Burn Now or Never? Climate Change Exposure and Investment of Fossil Fuel Firms*

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Abstract

We investigate the impact of expectations about future climate policy on investment decisions of fossil fuel firms. Our empirical analysis, which employs a differences-in-differences approach, reveals that firms in the fossil fuel industry with greater exposure to climate change significantly increased their investment in response to the Paris Agreement, compared to firms with lower exposure. Importantly, investment was directed towards traditional activities in the fossil fuel industry. By contrast, there are no indications that firms invested to transition towards renewable energy sources nor in making production less carbon-intensive. Our findings contribute to the ongoing discussion about the potential adverse effects of delays in the implementation of climate regulation. More specifically, it lends support to the "Green Paradox" hypothesis, which would predict that in anticipation of future climate policy, fossil fuel firms have a short-term incentive to raise production.

Keywords: climate change, fossil fuels, policy, investment, green paradox

JEL classification: G31, G38, Q58.

Non-Technical Summary

How do fossil fuel firms react to expected climate policies? Fossil fuels remain the predominant source of energy despite high carbon dioxide (CO_2) emissions and the contribution to global warming. Therefore, the International Energy Agency estimates that the use of fossil fuels would need to be reduced by more than 25% in this decade and by 80% before 2050 to limit global warming to temperature rises below 1.5 °C (IEA, 2023). The 2015 Paris Agreement, a global pact aiming for carbon neutrality, has raised concerns about the future of the fossil fuel industry. The increased likelihood of stringent regulation limiting the consumption of fossil fuels raises questions on whether fossil fuel firms would adjust their business plans and investment decisions during the transition period. Against this background, we aim to understand how fossil fuel companies changed their investment pattern during the post-2015 period in view of expected changes related to climate policy. In this paper, we aim to pin down the reaction of fossil fuel firms to changes in expected climate policy. We apply a differences-in-differences approach where we exploit the Paris Agreement in 2015 and intra-sector variation in climate change exposure to determine how fossil fuel firms reshape investment paths when facing a climate policy shock that would alter expectations concerning future demand and production costs.

To identify variation in climate change exposure, we employ a text based measure developed by Sautner, Van Lent, Vilkov, and Zhang (2023), that enables us to distinguish between fossil fuel firms with low and high exposure to climate change. The climate change exposure measure captures the extent to which firms' management and financial analysts discuss broadly defined aspects of climate change (related to opportunity, physical, and regulatory shocks) in earnings calls. The measure is constructed using textual analysis and machine learning based on a short list of initial keywords associated with climate change. Because it relies on the frequency of climate change topics in conversations, this is a soft measure of climate change exposure.

Importantly, the measure captures the perception and awareness expressed by management regarding various facets of climate change as well as their communication strategies on such topics. We argue that this is the relevant metric for our empirical exercise for two reasons: First, responses to anticipated shifts in climate policy are contingent on management perceptions about their firm's exposure to the policy. Second, hard measures of climate change, such as CO_2 emissions, fail to account for key dimensions of the investment response function to changes in climate policy such as changes in future expected demand for fossil fuel products.

The main finding of this paper is that fossil fuel firms with high exposure to climate change responded to expected changes in future climate policies by raising investment relative to firms with low exposure. We find that investment for firms with high climate change exposure has been between 30% and 40% higher relative to firms with low climate change exposure after the Paris Agreement. Our results align with the prediction that fossil fuel firms are initially inclined to intensify extraction in response to the expected introduction of stringent carbon policies that would impact their operations in the future.

Additionally, we show that the positive reaction of investment to climate change policy in highly exposed fossil fuel firms predominantly rests on firms that invest in the extraction of fossil fuels as opposed to firms that also engage in other types of investment. This result lends further support to the finding that fossil fuel firms with high climate change exposure appear to continue with their traditional business models over transitioning to renewable energy sources. Furthermore, we observe that these firms increased their emissions relative to the fossil fuel firms with lower exposure, further reinforcing the idea that these companies did not investment with the purpose of reducing the carbon-intensity of their production processes in response to the Paris Agreement.

Our findings have important policy implications. Firstly, multilateral climate policy deals such as the Paris Agreement should optimally be accompanied by concrete policy measures and a limited implementation time lag to prevent unwarranted consequences on the environment. Secondly, in the absence of such features, the global economy might find itself increasingly dependent on fossil fuels during some phases of the green transition, with only limited incentives for fossil fuel firms to invest in transforming their business models. Consequently, governments might be compelled to enforce more abrupt policy measures as climate target deadliness draw near. This in turn could create a period of higher energy price volatility and economic losses. Thus, governments face a delicate balancing act, needing to advance the climate change agenda while averting energy cost-push pressures during the transition period.

1 Introduction

How do fossil fuel firms react to expected climate policies? Fossil fuels remain the predominant source of energy despite high carbon dioxide (CO_2) emissions and the contribution to global warming. Therefore, the International Energy Agency estimates that the use of fossil fuels would need to be reduced by more than 25% in this decade and by 80% before 2050 to limit global warming to temperature rises below 1.5 °C (IEA, 2023). The 2015 Paris Agreement, a global pact aiming for carbon neutrality, has raised concerns about the future of the fossil fuel industry. The increased likelihood of stringent regulation limiting the consumption of fossil fuels raises questions on whether fossil fuel firms would adjust their business plans and investment decisions during the transition period. Against this background, we aim to understand how fossil fuel companies changed their investment pattern during the post-2015 period in view of expected changes related to climate policy.

Judging the impact of expected climate policies on fossil fuel investment is not straight-forward because fossil fuel firms may react in two opposite ways. On the one hand, firms may curtail operations and withdraw from fossil fuel exploration and extraction activities due to lower expected future demand and escalating production expenses stemming from climate change mitigation taxation. On the other hand, firms could decide to raise investment to exploit resources and secure profits until more forceful policy measures are implemented. This type of behaviour has been referred to as the "Green Paradox" (Sinn, 2008, 2012).

In this paper, we aim to pin down the reaction of fossil fuel firms to changes in expected climate policy. We apply a differences-in-differences approach where we exploit the Paris Agreement in 2015 and intra-sector variation in climate change exposure to determine how fossil fuel firms reshape investment paths when facing a climate policy shock that would alter expectations concerning future demand and production costs.

To identify variation in climate change exposure, we employ a text based measure developed by Sautner et al. (2023), that enables us to distinguish between fossil fuel firms with low and high exposure to climate change. The climate change exposure measure captures the extent to which firms' management and financial analysts discuss broadly defined aspects of climate change (related to opportunity, physical, and regulatory shocks) in earnings calls. The measure is constructed using textual analysis and machine learning based on a short list of initial keywords associated with climate change. Because it relies on the frequency of climate change topics in conversations, this is a soft measure of climate change exposure.

Importantly, the measure captures the perception and awareness expressed by management regarding various facets of climate change as well as their communication strategies on such topics. For ease of reference, we will refer to this measure as "climate change exposure" throughout the rest of the paper. We argue that this is the relevant metric for our empirical exercise for two reasons: First, responses to anticipated shifts in climate policy are contingent on management perceptions about their firm's exposure to the policy. Second, hard measures of climate change, such as CO_2 emissions, fail to account for key dimensions of the investment response function to changes in climate policy such as changes in future expected demand for fossil fuel products.

The main finding of this paper is that fossil fuel firms with high exposure to climate change responded to expected changes in future climate policies by raising investment relative to firms with low exposure.[1] We find that investment for firms with high climate change exposure has been between 30% and 40%

[1] We differentiate between two groups of fossil fuel firms by distinguishing between firms with climate change exposure below and above the median in our pre-treatment period, 2010-15. We denote the first group low exposure firms and the latter high exposure firms.

higher relative to firms with low climate change exposure after the Paris Agreement. Our results align with the prediction that fossil fuel firms are initially inclined to intensify extraction in response to the expected introduction of stringent carbon policies that would impact their operations in the future.

Moreover, we also find that investment was stronger in the group of fossil fuel firms where the perceived climate change exposure was positive. We arrive at this result by varying the climate change exposure measure in our set-up to capture various upside and downside factors related to climate change.

Lastly, we show that the positive reaction of investment to climate change policy in highly exposed fossil fuel firms predominantly rests on firms that invest in the extraction of fossil fuels as opposed to firms that also engage in other types of investment. This result lends further support to the finding that fossil fuel firms with high climate change exposure appear to continue with their traditional business models over transitioning to renewable energy sources. Furthermore, we observe that these firms increased their emissions relative to the fossil fuel firms with lower exposure, reinforcing the idea that these companies did not invest with the purpose of reducing the carbon-intensity of their production processes in response to the Paris Agreement.

Having established that fossil fuel firms with high climate change exposure invested more after the Paris Agreement, we conduct a series of tests to validate the robustness of our results and tackle potential endogeneity concerns: (i) We provide supportive evidence that the key parallel trends assumption holds. The assumption posits that in the absence of expected changes in climate policy following the Paris Agreement, investment of both the treatment and the control group would have been similar. Our analysis reveals that pre-Paris trends in investment for the two groups followed similar trajectories. (ii) Our results are robust to controlling for observed differences in firm characteristics. In our sample, treated firms are, on average, larger than firms in the control group. That could raise concerns that investment trends in larger and smaller firms would not have followed parallel paths in the absence of the Paris Agreement. It is plausible for large firms to be better equipped to navigate the challenges posed by stricter climate policies, potentially resulting in higher investment in these firms. However, when controlling for different trends in investment based on firm size, our results remain consistent with the baseline specification, both in terms of significance and economic magnitude. (iii) Our findings are not driven by the large drop in oil prices that occurred around the same time as the Paris Agreement. Firms' investment sensitivity to changes in oil prices constitute an omitted variable that could potentially bias our results. For example, firms characterized by high climate change exposure might exhibit lower sensitivity to fluctuations in oil prices, potentially resulting in a lesser reduction in investment in response to a decline in oil prices. To mitigate this concern, we introduce several proxies for oil price sensitivity into our empirical specifications and find that our results are robust to these alternative specifications. (iv) Expectations about timeline and stringency of future climate change regulation are likely to vary by geographic location. For instance, relative to North America, European countries stand out for their proactive stance on climate policies. Accordingly, we would expect a stronger impact of the Paris Agreement on European firms. This conjecture is confirmed when running our specification differentiating between the two regions. (v) Lastly, we corroborate our findings when applying a propensity matching score procedure. This test addresses lingering concerns about observable differences between the treatment and control groups. Additionally, our results remain robust to alternative tests (e.g., varying the definition of the fossil fuel company, balanced vs unbalanced panel of firms, pre-pandemic sample).

