The Effect of Carbon Pricing on Firm Performance: Worldwide Evidence*

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Abstract

Economists recommend combating climate change with carbon pricing; however, a major block to pricing emissions is concern about the economic costs. This paper examines the impacts of carbon pricing initiatives on the operating performance and market value of publicly listed firms around the world. Using staggered enactment of carbon pricing initiatives across jurisdictions and a triple difference approach, we find a significant reduction in the profitability and value of carbon-intensive firms relative to low-emission firms after the enactment of carbon pricing policies. The reduction in firm profits is driven by both a decrease in sales growth and an increase in operating costs. The reduction in firm value is driven by both an increase in the cost of capital and a decrease in expected future cash flows. Carbon-intensive firms also cut investments and lay off employees more, and hold more cash, indicating tightened financial constraints. Cross-country analyses show a stronger effect for firms headquartered in North America and in countries that rely more on fossil fuel energy. Overall, our findings uncover the large distributional impacts of carbon pricing policies on individual firms and complement prior studies documenting an insignificant effect on the macroeconomy.

JEL Classification : G15, G32, E62, H23

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1. Introduction

Climate change, caused mainly by the concentration of greenhouse gas (GHG) in earth's atmosphere, is one of the most pressing challenges of this century. Economists widely agree that the most effective way to reduce GHG emissions is to internalize the externality through putting a price on carbon emissions (Stiglitz, 2019; Adrian, Bolton, and Kleinnijenhuis, 2022; Pedersen 2023). To date, quite a few regional, national, and subnational jurisdictions have enacted carbon pricing initiatives, in the form of either carbon taxes or cap-and-trade programs. On one hand, existing studies show that carbon pricing is effective in reducing GHG emissions (Lin and Li, 2011; Andersson, 2019; Bayer and Aklin, 2020; Bai and Ru, 2022; Martinsson et al., 2024). On the other hand, policy makers are also concerned about the (potential) negative impacts of carbon pricing on economic growth, employment, inflation, and the competitiveness of domestic industries in international trade.[1] This concern is further amplified by the large discrepancies in carbon prices across different jurisdictions in the world. In a global economy, a high local carbon price in one jurisdiction would simply move the most carbon-intensive activities elsewhere – known as "carbon leakage".[2]

Most empirical studies so far show that the enactment of carbon pricing policies does not have a discernible negative impact on aggregate economic growth.[3] However, it is reasonable to conjecture that carbon pricing policies could have a heterogeneous effect across firms and industries within an economy. Naturally, the effect should be more negative for high

[1] As an example, the Trump administration's decision to retreat from the Paris Accord is motivated by its heavy economic costs to the US economy. In his June 1, 2017, statement on the Paris accord, for example, the former president claimed that the cost to the economy would be "close to three trillion dollars in lost GDP and 6.5 million in industrial jobs" (Trump 2017).

[2] Consistent with carbon leakage, Bartram, Hou, and Kim (2022) document that financially constrained firms shift emissions and output from California to other states after the adoption of the California cap-and-trade program. Dai et al. (2021) document that US firms outsource part of their pollution to suppliers overseas. Ben-David et al. (2021) document that firms headquartered in countries with strict environmental policies perform their polluting activities abroad in countries with relatively weaker policies. Laeven and Popov (2023) find the introduction of a carbon tax is associated with an increase in domestic banks' lending to coal, oil, and gas companies in foreign countries.

[3] See, for example, Metcalf and Stock (2020, 2023), Yamazaki (2017), and de Silva and Tenreyro (2021).

emission firms, which need to either purchase carbon allowances to offset emissions or downsize production to reduce emissions. The fact that we do not observe an aggregate impact could be because low-emission firms benefit significantly from carbon pricing policies. For example, low-emission firms could sell their unused carbon allowances to make a profit.[4] In addition, governments typically recycle revenues raised through carbon pricing back to the economy to promote the development of green technologies or business practices, which can boost the performance of low-emission firms. However, it is possible that even high-emission firms may not be materially affected by carbon pricing initiatives, if they can pass higher operating costs to customers, relocate their production facilities to places with more lenient carbon pricing policies, or adopt green technologies rapidly (Shapiro and Metcalf, 2023).[5] Therefore, whether the enactment of carbon pricing policies adversely affects firm performance is ultimately an empirical question and has important policy implications as the costs of stringent carbon pricing policies may not be shared evenly within the economy.

In this paper, we examine the economic impacts of carbon pricing by conducting a comprehensive analysis of the impact of carbon pricing policies (including both carbon taxes and emission trading systems (ETS)) on the operating performance and market value of *individual* firms around the world. To that end, we use the newly available carbon pricing data from the World Bank and combine it with firm-level carbon emissions from the S&P Global Trucost, accounting variables from the Worldscope, and stock price variable from Compustat Global. Our sample includes 104,100 firm-year observations covering 16,222 unique firms across 52 countries from 2002 to 2019. 32 countries have adopted some form of carbon pricing initiatives at either national (regional) or subnational level by the end of 2019. Our first test

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[4] For example, reports show that Tesla made $1.78 billion in revenues from the sale of carbon credits in 2022. https://carboncredits.com/tesla-carbon-credit-sales-reach-record-1-78-billion-in-2022/

[5] Another reason for the insignificant effects could be that the average global carbon price is still far below the social cost of carbon. Currently the global average carbon price is $6 per ton of CO2, far below the mean social cost of carbon of $185 per tonne of CO2 ($44–$413 per tCO2: 5%–95% range) estimated by Rennert et al (2022).

shows that carbon pricing policies are indeed effective in reducing firm-level carbon emissions, which is consistent with prior studies documenting substantial environmental benefits of carbon pricing at the country and industry level.

The staggered enactment of carbon pricing initiatives across jurisdictions at different points in time allows us to estimate the causal impacts of carbon pricing on firm performance. Our key variable of interest is a dummy variable *Post* indicating years when a jurisdiction has enacted carbon pricing policies and its interaction with a firm's carbon intensity. Our main empirical specification is a differences-in-difference-in-difference (triple difference) approach, comparing the change in performance around the carbon pricing enactment (first difference) across firms in treated versus untreated jurisdictions (second difference), and across firms with differential carbon intensity (third difference). The advantage of the triple difference approach is that the third difference is arguably exogeneous with respect to the adoption of carbon pricing initiatives, which are enacted at jurisdiction level and less likely influenced by individual firms' (current and expected) performance.

Our baseline results suggest that more carbon-intensive firms experience a significant reduction in profitability after their jurisdictions enact carbon pricing initiatives, as compared to low-emission firms. We measure firm profitability by return-on-assets (ROA) and return-on-equity (ROE). Economically, firms with above-median carbon intensity experienced a 55 (123) bps reduction in *ROA* (*ROE*) after the enactment of carbon pricing. This is equivalent to 13% and 6.7% of the mean and standard deviation of *ROA*, respectively, indicating that the effect is not only statistically significant but also economically important.[6] Our baseline specification controls for firm and year fixed effects, which absorb time-invariant firm heterogeneity and aggregate trend in profitability. To mitigate endogeneity concern that a

[6] The effect we estimate could potentially underestimate the economic costs as private firms with fewer financial resources are more vulnerable to stringent climate policies.

government's decision to adopt carbon pricing policies is driven by local macroeconomic conditions, we further include jurisdiction*year fixed effects, which absorb the effect of time-varying local economic conditions. Our baseline results are also unchanged when we include industry*year fixed effects, which absorb the effect of industry-specific trends in profitability.[7] We further conduct a dynamic effect analysis and find that the effect of carbon pricing policies only becomes significant in the year when carbon pricing policies are enacted and subsequent years. The insignificant pre-trend supports the parallel trend assumption underlying the triple difference estimation.

We conduct several tests to ensure the robustness of our baseline finding. First, our baseline specification uses firm-level carbon intensity as the continuous treatment variable. We show that the results are similar if we use dummy variables to indicate treatment firms as those with above median or in the top quartile of carbon intensity. Second, we examine the effect of carbon taxes and ETS separately and find both types of carbon pricing initiatives significantly reduce the profitability of carbon-intensive firms. Third, the results are also robust when we remove US firms from our sample, suggesting that the effect is not solely driven by US firms. Fourth, our main analysis focuses on scope 1 emissions, which is the target of most carbon pricing policies. However, carbon pricing initiatives may nonetheless affect firms with higher scope 2 and scope 3 emissions if upstream suppliers can partially pass the costs to downstream customers. Consistent with this conjecture, we find that firms with higher scope 2 and 3 emission intensity also experience a significant reduction in profitability after the enactment of carbon pricing, although the economic effect is smaller. Finally, recent studies show that coefficient estimates from staggered difference-in differences (DD) estimation could be biased

[7] We group firms into 11 industries based on the Global Industry Classification Standard (GICS):Healthcare, Materials, Real Estate, Consumer Staples, Consumer Discretionary, Utilities, Energy, Industrials, Consumer Services, Financials, and Technology sectors.

(e.g., Abraham and Sun 2018; Chaisemartin and D'Hautfeuille, 2020). We show that the results are robust when we correct the bias using the stacked DD regression approach.

We use a complementary approach to examine the impact of carbon pricing on firm profitability. Specifically, we use the annual prices of carbon taxes and ETS to quantify the economic effect of carbon price increase on the profitability of carbon-intensive firms relative to low-emission firms. For this test, we restrict our examination to the subsample of firms headquartered in jurisdictions with carbon pricing initiatives. We find a significantly negative effect on firm profits for the price of carbon taxes, while the effect of ETS price is insignificant. This result supports our intuition that the negative impacts of carbon pricing policies on carbon-intensive firms are more pronounced when the carbon price is higher.

Having established a robust negative effect of carbon pricing policies on carbon-intensive firms' profitability, we next investigate the channels through which carbon pricing affects firm profitability. Since firm profits equal sales minus costs, the impact could come from either an increase in operating costs or a decline in sales growth, or both. Intuitively, carbon-intensive firms could keep the same production/emissions and choose to pay higher carbon taxes or buy additional allowances to offset emissions. Another way to comply with carbon pricing is to reduce emission intensity by switching to green technologies or using renewable energy, which should also manifest as higher costs. Alternatively, since the level of carbon emissions is closely related to a firm's production activity, carbon-intensive firms can also reduce the compliance cost of carbon pricing by downsizing their production, which will manifest as slower sales growth. We find the impact of carbon pricing on firm profitability comes from both channels, as carbon-intensive firms' costs of goods increase and sales growth declines after the enactment of carbon pricing.

In addition to firm profitability, we also examine several other important firm outcomes that are theoretically linked to profits, including firm value and real investments. As firm value is simply the present value of expected future cashflows, we first examine the impacts of carbon pricing policies on expected future cash flows, as proxied by analyst consensus forecasts of earnings-per-share (EPS) over various horizons. We find that analysts expect carbon pricing policies to mainly reduce the earnings of carbon-intensive firms relative to low-emissions firms over the short run, but do not exert a negative impact on long-term earnings growth. We then test whether carbon pricing policies lead to higher expected returns for carbon-intensive firms. Consistent with the "carbon premium" hypothesis (Bolton and Kacperczyk, 2021, 2023), we find that carbon-intensive firms experience a significant increase in the cost of debt financing and implied cost of equity. Using an earnings call-based measure of firm exposure to climate risk (Sautner et al., 2023), we further show that the increased carbon premium is likely driven by firms' increased exposure to climate regulatory risk (but not physical risks). Finally, using Tobin's *q* and annual stock return as measures of firm value change, we find carbon-intensive firms experience a significant reduction in firm value, which can almost entirely be attributed to higher discount rates and lower expected future cash flows.

The *q* theory of investment predicts a strong relation between firms' market values and their investment rates. As carbon pricing policies reduce the value of carbon-intensive firms, we examine how firm investments respond to the enactment of such policies. We use multiple measures of firm investment including capital expenditures, R&D expenses, and number of employees, which represent investment in physical assets, growth opportunities, and human capital, respectively. Consistent with the prediction of the *q* theory of investment, we find carbon-intensive firms significantly reduce all three types of investments after the enactment of carbon pricing policies.

We conduct cross-country analyses to shed light on how country characteristics affect the costs of carbon pricing policies. First, we conduct a separate analysis for the region of Asia, North America, and Europe, and use the rest of the world as the benchmark. We find the effect of carbon pricing on firm profitability to be negative for all three regions, with the effect strongest for firms headquartered in North America. The effect is weaker and insignificant for Europe, which is probably due to the free allocation and oversupply of emission permits in the early phases of the EU ETS. Second, we explore cross-country variation in the exposure to fossil fuel energy. The results show that the negative effect of carbon pricing on firm profits is stronger for firms headquartered in countries with larger fossil fuel energy sectors and where energy consumption per capita is higher. Third, we explore the interaction between a country's exposure to physical risk and transition risk. Using country-level physical climate risk measures from the Notre Dame Global Adaptation Initiative, we find the profitability effect of carbon pricing does not vary with a country's exposure to physical risks. One possible explanation is that physical risks are mainly determined by the climate system of the entire planet and unlikely influenced by carbon pricing policies in a single jurisdiction.

The rest of the paper proceeds as follows. Section 2 provides institutional background about carbon pricing initiatives and highlights our contribution to the literature. Section 3 details the datasets used in this study and presents the summary statistics. Section 4 presents our main results regarding the effect of carbon pricing on firm profitability. We examine the effect of carbon pricing on firm value and real investment in Section 5. Section 6 concludes the paper.

2. Institutional Background and Contribution to the Literature

2.1 Carbon pricing background

Greenhouse gas emissions are a key driver of climate change and have continued to increase globally in recent years. With current climate policies, standard climate models predict an increase of 3°C in global temperature compared with pre-industrial levels by the end of this century (IPCC, 2014). Climate policies therefore need to be enhanced to reduce GHG emissions (Stern, 2008). Carbon pricing can be an effective policy tool to reduce GHG emissions (Kohlscheen et al., 2021). Higher carbon prices make renewable energy more competitive, provide incentives to reduce emissions, and reduce demand for carbon-intensive fuels (Martin et al., 2016).

The main types of carbon pricing policies are carbon taxes and emission trading systems. For carbon taxes, governments set a price on carbon by defining a tax rate on GHG emissions or – more commonly – on the carbon content of fossil fuels, and let private agents determine emissions quantities. Carbon tax is an attractive option for jurisdictions with limited administrative capacity or resources available for implementation or that want to introduce carbon pricing quickly. The first carbon tax was introduced in Finland in 1990.

