001***	0.000	0.001**	0.000	0.001**	0.000	0.001***
	(2.27)	(0.86)	(2.58)	(0.18)	(2.16)	(0.13)	(2.30)	(0.85)	(2.58)
Equity Issuance	0.001*	0.001	0.001	0.001***	0.001***	0.001***	0.001*	0.001	0.001
	(1.79)	(1.59)	(1.50)	(3.14)	(3.48)	(3.12)	(1.79)	(1.59)	(1.48)
Financial Reporting	0.051***	0.058***	0.050***	0.056***	0.054***	0.054***	0.051***	0.058***	0.050***
	(8.31)	(6.13)	(7.65)	(8.94)	(9.62)	(8.80)	(8.31)	(6.13)	(7.65)
Statutory Tax Rate	-0.001	0.071***	-0.008	0.013	0.023***	0.013	-0.003	0.072***	-0.008
	(-0.06)	(5.86)	(-0.63)	(1.21)	(2.59)	(1.17)	(-0.28)	(5.88)	(-0.62)
GDP Growth	-0.000***	-0.000***	-0.000***	0.000	-0.000	-0.000	-0.000***	-0.000***	-0.000***
	(-3.09)	(-3.44)	(-2.69)	(0.02)	(-1.02)	(-0.31)	(-3.17)	(-3.44)	(-2.72)
GDP per Capita	-0.011***	-0.004*	-0.012***	-0.009***	-0.009***	-0.010***	-0.011***	-0.004**	-0.012***
	(-6.43)	(-1.96)	(-6.51)	(-5.14)	(-5.66)	(-5.35)	(-6.47)	(-1.96)	(-6.52)
Inflation	-0.000	0.000	-0.000	-0.000	-0.000*	-0.000	-0.000	0.000	-0.000
	(-0.37)	(0.53)	(-0.28)	(-1.31)	(-1.89)	(-1.07)	(-0.22)	(0.50)	(-0.30)
Unemployment Rate	-0.001***	-0.001***	-0.001***	0.001***	0.001***	0.001***	-0.001***	-0.001***	-0.001***
	(-2.71)	(-4.76)	(-2.87)	(4.29)	(3.27)	(3.66)	(-2.70)	(-4.78)	(-2.90)
Observations	364,530	364,530	364,530	3,631,950	1,951,828	3,593,801	364,530	364,530	364,530
Adjusted R-squared	0.4712	0.5152	0.4676	0.4568	0.4953	0.4602	0.4712	0.5152	0.4676
Firm & Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Entropy Balance	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Table 7 presents analyses of the effect of carbon pricing interventions on capital investment efficiency. The dependent variable in all specifications is *Capital Investment Efficiency*. The main variables of interest are *Regulated Firm*, *CT Regulated Firm*, *ETS Regulated Firm*, *CT Anticipation*, and *ETS Anticipation*. Columns (1)–(3) report estimates from a two-way fixed effects difference-in-differences design. Columns (4)–(6) report estimates from a stacked difference-in-differences design, and Columns (7)–(9) report two-way fixed effects difference-in-differences estimates that incorporate the anticipation period between the official announcement and implementation of each policy. All specifications use the entropy-balanced sample and include firm and industry-year fixed effects and the control variables defined in Table 1. The table reports coefficient estimates with *t*-statistics in parentheses. Standard errors are clustered at the firm level. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Constant terms are omitted for brevity.

Table 8: Carbon Pricing Regime Sequence and Capital Investment Efficiency (DiD estimation)

	Baseline	Regime Sequence
	(1)	(2)
Regulated Firm	**-0.004***** **(-4.02)**	
CT First		**-0.006***** **(-4.18)**
ETS First		**-0.002**** **(-2.03)**
CT After ETS		**-0.006***** **(-3.33)**
ETS After CT		**-0.006** **(-0.82)**
Controls	Yes	Yes
Observations	362,731	362,731
Adjusted R-squared	0.4693	0.4693
Firm & Industry-Year FE	Yes	Yes
Cluster	Firm	Firm
Entropy Balance	Yes	Yes

Notes: Table 8 presents analyses of how the sequence of carbon pricing regimes affects corporate capital investment efficiency using a two-way fixed effects difference-in-differences design. The dependent variable is *Capital Investment Efficiency*. The main variables of interest are *Regulated Firm*, *CT First*, *ETS First*, *CT After ETS*, and *ETS After CT*. All specifications use the entropy-balanced sample and include firm and industry-year fixed effects. The regressions also include the same control variables as the main specifications reported in Table 7, but the corresponding coefficient estimates are omitted from the table for brevity. The table reports coefficient estimates with *t*-statistics in parentheses. Standard errors are clustered at the firm level. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. All variables are defined in Table 1.