The findings of this paper lend support to the Green Paradox hypothesis, while they stand in opposition to the results of Bogmans, Pescatori, and Prifti (2023). Bogmans et al. (2023) argue that fossil fuel firms have preemptively reduced investment in reaction to the prospects of lower future demand posed by the Paris Agreement. To the best of our knowledge, Bogmans et al. (2023) is the paper that comes closest to our work because the authors also study fossil fuel investment after the Paris Agreement using a differences-in-differences set-up. However, while we focus exclusively on fossil fuel firms and exploit variation in climate change exposure within the industry, Bogmans et al. (2023) aim to understand the reaction of fossil fuel firm investment to climate policy by using non-fossil fuel firms as a control group. We depart from their approach because the drop in oil prices around the Paris Agreement is likely to have supported investment of non-fossil fuels companies, which benefited from lower energy costs, while in contrast it likely weighed on the profitability of fossil firms and deterred their investment. Moreover, the exposure of fossil fuel firms to climate policies is fundamentally different compared to the rest of the economy because they are the producer of the energy input that climate policies eventually strive to phase out.

Notably, our findings also contribute to the literature investigating the impact of expected oil price volatility on drilling. In particular, Kellogg (2014) found that such uncertainty typically leads to a reduction in drilling, leveraging data predating the Paris Agreement. Our findings complement these results, by suggesting that price uncertainly driven by long term policy shifts can lead to fundamentally different outcomes.

Our findings have important policy implications. Firstly, multilateral climate policy deals such as the Paris Agreement should optimally be accompanied by concrete policy measures and a limited implementation time lag to prevent unwarranted consequences on the environment. Secondly, in the absence of such features, the global economy might find itself increasingly dependent on fossil fuels during some phases of the green transition, with only limited incentives for fossil fuel firms to invest in transforming their business models. Consequently, governments might be compelled to enforce more abrupt policy measures as climate target deadliness draw near. This in turn could create a period of higher energy price volatility and economic losses. Thus, governments face a delicate balancing act, needing to advance the climate change agenda while averting energy cost-push pressures during the transition period.

The paper proceeds as follows: Section 2 briefly introduces the predictions of the Green Paradox. Section 3 presents the empirical design and the data, while Section 4 discusses our results together with a comprehensive set of robustness tests. Section 5 discusses the policy implications of our results by running a counterfactual analysis of fossil fuel investment in a stable macroeconomic environment. Section 6 concludes.

2 The Green Paradox

This paper is closely linked to the theoretical literature on the "Green Paradox", an idea introduced by Sinn (2008), who built on the work of Hotelling (1931), to illustrate how policies to address climate change may have unwarranted consequences. In short, the paradox pertains to the hypothesis that well-intentioned climate policies aimed at reducing carbon emissions could paradoxically lead to an increase in emissions instead. The paradox arises from the interaction between market forces, fossil fuel scarcity, and the expectations of resource owners regarding future climate policies.

Fossil fuel producers, anticipating future regulation that would reduce the demand for their resources, may accelerate their extraction rates in the present to maximize their profits before the price of fossil fuels plummets. This premature extraction counteracts the intended effect of climate policies, potentially leading to an overall increase in carbon emissions in the short term.

We briefly introduce the concept through a cash flow tax borrowing from Sinn (2008). Consider a fossil fuel firm maximizing the stream of cash flows:[2]

$$\begin{array}{ll} \max\limits_{R} & V = \int_0^\infty \theta(0)\left[P(u) - c(S(u))\right] R(u) e^{-(i-\hat{\theta}))u} du \\ \text{s.t.} & \dot{S} = -R \\ & S(0) = S_0 \end{array} \tag{1}$$

Changes in the stock of fossil fuel reserves, $\dot{S}$, follow from the firm's choice of fossil fuel extraction, R, such that it maximizes the extraction-generated cash flow, where $P = P(R,t)$ is the unit price of the fossil fuel and $c(S)$ is extraction costs per unit of the fossil fuel. i is the interest rate on capital. We consider the example of a tax on cash flows, $\tau(t)$, with a tax factor, $\theta = 1 - \tau$ that changes at a constant rate, $\hat{\theta}$, to illustrate the Green Paradox. We also assume no technological progress such that $P(R,t) = P(R)$. Optimality implies that in every period, the firm must be indifferent between extracting one unit of fossil fuel today and investing the money in the capital market yielding the return, $(1+i)(P-c(S))$, or alternatively postponing extraction by one period to obtain a return from the change in the fossil fuel price but taking the return from the growth in the cash flow tax into account, $\dot{P} + (1+\hat{\theta})(P - c(S))$.[3] By rearranging this condition and using that the price elasticity of demand is $\varepsilon(R,t) = -\frac{\partial R}{\partial P}\frac{P}{R}$, the slope of the (R,S)-curve can easily be derived:

$$\frac{dR}{dS} = \varepsilon(R)(i - \hat{\theta})\left(1 - \frac{c(S)}{P}\right) \tag{2}$$

Eq. (2) illustrates the essence of the Green Paradox, namely that if the tax rate is expected to grow, $\hat{\theta} < 0$, the slope of the (R,S)-curve is steeper than in the case of a constant tax rate or in the absence of a tax.[4] That is, if fossil fuel firms expect the cash flow tax rate to grow, they would have an incentive to move to a higher extraction path. The author thus stresses that effective climate policies should not just be designed to reduce demand, but also to flatten the supply curve, making equilibrium prices less reactive to demand reductions.

The hypothesis has spurred a wider debate in the climate economics literature, delving into the validity of the theoretical argument and its resulting policy implications. Jensen et al. (2015) extended the theoretical analysis to explore the mechanism driving potential paradoxical reactions to climate policy. Their findings reveal that whether economic theory predicts such a reaction depends on assumptions. Specific factors such as extraction costs, the availability of alternative energy sources, and the precise implementation of climate policies can play a crucial role, suggesting that the Green Paradox is a conceivable rather than a definite outcome.

Bauer et al. (2018) further delve on the impact of climate policies on fossil fuel investment, highlighting that the lag between announcement and implementation of climate policies can generate two distinct, and opposite, behavioural responses. While they recognise the possibility of the Green Paradox materialising, they also analyse the role divestment effects could play. The latter pertain to the expectation that future taxes on emissions would make the operation of highly emitting power plants uncompetitive, thus putting downward pressures on fossil fuel investments. Under this scenario, emissions would decrease as fossil fuel producers divest away from infrastructure that is at risk of becoming a stranded asset and search

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[2] We assume that $i > \hat{\theta} > k$ where $k < 0$ and that the transversality condition holds.

[3] $\theta(0)$ drops out of the optimization problem due to the neutrality of a constant cash flow tax.

[4] Eq. (2) could also be derived using optimal control theory and similar results could easily be obtained from the introduction of a consumption tax under the condition that the consumption tax satisfies the condition, $\hat{\tau}^c > i\frac{c(\tilde{S})}{P(\tilde{R})}$ where $(\tilde{R}, \tilde{S})$ is the extraction path from before the change in the tax, as shown by Sinn (2008).

for alternative investment opportunities. The authors investigate the potential outcomes resulting from these counteracting effects on near-term aggregate emissions using two multi-regional global models. For a wide range of future climate policies, they find that anticipation effects reduce emissions in line with the divestment effect hypothesis, while the Green Paradox effect plays a smaller role under reasonable assumptions. They argue that these results stem from the fact that the divestment effect would intensify and dominate as climate policies pick up and the policy implementation date approaches, while the Green Paradox effect would materialise directly after the policy announcement. They find that the Green Paradox effect gains prominence as the implementation lag exceeds ten years and when climate policies are weak, making strong and timely signals from policymakers crucial to determine outcomes.

Overall, while theoretical studies support the existence of a Green Paradox, the magnitude and timing of its effects are contingent on a range of factors. Thus, empirical investigations are crucial to pin down the mechanisms at work.

3 Empirical Design and Data

3.1 Data Sources

3.1.1 Compustat Data

For firm balance sheet data, we rely on Standard & Poor's Compustat North America and Compustat Global, which provide an unbalanced panel of yearly data, encompassing publicly listed firms.[5] We exclude observations with negative values for total assets, sales, property, plant and equipment, or capital expenditures. The period covered is from 2010 to 2021.[6] Throughout the empirical analysis, we identify firms as active in the fossil fuel industry based on classification in one of the following industries: Crude Petroleum and Natural Gas (SIC: 1311), Drilling Oil and Gas Wells (SIC: 1381), Petroleum Refining (SIC: 2911), and Bituminous Coal and Lignite Surface Mining (SIC: 1221).[7] We also restrict the analysis to firms with total assets greater than USD 50 million.

The dependent variable, the investment ratio, is constructed as the fraction of capital expenditures to the previous year's level of property, plant and equipment, i.e. the capital stock, and is expressed in log terms.

$$\log(\text{Inv. Ratio}_{f,t}) = \log\left(\frac{Capex_t}{PP\&E_{t-1}}\right) \tag{3}$$

Additional details on variable construction are outlined in Table A1 of the Appendix.

3.1.2 Climate Change Exposure

We obtain data on firm-level climate change exposure from Sautner, Van Lent, Vilkov, and Zhang (2023, hereafter referred to as SvLVZ). They apply a machine learning keyword discovery algorithm on transcripts from earnings calls to identify bigrams associated with climate change. By counting the relative frequency of these bigrams, both quarterly and annual measures of climate change exposure for over

[5] All variables are converted into USD through the conversion tables made available by Compustat.

[6] Sample period is chosen to reflect the availability of our complementary data sources and because these years encompass well the shift in expected climate change policies.

[7] Our initial filter also includes firms that engage in Bituminous Coal Underground Mining (SIC: 1222), however, all firms from this sector are later eliminated due to missing data from other data sources.

10,000 public firms worldwide are constructed. We focus on the annual data to match the data frequency with other data sources.[8]

Sautner et al. (2023) argue that the measure captures attention financial analysts and management devote to climate change topics. The text-based measure reflects not only objective "hard" information about climate change exposure but also stakeholder perceptions of these risks. Sautner et al. (2023) show that the "soft" information captured by the measure is positively related to carbon emissions and predicts green-tech hiring as well as green patenting. The measure is well suited for our analysis for two reasons: First, investment decisions as a response to expected changes to climate policy should primarily depend on management perception about the exposure of the firm to the policy. Second, in the fossil fuel industry, hard measures of climate change exposure, such as CO_2 emissions, do not take into consideration key components of the investment function. CO_2 emissions fail to account for a potential drop in demand of fossil fuel products from stricter climate policy, which would arguably be a main driver of investment decisions.[9]

Unless indicated otherwise, our analysis uses the main equal-weighted measure of *general* climate change *exposure*.[10] To identify the climate change exposure of fossil fuel firms, we calculate an average of the SvLVZ measure per firm for the pre-Paris period from 2010-2015. For each firm f, we derive:

$$Exposure_f = \frac{1}{n} \sum_{t=2010}^{2015} CCExpo_{f,t} \tag{4}$$

where n is the number of years for which we have data on climate change exposure until 2015.

After obtaining the firm-specific exposure measure, we perform a median split into treatment and control groups. We label the group with an above-median relative frequency of climate change bigrams as *High CC Exposure*.

We prefer a time-invariant exposure measure to avoid firms switching between high and low exposure groups over the sample period. Otherwise, we would have to make assumptions about the timing of a firm's investment response to an increase in climate change exposure. Additionally, our empirical choice to calculate climate change exposure only for the pre-Paris period was made to avoid concerns about reverse causality, i.e. firms discussing their investments in earnings calls in the context of a change to expected climate policies.[11]

In Figure 1, we show a box plot of firm's average climate change exposure values by sample group. The *CC Exposure* measure calculates the relative frequency of climate change bigrams in earnings calls. Before the Paris-Agreement, 0.04% (0.16%) of words were related to climate change for the control

[8] The SvLVZ climate change exposure measure is freely available on https://osf.io/fd6jq/.