ETS has been considered a possible tool for mitigating GHG emissions since the early 1990s and formed a key part of the Kyoto Protocol agreement. ETS can be in the form of cap-and-trade and baseline-and-credit ETS. In cap-and-trade systems, governments cap the total level of GHG emissions and allow firms with low emissions to sell their extra allowances to larger emitters. By creating supply and demand for carbon allowances, an ETS establishes a market price for GHG emissions. The cap helps ensure that the required emission reductions will take place to keep the emitters (in aggregate) within their pre-allocated carbon budget (World Bank, 2021). Compared to carbon taxes, ETS provides certainty over the quantity of emissions reduced, but not over the carbon price. It also provides flexibility regarding where and when emissions reductions occur, which can lower mitigation costs, and makes international cooperation on climate polices easier. However, an ETS is usually more complex to create and administer than carbon taxes as it involves additional infrastructure and administrative setup. The European Union established ETS in 2005; it is currently the largest carbon market in the world and covers 40% of the region’s GHG emissions. China established

8 regional pilot ETS in 2013: Beijing, Shanghai, Tianjin, Chongqing, Shenzhen, Guangdong, Hubei, and Fujian, which preceded the national ETS established in 2021.

2.2 Contribution to the literature

Our paper contributes to several strands of the literature. First, we contribute to a growing literature that empirically examines the economic impacts of carbon pricing policies. Studies examine the impacts of carbon pricing on the macroeconomic aggregates generally find no discernible negative impacts on economic growth, employment, or inflation. For example, Metcalf and Stock (2020, 2023) study the macroeconomic impacts of carbon taxes in European countries. They find no robust evidence of a negative effect of the tax on employment or GDP growth. Yamazaki (2017) find that the British Columbia carbon tax generated, on average, a small but statistically significant 0.74 percent annual increase in employment over the 2007–2013 period. Moessner (2022) shows that higher carbon prices have not led to large increases in headline inflation. de Silva and Tenreyro (2021) document that the impact of climate policies on GDP growth or inflation was largely insignificant.[8] One exception is Känzig (2022), who uses carbon policy shocks to identify the causal impacts of carbon price change on macroeconomic quantities. He finds that a tighter carbon pricing regime leads to a significant increase in energy prices and a fall in economic activity. At micro level, evidence is also inconclusive. Martin et al. (2014) estimate the impact of a carbon tax on manufacturing plants using panel data from the UK production census, and find no significant impacts for employment, revenue, or plant exit. Känzig (2022), however, finds that a tighter carbon pricing regime leads to a significant reduction in poor households' income and consumption. Kumar and Purnanandam (2022) document that publicly traded power utility companies in the affected

[8] These findings are in stark contrast with most theoretical studies, which estimate the economic impacts of carbon pricing using computable general equilibrium (CGE) models and show non-trivial negative effect of carbon pricing on the economy.

states experienced a drop in profitability but a higher market-to-book ratio after the implementation of the Regional Greenhouse Gas Initiative. Compared to prior studies focusing on either ETS or carbon tax within a single jurisdiction, we conduct a more comprehensive analysis of the economic impacts of both ETS and carbon tax initiatives on individual firms around the world. Our paper highlights the large distributional impacts of carbon pricing policies at firm level, which complements prior studies documenting an insignificant effect on the macroeconomy.

Second, our study provides causal evidence to the pricing of transition risk in financial markets. Bolton and Kacperczyk (2021, 2023) show that carbon-transition risk is priced in the US and global equity markets as they find stocks of high-emissions firms earn higher average returns than those of low-emission firms. Using earnings conference call data to construct firm-level exposure to climate change, Sautner et al. (2023) find an unconditionally positive risk premium associated with firm-level climate change exposure. However, several recent studies challenge the existence of carbon premium in stock markets (Aswani et al., 2024; Zhang, 2022; Atilgan et al., 2023).[9] The inconclusive findings in the literature could arise because the traditional asset pricing methodologies (such as portfolio sorting and Fama-MacBeth regressions) cannot fully address the omitted variable concern. Unlike these studies, we exploit the staggered adoption of carbon pricing initiatives across different jurisdictions and use a triple difference approach and various fixed effects to mitigate the omitted variable concern. We show that the carbon premium increases after the enactment of carbon pricing initiatives in a jurisdiction, consistent with Bolton and Kacperczyk (2021).

[9] Recent studies have also examined the pricing of climate transition risk in fixed income markets.While Seltzer, Starks, and Zhu (2022) show that environmental policy risk is priced in the yield of US corporate bonds, Duan, Li, and Wen (2023) and Kontz (2022) provide evidence that carbon risk is not fully priced in the US corporate bond returns and securitized auto loans, respectively. Ilhan, Sautner, and Vilkov (2021) show that downside tail risk associated with climate policy uncertainty is priced in the option markets.

Several studies specifically examine how carbon pricing initiatives affect stock return, with inconclusive evidence. For example, Oestreich and Tsiakas (2015) find that during the early phase of the EU ETS, firms that received free carbon emission allowances on average significantly outperformed firms that did not. Bushnell et al. (2013) finds that firms with higher carbon intensity obtained higher abnormal stock returns following the unexpected collapse of EU carbon prices in April 2006. These studies suggest that carbon-intensive firms benefit from carbon pricing policies more than low-emission firms do, which may not be generalizable to other countries due to the specific design of EU ETS in early phases. In contrast, Millischer et al. (2023) and Bolton et al. (2023) show that an increase in carbon prices of EU ETS is associated with a decrease in contemporaneous stock prices of carbon-intensive firms, especially for firms with a significant shortfall in emissions allowances. Compared to these studies, our paper covers a much broader sample of carbon pricing initiatives around the world, and we examine the impacts on both firms' financial and operating performance. We find carbon-intensive firms experience a decline in firm value relative to low-emission firms after the enactment of carbon pricing policies, which is driven by both the cash flow and discount rate channels.

Last, our paper is also related to the broader environmental economics literature that examines the real and financial impacts of environmental policies. Studies have shown that stringent environmental policies reduce firm productivity (He, Wang, and Zhang, 2020), restrict bank lending (Ivanov, Kruttli, and Watugala, 2023), lead to more conservative capital structure (Dang, Gao, and Yu, 2022), but also encourage more R&D investments and green patents (Brown et al., 2022; Gugler et al., 2024). Bartram, Hou, and Kim (2022) and Dai et al. (2021) show that environmental policies without coordination among jurisdictions lead to firm opportunistic behavior such as relocation of polluting activities to and outsourcing from jurisdictions with more lenient environmental regulations. Ramadorai and Zeni (2024) shows that firms' reported beliefs about future climate regulation influence their emissions reduction activities. Our paper differs by studying how carbon pricing policies affect the *relative* performance and market value of firms conditional on their carbon intensity.

3. Data and summary statistics

3.1 Data

We first obtain firm-level carbon emissions data from the S&P Global Trucost database, covering the period from 2002 to 2019.[10] Trucost classifies firms' carbon emissions into three scopes, following the Greenhouse Gas Protocol. Scope 1 emissions are direct GHG emissions that occur from sources that are controlled or owned by an organization (e.g., emissions associated with fuel combustion in boilers, furnaces, vehicles). Scope 2 emissions are indirect GHG emissions associated with the purchase of electricity, steam, heat, or cooling. Scope 3 emissions, which are mostly estimated using an input-output model, include indirect emissions produced by the extraction and production of purchased materials and fuels, electricity-related activities not covered in Scope 2, outsourced activities, waste disposal, etc. The data vendor reports both the carbon emissions in units of tons of CO_2 equivalents and CO_2 emission intensity (i.e., tons of CO_2 emissions divided by the firm's total revenue in millions of U.S. dollars) for each scope.

Second, we obtain the data of carbon pricing initiatives at regional, national, and subnational level between 1990 and 2019 from the World Bank Carbon Pricing Dashboard.[11] Carbon pricing initiatives mainly consist of two types: carbon taxes and emissions trading systems. By 2023, 39 national jurisdictions and 33 subnational jurisdictions are covered by

[10] Trucost collects firm-level emissions data from various sources including company reports, environmental reports (CSR/ESG reports, the Carbon Disclosure Project, Environmental Protection Agency filings), and data from company websites. When a covered firm does not publicly disclose its carbon emissions, Trucost estimates a firm's annual carbon emissions based on an environmental profiling model.
[11] The data is available for download at https://carbonpricingdashboard.worldbank.org/map_data.

carbon pricing initiatives, which in total cover 11.66 Gt CO_2 equivalents and represent 23% of global GHG emissions.

Table 1 lists the name and the enactment year of the carbon pricing initiatives at regional/national level in Panel A and at subnational level in Panel B. By the end of 2019, 32 countries in our sample have implemented some forms of carbon pricing initiatives at either national or subnational level. The earliest carbon pricing initiatives are the carbon tax in Finland and Poland in 1990. The European Union established ETS in 2005 and China established 8 regional pilot ETS in 2010s, which preceded the national ETS in 2021. The United States so far has no carbon pricing initiatives at the federal level but does have several carbon pricing initiatives at subnational level, including the Regional Greenhouse Gas Initiative (RGGI) and the California Cap-and-Trade Program.

Finally, we obtain firm-level accounting data from the Worldscope database, stock price information from Compustat Global, and analyst forecast data from I/B/E/S. We also obtain country-level macroeconomic data from IMF, legal institution data from International Country Risk Guide (ICRG), energy structure data from the World Bank, and country-level physical climate risk data from the Notre Dame Global Adaptation Initiative.

3.2 Descriptive statistics

To construct our sample, we merge the Trucost database with the Worldscope database based on the ISIN code, and with IMF and ICRG databases based on country name. After filtering out firm-years with missing values, we further remove firm-year observations based on the following criteria: (1) stock price less than one unit of local currency; (2) market capitalization less than USD $10 million at the end of the fiscal year; (3) negative net sales and shareholder equity; (4) countries with fewer than ten unique firms. Our final sample includes

104,100 firm-year observations covering 16,222 unique firms from 52 countries over 2002-2019.

Table IA.1 in the Online Appendix presents the distribution of our sample across countries. Column (1) reports the number of firm-years in each country. Column (2) reports the percentage of firm-years from each country. Column (3) reports the number of unique firms in each country. Columns (4) to (6) report the average firm-level carbon intensity in each country. The U.S. accounts for the largest percentage of firm-year observations (20.95%) and unique firms (3,208), while Kenya has the smallest number of firm-year observations (0.07%) and unique firms (11). The country with the highest mean (scope 1) carbon intensity is Netherlands (1634.73), while the country with the lowest average carbon intensity is Sweden (54.75). The average scope 1, scope 2, and scope 3 emissions intensity across all countries in our sample are 268.26, 43.48, and 191.33, respectively. Table 2 presents the summary statistics of the main variables used in this study. All continuous variables in our sample are winsorized at the 1% level. The average (median) *ROA* and *ROE* in our sample are 0.04 (0.04) and 0.09 (0.10), respectively. The average (median) Tobin's *q* is 1.80 (1.31). The average (median) price of carbon tax and ETS are $31($26.7) and $15.3 ($15.6), respectively.

3.3 Are Carbon pricing initiatives effective in reducing emissions?

As the main policy objective of carbon pricing is to curb GHG emissions and mitigate climate change, the first question we examine is whether the enactment of carbon pricing initiatives reduces GHG emissions in the economy. Previous studies find evidence that carbon pricing policies indeed lead to lower emissions at the industry and firm level (Andersson, 2019; Bayer and Aklin, 2020; Bai and Ru, 2022; Martinsson et al., 2024). In this subsection, we examine the impact of carbon pricing initiatives on firm-level carbon intensity. We use the difference-in-differences approach with the following specification.

$$Log(Intensity)_{i,c,t} = \beta_0 + \beta_1 Post_{c,t} + \gamma' \boldsymbol{X}_{\boldsymbol{i,c,t}} + \boldsymbol{k}' \boldsymbol{Z}_{\boldsymbol{c,t}} + \varepsilon_{i,t} \qquad (1)$$

The dependent variable is the natural log of carbon intensity of firm i headquartered in jurisdiction c in year t. $Post_{c,t}$ is a dummy variable equal to one if jurisdiction c has implemented some form of carbon pricing initiatives (either the carbon tax or the ETS initiative) in year *t*. $\boldsymbol{X}_{\boldsymbol{i,c,t}}$ is a set of firm-level control variables, including *Log(Assets)*, *Leverage*, *Cash*, *Sales growth*, *CapEx_assets*, *R&D_sales*. $\boldsymbol{Z}_{\boldsymbol{c,t}}$ is a list of country-level variables including *Log(GDP per capita)* and *Law and order*. We also include firm and year fixed effects and cluster the standard errors at the firm level.

Table IA.2 in the Online Appendix reports the results. Columns (1) and (2) report the results with scope 1 intensity as the measure of carbon emissions. Consistent with existing country-level evidence, we find that firms significantly reduce emission intensity after a jurisdiction adopts carbon pricing initiatives. The coefficient estimate suggests that the reduction in carbon intensity represents 4.35% of standard deviation of carbon intensity. In columns (3) and (4), we find similar evidence that firms reduce scope 2 emission intensity, although the economic effect is smaller compared to scope 1 emissions. Interestingly, columns (5) and (6) show that carbon pricing policies have no discernible impact on scope 3 emission intensity, consistent with the fact that most carbon pricing initiatives do not cover scope 3 emissions. Overall, carbon pricing policies are effective in driving down firms' GHG emission, which should benefit society in terms of curbing environmental externality. In the next section, we examine the potential costs that firms pay to achieve lower emissions.

4. The Effects of Carbon Pricing on Firm Profitability

4.1 Baseline results

The focus of our study is to examine the impacts of carbon pricing initiatives on firm operating performance and value. To that end, we run the baseline specification as follows:

$$Y_{i,c,\,t} = \beta_0 + \beta_1 Log(Intensity1 + 1)_{i,c,t} + \beta_2 Post_{c,t} + \beta_3 Post_{c,t} \times Log(Intensity1 + 1)_{i,c,t} + \gamma' \boldsymbol{X_{i,c,t}} + k' \boldsymbol{Z_{c,t}} + \varepsilon_{i,c,t} \quad (2)$$

where i, c, and t indicate firms, jurisdictions, and years, respectively. $Y_{i,\mathrm{c},t}$ indicates the outcome of firm i headquartered in jurisdiction c in year t, which could be profitability (*ROA/ROE*), Tobin's q, or investments. Control variables are the same as in equation (1). In the baseline model, we include year and firm fixed effects, which account for aggregate trend and time-invariant heterogeneity in firm performance. We cluster standard errors at firm level in main specifications and show the results are robust when we use alternative ways to cluster standard errors.