Table 9: Carbon Pricing and Corporate Labor Investment

	TWFE DID			*Stacked DID*			*TWFE DID with anticipation*		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Regulated Firm	**-0.012***** **(-4.39)**			**-0.007***** **(-2.90)**			**-0.013***** **(-4.60)**		
CT Regulated Firm		**-0.002** **(-0.55)**			**-0.007***** **(-3.28)**			**-0.005** **(-1.30)**	
ETS Regulated Firm			**-0.013***** **(-4.11)**			**-0.005** **(-1.59)**			**-0.016***** **(-4.31)**
CT Anticipation							**-0.007** **(-1.31)**	**-0.019**** **(-2.10)**	
ETS Anticipation							**-0.005** **(-1.55)**		**-0.007*** **(-1.71)**
Leverage	0.043*** (3.92)	0.032** (1.98)	0.037*** (3.21)	0.047*** (4.26)	0.033*** (3.67)	0.043*** (3.95)	0.043*** (3.92)	0.032** (1.98)	0.037*** (3.21)
Dividends	0.015*** (7.21)	0.018*** (7.10)	0.014*** (6.10)	0.010*** (4.37)	0.011*** (5.84)	0.011*** (5.01)	0.015*** (7.20)	0.018*** (7.11)	0.014*** (6.08)
Return on Asset	0.078*** (5.89)	0.074*** (3.58)	0.078*** (5.67)	0.097*** (6.11)	0.111*** (7.48)	0.089*** (5.97)	0.078*** (5.88)	0.074*** (3.57)	0.078*** (5.67)
Loss Indicator	-0.006*** (-2.74)	-0.003 (-1.06)	-0.008*** (-3.08)	-0.009*** (-3.32)	-0.006*** (-2.71)	-0.008*** (-3.47)	-0.006*** (-2.74)	-0.003 (-1.09)	-0.008*** (-3.07)
Asset Growth	0.166*** (26.35)	0.192*** (19.47)	0.164*** (24.59)	0.175*** (20.43)	0.188*** (28.09)	0.177*** (20.05)	0.166*** (26.34)	0.192*** (19.46)	0.164*** (24.58)
Sales Growth	0.079*** (20.76)	0.078*** (14.20)	0.077*** (19.55)	0.089*** (15.35)	0.086*** (15.98)	0.087*** (14.93)	0.079*** (20.76)	0.078*** (14.22)	0.077*** (19.55)
Tangibility	0.161*** (11.00)	0.132*** (6.42)	0.173*** (10.61)	0.113*** (7.20)	0.106*** (7.93)	0.124*** (7.74)	0.161*** (11.01)	0.132*** (6.42)	0.174*** (10.62)
Inventory	0.254*** (11.64)	0.209*** (7.00)	0.268*** (11.10	0.165*** (8.14)	0.167*** (9.94)	0.163*** (8.00)	0.254*** (11.64)	0.209*** (7.01)	0.268*** (11.10)
CFOSale	-0.009*** (-8.26)	-0.009*** (-5.75)	-0.009*** (-7.93)	-0.008*** (-5.47)	-0.009*** (-8.11)	-0.008*** (-5.25)	-0.009*** (-8.26)	-0.009*** (-5.75)	-0.009*** (-7.92)
Slack	-0.001*** (-8.92)	-0.001*** (-7.59)	-0.001*** (-8.33)	-0.001*** (-6.15)	-0.001*** (-7.22)	-0.001*** (-6.65)	-0.001*** (-8.91)	-0.001*** (-7.59)	-0.001*** (-8.31)
σCash Flows	0.017 (1.40)	0.035** (2.31)	0.014 (1.07)	0.024** (1.97)	0.023* (1.82)	0.026** (2.05)	0.017 (1.39)	0.035** (2.30)	0.014 (1.07)
σROA	0.01 (0.81)	-0.001 (-0.05)	0.014 (1.06)	-0.011 (-0.83)	-0.012 (-1.00)	-0.01 (-0.69)	0.010 (0.82)	-0.001 (-0.04)	0.014 (1.07)
σSales	0.007* (1.65)	-0.001 (-0.11)	0.009* (1.92)	0.011** (2.35)	0.009** (2.14)	0.011** (2.17)	0.007* (1.67)	-0.001 (-0.10)	0.009* (1.93)