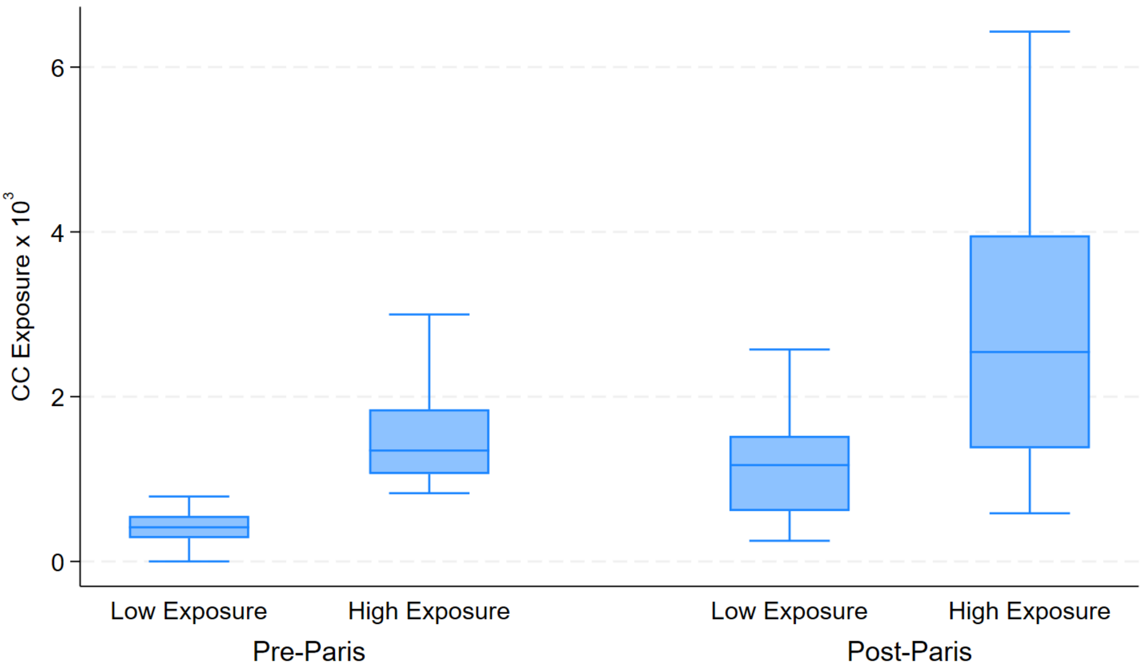
[9] An additional drawback of hard measures of climate change exposure such as emissions arises from data quality. Data providers such as Trucost, ISS or Urgentum provide historical coverage for Scope 1 emissions for a large fraction of fossil fuel firms. While some of this data is collected from self-reporting mechanisms such as the Carbon Disclosure Project, broad coverage stems from data providers estimating emissions based on industry peers and on measures of productivity such as sales. By construction, Scope 1 emission intensities therefore exhibit little variation within sectors. The SvLVZ measure, on the other hand, provides significant variation in climate change exposure within sectors.

[10] Sautner et al. (2023) distinguish between four distinct climate change categories: *opportunity, physical, regulatory*, and *general* climate change. Furthermore, the measures distinguish between *exposure, risks*, and *sentiment*. While the different sub-dimensions of climate change exposure are appealing to study in our context, there is not much variation that we can exploit. In fact, we observe that these measures are frequently zero during the early part of our sample.

[11] Nevertheless, the results are qualitatively similar when we calculate climate change exposure for the entire period from 2010-2021.

(treatment) group. Both groups of firms devote more attention to climate change in the post-Paris period. Importantly, firms that were more exposed to climate change before the Paris Agreement continue to be so after 2015.[12] When we compare climate change exposure for the fossil fuel sector with other sectors in Figure A2 we find that fossil fuel firms are most exposed along with firms in construction, transportation and public utilities.

Figure 1: Distribution of Climate Change Exposure



Note: Box plot of sample firm's *CCExposure* values from 2010-2021. The Paris Agreement marks the cutoff date for assignment to treatment (high exposure) and control (low exposure) groups.

3.1.3 Trucost: Breakdown of Capital Expenditures

To assess whether firms are investing to enhance firm value by increasing the production of fossil fuels in the near future or by transitioning to more renewable technologies, we need to distinguish the types of investments made. Standard datasets, typically obtained from firms' quarterly and annual reports, only provide information on total capital expenditures.

Hence, we introduce a novel dataset called *Fossil Fuels and Energy Data* from S&P Trucost. This dataset includes capital expenditures on fossil fuel exploration for approximately 18,000 firms worldwide.[13]

For each firm-year in our sample, we utilize this data to compute *Fossil Fuel Capex* as the sum of all coal, oil, gas, and undefined fossil fuel exploration activities. Comparing the proportion of fossil fuel capital expenditures (Trucost) to the total capital expenditures (Compustat) later enables us to

[12] We plot the announcement returns of low versus high climate change exposed firms in Figure A1. Indeed, firms more exposed to climate change experienced lower returns around the Paris Agreement relative to firms that are less exposed.

[13] It also includes data on proven and probable fossil fuel reserves and power generated from various sources of energy.

distinguish between firms that exclusively invest in fossil fuel activities and firms that engage in a more diversified set of investment activities.

3.1.4 Supplementary Data

Our analysis also relies on several additional data sources. First, we acquire daily and monthly stock prices for a subset of our firms from the Center for Research in Security Prices (CRSP). We use the stock return data to calculate the sensitivity of a firm's monthly stock returns to monthly changes in the oil and gas price (i.e. also referred to as the oil or gas beta). Monthly spot oil prices are sourced from IMF Primary Commodity Prices, while futures prices for West Texas Intermediate oil and Henry Hub gas are obtained from Bloomberg.

We obtain data on firm's carbon emissions from ISS. Lastly, we incorporate global GDP forecasts from the World Bank into our analysis.

3.2 Descriptive Statistics

We begin with 844 firms identified as fossil fuel firms from Compustat Global and North America. Merging with the SvLVZ measure of climate change exposure and Trucost data (i.e. the breakdown of capex) leaves 177 firms in the sample. Conditioning on the availability of climate change exposure before the Paris Agreement reduces the sample to 103 distinct firms and 1,147 firm-year observations.[14]

Notably, these 103 firms account for 78% of the total revenue generated by the 844 firms included in the Compustat dataset.[15] The sample selection process eliminates many smaller fossil fuel companies but retains the larger firms. As a result, the sample accounts for over three-quarters of publicly listed fossil fuel firm revenue, thus offering valuable insights on the aggregate behaviour of the sector.

Our sample of firms also contribute significantly to global CO_2 emissions. Using data from ISS, we estimate that the sum of scope 1, 2 and 3 emissions from our sample of firms exceeded 12 billion tons in 2019.[16] This is equal to one-third of total energy-related CO_2 emissions according to the International Energy Agency (IEA, 2019).

We provide summary statistics in Table A2. The average investment ratio (Capex/PP&E) is 15% while the distribution is symmetric. Firm size, ranging from the 10th to the 90th percentile, lies between USD 1.4 billion and USD 146 billion. Throughout the sample period, these firms were not profitable, with the average return on assets (ROA) equalling zero. The low ROA for fossil fuel firms is likely due to a substantial decrease in oil prices at the beginning of the sample period. Correspondingly, we note a positive correlation between these firms' stock prices and changes in oil prices, with the average oil beta equalling 0.4.

When we split fossil fuel firms by climate change exposure in Table 1, we observe that larger firms are more exposed than smaller firms. The median total assets for firms with low exposure is USD 6.6 billion, while the median firm size for firms with high climate change exposure is approximately USD 26.6 billion. Consequently, firms with high climate change exposure exhibit higher capital expenditures, sales, earnings, R&D expenses, and distribute more capital to investors. Highly exposed firms also have higher returns on assets, lower leverage ratios, and fewer tangible assets than firms with lower exposure.

[14] The full list of sample firms is available in Table A3 of the Appendix.
[15] Refer to Table A4 for details regarding the sample selection process.
[16] The 12 billion tons of CO_2 are emitted only by the firms for which we have non-missing emissions data. ISS provides emissions data for roughly three quarters of our sample. See Figure A3 for an annual breakdown.

Notably, the share prices of these firms are less reactive to changes in oil prices, illustrated by a lower oil beta.

Table 1: Differences in Firms by Climate Change Exposure

	Low Exposure		**High Exposure**		T-Test
	Mean	Median	Mean	Median	Difference
Observations	577		570		
Firm Characteristics					
Capital Expenditures	1,464	688	6,834	2,117	-5,370***
Sales/Turnover (Net)	6,980	1,972	61,220	17,879	-54,239***
Assets - Total	12,919	6,661	74,609	26,916	-61,690***
Retained Earnings	2,931	856	36,716	7,287	-33,785***
Earnings Before Interest and Taxes	473	172	5,239	1,295	-4,766***
Research and Development Expense	66	16	439	222	-373***
Purchase of Common & Preferred Stock	123	0	377	0	-254***
Cash Dividends (Cash Flow)	272	55	1,601	554	-1,329***
Net Income	225	46	2,697	759	-2,472***
Balance-Sheet Ratios					
RoA	-0.018	0.015	0.025	0.037	-0.044***
Debt-to-Equity	1.243	1.049	1.132	1.082	0.111**
Tangibility	0.717	0.764	0.640	0.652	0.077***
Fossil Fuel Dependency					
Oil Beta	0.632	0.502	0.431	0.349	0.201***
High Fossil Fuel Dep.	0.765		0.458		0.307***
Company Probable Reserves: Oil & Gas	203	194	22,150	197	-21,947*
Climate Exposure Measures					
CCExp	0.849	0.450	2.360	1.439	-1.511***
ISS Scope 1 Emissions	3,019	1,129	22,481	9,829	-19,462***

Note: Table compares firms with low versus high climate change exposure. The split is obtained by calculating the average value of *CCExp* per firm in the pre-Paris period until 2015. Firms with low (high) exposure are then firms with below (above) median exposure.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, t-statistics in parentheses.