The key variable of interest in this specification is the interaction between the *Post* dummy and firm-level carbon intensity. The parameter of interest is β_3 which should be significantly negative when the outcome variable is firm profitability. With the triple difference estimator, we are essentially comparing the change in performance around the carbon pricing enactment (first difference) across firms in treated versus untreated jurisdictions (second difference), and across firms with differential carbon intensity (third difference). The third difference is arguably more exogeneous with respect to carbon pricing initiatives, which are enacted at jurisdiction level and unlikely influenced by individual firms' (current and expected) performance.

Table 3 presents the results. Columns (1) and (3) report results without any control variables. Consistent with our hypothesis, the coefficients of $Post_{c,t} \times Log(Intensity1 + 1)_{i,c,t}$ are negative and highly significant for both *ROA* and *ROE,* indicating that the profitability of carbon-intensive firms is significantly reduced relative to that of low-emission firms after the jurisdiction adopts carbon pricing policies. In columns (2) and (4), we add control variables in the regression model. We find the coefficients of the interaction term are similar across different specifications, and the statistical significance becomes stronger.

To gauge the economic effect, we create a dummy variable, *D(Intensity1>Median)*, which represents firms with above-median (scope 1) carbon intensity in a jurisdiction. We then interact this dummy with the *Post* dummy and run the same triple difference regression. Panel A of Table IA.3 reports the results. The negative and significant coefficients on *Post* D(Intensity1>Median)* suggest that the baseline results hold using the dummy treatment indicator. With an estimated coefficient of -0.0055 and -0.0123 for *ROA* and *ROE*, respectively, the results suggest firms with above-median carbon intensity experienced 55 (123) bps reduction in *ROA* (*ROE*) relative to firms with below-median carbon intensity after carbon pricing initiative is enacted. The economic effect is non-trivial, as it is equivalent to 13% and 6.7% of the mean and standard deviation of firm profitability in our sample, respectively.[12]

The triple difference estimator compares the change in performance of the carbon-intensive firms relative to low emission firms but does not tell us whether the difference is also driven by low-emission firms benefiting from carbon pricing policies. To test the impacts of carbon pricing on low and high-emission firms separately, we create two dummy variables, *D(Intensity1=Top Quartile)* and *D(Intensity1=Bottom Quartile)*, indicating firms with carbon intensity in the top and bottom quartiles of the distribution within a country. We then interact these two dummies with the *Post* dummy and run the triple difference regression. Panel B of Table IA.3 shows that the coefficients of *Post*D(Intensity1=Top quartile)* are negative and significant across all specifications, while the coefficients of *Post*D(Intensity1=Bottom quartile)* are insignificantly positive. This suggests that carbon pricing mainly exerts a negative

[12] We conduct a back-of-envelope calculation for the financial impacts of carbon pricing on firm profits. The median carbon tax and ETS price is 26 USD and 15 USD, respectively. Since carbon price is zero before carbon pricing enactment, the change in median carbon prices from pre to the post period is around 20.5 USD per ton of CO_2. The average scope 1 emission intensity in our sample is 268 tons per million USD sales. Evaluating at the mean, the average dollar cost of carbon pricing is 0.549% of firm sales. If we assume the average net profit margin is 5%, the average dollar cost of carbon pricing is 11% of firm profit. This is close to the economic effect we report in the paper.

effect on the profits of carbon-intensive firms relative to firms with average carbon intensity, while its beneficial effect on low-emission firms is smaller and less significant.

Overall, the results suggest that carbon-intensive firms experience a significant reduction in profitability relative to low-emission firms, suggesting that they are not able to fully pass the increased costs arising from carbon pricing to customers or undo the negative impact through relocation to or outsourcing from countries with laxer carbon pricing policies.

4.2 Dynamic effect analysis

The validity of the triple difference approach depends crucially on the parallel trend assumption. That is, in the absence of carbon pricing initiatives, the profitability of treated firms would have evolved in the same way as that of the control firms. In this subsection, we conduct the dynamic effect analysis to examine whether the parallel trend assumption holds. Specifically, we create time dummies to flag the year relative to the enactment year of the carbon pricing initiatives. $Before^{-t}$ is a dummy variable equal to one in the year *t* before the enactment of the carbon pricing initiative, and zero otherwise. *Current* is a dummy variable equal to one for the enactment year of the carbon pricing initiative, and zero otherwise. $After^{+t}$ is a dummy variable equal to one in the year *t* (t=1, 2) after the enactment of the carbon pricing initiative, and zero otherwise. $After^{3+}$ is a dummy variable that equals to one for three years and later after the enactment of the carbon pricing initiative, and zero otherwise. We then re-estimate equation (2) by interacting firms' carbon intensity with these seven timing indicators.

Table 4 reports the results. For both measures of firm profitability, the coefficients on the interaction terms between carbon intensity and the years before carbon pricing enactment are close to zero and statistically insignificant. This supports the parallel trend assumption that carbon-intensive firms exhibit trends in profitability similar to that of low-emission firms before the enactment of carbon pricing policies. Importantly, the coefficients of the interaction terms start to turn negative and significant in the year of carbon pricing enactment, suggesting the immediate impact of carbon pricing on firm performance. Finally, the interaction terms between carbon intensity and years after the carbon pricing enactment are all negative and significant, implying a long-lasting effect of carbon pricing on firm profits.

To show the dynamic effect of carbon pricing initiatives on the profitability of carbon-intensive firms, Figure 1 plots the estimated coefficients (along with the 95% confidence intervals) of the 7 interaction terms from Table 4. Overall, the insignificant pre-trend suggests that the negative effect of carbon pricing policies on the profitability of carbon intensive firms is plausibly causal.

4.3 Stacked regression

Recent studies argue that the staggered diff-in-diffs estimation could be biased (e.g., Abraham and Sun 2018; Chaisemartin and D'Hautfeuille, 2020).[13] We first follow the recommendation in Baker, Larcker, and Wang (2022) to evaluate the likelihood of the bias. Baker, Larcker, and Wang (2022) show that the potential biases associated with staggered DD estimate are less severe if the percentage of never-treated observations is high. As the never-treated observations account for 40.84% of our sample, the potential biases associated with our triple difference estimation are less problematic.[14]

Following Cengiz, Dube, Lindner, and Zipperer (2019), we use the stacked regression approach to further address the potential biases associated with staggered DD estimation.[15] To implement the idea, we first drop all firms which are treated before the first year in our sample

[13] The coefficient estimates from the two-way fixed effects (TWFE) DD regressions are a weighted average of many different "2x2" DD regressions. In some of these 2x2s, the early treated firms act as effective controls for the late treated firms, which may lead to biased estimate if there are dynamic treatment effects.
[14] The decomposition analysis of the static TWFE DD estimator proposed (Goodman-Bacon, 2021) is not possible in our setting because the database is unbalanced with gaps.
[15] The idea is to create separate event-specific datasets including the treated cohort and all never-treated firms (i.e., the clean controls) within the treatment window, and then stack all separate event-specific datasets together.

as they do not help uncover the average treatment effect. Then, for each treatment event, we create a separate dataset including firms treated by the event and all never-treated firms and restrict the sample period to six years before and after the event. Finally, all the event-specific datasets are stacked together to obtain the stacked database.

We re-run the triple difference regression using the stacked dataset and report the results in Table IA.4 in the Online Appendix. We include cohort*firm and cohort*year fixed effects in all specifications, and cluster standard errors at firm by cohort level. Across all specifications, the coefficient of the interaction term between *Post* and *Log(Intensity1+1)* is negative and significant at 1% level for both *ROA* and *ROE*. In terms of the economic magnitude, the negative effect of carbon pricing is about 20% smaller compared to the baseline results in Table 3, suggesting that the stacked regression partially corrects the downward bias inherent in staggered DD estimation.

4.4 Robustness tests

We conduct several robustness checks. First, we examine separately the effect of carbon taxes and ETS on firm profitability. To that end, we create two variables, *Post_Tax* and *Post_ETS* which are dummy variables indicating years when the jurisdiction has enacted carbon taxes and ETS, respectively. Panel A of Table 5 shows that the coefficients of *Post_Tax*Log(Intensity+1)* and *Post_ETS*Log(Intensity+1)* are negative and significant across all specifications. This suggests that both types of carbon pricing initiatives reduce the profitability of carbon-intensive firms relative to low-emission firms.

Second, in Panel B of Table 5, we use more stringent fixed effects to mitigate the endogeneity concern that governments' decision to enact carbon pricing policies may be affected by local economic conditions. In columns (1) and (3), we include *Jurisdiction*Year* fixed effects to absorb the confounding effect of local macroeconomic condition, and find the coefficients of *Post*Log(Intensity+1)* remain negative and significant at the 1% level. With *Jurisdiction*Year* fixed effects, the results suggest that the profitability of carbon-intensive firms reduced significantly after carbon pricing enactment, relative to low-emission firms headquartered in the same jurisdiction in the same year. Columns (2) and (4) show similar results when we include *Industry*Year* fixed effects, which absorb industry-specific trends in profitability.

Third, one may be concerned that our main finding is predominantly driven by US firms, which account for around 20% of our sample. We thus re-run the baseline regression excluding US firms from our sample. Panel C of Table 5 shows that the results still hold, and the economic effect is similar to the baseline results.

One concern for our baseline test is that firms headquartered in a country may have facilities located in foreign countries that are not subject to domestic carbon pricing policies. However, this measurement error in firm location should only bias us against finding any significant negative effect of carbon pricing on the performance of carbon-intensive firms. To further address this concern, we select firms with no foreign facilities (measured by firms without foreign assets in Worldscope) and re-run the baseline test. Panel D of Table 5 shows results similar to the baseline findings, suggesting that the measurement error in firm location does not significantly bias our estimate.

In our baseline analyses, we use scope 1 emission intensity to define firms' treatment status, as many carbon pricing policies so far only cover scope 1 emissions.[16] However, carbon pricing initiatives may nonetheless affect firms with high scope 2 and 3 emissions if upstream firms can partially pass the costs to downstream customers. For example, a (scope 2) carbon-intensive manufacturing firm, by definition, relies heavily on a utility provider for electricity,

[16] For example, China's national ETS only covers more than 2,000 companies from the power sector with annual emissions of more than 26,000 tCO2.

which could be generated from burning fossil fuel. After carbon pricing policies are adopted, the utility company needs to pay higher operating costs to generate the same amount of electricity and may decide to (partially) pass the costs to its customer – the carbon-intensive manufacturing firm. In Panel E of Table 5, we explore this question by using scope 2 and 3 emission intensity to define firms' treatment status. Columns (1) and (2) show that the coefficients of *Post*Log(Intensity2+1)* and *Post*Log(Intensity3+1)* are significantly negative for *ROA*, while columns (3) and (4) show a much weaker effect for *ROE*. The evidence suggests that upstream firms, which are most affected by carbon pricing policies, can partially pass the increased costs to downstream firms through the energy/electricity price and the supply-chain.

Finally, we re-run the baseline regressions with alternative ways of clustering standard errors. Panel F of Table 5 shows that our results are robust when we cluster standard errors at jurisdiction, jurisdiction and year, and firm and year level, respectively.

4.5 The effect of carbon prices on firm profitability

Our triple difference tests essentially examine whether the existence of any carbon pricing policies affect firm performance, regardless of the level of carbon price. However, there is significant heterogeneity in carbon prices across jurisdictions, and it is natural to think that the economic impacts of carbon pricing should also depend on the level of carbon prices. In this subsection, we take a complementary approach by using the annual prices of carbon taxes and ETS to quantify the economic effect of change in carbon prices on the profitability of carbon-intensive firms relative to low-emission firms. The key variables of interest for this test are thus the interactions between firms' (scope 1) carbon intensity with two variables, *Log(Carbon tax price+1)* and *Log(ETS price+1)*. Panel A of Table IA.5 reports the results using the full sample. We set the carbon prices in jurisdictions without any form of carbon pricing initiatives at zero. The coefficients of the two interaction variables, *Log(Carbon tax* *price+1)*Log(Intensity1+1)* and *Log(ETS price+1)*Log(Intensity1+1)*, are both negative and significant across all specifications, with similar economic magnitude. Panel B shows similar findings for carbon tax prices when we restrict to the subsample of firms headquartered in jurisdictions with carbon pricing policies. However, the effect of ETS prices is negative but statistically insignificant.[17] This result supports our prediction that the negative impacts of carbon pricing policies on the performance of carbon-intensive firms are more pronounced when the average carbon price in the jurisdiction is higher.

4.6 Carbon pricing and the components of firm profits

We next explore the channels through which carbon pricing initiatives affect firms' profitability. Since firm profit is calculated as the sales minus costs, the effect could come from either an increase in costs, a decline in sales growth, or both. In practice, carbon-intensive firms can use several approaches to comply with carbon pricing policies. For example, they can keep the same level of production and emissions but need to pay carbon taxes or buy allowances from the carbon market to offset excess emissions. Alternatively, since the level of carbon emissions is closely related to the scope of a firm's production activities, carbon-intensive firms can also reduce the regulatory costs by downsizing their production, which will be reflected in lower sales growth. Another way to comply with carbon pricing is to reduce emission intensity by switching to green technologies or using renewable energy, which could manifest as higher costs.

To test which channel(s) lead to the reduction in profits, we re-run the baseline regression by replacing firm profits with three variables that capture firm sales and costs. Table 6 reports the results. The dependent variables are cost of goods sold divided by sales

[17] The insignificant effect of ETS price could be because ETS price is determined by demand and supply of carbon allowance. While lower supply of carbon credits should increase costs for carbon-intensive firms, higher demand for carbon credits usually occurs when carbon-intensive firms are doing well, thus bias the coefficient estimate of ETS price upward.