Table 9: Carbon Pricing and Corporate Labor Investment (Cont.)

	TWFE DID			*Stacked DID*			*TWFE DID with anticipation*		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
σInvestment	-0.012	-0.021	-0.017	-0.001	0.021	-0.01	-0.012	-0.021	-0.017
	(-0.77)	(-0.85)	(-0.99)	(-0.03)	(1.56)	(-0.65)	(-0.77)	(-0.84)	(-0.99)
Lagged Sales Growth	0.024***	0.024***	0.024***	0.022***	0.022***	0.023***	0.024***	0.024***	0.024***
	(10.11)	(7.01)	(9.77)	(8.09)	(9.32)	(8.44)	(10.10)	(7.03)	(9.77)
Debt Issuance	0.021***	0.018***	0.023***	0.020***	0.018***	0.021***	0.021***	0.018***	0.023***
	(15.77)	(10.7)	(14.62)	(12.59)	(13.46)	(13.32)	(15.75)	(10.67)	(14.63)
Equity Issuance	-0.005***	-0.008***	-0.004**	-0.001	-0.005***	-0.002	-0.005***	-0.008***	-0.004**
	(-3.61)	(-4.66)	(-2.49)	(-0.92)	(-3.74)	(-1.09)	(-3.67)	(-4.68)	(-2.53)
Financial Reporting Quality	0.02	0.012	0.026	0.031	0.023	0.036*	0.020	0.012	0.026
	(1.02)	(0.44)	(1.22)	(1.51)	(1.43)	(1.73)	(1.02)	(0.43)	(1.22)
Statutory Tax Rate	-0.048*	-0.059**	-0.045	0.006	0.004	0.007	-0.042*	-0.053*	-0.042
	(-1.91)	(-2.07)	(-1.59)	(0.23)	(0.17)	(0.28)	(-1.66)	(-1.85)	(-1.47)
GDP Growth	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***
	(5.13)	(3.32)	(4.30)	(4.12)	(4.41)	(4.63)	(5.14)	(3.36)	(4.29)
GDP per Capita	-0.003	0.006	-0.008	-0.003	-0.008	-0.002	-0.004	0.004	-0.009
	(-0.36)	(0.56)	(-0.73)	(-0.32)	(-0.85)	(-0.16)	(-0.46)	(0.38)	(-0.84)
Inflation	-0.002***	-0.001***	-0.002***	-0.002***	-0.001***	-0.002***	-0.002***	-0.001***	-0.002***
	(-5.79)	(-3.98)	(-7.77)	(-5.74)	(-4.99)	(-7.99)	(-5.85)	(-4.03)	(-7.81)
Unemployment Rate	0.001	0.002***	0	-0.001	0	-0.001	0.000	0.002***	0.000
	(1.10)	(2.85)	(0.37)	(-1.29)	(-0.01)	(-1.41)	(1.01)	(2.68)	(0.31)
Observations	260,186	260,186	260,186	2,951,428	2,580,960	2,454,065	260,186	260,186	260186
Adjusted R-squared	0.3122	0.2928	0.3276	0.2752	0.2707	0.293	0.3122	0.2928	0.3276
Firm & Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Entropy Balance	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Table 9 presents analyses of the effect of carbon pricing interventions on corporate labor investment. The dependent variable in all specifications is *Net Hiring*. The main variables of interest are *Regulated Firm*, *CT Regulated Firm*, *ETS Regulated Firm*, *CT Anticipation*, and *ETS Anticipation*. Columns (1)–(3) report estimates from a two-way fixed effects difference-in-differences design. Columns (4)–(6) report estimates from a stacked difference-in-differences design using firms in never-treated jurisdictions as the control group, and Columns (7)–(9) report two-way fixed effects difference-in-differences estimates that incorporate the anticipation period between the official announcement and implementation of each policy. All specifications use the entropy-balanced sample and include firm and industry-year fixed effects and the control variables defined in Table 1. The table reports coefficient estimates with *t*-statistics in parentheses. Standard errors are clustered at the firm level. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Constant terms are omitted for brevity.