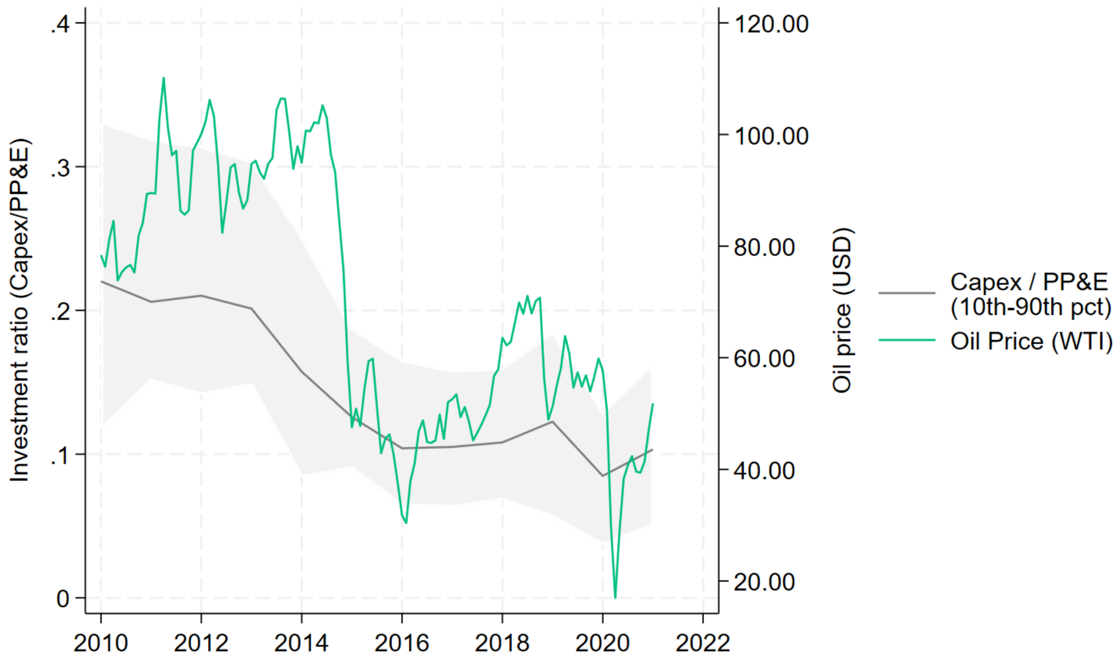
The observation that large firms are more highly exposed to climate change is no surprise. Large firms are more likely to attract analyst coverage, leading to more questions about controversial topics such as climate change during earnings calls. Additionally, large firms are more prone to engage in diverse business activities, and climate change may impact these areas in distinct ways, motivating discussions in earnings calls.

To address concerns regarding the comparability of the treatment and control groups, we will incorporate firm fixed effects, implement a propensity score matching procedure, and thoroughly investigate how firm size and oil price sensitivity contribute to our findings.

3.3 Empirical Design

The primary challenge in identifying the impact of climate change exposure on fossil fuel firm investment after 2010 is the occurrence of a significant shock to the current and future profitability of fossil fuel firms. Oil prices decreased by around 50% after 2014.[17] The fall in oil prices followed from a supply glut driven by a period of weak demand and a boom in supply as a consequence of high US shale production and OPEC lifting export quotas (Baumeister and Kilian, 2016; Quint and Venditti, 2020). This shock substantially altered the economic outlook for fossil fuel firms with negative effects on expected return on investment. Indeed, as depicted in Figure 2, the investment ratio declined sharply and almost halved in 2014-16 coinciding with the large drop in oil prices and confirming findings in the literature that predicts investment of fossil fuel firms to react significantly to price changes (Anderson, Kellogg, and Salant, 2018).[18] The decline was concentrated in spending on fossil fuel exploration whereas other types of investment remained relatively constant as illustrated in Figure 3.[19]

Figure 2: Fossil Fuel Firm Investment and Oil Prices



Note: Average ratio of capital expenditures to property, plant and equipment by fossil fuel firms over the sample period from 2010 - 2021. Western Texas Intermediate spot oil prices are plotted as a reference.

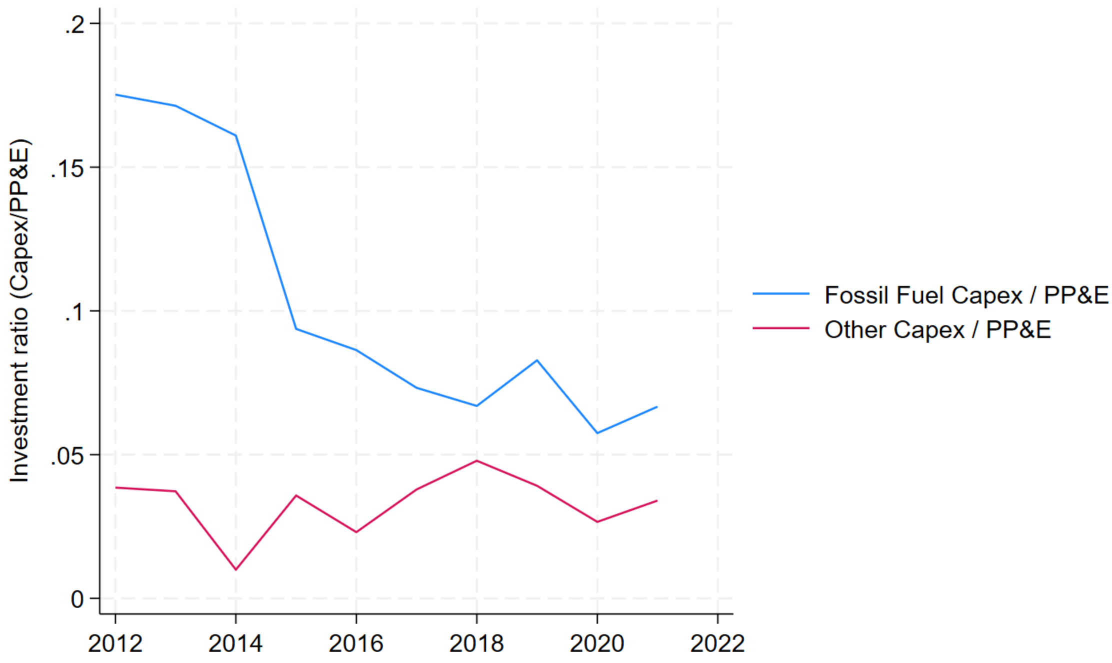
The drop in oil prices occurred around the same time as the Paris Agreement, which is widely used in the literature as a shock to study the impact of the green transition on the economy given its influence on perceptions of future climate policy (Bolton and Kacperczyk, 2023; Mueller and Sfrappini, 2022;

[17] In Figure A4, we show that oil and gas futures contract prices declined strongly between 2014 and 2016.

[18] That would especially be the case for the US shale companies that are highly exposed to futures prices when planning their drilling activity, since production costs are high (Aastveit, Bjørnland, and Gundersen, 2022).

[19] The fall in fossil fuel investment followed a period of very high investment levels of the industry at the beginning of the decade relative to the decade before which was partly driven by the US shale revolution (IEA, 2021). While this would suggest that the fall in investment reflected a normalization, the investment ratio also fell outside of the US indicating that other factors also played a role, see Figure A5 in the Appendix.

Figure 3: Breakdown of Capital Expenditures



Note: Average ratio of capital expenditures to property, plant and equipment by fossil fuel firms over the sample period from 2010 - 2021. Capital expenditures are broken into two categories. Fossil fuel capital expenditures are capex in oil, gas or coal exploration as reported in Trucost. We obtain *unspecified capex* as the residuals from total capital expenditures (Compustat) and fossil fuel capex (Trucost).

Carbone, Giuzio, Kapadia, Krämer, Nyholm, and Vozian, 2021; Ginglinger and Moreau, 2023). Along these lines, Bogmans et al. (2023) observe that investment in the fossil fuel industry was lower than in other sectors of the economy (see also Figure A6 in the appendix) and use the Paris Agreement in a differences-in-differences setup to conclude that climate policy is having a negative impact on fossil fuel investment.

However, we posit that the effect of lower oil prices on non-fossil fuel firms' business forecasts was positive. Production and transportation costs for these firms tend to positively co-vary with oil prices. The decline in oil prices likely bolstered profitability and investment. Hence, we do not consider non-fossil fuel firms an optimal choice for a control group. Instead, we leverage solely on the variation in climate change exposure within the fossil fuel industry. Therefore, we categorize fossil fuel firms into high and low climate change exposure groups and observe their investment behaviour before and after the Paris Agreement.

Our empirical framework employs a standard differences-in-differences setup:

$$\log(\text{Inv. Ratio}_{f,t}) = \beta_1 \times \text{High CC Exposure}_f \times \text{Post-Paris}_t + \gamma F_{f,t} + \alpha_t + \lambda_f + \epsilon_{f,t} \tag{5}$$

Inv. Ratio$_{f,t}$ is capital expenditures relative to property, plant, and equipment in $t-1$. *High CC Exposure* firms are in the group of firms with high climate change exposure according to the SvLVZ measure. We include a vector of time-varying firm characteristics $F_{f,t}$ which includes firm size (i.e. log total assets), profitability (i.e. return on assets), leverage ratio (i.e. debt-to-equity), and asset tangibility (i.e. ratio of tangible assets to total assets). α_t and λ_f denote time- and firm-fixed effects, respectively. Fixed effects absorb the average differences in the investment ratio between treatment and control firms as well as differences in the investment ratio for all firms before and after Paris. Since the assignment to treatment or control group occurs at the company-level, we cluster standard errors by firm.

The differences-in-differences setup accommodates common trends affecting both the treatment and control groups. It thereby controls for the impact of the drop in oil prices, which we assume affected all fossil fuel firms similarly. Additionally, the setup addresses time-invariant differences between the treatment and control groups. The identification assumption posits that, in the absence of an increase in climate change exposure, the change in the investment ratio would have been equal for the two groups of firms.

The assignment to treatment and control groups is not random. We are already aware that large firms have higher climate change exposure in our sample. A potential violation of the identification assumption could be that low and high climate change exposure firms reacted differently to the drop in oil prices, which almost coincided with the Paris Agreement. We address such endogeneity concerns in Section 4.3.

4 Results

4.1 Impact of Expected Climate Change Policies on Investment

The main findings from our differences-in-differences estimation are presented in Table 2.

Table 2: Investment Response to Expected Climate Policies

	(1)	(2)	(3)	(4)
High CC Exposure × Post-Paris	0.330***	0.259***	0.274***	0.279***
	(3.483)	(3.003)	(3.147)	(3.224)
High CC Exposure	-0.067	-0.062	-0.055	
	(-0.909)	(-0.781)	(-0.695)	
Post-Paris	-0.784***	-0.679***		
	(-11.771)	(-11.646)		
Log (Assets)		-0.050**	-0.046**	0.016
		(-2.380)	(-2.158)	(0.324)
RoA		2.321***	1.865***	1.705***
		(10.081)	(6.514)	(8.183)
Debt-to-Equity		-0.020	-0.019	-0.048
		(-0.531)	(-0.489)	(-1.392)
Tangibility		0.092	0.082	-0.173
		(0.506)	(0.454)	(-0.570)
Firm FE	No	No	No	Yes
Year FE	No	No	Yes	Yes
R^2	0.230	0.327	0.355	0.649
N	1,147	1,147	1,147	1,147

Note: Table reports results from a DiD framework around the 2015 Paris Agreement. Refer to Equation (5) for details. Standard errors are clustered at firm level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, t-statistics in parentheses.