(*CGS_sales*) in column (1), annual sales growth (*Sales growth*) in column (2), and the selling, general, and administrative expenses divided by sales (*SGA_sales*) in column (3). Column (1) shows that the coefficient of *Post*Log(Intensity1+1)* is 0.0025 (*t*=1.797), suggesting that carbon-intensive firms experience an increase in production costs following the enactment of carbon pricing initiatives. Column (2) reports the coefficient of *Post*Log(Intensity1+1)* is -0.0039 (*t*=-1.962), suggesting that carbon-intensive firms also reduce sales growth after jurisdictions adopt carbon pricing. Column (3) shows the coefficient of *Post*Log(Intensity1+1)* is -0.0013 (*t*=-1.140), suggesting that the enactment of carbon pricing initiatives does not significantly influence the SG&A components of operating costs.

Overall, we conclude that the negative impact of carbon pricing initiatives on firm profits is driven by both an increase in the costs of goods sold and a decline in sales growth for carbon-intensive firms relative to low-emission firms.

4.7 The impacts of carbon pricing on industry-level profitability

We conduct the analysis at industry level to examine the distributional impacts of carbon pricing across industries within the same jurisdiction. We first construct average profitability measures and all control variables at jurisdiction-industry-year level, where industry is defined at the level of 11 GICS sectors. Our key variable of interest is the interaction of *Post* dummy with the natural log of industry-average carbon intensity (*log(Average intensity1 +1)*).

Table IA.6 in the Internet Appendix shows that the industry-level results are generally similar to the firm-level results. Columns (1) and (2) shows thar relative to low-emission industries, carbon-intensive industries experience a significant reduction in *ROA* and *ROE*, respectively, after the jurisdiction enact carbon pricing policies.[18] Columns (3) and (4) show

[18] The mean values of industry-average ROA and ROE are 5.1% and 12.1%, respectively.

that the reduction in industry-level profitability come from both an increase in the costs of goods sold and lower sales growth, although the impact on costs is less significant. These results are consistent with firm-level results and suggest that a significant part of firm-level impacts of the carbon pricing policies occur at the industry level.

4.8 Cross-country heterogeneity tests

One important advantage of a global setting is that we can exploit cross-country heterogeneity to further examine which countries likely see a greater impact of carbon pricing policies. First, given that different regions have different exposures to transition risks and adaption capabilities, we conduct cross-sectional analysis based on geographic regions. To that end, we create three dummy variables, *Asia*, *North America*, and *Europe*, and use the remaining countries not from these regions as the benchmark. We re-run the baseline regressions by interacting these three dummy variables with *Post*Log(Intensity1+1),* and present the results in Panel A of Table 7. We find the coefficients are negative for all three triple interaction variables, and the effect is the strongest and most significant for North America. On the other hand, we find the interaction effect is weaker and insignificant for Europe, which is probably due to the free allocation and oversupply of emission permits in the early phase of EU ETS.

Second, since the main policy objective of carbon pricing is to reduce the economy's reliance on fossil fuels, we expect the effect of carbon pricing on firm performance to vary with countries' exposure to fossil fuel energy. We use two variables, *Energy intensity* and *Energy use*, to measure country exposure to fossil fuel energy. *Energy intensity* is energy consumption per capita, which measures the expected demand for fossil fuel energy per person in a country. *Energy use* is the kg of oil equivalent per capita, which proxies for the size of the fossil fuel consumption per person in a country. We re-run the baseline regression by interacting these two variables with *Post*Log(Intensity1+1),* and present the results in Panel B of Table 7.

Consistent with our expectation, the negative effect of carbon pricing on firm profits is indeed stronger for firms in countries with larger fossil fuel energy sectors and where consumption of energy per capita is high.

Our third cross-country test exploits the interaction between a country's exposure to physical climate risk and transition risk. In our setting, climate transition risk is measured by enactment of carbon pricing initiatives. We use two country-level indexes, *ND_vulnerability* and *ND_gain*, from the Notre Dame Global Adaptation Initiative to capture a country's exposure to physical risk.[19] We run the baseline regression by interacting the two country variables with *Post*Log(Intensity1+1)*. Panel C of Table 7 shows no significant difference in the effect of carbon pricing conditional on a country's exposure to physical risk. The evidence is consistent with the fact that physical risks are mainly determined by the climate system of the entire planet and hence less likely influenced by climate policies in a single jurisdiction.

5. The Effects of Carbon Pricing on Firm Value and Real Investments

Having established a strong negative effect of carbon pricing policies on the profitability of carbon-intensive firms, we next examine several other important firm outcomes that are theoretically related to profits, such as firm value and real investments. As firm value is determined by the present value of expected future cashflows, we first examine the impacts of carbon pricing on expected future cash flows and cost of capital in subsections 5.1 and 5.2, respectively. In subsections 5.3 and 5.4, we further examine the effect of carbon pricing on firm value and real investments, respectively.

5.1 Carbon pricing and earnings expectation

[19] Specifically, *ND_vulnerability* reflects propensity or predisposition of human societies to be negatively impacted by climate hazards. *ND_gain* summarizes a country's vulnerability to climate change and other global challenges in combination with its readiness to improve resilience.

In the previous section, we show that carbon pricing policies reduce the realized profits of carbon-intensive firms. In this subsection, we examine whether carbon pricing policies also lead investors to lower their expectation of future cash flows of carbon-intensive firms relative to low-emission firms. We use analyst consensus forecast of annual earnings-per-share (EPS) one to three years ahead as proxies for investors' expectation of short-term earnings. We use the consensus EPS forecast available in the first month after annual earnings announcement date and scale it by lagged stock prices. In addition to these short-term EPS forecasts, we also examine whether carbon pricing initiatives affect analyst forecasts of long-term earnings growth (*LTG*).

Table 8 reports the results. Columns (1) to (3) show that the coefficients of *Post*Log(Intensity1+1)* are negative and significant for 1- to 3-year ahead EPS forecast, while column (4) reports that the coefficient of *Post*Log(Intensity1+1)* is insignificantly positive for *LTG* forecast. This suggests that analysts expect carbon pricing policies to mainly reduce the earnings of carbon-intensive firms over the short run, but not to have a negative impact on their long-term earnings growth, potentially because firms can adapt in the long run by adopting low-carbon business models or green technologies. Economically, a firm with one standard-deviation higher *Log(Intensity1+1)* experiences 13.5%, 14.1%, and 15.8% reduction of 1-year, 2-year, and 3-year ahead EPS (as a fraction of stock prices) after carbon pricing initiatives, respectively.

Given our earlier finding on firm profits, the results suggest that analysts correctly revise downward their earnings expectation of carbon-intensive firms. A natural question to ask is whether analyst forecast is rational or systematically biased given available information. We run baseline regressions with signed EPS forecast errors as the dependent variable to examine this question. Specifically, we define signed forecast errors as the difference between actual EPS and consensus EPS forecast, scaled by lagged stock price. Table IA.7 in the Internet

Appendix reports the results, with different columns corresponding to 1- to 3-year ahead errors in EPS forecasts. We find the coefficients of *Post*Log(Intensity1+1)* are statistically insignificant and economically small for all three forecast horizons, suggesting that analysts are not systematically biased when forecasting the impacts of carbon pricing on firms' future earnings.

To the extent that analyst consensus earnings forecast is a good proxy for investor expectation of future cash flows, we expect carbon pricing policies to reduce firm value of carbon-intensive firms relative to low-emission firms. We can even quantify the impact on firm value by assuming a constant annual discount rate of 8% and a constant long-term earnings growth rate of 3% for all firms. Based on the coefficients estimated from Table 8, we calculate that reduced earnings expectation alone can lead to 2.17% reduction in market value for a firm with one standard-deviation higher *Log(Intensity1+1)*.

5.2 Carbon pricing, firm-level climate risk exposure and cost of capital

Recent studies (Bolton and Kacperczyk, 2021) propose the "carbon premium" hypothesis in the financial markets. Asset pricing theory posits that a positive carbon premium arises when more stringent emission regulations are likely to be proposed and implemented as the global climate worsens, leading to deteriorating values of carbon-intensive firms just when climate change matters most to investors' welfare. Under such a scenario, carbon-intensive firms are riskier and should earn higher expected returns than low-emission firms. While Bolton and Kacperczyk (2021 and 2023) document a significant positive carbon premium in the US and global equity markets, several other studies (Zhang 2022; Aswani et al., 2023) challenge those findings. In this subsection, we exploit our setting of carbon pricing enactment across countries to examine the carbon premium. If the enactment of carbon pricing initiatives increases the riskiness of carbon-intensive firms, the carbon premium should also increase.

To test the effect of carbon pricing initiatives on the carbon premium, we construct proxies of expected return on debt and equity securities. We use the simple measure of interest expenses over total amount of debt outstanding as a proxy for the cost of debt. We construct the implied cost of equity following the approach of Easton (2004) to proxy for expected stock return.[20] We then run the triple difference regression with the cost of debt and equity as the dependent variables. Panel A of Table 9 reports the results. Column (1) shows that the coefficient of *Post*Log(Intensity1+1)* is positive and significant at the 5% level, suggesting that carbon pricing policies lead to increased cost of debt for carbon-intensive firms. Similarly, column (2) shows that carbon pricing policies also significantly increase the implied cost of equity for carbon-intensive firms. The results are consistent with Bolton and Kacperczyk (2021) and Hsu, Li, and Xu (2022), who document a positive carbon premium and pollution premium, respectively, in the US equity market. The estimated coefficient in column (2) suggests that a firm with one standard-deviation higher *Log(Intensity1+1)* experiences 0.43% (1.9375*0.0022) increase in implied cost of equity after carbon pricing initiatives. The economic effect is non-trivial as the median implied cost of equity (r_mpeg) for our sample is 10.90%.

We further examine whether the increased carbon premium occurs because investors perceive greater transition risk after the adoption of carbon pricing policies. To test this, we examine the effects of carbon pricing initiatives on firm-level climate risk exposures, which are constructed by Sautner et al. (2023) using earnings conference call data. The results are reported in Panel B of Table 9. Column (1) shows that the coefficient of *Post*Log(Intensity1+1)* is positive and significant at the 1% level when the dependent variable is firm-level exposure to climate regulatory risk, supporting our conjecture that the increased carbon premium is driven by increased exposure to climate regulatory risk. In contrast, column (2) shows that the

[20] We use implied cost of equity rather than realized stock return to proxy for expected return because Pastor, Stambaugh, and Taylor (2022) show that realized return is not a good proxy for expected return when the demand for green assets unexpectedly increases over a short sample period.

coefficient of *Post*Log(Intensity1+1)* is insignificant and close to zero when the outcome variable is firm-level exposure to physical risk. As physical climate risk exposure is unlikely affected by carbon pricing policies in a single jurisdiction, the insignificant result serves as a placebo test and suggests our finding on regulatory risk is not spurious.

5.3 Carbon pricing and firm value

As we find that carbon pricing leads to lower expected future cash flows and higher discount rates for carbon-intensive firms, an immediate implication is that such firms should also experience a reduction in firm value. Our first measure of firm value is Tobin's *q*, defined as the market value of a firm divided by the book value of total assets. The market value of a firm is equal to market capitalization plus the book value of total assets minus the book value of equity.

We run the same triple difference regression with Tobin's *q* as the dependent variable of interest and report the result in column (1) of Table 10. Consistent with our conjecture, the coefficient of *Post*Log(Intensity1+1)* is indeed negative and significant at the 1% level. In terms of economic effect, a firm with one standard-deviation higher *Log(Intensity1+1)* experiences 3.47% (1.9375*0.0179) reduction in Tobin's *q*. To examine the extent to which the combined effects of earnings expectation and discount rate can explain the change in firm value, we conduct the following back-of-envelope calculation. Table 9 shows that a firm with one standard-deviation higher *Log(Intensity1+1)* experiences a 0.43% increase in implied cost of equity, which translates into a 0.51% reduction in firm value.[21] This, when combined with an estimated 2.17% reduction of firm value due to lower cash flow expectation, implies a reduction of firm value by 2.68%. The calculation suggests that the negative effect on firm

[21] We run panel regression of Tobin's *q* on implied cost of equity (r_mpeg) and lagged ROE using the full sample of firm-years. Untabulated result shows the estimated coefficient in front of r_mpeg is -1.1923 (t=-20.833), which is our estimated sensitivity of firm value change to implied cost of equity change.

value can almost entirely be attributed to higher discount rate and lower expected future cash flows, with the cash flow channel explaining most of the firm value change.

We run a complementary test on the effect of carbon pricing on firm value by examining the impact of carbon pricing on contemporaneous stock returns. Both a positive shock to discount rate and a negative shock to expected cash flows imply that carbon-intensive firms should experience lower realized stock return after the enactment of carbon pricing policies. We run the triple difference regression with annual stock return (*Ret_annual*) as the dependent variable. We report the result in column (2) of Table 10. The negative and significant coefficient of *Post*Log(Intensity+1)* is consistent with our prediction that carbon pricing initiatives lead to lower stock return of carbon-intensive firms relative to low-emission firms. The economic effect on stock return is slightly smaller than the effect on Tobin's *q*, as a firm with one standard-deviation higher *Log(Intensity1+1)* experiences 2.89% (1.9375*0.0149) lower annual stock return after carbon pricing enactment.

5.4 Carbon pricing and real investment

The *q* theory of investment predicts a strong relation between corporations' market values and their investment rates (Hayashi, 1982). As carbon pricing initiatives reduce the value of carbon-intensive firms, we examine how firm investment responds to the enactment of carbon pricing policies. We use multiple measures of real investment, including investment in fixed assets, growth opportunity, and human capital. Following the literature, *CapEx_assets* is computed as the capital expenditures divided by the book value of total assets. *R&D_sales* is computed as the R&D expenditures divided by total sales. *Employees_sales* is computed as the total number of employees divided by total sales. We run the same triple difference regression with *CapEx_assets*, *R&D_sales* and *Employees_sales* as the dependent variables and report the results in Panel A of Table 11. The coefficients of *Post*Log(Intensity1+1)* are negative and significant for all three measures of investment. This is consistent with our prediction that as the marginal profits from brown projects decline after the enactment of carbon pricing initiatives, carbon-intensive firms reduce the optimal level of investment relative to low-emission firms.