Table 10: Carbon Pricing Regime Sequence and Corporate Labor Investment (DiD estimation)

	Baseline	Regime Sequence
	(1)	**(2)**
Regulated Firm	**-0.012***** **(-4.48)**	
CT First		**-0.009***** **(-2.61)**
ETS First		**-0.015***** **(-4.24)**
CT After ETS		**-0.017***** **(-4.28)**
ETS After CT		**-0.027***** **(-2.78)**
Controls	Yes	Yes
Observations	257,593	257,593
Adjusted R-squared	0.3116	0.3116
Firm & Industry-Year FE	Yes	Yes
Cluster	Firm	Firm
Entropy Balance	Yes	Yes

Notes: Table 10 presents analyses of how the sequence of carbon pricing regimes affects corporate labor investment using a two-way fixed effects difference-in-differences design. The dependent variable is *Net Hiring*. The main variables of interest are *Regulated Firm*, *CT First*, *ETS First*, *CT After ETS*, and *ETS After CT*. All specifications use the entropy-balanced sample and include firm and industry-year fixed effects. The regressions also include the same control variables as the main specifications reported in Table 9, but the corresponding coefficient estimates are omitted from the table for brevity. The table reports coefficient estimates with *t*-statistics in parentheses. Standard errors are clustered at the firm level. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. All variables are defined in Table 1.