In the absence of controls or fixed effects (column (1)), firms with high climate change exposure exhibit a 40% increase in investment relative to firms with low exposure after the Paris Agreement. After the gradual introduction of time varying firm characteristics, year-fixed effects and firm-fixed effects in columns (2) through (4), the economic magnitude appears to vary around 30%.[20]

No statistically significant difference is found in the investment behaviour of low versus high climate change exposure firms in the pre-Paris period. Nevertheless, our results indicate that both groups of firms significantly reduced investment after 2015. The coefficient on *Post-Paris* ranges between -0.78 and -0.68, implying that firms in the control group halved their investment after the Paris Agreement.

Two competing narratives could explain the *Post-Paris* coefficient. First, the Paris Agreement and the resulting change in beliefs about future climate policies might lead to lower investment in treatment and control firms. Alternatively, the coefficient might capture changes in the business environment for fossil fuel firms due to significantly lower oil prices post-Paris. Importantly, the second explanation is unrelated to climate risk.

We favor the second narrative through a process of elimination. If the first narrative were true, we would expect firms with higher exposure to climate change to reduce investment more in response to the Paris Agreement ($\beta_1 < 0$). However, our findings contradict this expectation, leading us to argue that lower investment by treatment and control firms post-Paris is not attributable to climate change exposure. The most plausible alternative explanation is the impact of reduced oil prices on investment after 2015.

In column (2), we introduce firm characteristics that could be related to the investment of fossil fuel firms. As expected, profitability appears to be a key determinant of firm investment, as a higher return on assets is associated with a significantly higher investment ratio. Unsurprisingly, the evidence also suggests that firms scale down investment as they become larger.

Next, the inclusion of year dummies in column (3) controls for macroeconomic changes over time common to all firms. Firm time-invariant differences in the investment ratio are addressed with firm-fixed effects in column (4). The main takeaway from Table 2 is a robust and economically meaningful relationship between higher climate change exposure and a higher investment ratio in the post-Paris period.

Next, we exploit the multiple subdimensions of the SvLVZ measure of climate change exposure. As Sautner et al. (2023) assign words in the vicinity of climate change related bigrams into various subcategories for a nuanced exposure measure, it allows us to incorporate measures related to sentiment in our empirical framework. The results of this extended analysis are presented in Table 3.

In column (2), we employ the positive sentiment measure, comparing firms that frequently express positive sentiments about climate change with those that either do not discuss climate change or only do so in a negative way. In column (3) we repeat the analysis replacing positive sentiment with negative sentiment.

Intuitively, our findings seem to be primarily influenced by firms discussing climate change in a positive context. For those firms that discuss climate change in a negative way, we observe a smaller insignificant effect on investment.

In column (4), we compare firms that have a positive sentiment towards climate change with firms with a more negative sentiment. We find additional evidence that firms' positive sentiment towards

[20] With our logarithmic investment ratio a coefficient of 0.279 corresponds to a 32.2% relative increase in investment.

Table 3: Different Climate Change Exposure Measures: Sentiment

	(1)	(2)	(3)	(4)
High CC Exposure × Post-Paris	0.279***	0.181**	0.104	0.177**
	(3.224)	(2.024)	(1.138)	(2.003)
Firm controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
R^2	0.649	0.643	0.640	0.643
N	1,147	1,147	1,147	1,147
Measure used	$CCExp$	$CCExp_{pos}$	$CCExp_{neg}$	$CCExp_{sent}$

Note: Table reports results from a DiD framework around the 2015 Paris Agreement. The $CCExp$ measure in column (1) is the baseline measure used throughout the paper. The positive ($CCExp_{pos}$), negative ($CCExp_{neg}$) and overall ($CCExp_{sent}$) sentiment variables are constructed by measuring the relative frequency of climate bigrams that occur in the vicinity of positive versus negative tone words (Loughran and McDonald, 2011).
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, t-statistics in parentheses.

climate change is related to higher investment.

4.2 Distinguishing between Fossil Fuel and Alternative Investments

Our results indicate a relative increase in investment by firms with high climate change exposure after the Paris Agreement. However, the nature of these investments remains unclear. Our particular interest lies in discerning whether more exposed firms are more inclined to invest in fossil fuel technologies or renewable energy technologies. This distinction is crucial as it carries significant implications for policymakers.

While we cannot directly observe the assets financed through capital expenditures by fossil fuel firms, data from Trucost Fossil Fuel provides information on total capital expenditures in fossil fuel exploration activities. Based on this data, we quantify the percentage of a firm's total capital expenditures allocated to fossil fuel exploration. We categorize firms based on whether they allocate more or less than 90% of their total investment to fossil fuel exploration and conduct a differences-in-differences analysis on these two subsamples of firms.

Table 4 reveals that our baseline effect is primarily driven by firms that predominantly invest in fossil fuel extraction. Focusing specifically on these firms in column (1), we observe that β_1 is estimated to be around 0.24. β_1 declines to approximately 0.15 and is statistically indistinguishable from zero when focusing on the subsample of firms that engage in more diversified investment activities.

These findings lead us to interpret the results as evidence that fossil fuel firms with high climate change exposure tend to increase their investments in traditional fossil fuel activities. Notably, our results do not support an interpretation suggesting that these firms are transitioning away from their traditional business model towards renewable energy sources.

Perhaps climate change exposure does not prompt a transition from fossil fuel to renewable energy for these firms, but rather incentivizes them to extract fossil fuels in a more efficient and environmentally friendly manner. In other words, investment may be geared towards making fossil fuel extraction less carbon-intensive. To explore this hypothesis, we compare the evolution of carbon emissions between fossil fuel firms with high and low climate change exposure.

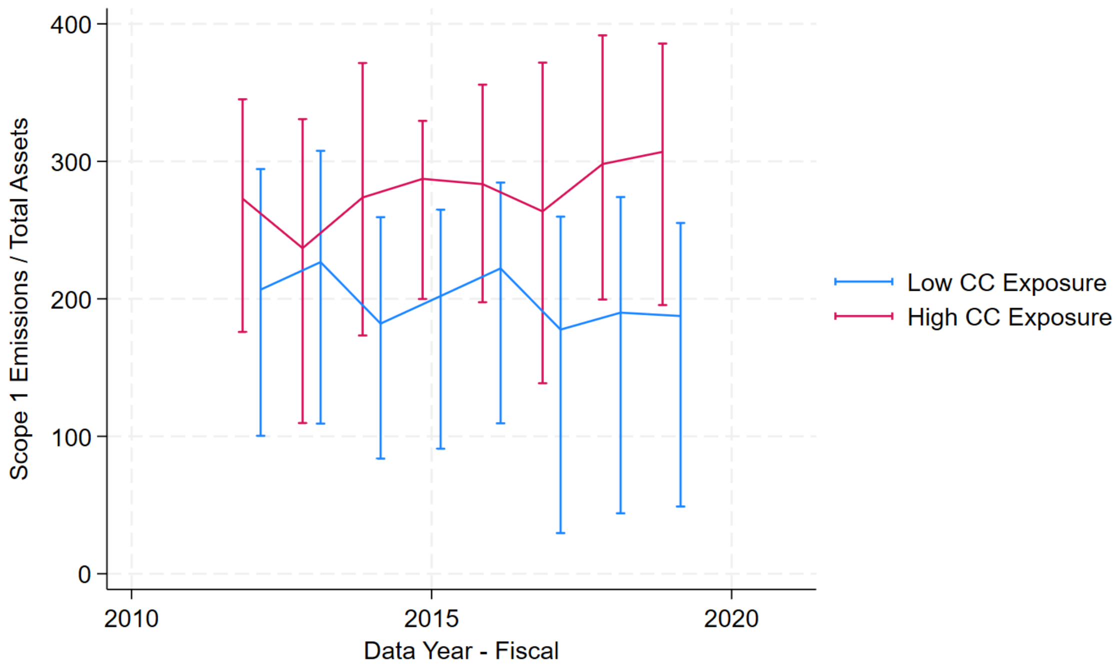
Figure 4 illustrates that the carbon emissions relative to total assets of firms with high climate change exposure have increased compared to firms with low exposure. This lends further support to the hypothesis that that investments are directed towards technologies that are more carbon-intensive.

Table 4: Fossil Fuel versus Other Investment

	(1)	(2)
High CC Exposure × Post-Paris	0.240*	0.152
	(1.950)	(1.010)
Firm controls	Yes	Yes
Firm FE	Yes	Yes
Year FE	Yes	Yes
R^2	0.700	0.629
N	628	393
Subsample	Primary investment in extraction	Diversified investment
Mean(High CC Exposure)	0.36	0.69

Note: Table reports results from a DiD framework around the 2015 Paris Agreement. The analysis is run for two subsamples. In column (1), we focus on firms that are investing more than 90% of their capital expenditures into fossil fuel extraction according to Trucost data. In column (2), we focus on the remaining firms that invest in a more diversified manner. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, t-statistics in parentheses.

Figure 4: Evolution of Carbon Emissions



Note: Figure plots annual carbon intensities for low versus high climate change exposure firms. Carbon emissions are scaled by total assets, as revenues are very volatile in the sample period due to the oil price fluctuations. Bars denote confidence intervals from the 25th to 75th percentiles.

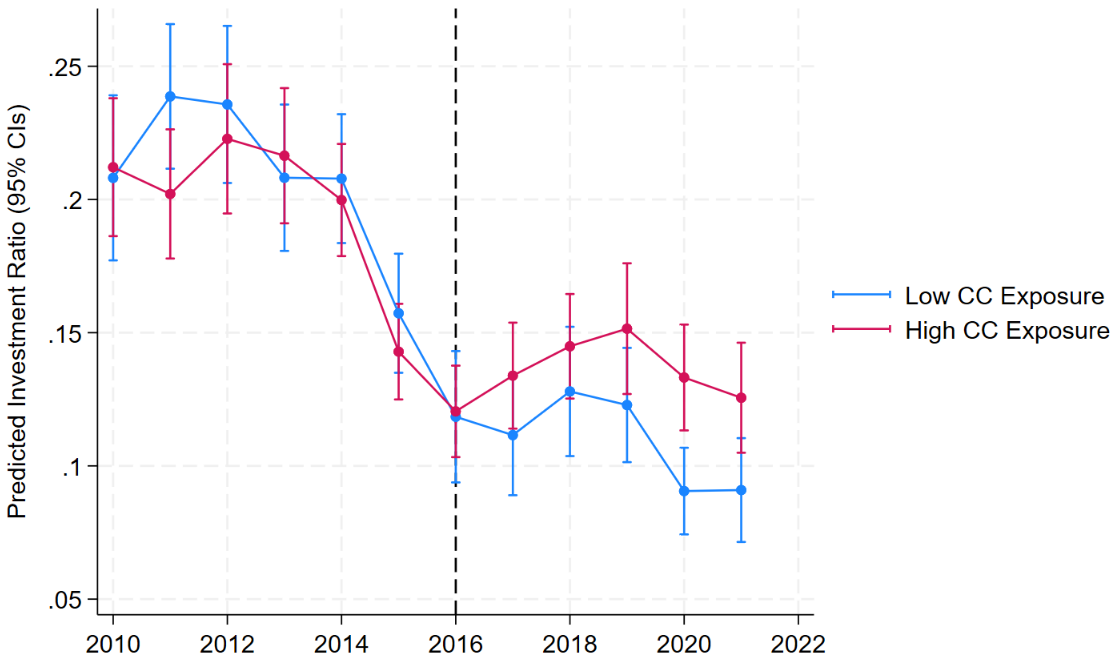
4.3 Tackling Endogeneity Concerns

4.3.1 Parallel Trends

The key assumption that would ensure consistency of our estimators within the differences-in-differences framework is the parallel trends assumption. In economic terms, this assumption posits that, in the absence of the surge in regulatory uncertainty that followed from the Paris Agreement, the change in investment for firms in both the treatment and control groups would have been equivalent.