Another potential reason that carbon-intensive firms cut investment could be financial constraints, as we show such firms face higher costs of debt and equity financing and have less internal cash flows. In Panel B and Panel C of Table 11, we test the implications of carbon pricing for firm financial constraints. Our first prediction of tightened financial constraints is that carbon-intensive firms will hold more cash due to the precautionary savings motive. The dependent variable in column (1) of Panel B is the cash holdings, defined as the cash and cash equivalents divided by the book value of total assets. The coefficient of *Post*Log(Intensity1+1)* is positive and significant at the 1% level, suggesting that carbon-intensive firms face more binding financial constraints. Column (2) shows that carbon-intensive firms do not increase leverage, probably because the cost of debt financing is higher for such firms. We further use the cash flow sensitivity of cash measure as the proxy for financial constraints (Almeida et al., 2004), and report the result in Panel C of Table 11. We find that carbon-intensive firms save more cash out of cash flows after carbon pricing enactment in their jurisdictions, supporting our conjecture that carbon-intensive firms face tightened financial constraints due to the regulatory burden of carbon pricing initiatives.

6. Conclusion

Economists have long argued that carbon pricing is the most flexible and cost-effective method to mitigate climate change. A major block to pricing carbon pollution, however, is the concern about the economic costs. In this paper, we examine the impacts of carbon pricing policies on the operating performance and market value of publicly listed firms across the world. We conduct the most comprehensive study of the impacts of carbon pricing on firm performance, using a sample of 104,100 firm-year observations covering 16,222 unique firms across 52 countries.

Using staggered enactment of carbon pricing initiatives across jurisdictions and a triple difference approach, we find a significant reduction in the profitability and market value of carbon-intensive firms relative to low-emission firms after the enactment of carbon pricing. Further analyses show that the reduction in firm profits is driven by both a decrease in sales growth and an increase in operating costs. The reduction in firm value is driven by both an increase in costs of capital and a decrease in expected future cash flows. Carbon-intensive firms also cut investments and lay off employees more, and save more out of cash flows, indicating tightened financial constraints. Exploiting cross-country heterogeneity, we find a stronger effect of carbon pricing on the profits of firms headquartered in North America and in countries that rely more on fossil fuel for energy.

Overall, our findings uncover the large distributional impacts of carbon pricing policies on individual firms and complements prior studies documenting an insignificant effect on the macroeconomy. The large distributional impacts of carbon pricing policies suggest that targeted fiscal policies could be an effective way not only to reduce the economic costs of carbon pricing on most affected firms and workers, but also to gain public support.

Appendix A Variable definitions

Variables	Definitions	Data sources
Dependent variables		
ROA	The net income divided by the book value of total assets.	Worldscope
ROE	The net income divided by the book value of equity.	Worldscope
CGS_sales	The cost of goods sold divided by sales.	Worldscope
Sales growth	The ratio of growth sales.	Worldscope
SGA_sales	The selling, general, and administrative expenses divided by sales.	Worldscope
EPS forecast/price	The earliest available consensus forecast of EPS after the earnings announcement for 1-year to 3-year horizons, scaled by stock price. For the post-treatment years, the price is fixed to be one year before the enactment year. For the pre-treatment years and never treated firms, we use stock price from the previous year.	I/B/E/S
LTG forecast	The earliest available consensus forecast of LTG after the earnings announcement.	I/B/E/S
Interests/Debt	The interest expenses divided by the average total debt.	Worldscope
r_mpeg	Implied cost of equity derived from Equation (10) of Easton (2004): $r\_mpeg = \sqrt{\frac{FEPS_{h+2} + r\_mpeg \times FDPS_{h+1} - FEPS_{h+1}}{P_h}}$ $FEPS_{h+2}$ is earliest available two-year-ahead consensus analyst EPS forecast; $FEPS_{h+1}$ is earliest available one-year-ahead consensus analyst EPS forecast; $FDPS_{h+1}$ is one-year-ahead mean analyst forecasted dividend per share; and P_h is fiscal-year end closing price.	I/B/E/S
Regulatory risk	Relative frequency with which bigrams that capture regulatory shocks related to climate change occur in the transcripts of earnings conference calls. We count the number of such bigrams and divide by the total number of bigrams in the transcripts.	Sautner, Van Lent, Vilkov and Zhang (2023)
Physical risk	Relative frequency with which bigrams that capture physical shocks related to climate change occur in the transcripts of earnings conference calls. We count the number of such bigrams and divide by the total number of bigrams in the transcripts.	Sautner, Van Lent, Vilkov and Zhang (2023)
Tobin's *q*	The market value of a firm divided by the book value of total assets. The market value of a firm is equal to the market capitalization plus the book value of total assets minus the book value of equity.	Worldscope
Ret_annual	The cumulative return from July of year t to June of year t+1	Compustat
CapEx_assets	The capital expense divided by the book value of total assets	Worldscope
R&D_sales	The research and development expenditure divided by sales	Worldscope

Employees_sales	The number of employees divided by sales.	Worldscope
Signed Forecast Error	The difference between actual EPS and the earliest available consensus forecast of EPS scaled by the absolute value of actual EPS, for 1-year to 3-year horizons.	I/B/E/S
Independent variables		
Post	A dummy variable equal to one in years if the region (i.e., the country or the sub-country) has implemented the carbon pricing initiative (i.e., either the carbon tax initiative or the ETS initiative) and zero otherwise.	World Bank
Post_tax	A dummy variable equal to one in years if the region has implemented the carbon tax initiative and zero otherwise.	World Bank
Post_ETS?	A dummy variable equal to one in years if the region has implemented the ETS initiative and zero otherwise.	World Bank
Log(Carbon tax price+1)	The natural log of the price of carbon tax plus one. The price of carbon tax applies for post-implementation periods.	World Bank
Log(ETS price+1)	The natural log of the price of ETS plus one. The price of ETS applies for post-implementation periods.	World Bank
Log(Intensity1+1)	The natural log of scope 1's carbon emission intensity plus one.	Trucost
Log(Intensity2+1)	The natural log of scope 2's carbon emission intensity plus one.	Trucost
Log(Intensity3+1)	The natural log of scope 3's carbon emission intensity plus one.	Trucost
Control variables		
Log(Assets)	The natural log of the book value of total assets.	Worldscope
Leverage	The book value of total debt divided by the book value of total assets.	Worldscope
Cash	The cash and cash equivalent divided by the book value of total assets.	Worldscope
Operating cash flow	The operating cash flow divided by the lagged total assets.	Worldscope
Log(GDP per capita)	The natural log of the GDP per capita.	IMF
Law and order	The standardized value between 0 and 6 capturing the strength and impartiality of the legal system, and the popular observance of the law. The higher value indicates the better law and order.	ICRG
Energy intensity	The consumption of energy per capita.	World Bank
Energy use	The kg of oil equivalent per capita.	World Bank
Asia	A dummy variable equal to one if the firm is headquartered in Asia and zero otherwise.	Worldscope
North America	A dummy variable equal to one if the firm is headquartered in North America and zero otherwise.	Worldscope
Europe	A dummy variable equal to one if the firm is headquartered in Europe and zero otherwise.	Worldscope
ND_vulnerability	Country index reflecting propensity or predisposition of human societies to be negatively impacted by climate hazards	Notre Dame Global Adaptation Initiative

ND_gain	Country index summarizing a country's vulnerability to climate change and other global challenges in combination with its readiness to improve resilience.	Notre Dame Global Adaptation Initiative

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Figure 1 Dynamic effects of carbon pricing initiatives on firm profitability

This figure plots the coefficient estimates of seven interaction terms between time dummies indicating years relative to the enactment of carbon pricing and *Log(Intensity1+1)*. Figure 1a plots the dynamic effects of carbon pricing on *ROA* (Column 1 of Table 4). Figure 1b plots the dynamic effects of carbon pricing on *ROE* (Column 2 of Table 4). The 95% confidence intervals are based on standard errors clustered at firm level.

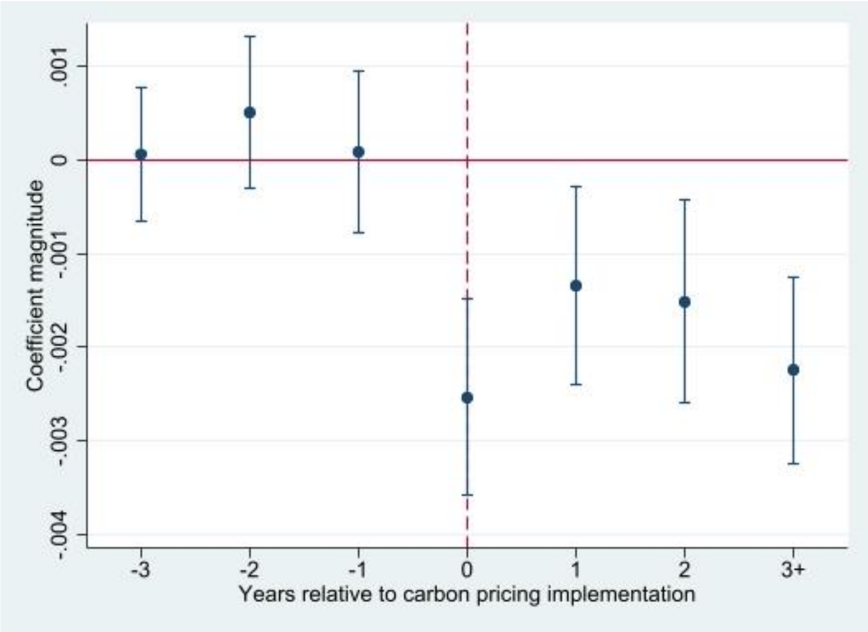

Figure 1a

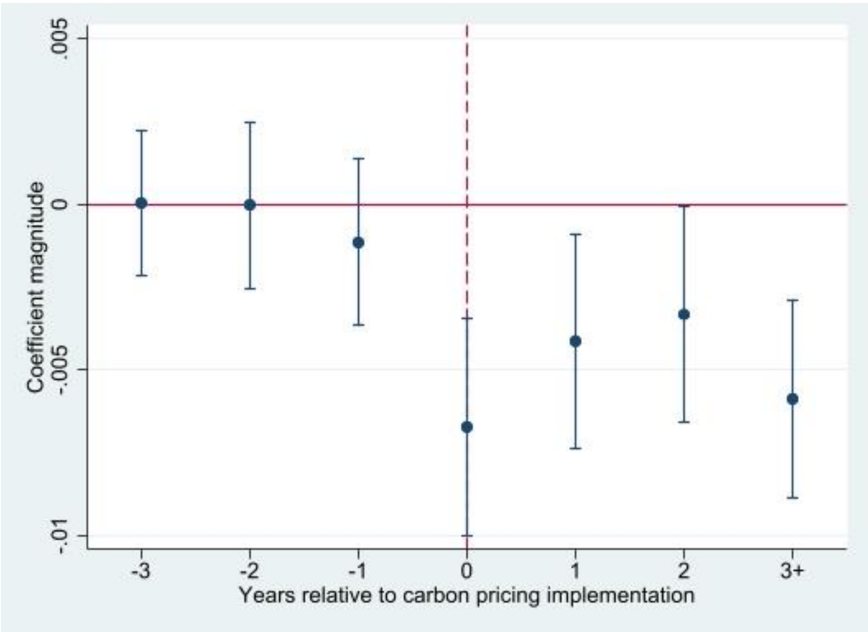

Figure 1b

Table 1 Carbon pricing initiatives around the world

This table presents the type of carbon pricing initiatives at national (supranational) and subnational level. Panel A presents the national (supranational) carbon pricing initiatives. Panel B reports the subnational carbon pricing initiatives. Columns (1) and (2) present the implementation year and the name of the carbon tax initiatives, respectively. Columns (3) and (4) present the implementation year and the name of the ETS initiatives, respectively.

Panel A: National (supranational) carbon pricing initiatives

Country	Carbon tax		ETS	
	Year (1)	Name of initiative (2)	Year (3)	Name of initiative (4)
Argentina	2018	Argentina carbon tax	-	-
Austria	-	-	2005	EU ETS
Belgium	-	-	2005	EU ETS
Chile	2017	Chile carbon tax	-	-
Colombia	2017	Colombia carbon tax	-	-
Canada	2019	Canada federal fuel charge	2019	Canada federal OBPS
Denmark	1992	Denmark carbon tax	2005	EU ETS
Finland	1990	Finland carbon tax	2005	EU ETS
France	2014	France carbon tax	2005	EU ETS
Germany	2019	-	2005	EU ETS
Greece	-	-	2005	EU ETS
Ireland	2010	Ireland carbon tax	2005	EU ETS
Italy	-	-	2005	EU ETS
Japan	2012	Japan carbon tax	-	-
South Korea	-	-	2015	Korea ETS
Luxembourg			2005	EU ETS
Mexico	2014	Mexico carbon tax	-	-
Netherlands	-	-	2005	EU ETS
New Zealand	-	-	2008	New Zealand ETS
Norway	1991	Norway carbon tax	2008	EU ETS
Poland	1990	Poland carbon tax	2005	EU ETS
Portugal	2015	Portugal carbon tax	2005	EU ETS
Singapore	2019	Singapore carbon tax	-	-
South Africa	2019	South Africa carbon tax	-	-
Spain	2014	Spain carbon tax	2005	EU ETS
Sweden	1991	Sweden carbon tax	2005	EU ETS
Switzerland	2008	Switzerland carbon tax	2008	Switzerland ETS
United Kingdom	2013	UK carbon price support	2005	EU ETS

Panel B: Subnational-level carbon pricing initiatives

Sub-country	Carbon tax		ETS	
	Year	Name of initiative	Year	Name of initiative
	(1)	(2)	(3)	(4)
Canada, Alberta	-	-	2007	Alberta TIER
Canada, British Columbia	2008	BC carbon tax	2016	BC GGIRCA
Canada, Newfoundland and Labrador	2019	Newfoundland and Labrador carbon tax	2019	Newfoundland and Labrador PSS
Canada, Northwest Territories	2019	Northwest Territories carbon tax	-	-
Canada, Nova Scotia	-	-	2019	Nova Scotia CaT
Canada, Prince Edward Island	2019	Prince Edward Island carbon tax	-	-
China, Beijing	-	-	2013	Beijing pilot ETS
China, Chongqing	-	-	2014	Chongqing pilot ETS
China, Fujian	-	-	2016	Fujian pilot ETS
China, Guangdong (except Shenzhen)	-	-	2013	Guangdong pilot ETS
China, Hubei	-	-	2014	Hubei pilot ETS
China, Shenzhen	-	-	2013	Shenzhen pilot ETS
China, Shanghai	-	-	2013	Shanghai pilot ETS
China, Tianjin	-	-	2013	Tianjin pilot ETS
Japan, Tokyo	-	-	2010	Tokyo CaT
Japan, Saitama	-	-	2011	Saitama ETS
United States, California	-	-	2013	California CaT
United States, Connecticut	-	-	2009	RGGI
United States, Delaware	-	-	2009	RGGI
United States, Maine	-	-	2009	RGGI
United States, Maryland	-	-	2009	RGGI
United States, Massachusetts	-	-	2018	RGGI
United States, New Hampshire	-	-	2009	RGGI
United States, New Jersey	-	-	2009	RGGI
United States, New York	-	-	2009	RGGI
United States, Rhode Island	-	-	2009	RGGI
United States, Vermont	-	-	2009	RGGI

Table 2 Summary statistics

This table reports the summary statistics of the main variables used in the study. Variable definitions are in the Appendix A.