Table 11: Carbon Pricing and Corporate Labor Investment Efficiency

	TWFE DiD			*Stacked DiD*			*TWFE DiD with anticipation*		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Regulated Firm	**-0.002**			**-0.002**			**-0.000**		
	(-0.83)			**(-0.82)**			**(-0.19)**		
CT Regulated Firm		**-0.003**			**-0.000**			**-0.004**	
		(-1.10)			**(-0.12)**			**(-1.50)**	
ETS Regulated Firm			**-0.000**			**-0.001**			**0.003**
			(-0.09)			**(-0.18)**			**(0.84)**
CT Anticipation							**-0.007**	**-0.010**	
							(-1.34)	**(-1.18)**	
ETS Anticipation							**0.008*** **		**0.008** **
							(2.86)		**(2.31)**
Leverage	-0.047***	-0.041***	-0.044***	-0.049***	-0.051***	-0.048***	-0.047***	-0.041***	-0.044***
	(-5.43)	(-3.16)	(-4.80)	(-5.99)	(-7.01)	(-6.08)	(-5.39)	(-3.15)	(-4.79)
Dividends	0.004**	0.004**	0.004**	0.006***	0.004**	0.008***	0.004**	0.004**	0.004**
	(2.34)	(2.04)	(2.04)	(2.62)	(2.22)	(4.03)	(2.35)	(2.05)	(2.07)
Return on Asset	0.023**	0.050***	0.018*	0.023*	0.058***	0.018	0.024**	0.050***	0.018*
	(2.16)	(3.08)	(1.69)	(1.65)	(4.42)	(1.49)	(2.18)	(3.08)	(1.69)
Loss Indicator	-0.022***	-0.019***	-0.024***	-0.029***	-0.022***	-0.028***	-0.023***	-0.019***	-0.024***
	(-12.90)	(-9.49)	(-12.13)	(-12.50)	(-11.85)	(-13.80)	(-12.92)	(-9.51)	(-12.14)
Lagged Capital Investment	-0.018**	-0.031**	-0.021**	-0.014*	-0.014*	-0.014*	-0.018**	-0.031**	-0.021**
	(-2.11)	(-2.07)	(-2.34)	(-1.87)	(-1.92)	(-1.90)	(-2.10)	(-2.07)	(-2.33)
Asset Growth	-0.085***	-0.103***	-0.084***	-0.084***	-0.093***	-0.085***	-0.085***	-0.103***	-0.084***
	(-16.35)	(-12.30)	(-15.41)	(-12.97)	(-15.95)	(-13.70)	(-16.34)	(-12.30)	(-15.41)
Sales Growth	-0.062***	-0.059***	-0.062***	-0.068***	-0.066***	-0.067***	-0.062***	-0.059***	-0.062***
	(-26.46)	(-14.70)	(-26.29)	(-30.97)	(-25.37)	(-31.82)	(-26.46)	(-14.71)	(-26.29)
Tangibility	-0.029***	-0.027*	-0.032**	-0.017	-0.016	-0.017	-0.029***	-0.027*	-0.032***
	(-2.60)	(-1.79)	(-2.57)	(-1.41)	(-1.31)	(-1.45)	(-2.62)	(-1.79)	(-2.59)
Inventory	0.026	0.034	0.024	0.069***	0.075***	0.065***	0.026	0.034	0.024
	(1.56)	(1.59)	(1.28)	(4.52)	(5.70)	(4.54)	(1.54)	(1.59)	(1.28)
CFOSale	0.006***	0.005***	0.005***	0.006***	0.005***	0.006***	0.006***	0.005***	0.005***
	(7.25)	(4.47)	(6.87)	(5.43)	(4.82)	(5.40)	(7.24)	(4.48)	(6.87)
Slack	0.000	-0.000	0.000	0.000	-0.000	0.000	0.000	-0.000	0.000
	(1.13)	(-0.29)	(1.47)	(0.26)	(-0.18)	(0.80)	(1.12)	(-0.29)	(1.46)
σCash Flows	0.003	-0.006	0.007	-0.007	0.003	-0.009	0.003	-0.006	0.007
	(0.35)	(-0.53)	(0.74)	(-0.68)	(0.28)	(-0.84)	(0.35)	(-0.54)	(0.75)
σROA	-0.008	-0.001	-0.012	-0.002	-0.015	0.002	-0.008	-0.001	-0.012
	(-0.87)	(-0.10)	(-1.20)	(-0.17)	(-1.45)	(0.22)	(-0.87)	(-0.09)	(-1.21)

Table 11: Carbon Pricing and Corporate Labor Investment Efficiency (Cont.)