To scrutinize the parallel trends assumption, we conduct a re-estimation of Equation (5), where we replace the *Post-Paris* indicator with a vector of year dummies. The predicted values for the investment ratio are graphically presented in Figure 5.

Figure 5: Parallel Trends



Note: This figure depicts predicted values for low versus high climate change exposure firms from a regression interacting the treatment indicator *High CC Exposure* with a vector of year dummies. The regression includes time-varying firm characteristics as controls. Note that we do not take logs on our outcome variable in this estimation to allow for easier interpretation of the results. In Figure A7, we demonstrate that the results are equivalent with the *Log Inv. Ratio.*

The graph does not indicate divergent trends in investment between the treatment and control groups during the pre-Paris period. Notably, it illustrates a marked decline in investment for both groups from 2014 to 2016. Consistent with our baseline findings, the graph suggests that firms with higher exposure to climate change exhibited relatively higher investment ratios compared to firms with low climate change exposure in the post-Paris period.

4.3.2 Differences in Firm Size

Firms with high climate change exposure are on average larger than their low exposure peers. Despite controlling for firm size using firm fixed effects and a time-varying measure of total assets in our regressions, there may still be concerns that large firms react differently to changes in the economic environment than small firms in the post-Paris period. We explore these concerns in Table 5.

Table 5: Accounting for Firm Size Differences

	(1)	(2)
High CC Exposure × Post-Paris	0.279***	0.249**
	(3.224)	(2.169)
Firm controls	Yes	Yes
Firm FE	Yes	Yes
Year FE	Yes	Yes
Firm Size x Year FE	No	Yes
R^2	0.649	0.665
N	1,147	1,130
Specification	Baseline	Firm Size Quartile x Year FE

Note: Table reports results from a DiD framework around the 2015 Paris Agreement. In column (2), we add dummies for every firm size quartile and year combination. Firm size quartiles are calculated based on total assets at the end of 2015.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, t-statistics in parentheses.

In column (2), we introduce interactions between dummies for firm size quartiles and years. The inclusion of fixed effects is designed to mitigate divergent trends in investment behaviour over time for firms of different sizes. While our coefficient of interest, β_1, experiences a slight reduction in economic magnitude from approximately 0.28 to 0.25, it remains positive and highly significant.

4.3.3 Oil Price Sensitivity

We also consider sensitivity to changes in oil prices as a potential omitted variable that could bias our results. Suppose that firms with high climate change exposure were less sensitive to changes in the oil price. Then, an alternative explanation for our findings would be that these firms reduced investment less as a response to the drop in oil price because their business model depended less on the evolution in oil prices. To address this concern, we run a triple differences model with an additional interaction term capturing firms' sensitivity to changes in the oil price in Table 6.

In column (1), we calculate oil betas that measure the sensitivity of firms' monthly stock returns to monthly returns on oil futures. Since CRSP data is only available for firms listed in the US, we lose approximately 40% of the firms in our sample.

We also calculate firm's cost ratio, i.e. the ratio of costs of goods sold to total sales and include it as an interaction in column (2). Presumably, firms with lower production costs should be less affected by the change in oil prices, as they would face a larger difference between breakeven and actual prices. The cost ratio also proxies for different production technologies.

If our baseline effect was driven by an omitted variable such as the sensitivity to oil prices, we would

Table 6: Accounting for Oil Price Sensitivity

	(1)	(2)
High CC Exposure × Post-Paris	0.336**	0.448*
	(2.077)	(1.974)
Post-Paris × Oil Beta	-0.002	
	(-0.008)	
High CC Exposure × Post-Paris × Oil Beta	-0.344	
	(-1.021)	
Post-Paris × Cost of Sales Ratio		0.522**
		(2.202)
High CC Exposure × Post-Paris × Cost of Sales Ratio		-0.313
		(-1.046)
Firm controls	Yes	Yes
R^2	0.737	0.654
N	709	1,147

Note: Table reports results from a triple differences framework around the 2015 Paris Agreement. We amend the baseline DiD framework by adding an initial interaction term that captures sensitivity of a firm's business to changes in the oil price. Oil betas measure the sensitivity of firms' monthly stock returns to monthly changes in the oil price. Cost ratios are calculated as the ratio of costs of goods sold to sales.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, t-statistics in parentheses.

expect the coefficient on high climate change exposure firms after the Paris Agreement to decrease sizeably in the triple differences framework. However, Table 6 does not provide evidence for an omitted variable related to oil prices. The coefficient on *High CC Exposure x Post-Paris* is positive and statistically significant. Relative to the baseline, the effect of the Paris Agreement on investment increases slightly.

4.3.4 Policy Exposure in Europe versus North America

Countries have endorsed a shared target with the Paris Agreement in 2015 (1.5 °C target), but expectations about the timing and stringency of future climate change regulation to achieve that goal are likely different across regions. While our relatively small sample does not allow us to exploit variation between different countries, we at least distinguish between firms located on different continents, i.e. Europe and North America. Europe, often recognised as a leader in climate change regulation, stands out for its proactive stance on this issue. In turn, in North America, expectations about climate change policies are more likely to be influenced by the political parties in power. For instance, the Paris Agreement was initially signed under President Obama, subsequently withdrawn from during the presidency of Donald Trump, and later re-joined following the election of President Biden. Consequently, it is reasonable to anticipate that firms based in Europe may anticipate more stringent and potentially timelier policies compared to their North American counterparts.

We repeat our baseline analysis with subsamples of European and North American firms in Table 7. While we find evidence for a positive impact of higher climate change exposure on investment after the Paris Agreement on both continents, the effect is about twice as large in Europe than in North America. This evidence supports our main channel. Fossil fuel companies tend to intensify their investments when they are likely to have more limited time to continue fossil fuel production. The increased likelihood that stricter and sooner climate change regulation will be passed in Europe compared to the United States creates an urgency for fossil fuel firms based in Europe to expedite exploration, extraction, and development efforts in an attempt to maximize returns before potential constraints arise.

Table 7: Europe versus North America

	(1)	(2)	(3)	(4)
High CC Exposure × Post-Paris	0.279***	0.446**	0.212**	0.204**
	(3.224)	(2.105)	(2.157)	(2.073)
Post-Paris × Europe				0.029
				(0.149)
High CC Exposure × Post-Paris × Europe				0.238
				(0.993)
Firm controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
R^2	0.649	0.518	0.718	0.659
N	1,147	311	666	977
Specification	Baseline	Europe	North America	Triple Diff

Note: Table reports results from a DiD framework around the 2015 Paris Agreement. We repeat the baseline regression for subsamples of European (column 2) and North American (column 3) firms. In the last specification, we run a triple differences model comparing the investment response of European and US firms.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, t-statistics in parentheses.

Column (4) in Table 7 shows the results from the triple differences analysis. This specification addresses concerns about unobservable differences between treatment and control groups because we can compare effects within the treatment group. As anticipated, the coefficient on the triple interaction *High CC Exposure x Post-Paris x Europe* is positive and economically large at about 25%. However, the estimated coefficient is not found to be statistically significant, which could be related to our limited sample size.

4.3.5 Propensity Score Matching

To address lingering concerns about observable differences between the treatment and control groups, we also implement a matching exercise using a propensity score matching procedure (Rosenbaum and Rubin, 1983). We initially estimate the probability of being treated based on a vector of firm characteristics, including total assets, return on assets, leverage, asset tangibility, and the oil beta. Using this estimation, we determine how frequently a control firm would be considered the nearest neighbor for a treatment firm. Subsequently, we incorporate these frequencies as weights in our differences-in-differences framework. The results of this exercise are presented in Table 8.

Column (1) affirms our observation that large firms are more likely to be treated. Additionally, firms with a lower proportion of tangible assets and lower sensitivity to oil prices exhibit greater exposure to climate change. When we match on these characteristics and re-run the baseline specification, the effect of high climate change exposure on investment in the post-Paris episode remains positive and significant at a 5% level. This suggests that observable differences between the treatment and control groups are

Table 8: Propensity Score Matching

	(1) High CC Exposure	(2) Log(IR)
High CC Exposure × Post-Paris		0.298**
		(2.404)
Log (Assets)	0.289***	
	(5.341)	
RoA	0.655	
	(0.678)	
Debt-to-Equity	0.067	
	(0.517)	
Tangibility	-0.798*	
	(-1.648)	
Oil Beta	-0.834***	
	(-2.795)	
Firm FE	No	Yes
Year FE	No	Yes
Pseudo R^2	0.178	
R^2		0.616
N	353	1,056

Note: Table reports results from a propensity score matching exercise. Column (1) reports estimates of a probit regression of firm characteristics on the *High CC Exposure* dummy. Column (2) uses the weights obtained from the first stage propensity score matching in the baseline DiD framework.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, t-statistics in parentheses.

unlikely to account for a significant portion of our observed effect.

4.3.6 Alternative Treatment Periods

In an additional test, we replicate our differences-in-differences analysis using different placebo treatment years between 2012 and 2016. Note that our specification estimates an average treatment effect for the post period. It is important to note that, since the post-2012 timeframe includes the post-Paris episode, we do not anticipate the treatment effect to be zero when using placebo treatment years. Nevertheless, we expect the results to be most pronounced when employing the actual post-Paris dummy as our treatment indicator. The findings from this analysis are summarized in Table 9.

As anticipated, a positive and significant relationship between climate change exposure and investment is observed across all treatment episodes. Notably, the relationship is both economically and statistically strongest when the treatment occurs in 2015, the year of the Paris Agreement.