Variables	N (1)	Mean (2)	p25 (3)	p50 (4)	p75 (5)	Std. Dev. (6)
Firm-level variables						
ROA	104,100	0.0424	0.0120	0.0392	0.0767	0.0823
ROE	104,100	0.0949	0.0472	0.1027	0.1706	0.2119
CGS_sales	93,329	0.5800	0.4202	0.6298	0.7678	0.2418
SGA_sales	87,615	0.2467	0.0914	0.1723	0.3012	0.2874
Employees_sales	89,537	4.6416	1.5754	3.0904	5.3686	5.4578
EPS forecast/price (1-year)	76,951	0.6422	0.0474	0.0737	0.1208	2.6288
EPS forecast/price (2-year)	74,576	0.7375	0.0571	0.0844	0.1381	2.9681
EPS forecast/price (3-year)	57,315	0.9474	0.0644	0.0943	0.1561	3.6598
LTG forecast	49,736	0.1348	0.0600	0.1100	0.1750	0.1520
Interests/Debt	96,184	0.0533	0.0222	0.0425	0.0633	0.0601
r_mpeg	78,718	0.1753	0.0807	0.1090	0.1631	0.2184
Regulatory risk	41,140	0.0042	0.0000	0.0000	0.0000	0.0150
Physical risk	41,140	0.0010	0.0000	0.0000	0.0000	0.0046
Tobin's Q	104,100	1.7960	1.0322	1.3110	1.9745	1.3656
Ret_annual	104,074	0. 0951	-0.1202	0.0031	0. 2476	0.3926
Employees_sales	89,537	4.6416	1.5754	3.0904	5.3686	5.4578
Operating cash flow	101,596	0.0848	0.0314	0.0762	0.1297	0.0998
Log(Intensity1+1)	104,100	3.2439	2.0844	2.9648	4.0579	1.9375
Intensity1	104,100	268.2640	7.0400	18.3900	56.8500	945.0582
Log(Intensity2+1)	104,100	3.0761	2.3106	3.0865	3.8707	1.2124
Intensity2	104,100	43.4775	9.0800	20.9000	46.9750	68.9665
Log(Intensity3+1)	104,100	4.7720	3.9174	4.7739	5.5635	0.9987
Intensity3	104,100	191.3307	49.2700	117.3800	259.7400	208.4555
Log(Assets)	104,100	21.6673	20.3749	21.5859	22.8495	1.8541
Leverage	104,100	0.2339	0.0774	0.2169	0.3558	0.1795
Cash	104,100	0.1539	0.0428	0.1023	0.2079	0.1575
Sales growth	104,100	0.1225	-0.0078	0.0684	0.1755	0.3098
CapEx_assets	104,100	0.0443	0.0104	0.0305	0.0608	0.0476
R&D_sales	104,100	0.0266	0.0000	0.0000	0.0168	0.0811
Country-level variables						
Log(Carbon tax price+1)	175	2.8759	2.2073	3.3225	3.6116	1.3229
Carbon tax price	175	31.1873	8.091224	26.7294	36.0266	30.5667
Log(ETS price+1)	294	2.5435	1.9792	2.8064	3.1885	0.7509
ETS price	294	15.3701	6.2367	15.5508	23.2522	11.7816
Log(GDP per capita)	868	9.7210	8.8320	10.1242	10.7095	1.2050
Law and order	868	4.4010	3.5000	5.0000	5.0000	1.2774
Energy intensity	850	4.2741	3.0700	3.8500	5.1800	1.7089
Energy use	622	3347.9170	1624.8290	2983.9380	4708.2210	2152.6270
ND_vulnerability	832	0.3677	0.3116	0.3503	0.4089	0.0701
ND_gain	832	58.8130	48.7936	60.5443	67.6958	10.2325

Table 3 Carbon pricing and firm profitability

This table examines the impacts of carbon pricing initiatives on firm profitability. The dependent variables are *ROA* and *ROE*. *ROA* is defined as net income divided by the book value of total assets. *ROE* is defined as net income divided by the book value of equity. The key independent variables are *Post* and *Log(Intensity1+1)*. *Post* is a dummy variable equal to one for years when the jurisdiction has implemented carbon pricing initiatives (either the carbon taxes or the ETS), and zero otherwise. *Log(Intensity1+1)* is the natural logarithm of one plus scope 1 carbon intensity. All variables are defined in Appendix A. All regressions include firm and year fixed effects. Numbers in parentheses are *t*-statistics based on standard errors clustered at firm level. Sample period is from 2002 to 2019. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

Variables	ROA (1)	ROA (2)	ROE (3)	ROE (4)
Post*Log(Intensity1+1)	-0.0021***	-0.0024***	-0.0059***	-0.0061***
	(-4.635)	(-5.463)	(-4.358)	(-4.632)
Post	0.0139***	0.0145***	0.0360***	0.0360***
	(7.576)	(8.322)	(6.687)	(6.746)
Log(Intensity1+1)	-0.0025***	-0.0016***	-0.0066***	-0.0047***
	(-4.127)	(-2.712)	(-3.875)	(-2.813)
Log(Assets)		0.0046***		0.0153***
		(3.568)		(4.301)
Leverage		-0.1642***		-0.2892***
		(-35.129)		(-17.556)
Cash		0.0837***		0.1673***
		(16.115)		(13.044)
Sales growth		0.0289***		0.0768***
		(24.909)		(25.085)
CapEx_assets		0.1516***		0.3890***
		(15.619)		(14.586)
R&D_sales		-0.3504***		-0.6103***
		(-10.282)		(-8.402)
Log(GDP per capita)		-0.0092***		-0.0082
		(-3.656)		(-1.129)
Law and order		0.0019		-0.0008
		(1.167)		(-0.147)
Firm FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Adjusted R^2	0.5668	0.6213	0.4595	0.4928
Observations	104,100	104,100	104,100	104,100

Table 4 Dynamic effect analysis

This table reports the dynamic effect of carbon pricing initiatives on firm profitability. The dependent variables are *ROA* and *ROE*. $Before^{-t}$ is a time dummy that equals one in the year *t* before the implementation of the carbon pricing initiative, and zero otherwise. *Current* is a time dummy that equals one in the year of the implementation of the carbon pricing initiative, and zero otherwise. $After^{+t}$ is a time dummy that equals one in the year *t* (t=1, 2) after the implementation of the carbon pricing initiative, and zero otherwise. $After^{3+}$ is a time dummy that equals one if a firm-year observation is at least three years after the implementation of the carbon pricing initiative, and zero otherwise. Control variables are the same as in Table 3. Other variables are defined in Appendix A. All regressions include firm and year fixed effects. Numbers in parentheses are *t*-statistics based on standard errors clustered at firm level. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

Variables	ROA (1)	ROE (2)
$Before^{-3}$*Log(Intensity1+1)	0.0001	0.0000
	(0.172)	(0.041)
$Before^{-2}$*Log(Intensity1+1)	0.0005	-0.0000
	(1.234)	(-0.013)
$Before^{-1}$*Log(Intensity1+1)	0.0001	-0.0011
	(0.204)	(-0.895)
Current*Log(Intensity1+1)	-0.0025***	-0.0067***
	(-4.737)	(-3.995)
$After^{+1}$*Log(Intensity1+1)	-0.0013**	-0.0041**
	(-2.488)	(-2.502)
$After^{+2}$*Log(Intensity1+1)	-0.0015***	-0.0033**
	(-2.729)	(-1.994)
$After^{3+}$*Log(Intensity1+1)	-0.0022***	-0.0059***
	(-4.416)	(-3.853)
Post	0.0139***	0.0325***
	(7.788)	(5.861)
Log(Intensity1+1)	-0.0017***	-0.0048***
	(-2.804)	(-2.850)
Controls	YES	YES
Firm FEs	YES	YES
Year FEs	YES	YES
Adjusted R^2	0.6213	0.4928
Observations	104,100	104,100

Table 5 Robustness tests

This table reports results from several robustness tests. Panel A examines the effects of carbon taxes and ETS initiatives separately. The key independent variables are *Post_Tax*, *Post_ETS*, *Log (Intensity1+1)* and their interactions. Panel B reports the baseline results, but we replace year fixed effects with jurisdiction*year and/or industry*year fixed effects. Panel C reports the baseline results, but we exclude US firms from the sample. Panel D reports the baseline results, but we exclude firms with foreign assets from the sample. Panel E reports the results by using scope 2 and 3 carbon intensity. Panel F reports baseline results with standard errors clustered at jurisdictions level, jurisdiction and year level, and firm and year level, respectively. The regressions in all panels (except Panel B) include firm and year fixed effects. Control variables are the same as Table 3. All variables are defined in Appendix A. Numbers in parentheses are *t*-statistics based on standard errors clustered at firm level (except Panel F). ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

Panel A: Separate effects of carbon taxes and ETS

Variables	ROA	ROA	ROE	ROE
	(1)	(2)	(3)	(4)
Post_Tax*Log(Intensity1+1)	-0.0024***	-0.0015***	-0.0050***	-0.0032**
	(-3.929)	(-2.763)	(-2.985)	(-1.988)
Post_ETS*Log(Intensity1+1)	-0.0012**	-0.0018***	-0.0043***	-0.0052***
	(-2.286)	(-3.606)	(-2.801)	(-3.437)
Post_Tax	0.0170***	0.0063***	0.0264***	0.0058
	(7.434)	(2.898)	(4.194)	(0.932)
Post_ETS	0.0090***	0.0136***	0.0288***	0.0363***
	(4.413)	(6.871)	(4.834)	(6.044)
Log(Intensity1+1)	-0.0024***	-0.0015***	-0.0062***	-0.0045***
	(-3.869)	(-2.616)	(-3.660)	(-2.733)
Controls	NO	YES	NO	YES
Firm FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Adjusted R^2	0.5673	0.6214	0.4596	0.4929
Observations	104,100	104,100	104,100	104,100

Panel B: Alternative specifications of fixed effects

Variables	ROA	ROA	ROE	ROE
	(1)	(2)	(3)	(4)
Post*Log(Intensity1+1)	-0.0015***	-0.0014***	-0.0036***	-0.0048***
	(-3.270)	(-3.005)	(-2.757)	(-3.331)
Post		0.0103***		0.0276***
		(5.671)		(5.010)
Log(Intensity1+1)	-0.0017***	-0.0013**	-0.0050***	-0.0027
	(-2.907)	(-2.211)	(-3.063)	(-1.634)
Controls	YES	YES	YES	YES
Firm FEs	YES	YES	YES	YES
Jurisdiction*Year FEs	YES	NO	YES	NO
Industry*Year FEs	NO	YES	NO	YES
Adjusted R^2	0.6274	0.6276	0.5017	0.4991
Observations	104,100	104,100	104,100	104,100

Panel C: Excluding US firms from the sample

Variables	ROA (1)	ROE (2)
Post*Log(Intensity1+1)	-0.0018***	-0.0042***
	(-4.075)	(-3.155)
Post	0.0134***	0.0334***
	(7.525)	(6.374)
Log(Intensity1+1)	-0.0016**	-0.0042**
	(-2.553)	(-2.491)
Controls	YES	YES
Firm FEs	YES	YES
Year FEs	YES	YES
Adjusted R^2	0.6021	0.4645
Observations	82,337	82,337

Panel D: Excluding firms with foreign assets

Variables	ROA (1)	ROE (2)
Post*Log(Intensity1+1)	-0.0023***	-0.0053**
	(-3.244)	(-2.488)
Post	0.0120***	0.0255***
	(3.875)	(2.687)
Log(Intensity1+1)	-0.0015*	-0.0065***
	(-1.881)	(-2.905)
Controls	YES	YES
Firm FEs	YES	YES
Year FEs	YES	YES
Adjusted R^2	0.6511	0.5319
Observations	41,388	41,388

Panel E: Using scope 2 and 3 carbon intensity

Variables	ROA (1)	ROA (2)	ROE (3)	ROE (4)
Post*Log(Intensity2+1)	-0.0019***		-0.0019	
	(-3.045)		(-1.025)	
Post	0.0133***	0.0203***	0.0234***	0.0363***
	(5.910)	(5.245)	(3.455)	(3.095)
Log(Intensity2+1)	0.0001		-0.0009	
	(0.243)		(-0.525)	
Post*Log(Intensity3+1)		-0.0027***		-0.0039*
		(-3.521)		(-1.678)
Log(Intensity3+1)		-0.0016		-0.0087
		(-0.826)		(-1.593)
Controls	YES	YES	YES	YES
Firm FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Adjusted R^2	0.6209	0.6209	0.4923	0.4924
Observations	104,100	104,100	104,100	104,100