	TWFE DiD			*Stacked DiD*			*TWFE DiD with anticipation*		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
σSales	-0.010***	-0.003	-0.011***	-0.011***	-0.005*	-0.013***	-0.010***	-0.003	-0.011***
	(-2.73)	(-0.73)	(-2.74)	(-2.88)	(-1.68)	(-3.49)	(-2.76)	(-0.71)	(-2.75)
σInvestment	0.030**	0.053***	0.029**	0.024*	0.009	0.027**	0.030**	0.053***	0.029**
	(2.29)	(2.81)	(2.12)	(1.86)	(0.83)	(2.15)	(2.28)	(2.82)	(2.12)
Lagged Sales Growth	-0.012***	-0.014***	-0.012***	-0.011***	-0.010***	-0.011***	-0.012***	-0.014***	-0.012***
	(-7.12)	(-4.72)	(-6.78)	(-5.08)	(-6.28)	(-5.51)	(-7.12)	(-4.72)	(-6.78)
Debt Issuance	-0.003**	-0.002*	-0.003**	-0.002	-0.001	-0.002*	-0.003***	-0.002*	-0.003**
	(-2.55)	(-1.83)	(-2.23)	(-1.47)	(-0.89)	(-1.94)	(-2.59)	(-1.85)	(-2.24)
Equity Issuance	0.005***	0.005***	0.005***	0.005***	0.004***	0.004***	0.005***	0.005***	0.005***
	(4.47)	(3.69)	(4.11)	(3.58)	(3.81)	(3.44)	(4.48)	(3.68)	(4.17)
Financial Reporting Quality	0.180***	0.216***	0.173***	0.163***	0.191***	0.159***	0.180***	0.216***	0.173***
	(11.49)	(9.88)	(10.10)	(10.94)	(14.84)	(10.64)	(11.49)	(9.88)	(10.10)
Statutory Tax Rate	0.007	0.022	0.011	0.005	0.009	0.002	0.009	0.025	0.008
	(0.33)	(0.93)	(0.48)	(0.24)	(0.49)	(0.09)	(0.44)	(1.05)	(0.33)
GDP Growth	-0.000	0.000	-0.000	0.000	0.000	0.000	-0.000	0.000	-0.000
	(-0.16)	(0.16)	(-0.28)	(0.36)	(0.52)	(0.82)	(-0.13)	(0.19)	(-0.27)
GDP per Capita	-0.008	-0.023**	-0.006	-0.022**	-0.016**	-0.018**	-0.007	-0.024***	-0.005
	(-0.96)	(-2.51)	(-0.62)	(-2.49)	(-2.02)	(-2.14)	(-0.85)	(-2.60)	(-0.48)
Inflation	0.000	0.001**	0.000	0.000	0.000*	0.000	0.000	0.001**	0.000
	(1.53)	(2.55)	(1.29)	(1.53)	(1.74)	(1.45)	(1.49)	(2.50)	(1.32)
Unemployment Rate	-0.000	-0.001**	-0.000	-0.001*	-0.001	-0.001	-0.000	-0.001**	-0.000
	(-1.17)	(-2.28)	(-0.48)	(-1.75)	(-1.63)	(-1.48)	(-1.20)	(-2.37)	(-0.39)
Observations	234,751	234,751	234,751	2,639,151	2,303,102	2,209,237	234,751	234,751	234,751
Adjusted R-squared	0.3097	0.3030	0.3158	0.2879	0.2815	0.3054	0.3098	0.3030	0.3158
Firm & Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Entropy Balance	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Table 11 presents analyses of the effect of carbon pricing interventions on corporate labor investment efficiency. The dependent variable in all specifications is *Labor Investment Efficiency*. The main variables of interest are *Regulated Firm*, *CT Regulated Firm*, *ETS Regulated Firm*, *CT Anticipation*, and *ETS Anticipation*. Columns (1)–(3) report estimates from a two-way fixed effects difference-in-differences design. Columns (4)–(6) report estimates from a stacked difference-in-differences design using firms in never-treated jurisdictions as the control group, and Columns (7)–(9) report two-way fixed effects difference-in-differences estimates that incorporate the anticipation period between the official announcement and implementation of each policy. All specifications use the entropy-balanced sample and include firm and industry-year fixed effects and the control variables defined in Table 1. The table reports coefficient estimates with *t*-statistics in parentheses. Standard errors are clustered at the firm level. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Constant terms are omitted for brevity.

Table 12: Carbon Pricing Regime Sequence and Corporate Labor Investment Efficiency (DiD estimation)

	Baseline	Regime Sequence
	(1)	(2)
Regulated Firm	**-0.002**	
	(-0.67)	
CT First		**-0.002**
		(-0.67)
ETS First		**-0.001**
		(-0.46)
CT After ETS		**0.001**
		(0.27)
ETS After CT		**0.002**
		(0.19)
Controls	Yes	Yes
Observations	232,455	232,455
Adjusted R-squared	0.3092	0.3092
Firm & Industry-Year FE	Yes	Yes
Cluster	Firm	Firm
Entropy Balance	Yes	Yes

Notes: Table 12 presents analyses of how the sequence of carbon pricing regimes affects corporate labor investment efficiency using a two-way fixed effects difference-in-differences design. The dependent variable is *Labor Investment Efficiency*. The main variables of interest are *Regulated Firm*, *CT First*, *ETS First*, *CT After ETS*, and *ETS After CT*. All specifications use the entropy-balanced sample and include firm and industry-year fixed effects. The regressions also include the same control variables as the main specifications reported in Table 11, but the corresponding coefficient estimates are omitted from the table for brevity. The table reports coefficient estimates with *t*-statistics in parentheses. Standard errors are clustered at the firm level. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. All variables are defined in Table 1.