Table 9: Varying the Timing of the Climate Policy Shock

	(1)	(2)	(3)	(4)	(5)
High CC Exposure × Post-2012	0.206**				
	(2.236)				
High CC Exposure × Post-2013		0.191**			
		(2.238)			
High CC Exposure × Post-2014			0.224**		
			(2.530)		
High CC Exposure × Post-2015 (Paris)				0.279***	
				(3.224)	
High CC Exposure × Post-2016					0.271***
					(3.148)
Firm controls	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
R^2	0.643	0.643	0.645	0.649	0.648
N	1,147	1,147	1,147	1,147	1,147

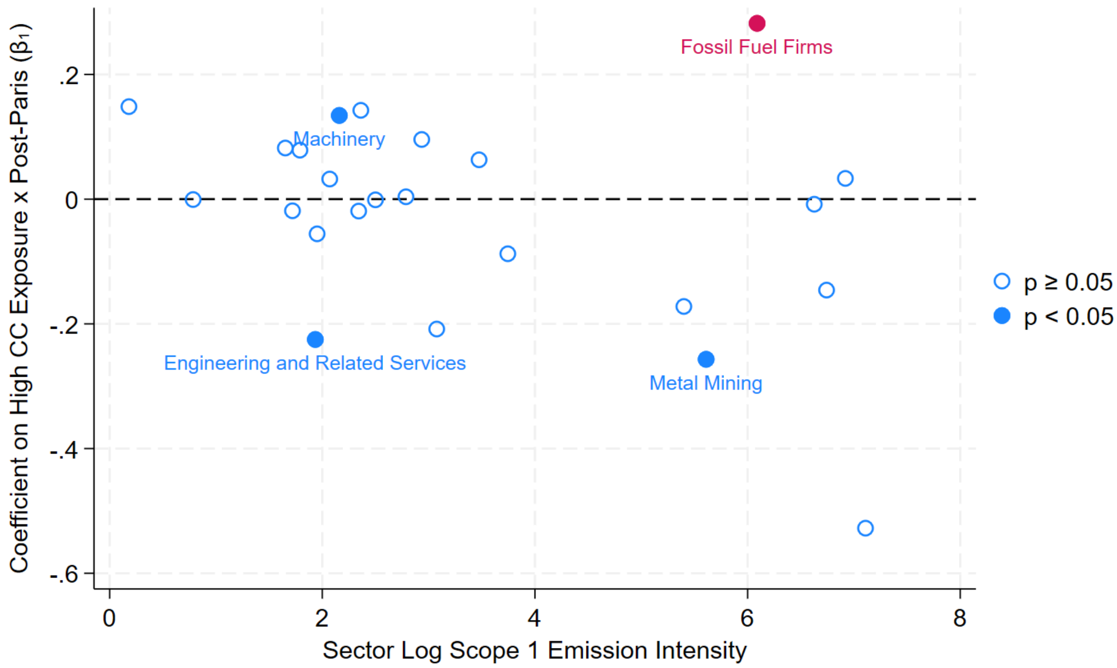
Note: Table reports results from a DiD framework with different post-periods. Column (4) replicates the baseline analysis.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, t-statistics in parentheses.

4.3.7 Alternative Sectors

Finally, we compare how investment behaviour changed after the Paris Agreement for firms with higher or lower climate change exposure in other sectors. We consider this a useful exercise because green paradox incentives are likely specific to the fossil fuel industry. Repeating our analysis allows us to compare the magnitude of our estimate for fossil fuel firms to other industries. Within each industry, we split firms by climate change exposure and calculate the effect of the Paris Agreement on investment in the baseline differences-in-differences framework. We order industries by emission intensity to understand the general level of climate change exposure for each sector. Figure 6 presents a scatter plot of an industry's emission intensity and the estimated coefficient β_1, i.e. the relative impact of the Paris Agreement for firms with high versus low climate change exposure.

For most industries, we do not observe a statistically different impact of the Paris Agreement on investment for high versus low climate change exposure firms. The coefficient estimate for the fossil fuel sector stands out in terms of economic and statistical magnitude. The result is consistent with our assumption that Green Paradox incentives are less likely to affect investment in other sectors.

Figure 6: Estimated Investment Response to Climate Policies: Other Sectors



Note: Markers represent 2-digit SIC industries. To calculate an industry's emission intensity (x-axis), we estimate the median firm-year Scope 1 emission intensity. We obtain β_1 (y-axis) by repeating our baseline analysis. Within each industry we split firms by high and low climate exposure and estimate a differences-in-differences specification around the Paris Agreement. As before, we define the coefficient on *High CC Exposure x Post-Paris* as β_1. We drop industries with less than 75 distinct firms or less than 500 firm-year observations. Filled markers represent coefficient estimates that are significant at 95% significance levels. .

4.4 Robustness

We conduct several additional robustness tests. First, we examine the sensitivity of our results to the definition of fossil fuel firms.

In Table 10, we repeat our analysis using the baseline definition of fossil fuel firms (SIC 1221, 1222, 1311, 1381, and 2911) but without requiring the availability of Trucost data. This gives us a larger data sample (see column (2)).[21] While the effect is economically smaller than in the baseline, we still find a meaningful 16% increase in investment of firms with high exposure to climate change after the Paris Agreement.

Our main result is also robust to alternative identifications of fossil fuel firms. First, we use NAICS codes (column (3)).[22] We continue to find a significantly positive β_1, although at a smaller size and a higher significance level. Second, in column (4), we define a firm as a fossil fuel firm if their SIC code is between 1200 and 1400 as in Delis, De Greiff, and Ongena (2019). This definition leaves out firms that are classified to be active in Petroleum Refining including the 15 largest firms in our baseline sample. Nevertheless, β_1 remains positive and is economically similar to the baseline specification.

In columns (5) through (8), we present other modifications of our baseline specification. In column

[21] Note that the firms entering the sample are primarily smaller firms in the fossil fuel sector.

[22] We assume that a firm is a fossil fuel firm when it is in an industry that belongs to Mining, Quarrying, and Oil and Gas Extraction (NAICS starting with 21) or in Petroleum Refining (NAICS: 324110).

Table 10: Additional Robustness Tests

	(1)	(2)	(3)	(4)
High CC Exposure × Post-Paris	0.282***	0.159**	0.119*	0.235**
	(3.241)	(2.121)	(1.693)	(2.419)
Firm controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
R^2	0.649	0.654	0.593	0.650
N	1,147	2,395	2,075	1,198
Sample	FF Firms Baseline	FF Firms Extended	FF Firms NAICS codes	FF Firms Delis et al. (2019)
N Firms	104	282	189	110

	(5)	(6)	(7)	(8)
High CC Exposure × Post-Paris	0.336***	0.231***	0.266***	0.254***
	(3.190)	(2.716)	(2.947)	(2.779)
Firm controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Region x Year FE	No	No	Yes	No
Country x Year FE	No	No	No	Yes
R^2	0.673	0.646	0.667	0.712
N	888	959	1,147	982
Specification	Balanced Panel	No Covid	Add. FEs	Add. FEs

Note: Table reports results from a DiD framework around the 2015 Paris Agreement. We apply alternative classifications of fossil fuel firms in columns (2) through (4). In column (5), we focus on a balanced panel of firms that we observe throughout the entire sample period from 2010-2021. Column (6) excludes the Covid-period. In columns (7) and (8), we add additional fixed effects.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, t-statistics in parentheses.

(5), we address potential bias from firm entry or exit by using a balanced panel of firms observed from 2010 to 2021.[23] Note that the number of observations in column (2) drops from 1,147 to 888 suggesting that entry or exit does not play a major role in our sample period. In line with this, we observe that our baseline result is robust to using a balanced panel.

To rule out the Covid-pandemic as a driver of our effect, we also exclude all observations after 2019 in column (6), finding that the results are robust.

Columns (7) and (8) include additional controls for local macroeconomic trends with region x year and country x year fixed effects, and β_1 remains unaffected.

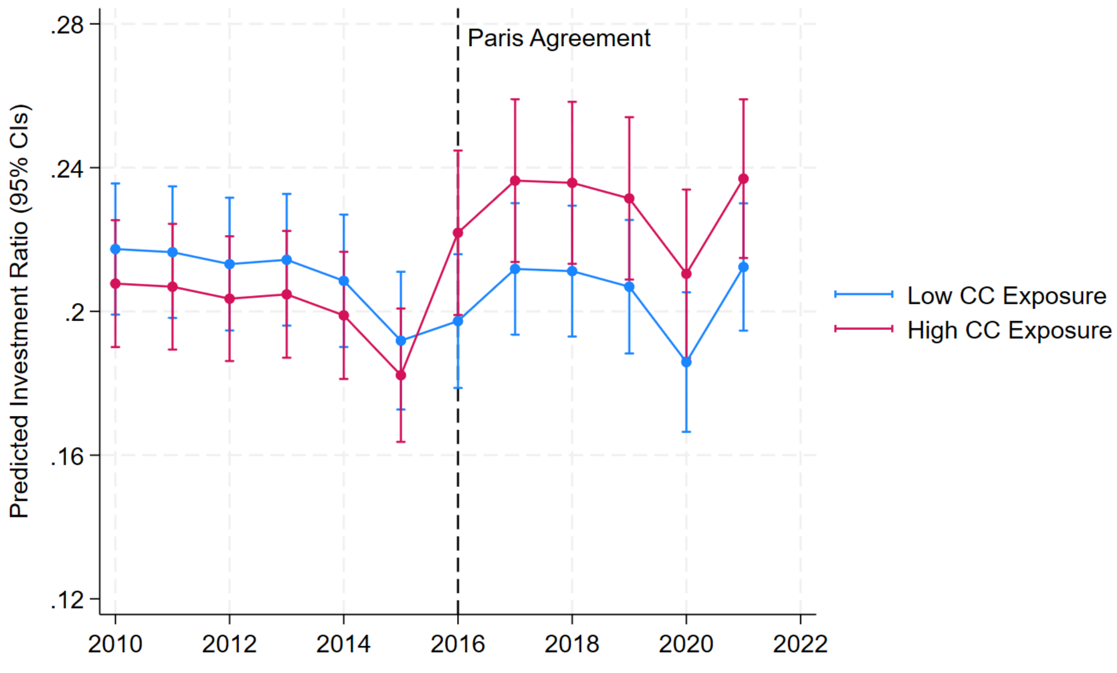
[23] Entry or exit in our sample may be caused by firms shifting from being private to public or vice versa. Additionally, M&A activity or bankruptcy can lead to exits of firms from the sample.

5 Policy Implications

Our results provide evidence that fossil fuel firms with high exposure to climate change react to an upward shift in the expected stringency of future climate policy by raising investment relative to other firms. Therefore, rather than climate policy, we would attribute the investment drop in the fossil fuel over the last decade mainly to the decrease in oil prices over that period. As noted earlier, a significant contributor to the drop in oil prices was lower demand due to a weakening economy (Baumeister and Kilian, 2016). This motivates us to conduct a simple counterfactual exercise, where we ask how investment in the fossil fuel industry would have developed in a stable macroeconomic environment. To address this question, we re-estimate our differences-in-differences model, but we replace time-fixed effects with controls for macroeconomic conditions. We report these estimates in the Appendix (Table A5).

Using these estimates, we predict the investment ratio under stable macroeconomic conditions, assuming that oil futures and expected GDP growth would have remained at their pre-Paris levels.[24] To ensure that changes in the macroeconomic environment affecting all firms equally are not picked up by the remaining regressors, we also omit the coefficient on *Post-Paris*. Figure 7 shows the predicted investment ratios for fossil fuel firms with low and high exposure to climate change.

Figure 7: Investment Under Stable Macroeconomic Conditions



Note: This Figure represents a counterfactual exercise, estimating the investment ratio for low versus high climate change exposure firms under the assumption of constant oil prices and GDP forecasts. Specifically, we run the following model:

$$\text{Inv. Ratio}_{f,t} = \beta_1 \times \text{High CC Exposure}_f \times \text{Post-Paris}_t + \beta_2 \times \text{High CC Exposure}_f + \gamma F_{f,t} + \phi \times \text{Macro Controls}_t + \epsilon_{f,t}$$

Relative, to our baseline DiD, we omit time FEs and replace these by time-varying macroeconomic controls encompassing the 1-year ahead WTI oil future as well as 1- and 5-year ahead GDP forecasts. When predicting investment ratios, we hold the oil price, oil future and GDP forecasts constant at their pre-Paris values.