Panel F: Alternative ways of clustering standard errors

Variable	ROA			ROE		
	(1)	(2)	(3)	(4)	(5)	(6)
Post*Log(Intensity1+1)	-0.0024***	-0.0024***	-0.0024***	-0.0061**	-0.0061**	-0.0061***
	(-3.246)	(-3.161)	(-4.536)	(-2.618)	(-2.399)	(-3.281)
Post	0.0145***	0.0145***	0.0145***	0.0360***	0.0360**	0.0360***
	(3.789)	(3.695)	(6.049)	(2.778)	(2.663)	(4.447)
Log(Intensity1+1)	-0.0016**	-0.0016**	-0.0016**	-0.0047**	-0.0047**	-0.0047**
	(-2.441)	(-2.379)	(-2.581)	(-2.577)	(-2.473)	(-2.649)
Controls	YES	YES	YES	YES	YES	YES
Firm FEs	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Clustered standard errors	Jurisdiction	Jurisdiction and Year	Firm and Year	Jurisdiction	Jurisdiction and Year	Firm and Year
Adjusted R^2	0.6213	0.6213	0.6213	0.4928	0.4928	0.4928
Observations	104,100	104,100	104,100	104,100	104,100	104,100

Table 6 Carbon pricing and the components of firm profitability

This table examines the effect of carbon pricing initiatives on the components of firm profits. The dependent variables are *CGS_sales*, *Sales growth*, and *SGA_sales*. The independent variables are *Post* and *Log(Intensity1+1)*. Control variables are the same as in Table 3 but exclude *Sales growth*. All variables are defined in Appendix A. All regressions include firm and year fixed effects. Numbers in parentheses are *t*-statistics based on standard errors clustered at firm level. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

Variables	CGS_sales (1)	Sales growth (2)	SGA_sales (3)
Post*Log(Intensity1+1)	0.0025*	-0.0039**	-0.0013
	(1.797)	(-1.962)	(-1.140)
Post	-0.0048	0.0314***	-0.0035
	(-0.876)	(4.000)	(-0.730)
Log(Intensity1+1)	0.0024*	-0.0042	0.0006
	(1.682)	(-1.554)	(0.342)
Controls	YES	YES	YES
Firm FEs	YES	YES	YES
Year FEs	YES	YES	YES
Adjusted R^2	0.8952	0.1968	0.9067
Observations	93,329	104,100	87,615

Table 7 Carbon pricing and firm profitability: Cross-country heterogeneity tests

This table reports the regression results for the effect of carbon pricing on firm performance conditional on country characteristics. The dependent variables are *ROA* and *ROE*. Panel A tests the effect of carbon pricing on firm performance conditional on geographic regions. The independent variables are *Post*, *Log(Intensity1+1)*, *Asia*, *North America* and *Europe*. Panel B tests the effect of carbon pricing on firm performance conditional on energy intensity of a country. The independent variables are *Post*, *Log(Intensity1+1)*, *Energy intensity*, and *Energy use*. Panel C tests the effect of carbon pricing on firm performance conditional on a country's exposure to physical climate risk. The independent variables are *Post*, *Log(Intensity1+1)*, *ND_vulnerability*, and *ND_gain*. Control variables are the same as in Table 3. All variables are defined in Appendix A. All regressions include firm and year fixed effects. Numbers in parentheses are *t*-statistics based on standard errors clustered at firm level. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

Panel A: Heterogeneity based on geographic regions

Variables	ROA (1)	ROE (2)
Post*Log(Intensity1+1)*Asia	-0.0023	-0.0070
	(-1.398)	(-1.367)
Post*Asia	0.0290***	0.0790***
	(4.217)	(3.963)
Log(Intensity1+1)*Asia	0.0014	0.0039
	(0.731)	(0.774)
Post*Log(Intensity1+1)*North America	-0.0057***	-0.0158***
	(-2.954)	(-2.669)
Post*North America	0.0475***	0.1295***
	(6.101)	(5.720)
Log(Intensity1+1)*North America	-0.0029	-0.0133**
	(-1.261)	(-2.084)
Post*Log(Intensity1+1)*Europe	-0.0010	-0.0015
	(-0.589)	(-0.270)
Post*Europe	0.0232***	0.0525**
	(3.154)	(2.324)
Log(Intensity1+1)*Europe	0.0002	-0.0014
	(0.093)	(-0.229)
Post*Log(Intensity1+1)	0.0003	0.0012
	(0.185)	(0.252)
Post	-0.0165**	-0.0459**
	(-2.503)	(-2.393)
Log(Intensity1+1)	-0.0020	-0.0045
	(-1.115)	(-0.959)
Controls	YES	YES
Firm FEs	YES	YES
Year FEs	YES	YES
Adjusted R^2	0.6219	0.4938
Observations	104,100	104,100

Panel B: Heterogeneity based on a country's energy intensity and energy use

Variables	ROA (1)	ROA (2)	ROE (4)	ROE (5)
Post*Log(Intensity1+1)*Energy intensity	-0.0006**		-0.0020**	
	(-2.168)		(-2.505)	
Post*Energy intensity	0.0017		0.0051*	
	(1.560)		(1.712)	
Post*Log(Intensity1+1)	0.0008	0.0009	0.0039	0.0053
	(0.617)	(0.652)	(0.990)	(1.207)
Log(Intensity1+1)*Energy intensity	0.0008***		0.0017**	
	(2.720)		(2.279)	
Post	0.0051	-0.0066	0.0100	-0.0302*
	(0.974)	(-1.251)	(0.668)	(-1.782)
Log(Intensity1+1)	-0.0051***	-0.0007	-0.0128***	0.0014
	(-3.406)	(-0.508)	(-3.287)	(0.338)
Energy intensity	-0.0066***		-0.0173***	
	(-4.147)		(-3.794)	
Post*Log(Intensity1+1)*Energy use		-0.0007**		-0.0025***
		(-2.091)		(-2.592)
Post*Energy use		0.0045***		0.0154***
		(3.662)		(4.001)
Log(Intensity1+1)*Energy use		-0.0001		-0.0011
		(-0.368)		(-1.207)
Energy use		-0.0037**		-0.0152***
		(-1.977)		(-2.609)
Controls	YES	YES	YES	YES
Firm FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Adjusted R^2	0.6175	0.5707	0.4915	0.4322
Observations	99,177	48,679	99,177	48,679

Panel C: Heterogeneity based on a country's exposure to physical climate risk

Variables	ROA (1)	ROA (2)	ROE (3)	ROE (4)
Post*Log(Intensity1+1)*ND_vulnerability	-0.0092		-0.0276	
	(-0.941)		(-0.924)	
Post*ND_vulnerability	-0.0271		-0.0511	
	(-0.722)		(-0.459)	
Log(Intensity1+1)*ND_vulnerability	0.0272***		0.0810***	
	(3.006)		(3.124)	
Post*Log(Intensity1+1)	0.0013	0.0025	0.0049	0.0118
	(0.381)	(0.595)	(0.450)	(0.907)
Post	0.0217	-0.0327*	0.0501	-0.1002**
	(1.604)	(-1.958)	(1.231)	(-2.060)
Log(Intensity1+1)	-0.0119***	0.0028	-0.0354***	0.0063
	(-3.408)	(0.894)	(-3.507)	(0.696)
ND_vulnerability	-0.0783		-0.3913	
	(-0.758)		(-1.269)	
Post*Log(Intensity1+1)*ND_gain		-0.0001		-0.0003
		(-1.036)		(-1.273)
Post*ND_gain		0.0007***		0.0020***
		(2.655)		(2.673)
Log(Intensity1+1)*ND_gain		-0.0001		-0.0002
		(-1.479)		(-1.291)
ND_gain		-0.0005*		-0.0007
		(-1.666)		(-0.853)
Controls	YES	YES	YES	YES
Firm FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Adjusted R^2	0.6183	0.6183	0.4908	0.4908
Observations	96,506	96,506	96,506	96,506

Table 8 Carbon pricing and analyst earnings forecasts

This table examines the impact of carbon pricing initiatives on analyst earnings forecasts. The dependent variables are *EPS forecast/price* in columns (1) to (3) and *LTG* in column (4). We use the stock price one year prior to carbon pricing enactment year to scale EPS forecasts. Control variables are the same as in Table 3. All variables are defined in Appendix A. All regressions include firm and year fixed effects. The unit of analysis is at firm-year level. Numbers in parentheses are *t*-statistics based on standard errors clustered at firm level. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

Variables	EPS forecast/price			LTG
	1-year ahead	2-year ahead	3-year ahead	
	(1)	(2)	(3)	(4)
Post*Log(Intensity1+1)	-0.0697***	-0.0728***	-0.0816***	0.0010
	(-4.170)	(-4.024)	(-3.757)	(0.663)
Post	0.2643***	0.2519***	0.2377***	-0.0019
	(4.748)	(4.225)	(3.335)	(-0.345)
Log(Intensity1+1)	-0.0209	-0.0231	-0.0322	0.0029
	(-1.077)	(-1.044)	(-1.145)	(1.572)
Controls	YES	YES	YES	YES
Firm FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Adjusted R^2	0.8671	0.8768	0.8792	0.2754
Observations	76,951	74,576	57,315	49,736

Table 9 Carbon pricing, cost of capital, and firm-level climate risk exposure

This table examines the impact of carbon pricing initiatives on cost of capital and firm-level climate change exposure. Panel A shows the effects of carbon pricing initiatives on cost of capital. The dependent variables are *Interests/Debt* and *r_mpeg*. Panel B examines the effects of carbon pricing initiatives on firm-level climate risk exposure, as constructed by Sautner et al. (2023). The dependent variables in Panel B are *Regulatory risk* and *Physical risk*. Control variables are the same as in Table 3. All variables are defined in Appendix A. All regressions include firm and year fixed effects. Numbers in parentheses are *t*-statistics based on standard errors clustered at firm level. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

Panel A: The effects of carbon pricing on cost of capital

Variables	Cost of debt	Implied cost of equity
	Interests/Debt	r_mpeg
	(1)	(2)
Post*Ln(Intensity+1)	0.0009**	0.0022*
	(2.138)	(1.921)
Post	-0.0019	-0.0046
	(-1.101)	(-1.206)
Ln(Intensity+1)	0.0002	0.0045***
	(0.293)	(3.529)
Controls	YES	YES
Firm FEs	YES	YES
Year FEs	YES	YES
Adjusted R^2	0.5324	0.8444
Observations	96,184	78,711

Panel B: The effects of carbon pricing on firm-level climate risk exposure

Variables	Regulatory risk	Physical risk
	(1)	(2)
Post*Log(Intensity1+1)	0.0010***	0.0001
	(3.352)	(1.536)
Post	-0.0024***	0.0001
	(-3.595)	(0.536)
Log(Intensity1+1)	0.0001	-0.0001
	(0.476)	(-0.970)
Controls	YES	YES
Firm FEs	YES	YES
Year FEs	YES	YES
Adjusted R^2	0.4596	0.2815
Observations	41,140	41,140

Table 10 Carbon pricing and firm value

This table examines the effect of carbon pricing initiatives on firm value. The dependent variable in column (1) is Tobin's *q*. In column (2), *Ret_annual* is the cumulative return from July of year *t* to June of year *t*+1. Control variables are the same as in Table 3. All variables are defined in Appendix A. All regressions include firm and year fixed effects. Numbers in parentheses are *t*-statistics based on standard errors clustered at firm level. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

Variables	Tobin's *q*	Ret_annual
	(1)	(2)
Post*Log(Intensity1+1)	-0.0179***	-0.0149***
	(-2.672)	(-6.597)
Post	0.0087	0.0904***
	(0.282)	(10.386)
Log(Intensity1+1)	-0.0133	0.0063**
	(-1.406)	(2.149)
Controls	YES	YES
Firm FEs	YES	YES
Year FEs	YES	YES
Adjusted R^2	0.7959	0.1476
Observations	78,711	104,074

Table 11 Carbon pricing, real investment, and financial constraints

This table examines the effects of carbon pricing initiatives on other firm outcomes. Panel A reports the results on firm investments. The dependent variables are *CapEx_assets*, *R&D_sales*, and *Employees_sales*. Control variables are the same as in Table 3 excluding *CapEx_assets* and *R&D_sales* for columns (1) and (2). Panel B reports the results on firms' cash holdings and leverage. The dependent variables are *Cash* and *Leverage*. Control variables are the same as in Table 3 but exclude *Cash* and *Leverage* for columns (1) and (2), respectively. Panel C reports results on financial constraints, measured by the cash flow sensitivity of cash. Control variables are the same as in Table 3 but exclude *Cash*. All variables are defined in Appendix A. All regressions include firm and year fixed effects. Numbers in parentheses are *t*-statistics based on standard errors clustered at firm level. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

Panel A: Effects on firm-level investments

Variables	CapEx_assets (1)	R&D_sales (2)	Employees_sales (3)
Post*Log(Intensity1+1)	-0.0008***	-0.0004**	-0.0767***
	(-2.820)	(-2.273)	(-3.837)
Post	0.0016	0.0038***	0.3982***
	(1.596)	(3.969)	(5.173)
Log(Intensity1+1)	-0.0003	0.0001	0.1264***
	(-0.855)	(0.254)	(3.424)
Controls	YES	YES	YES
Firm FEs	YES	YES	YES
Year FEs	YES	YES	YES
Adjusted R^2	0.6620	0.9285	0.8859
Observations	104,100	104,100	89,537

Panel B: Effects on firm-level cash holdings and leverage

Variables	Cash (1)	Leverage (2)
Post*Log(Intensity1+1)	0.0024***	-0.0009
	(2.999)	(-0.932)
Post	-0.0059*	-0.0008
	(-1.732)	(-0.208)
Log(Intensity1+1)	-0.0016*	0.0038***
	(-1.801)	(3.484)
Controls	YES	YES
Firm FEs	YES	YES
Year FEs	YES	YES
Adjusted R^2	0.8259	0.8217
Observations	104,100	104,100

Panel C: Effects on the cash flow sensitivity of cash

Variables	Cash
	(1)
Post*Log(Intensity1+1)*Operating cash flow	0.0112***
	(3.522)
Post*Log(Intensity1+1)	0.0014*
	(1.653)
Log(Intensity1+1)*Operating cash flow	0.0018
	(0.486)
Post	-0.0061*
	(-1.738)
Log(Intensity1+1)	-0.0013
	(-1.340)
Operating cash flow	0.1434***
	(9.934)
Tobin's Q $_{(t-1)}$	0.0061***
	(8.289)
Controls	YES
Firm FEs	YES
Year FEs	YES
Adjusted R^2	0.8297
Observations	101,596

Internet Appendix to “The Effect of Carbon Pricing on Firm Performance: Worldwide Evidence”

Table IA.1 Sample distribution by country
This table reports the distribution of firm-years by country over the period 2002-2019. Column (1) reports the number of firm-years in each country. Column (2) reports the percentage of firm-years for a country in the whole sample. Column (3) reports the number of unique firms in each country. Columns (4) to (6) report the average firm-level carbon intensity in a country.

Country	# Observations	Percentage	# Firms	Intensity1	Intensity2	Intensity3
	(1)	(2)	(3)	(4)	(5)	(6)
Argentina	108	0.10	14	785.3123	91.4165	244.5207
Australia	3,291	3.16	475	231.2504	60.4136	147.3684
Austria	407	0.39	45	267.6833	51.9160	197.7117
Belgium	586	0.56	74	143.8956	49.3037	179.0181
Brazil	1,348	1.29	174	290.0400	30.8120	193.0702
Canada	3,138	3.01	461	343.9316	61.9778	150.1527
Chile	441	0.42	44	552.6510	39.4075	155.6507
China	8,795	8.45	2,119	332.6440	45.1347	203.3084
Colombia	144	0.14	17	493.2355	31.6822	274.5233
Denmark	513	0.49	57	100.3774	26.1787	202.2821
Egypt	339	0.33	38	838.1683	57.9928	264.4201
Finland	627	0.60	70	158.6092	47.0165	236.4033
France	2,477	2.38	297	185.4023	34.4698	180.2105
Germany	2,132	2.05	275	141.9606	38.3391	181.5346
Greece	284	0.27	39	625.4156	32.0199	149.8504
Hong Kong	2,671	2.57	422	438.6479	51.7428	169.2285
India	3,582	3.44	589	703.4733	46.0475	239.4810
Indonesia	995	0.96	164	674.3483	59.4045	227.2659
Ireland	558	0.54	61	106.9213	25.9038	186.8217
Israel	793	0.76	149	98.1689	30.9947	134.3372
Italy	1,140	1.10	159	287.4067	38.3181	181.7780
Japan	14,525	13.95	2,454	138.3309	39.0482	210.8256
Kenya	78	0.07	11	204.5067	9.3341	80.5781
Luxembourg	224	0.22	38	172.3895	41.0998	243.2740
Malaysia	1,155	1.11	194	385.4054	58.8170	279.1756
Mexico	683	0.66	88	533.9277	44.3716	254.4779
Morocco	180	0.17	18	236.6902	66.1130	237.6339
Netherlands	872	0.84	104	1634.7270	87.8149	322.1230

New Zealand	339	0.33	64	79.3690	30.0181	171.6303
Nigeria	152	0.15	21	244.6262	28.7468	156.4621
Norway	618	0.59	96	700.8847	43.9636	321.8745
Pakistan	363	0.35	60	197.0351	45.6450	206.0831
Peru	130	0.12	15	1213.3930	63.5297	284.8164
Philippines	590	0.57	79	1417.0840	130.6846	158.7644
Poland	592	0.57	77	666.2277	65.3869	182.2249
Portugal	186	0.18	20	496.3057	49.4502	175.1722
Qatar	161	0.15	32	726.9752	54.8247	193.5843
Russian Federation	407	0.39	51	627.6118	36.9375	125.6682
Saudi Arabia	240	0.23	121	917.2562	80.7886	250.5138
Singapore	783	0.75	107	1043.7990	87.4802	235.3296
South Africa	1,635	1.57	170	184.5360	44.2747	152.7969
South Korea	6,505	6.25	1,071	241.9989	117.9901	175.9738
Spain	894	0.86	99	240.3094	35.2745	185.0405
Sweden	1,375	1.32	213	54.7495	29.7206	171.1873
Switzerland	1,905	1.83	225	92.8645	29.2586	193.5883
Taiwan	4,923	4.73	817	203.5948	55.6778	220.7177
Thailand	1,206	1.16	206	702.4802	46.4362	197.5894
Turkey	684	0.66	103	699.5670	63.7244	241.3075
United Arab Emirates	173	0.17	38	87.6462	28.4321	114.4343
United Kingdom	6,268	6.02	658	124.8551	38.1932	164.7486
United States	21,763	20.91	3,208	226.8207	34.0172	161.0140
Vietnam	122	0.12	21	389.3751	42.5962	338.7267
Total	104,100	100	16,222	268.2640	43.4775	191.3307

Table IA.2 The effects of carbon pricing initiatives on firm-level carbon intensity

This table examines the effect of carbon pricing initiatives on firm-level carbon intensity over the period 2002-2019. The dependent variables are *Log(Intensity1)*, *Log(Intensity2)*, and *Log(Intensity3)*. The independent variable is *Post*. Control variables are the same as in Table 3. All variables are defined in Appendix A. All regressions include firm and year fixed effects. Numbers in parentheses are *t*-statistics based on standard errors clustered at firm level. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

Variables	Log(Intensity1)	Log(Intensity1)	Log(Intensity2)	Log(Intensity2)	Log(Intensity3)	Log(Intensity3)
	(1)	(2)	(3)	(4)	(5)	(6)
Post	-0.0848***	-0.0841***	-0.0501***	-0.0506***	-0.0083	-0.0083
	(-5.079)	(-5.035)	(-3.053)	(-3.080)	(-1.567)	(-1.572)
Controls	NO	YES	NO	YES	NO	YES
Firm FEs	YES	YES	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES	YES	YES
Adjusted R^2	0.9337	0.9338	0.8440	0.8445	0.9759	0.9759
Observations	103,991	103,991	104,025	104,025	104,100	104,100

Table IA.3 Using dummy variables to indicate firms with high and low carbon emissions
This table reports baseline results but using dummy variables to indicate high and low emission firms. In Panel A, the high emission firms are indicated by the variable D(Intensity1>Median), which equals one if the firm's carbon intensity is above median. In Panel B, we use two dummy variables, D(Intensity1=Top quartile) and D(Intensity1=Bottom quartile), to indicate firms with high and low carbon intensity, respectively. Control variables are the same as in Table 3. All variables are defined in Appendix A. All regressions include firm and year fixed effects. Numbers in parentheses are *t*-statistics based on standard errors clustered at firm level. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

Panel A: Using dummy variable to indicate firms with above-median (scope 1) carbon intensity

Variables	ROA	ROA	ROE	ROE
	(1)	(2)	(3)	(4)
Post*D(Intensity1>Median)	-0.0044***	-0.0055***	-0.0111**	-0.0123***
	(-2.814)	(-3.724)	(-2.436)	(-2.755)
Post	0.0096***	0.0099***	0.0235***	0.0232***
	(6.981)	(7.710)	(5.824)	(5.834)
D(Intensity1>Median)	-0.0005	-0.0000	-0.0016	-0.0010
	(-0.309)	(-0.034)	(-0.376)	(-0.238)
Controls	NO	YES	NO	YES
Firm FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Adjusted R^2	0.5663	0.6209	0.4590	0.4924
Observations	104,100	104,100	104,100	104,100

Panel B: Using Top and bottom quartile dummies to indicate high and low emission firms

	ROA	ROA	ROE	ROE
	(1)	(2)	(3)	(4)
Post*D(Intensity1=Top quartile)	-0.0054***	-0.0088***	-0.0159***	-0.0214***
	(-2.617)	(-4.695)	(-2.679)	(-3.802)
Post*D(Intensity1=Bottom quartile)	0.0013	0.0004	0.0039	0.0017
	(0.714)	(0.209)	(0.721)	(0.304)
Post	0.0084***	0.0092***	0.0209***	0.0218***
	(6.325)	(7.484)	(5.501)	(5.913)
D(Intensity1=Top quartile)	-0.0013	0.0009	-0.0025	0.0012
	(-0.656)	(0.494)	(-0.444)	(0.224)
D(Intensity1=Bottom quartile)	0.0037**	0.0033**	0.0094*	0.0087*
	(2.244)	(2.072)	(1.927)	(1.758)
Controls	NO	YES	NO	YES
Firm FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Adjusted R^2	0.5664	0.6211	0.4591	0.4926
Observations	104,100	104,100	104,100	104,100

Table IA.4 Stacked regression

This table reports the baseline results estimated using the stacked regression approach. The dependent variables are *ROA* and *ROE*. The independent variables are *Post* and *Log(Intensity1+1)*. *Post* is a dummy variable equal to one if the jurisdiction has implemented the carbon pricing initiative (i.e., either the carbon tax or the ETS initiative) in the year, and zero otherwise. *Log(Intensity1+1)* is the natural log of one plus scope 1 carbon intensity. Control variables are the same as in Table 3. Other variables are defined in Appendix A. All regressions include Cohort*Firm fixed effects and Cohort *Year fixed effects. Numbers in parentheses are *t*-statistics based on standard errors clustered at firm level. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

Variable	ROA (1)	ROA (2)	ROE (3)	ROE (4)
Post*Log(Intensity1+1)	-0.0013***	-0.0017***	-0.0042***	-0.0046***
	(-2.739)	(-3.801)	(-2.982)	(-3.473)
Post	0.0130***	0.0127***	0.0330***	0.0309***
	(7.006)	(7.280)	(6.135)	(5.880)
Log(Intensity1+1)	-0.0018***	-0.0012***	-0.0043***	-0.0032***
	(-6.382)	(-4.389)	(-5.621)	(-4.265)
Controls	NO	YES	NO	YES
Cohort*Firm FEs	YES	YES	YES	YES
Cohort*Year FEs	YES	YES	YES	YES
Adjusted R^2	0.5834	0.6354	0.4736	0.5049
Observations	410,382	410,382	410,382	410,382

Table IA.5 The effects of carbon price on firm profitability

This table examines the effect of (continuous) carbon price on firm profitability over the period 2002-2019. Panel A reports the result for the full sample, while Panel B reports the results for the subsample of firms in jurisdictions with carbon pricing policies. The dependent variables are *ROA* and *ROE*. The independent variables are *Log(Carbon tax price+1)*, *Log(ETS price+1)*, and *Log(Intensity1+1)*. Control variables are the same as in Table 3. All variables are defined in Appendix A. All regressions include firm and year fixed effects. Numbers in parentheses are *t*-statistics based on standard errors clustered at firm level. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

Panel A: Full Sample

Variables	ROA (1)	ROE (2)
Log(Carbon tax price+1)*Log(Intensity1+1)	-0.0006***	-0.0013*
	(-2.652)	(-1.855)
Log(ETS price+1)*Log(Intensity1+1)	-0.0004***	-0.0012***
	(-2.724)	(-2.603)
Log(Carbon tax price+1)	0.0029***	0.0021
	(3.248)	(0.834)
Log(ETS price+1)	0.0030***	0.0088***
	(5.344)	(5.106)
Log(Intensity1+1)	-0.0018***	-0.0054***
	(-3.143)	(-3.308)
Controls	YES	YES
Firm FEs	YES	YES
Year FEs	YES	YES
Adjusted R^2	0.6211	0.4927
Observations	104,100	104,100

Panel B: Subsample of firms in jurisdictions with carbon pricing policies

Variables	ROA (1)	ROE (2)
Log(Carbon tax price+1)*Log(Intensity1+1)	-0.0009***	-0.0019**
	(-3.073)	(-2.157)
Log(ETS price+1)*Log(Intensity1+1)	-0.0001	-0.0006
	(-0.694)	(-1.093)
Log(Carbon tax price+1)	0.0034***	0.0030
	(3.046)	(0.964)
Log(ETS price+1)	0.0009	0.0054***
	(1.337)	(2.614)
Log(Intensity1+1)	-0.0012	-0.0049*
	(-1.227)	(-1.748)
Controls	YES	YES
Firm FEs	YES	YES
Year FEs	YES	YES
Adjusted R^2	0.6447	0.5427
Observations	46,257	46,257

Table IA.6 Carbon pricing and industry-level profitability

This table examines the impacts of carbon pricing initiatives on industry-level profitability. The dependent variables are jurisdiction-industry-year average *ROA*, *ROE*, *CGS_sales*, and *Sales growth*. The key independent variables are *Post* and the natural log of jurisdiction-industry-year average carbon intensity *Log (Average intensity1+1)*. All control variables are computed as jurisdiction-industry-year average values. All variables are defined in Appendix A. All regressions include jurisdiction by industry and year fixed effects. The unit of analysis is at jurisdiction-industry-year level. Numbers in parentheses are *t*-statistics based on standard errors clustered at jurisdiction-industry level. Sample period is from 2002 to 2019. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

Variables	Average ROA	Average ROE	Average CGS_sales	Average Sales growth
	(1)	(2)	(3)	(4)
Post*Log(Average intensity1+1)	-0.0029***	-0.0058**	0.0060	-0.0081*
	(-3.270)	(-2.099)	(1.634)	(-1.807)
Post	0.0135***	0.0267**	-0.0276	0.0511***
	(3.369)	(2.119)	(-1.601)	(2.996)
Log(Average intensity1+1)	0.0002	-0.0037	0.0042	-0.0006
	(0.134)	(-1.160)	(0.935)	(-0.106)
Controls	YES	YES	YES	YES
Jurisdiction*Industry FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Adjusted R^2	0.5292	0.4157	0.7530	0.2340
Observations	9,687	9,687	9,185	9,687

Table IA.7 The effect of carbon pricing on analyst forecast error

This table examines the impact of carbon pricing initiatives on analyst EPS forecast error. The dependent variables are *signed forecast errors* for 1-year to 3-year ahead EPS in columns (1) to (3). Signed forecast error is calculated as the difference between actual EPS and the earliest available consensus forecast of EPS scaled by the absolute value of actual EPS. Control variables are the same as in Table 3. All variables are defined in Appendix A. All regressions include firm and year fixed effects. The unit of analysis is at firm-year level. Numbers in parentheses are *t*-statistics based on standard errors clustered at firm level. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

	Signed Forecast Error		
Variables	1-year ahead EPS	2-year ahead EPS	3-year ahead EPS
	(1)	(2)	(3)
Post*Log(Intensity1+1)	-0.0196	-0.0192	0.0214
	(-1.419)	(-0.678)	(0.432)
Post	0.1810***	0.3339***	0.3992**
	(3.900)	(3.482)	(2.239)
Log(Intensity1+1)	-0.0163	0.0094	-0.0125
	(-1.058)	(0.312)	(-0.225)
Controls	YES	YES	YES
Firm FEs	YES	YES	YES
Year FEs	YES	YES	YES
Adjusted R^2	0.1460	0.1490	0.1754
Observations	84,056	79,814	61,238