[24] Specifically, we assume the 1-year WTI oil future remains at USD 65.5 per barrel and that the expected 1-year (5-year) ahead GDP growth is constant at 3.8% (4.3%) throughout the sample period.

Although, we interpret our results with due care, the counterfactual exercise allows for several interesting observations. Figure 7 illustrates that for fossil fuel firms with high exposure to climate change, one could have expected a 4 percentage points increase in investment between 2010 and 2021. In contrast, for firms with low exposure to climate change, our counterfactual exercise predicts only minor changes to the investment ratio between 2010 and 2021.

Regarding policy implications, we acknowledge that any delay in implementing climate policies reduces the available time to curtail emissions. Our paper suggests that time lags between announcing prudent regulation towards achieving net-zero emissions and their actual implementation prove detrimental through a complementary channel. During these intermediate periods, firms have strong incentives to raise investment, in line with the Green Paradox hypothesis. Consequently, delaying the implementation of climate policy not only necessitates more stringent policies in the future due to reduced time availability but also because emission trajectories may deviate onto a higher path than initially anticipated. The requirement for more abrupt policies could contribute to heightened energy price volatility in the future, with broader implications for economic stability. Thus, we advocate for an early and prudent climate policy implementation.

6 Conclusion

We ask how fossil fuel firms react to shifting expectations to future climate policy. In a differences-in-differences set-up, we show that fossil fuel firms with high exposure to climate change raised investment in response to the Paris Agreement relative to firms with low exposure. Importantly, investment sustained current business models, while there are no indications that fossil fuel firms transitioned towards renewable energy sources nor less carbon-intensive production technology after Paris. Our findings lend support to the Green Paradox hypothesis and have important policy implications. Notably, climate policy should be carefully and clearly designed to prevent policy uncertainty while implementation lags should be as short as possible. Otherwise, the future would call for even stricter and more abrupt regulation to comply with current targets. That could also have more broad economic consequences as it would likely cause higher energy price volatility.

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Burn Now or Never? Climate Change Exposure and Investment of Fossil Fuel Firms

Appendix

Table A1: Variable Definitions

Description	Unit	Data Source	Variable Name/Formula
Firm Characteristics			
Headquarter Country		Compustat	loc
Standard Industrial Code		Compustat	sic
Total Assets	mUSD	Compustat	at
Total Liabilities	mUSD	Compustat	lt
Total Equity	mUSD	Compustat	teq
Net Property, Plant & Equipment	mUSD	Compustat	ppent
Net Income	mUSD	Compustat	ni; nicon
Costs of Goods Sold	mUSD	Compustat	cogs
Capital Expenditures	mUSD	Compustat	capx
Research and Development Expense	mUSD	Compustat	xrd
Cash Dividends	mUSD	Compustat	dv
Purchase of Common and Preferred Stock	mUSD	Compustat	prstkc
Investment Ratio		own calculation	Capex/PP&E
Log Investment Ratio		own calculation	log(Investment Ratio)
Log Assets		own calculation	log(at)
Return on Assets		own calculation	ni/at
Debt-to-Equity		own calculation	lt/teq
Asset Tangibility		own calculation	ppent/at
R&D Ratio		own calculation	xrd/ppent
Log R&D Ratio		own calculation	log(R&D ratio)
Firm Cost Efficiency		own calculation	2010-2015: Mean(COGS/Sales)
Large firm	0/1	own calculation	2015 assets > Median 2015 assets
High COGS/Sales	0/1	own calculation	Firm Cost Efficiency > Median(Firm Cost Efficiency)
Climate Change Measures			
Climate Change Exposure		SvLVZ (JF 2023)	cc_expo_ew
Climate Change Exposure - Sentiment		SvLVZ (JF 2023)	cc_sent_ew
Climate Change Exposure - Positive Tone		SvLVZ (JF 2023)	cc_pos_ew
Climate Change Exposure - Negative Tone		SvLVZ (JF 2023)	cc_neg_ew
Pre-Paris Exposure		own calculation	2010-2015: Average(cc_expo)
High CC Exposure	0/1	own calculation	Pre-Paris Exposure > Median(Pre-Paris Exposure)
Scope 1 Emissions	tCO2	ISS	ClimateScope1Emissions
Scope 2 Emissions	tCO2	ISS	ClimateScope2Emissions

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Table A1 – continued from previous page

Description	Unit	Data Source	Variable Name/Formula
Scope 3 Emissions	tCO2	ISS	ClimateScope3Emissions
Scope 1 Emission Intensity	tCO2/USD	own calculation	Scope 1 Emissions / Total Assets
Capex Breakdown			
Coal Exploration	mUSD	Trucost FF	di_319392
Gas Exploration	mUSD	Trucost FF	di_319394
Oil & Gas Exploration	mUSD	Trucost FF	di_319396
Oil Exploration	mUSD	Trucost FF	di_319398
Undefined Fossil Fuel Exploration	mUSD	Trucost FF	di_319400
Fossil Fuel Capex	mUSD	own calculation	sum(di_319392, di_319394, di_319396, di_319398, di_319400)
Unspecified Capex	mUSD	own calculation	Capital Expenditures (Compustat) - Fossil Fuel Capex
Fossil Fuel Share		own calculation	Fossil Fuel Capex/Total Capex (Compustat)
High Fossil Fuel Dependence		own calculation	Fossil Fuel Share > 0.9
Year Founded		Trucost FF	yearfounded
Stock Returns			
Daily Return	%	CRSP	ret
S&P 500 Daily Return	%	CRSP	sprtrn
Monthly Return	%	CRSP	trt1m
Oil Beta		own calculation	β from regression of monthly stock returns on changes in oil prices (2010-2015)
High Oil Beta	0/1	own calculation	Oil Beta > Median(Oil Beta)
Commodity Prices			
Spot Oil Price	USD	IMF Primary Commodity Prices	n.a
Oil West Texas Intermediate 1m Future	USD	Bloomberg	CL1 COMB Comdty
Oil West Texas Intermediate 1y Future	USD	Bloomberg	CL12 COMB Comdty
Oil West Texas Intermediate 2y Future	USD	Bloomberg	CL24 COMB Comdty
Gas Henry Hub 1m Future	USD	Bloomberg	NG1 COMB Comdty
Forecasts			
GDP Forecasts	Percent	World Bank	n.a.
Other			
Post-Paris	0/1	own calculation	year > 2015

Table A2: Summary Statistics

	N	Mean	SD	Min	p10	p25	Median	p75	p90	Max
Outcome Variable										
Log(IR)	1,147	-2.02	0.68	-3.45	-3.00	-2.48	-1.95	-1.52	-1.13	-0.96
Inv. Ratio	1,147	0.16	0.10	0.03	0.05	0.08	0.14	0.22	0.32	0.38
SvLVZ Climate Exposure										
CCExp	1,054	1.60	2.24	0.00	0.16	0.38	0.91	1.82	3.87	24.46
High CC Exposure	1,147	0.50	0.50	0.00	0.00	0.00	0.00	1.00	1.00	1.00
Firm Controls										
Log (Assets)	1,147	9.46	1.61	6.73	7.31	8.25	9.37	10.62	11.89	12.54
RoA	1,147	0.00	0.10	-0.27	-0.13	-0.03	0.03	0.06	0.10	0.12
Debt-to-Equity	1,147	1.19	0.70	0.22	0.42	0.70	1.06	1.47	2.25	3.03
Tangibility	1,147	0.68	0.18	0.34	0.41	0.54	0.70	0.83	0.91	0.93
High Fossil Fuel Dep.	1,021	0.62	0.49	0.00	0.00	0.00	1.00	1.00	1.00	1.00
Oil Beta	709	0.54	0.30	0.08	0.21	0.32	0.48	0.70	0.96	1.47
High Oil Beta	709	0.53	0.50	0.00	0.00	0.00	1.00	1.00	1.00	1.00
Macro Controls										
Oil WTI 1y Future	1,147	56.09	11.48	37.51	43.76	46.16	52.24	65.82	70.28	74.63
Oil WTI 2y Future	1,147	55.21	10.66	38.30	45.33	45.70	49.62	64.96	69.61	72.37
GDP Forecast t+1	1,147	3.91	0.54	3.41	3.44	3.56	3.65	4.00	4.89	5.15
GDP Forecast t+5	1,147	3.96	0.46	3.28	3.52	3.59	3.78	4.12	4.62	4.86

Note: Table provides summary statistics of all variables used in the subsequent analysis. The outcome variables are logarithmized. Outcome and firm variables are winsorized at the 5th and 95th percentile throughout the paper.

Table A3: List of Sample Firms

Company Name	Country	High CC Exposure	Sales (USD)	SIC
PETROCHINA CO LTD	China	1	411552	2911
EXXON MOBIL CORP	United States	1	276692	2911
SHELL PLC	United Kingdom	1	261504	2911
TOTALENERGIES SE	France	1	184634	2911
BP PLC	United Kingdom	1	157739	2911
CHEVRON CORP	United States	1	155606	2911
GAZPROM PJSC	Russia	1	138970	2911
OIL CO LUKOIL PJSC	Russia	1	122881	2911
MARATHON PETROLEUM CORP	United States	1	119983	2911
ROSNEFT OIL COMPANY	Russia	1	117159	2911
PHILLIPS 66	United States	1	111476	2911
VALERO ENERGY CORP	United States	1	108332	2911
EQUINOR ASA	Norway	1	88744	2911
ENI SPA	Italy	1	88329	2911
PETROLEO BRASILEIRO SA- PETR	Brazil	1	83966	2911
OIL & NATURAL GAS CORP LTD	India	1	66456	1311
REPSOL SA	Spain	1	59334	2911
BHARAT PETROLEUM CO LTD	India	0	46912	2911
CONOCOPHILLIPS	United States	0	45960	1311
OMV AG	Austria	1	42049	1311
GAZPROM NEFT PJSC	Russia	1	40325	2911
CNOOC LTD	Hong Kong	1	38743	1311
CENOVUS ENERGY INC	Canada	1	36636	2911
ORLEN S A	Poland	1	34025	2911
SUNCOR ENERGY INC	Canada	1	30926	2911
OCCIDENTAL PETROLEUM CORP	United States	0	25956	1311
CANADIAN NATURAL RESOURCES	Canada	1	23754	1311
ECOPETROL SA	Colombia	1	22586	2911
MOL HUNGARIAN OIL	Hungary	1	19657	2911
GALP ENERGIA SGPS SA	Portugal	0	19061	2911
EOG RESOURCES INC	United States	0	18517	1311
HF SINCLAIR CORP	United States	0	18389	2911
PIONEER NATURAL RESOURCES CO	United States	0	17870	1311
TATNEFT PJSC	Russia	0	17171	2911
TUPRAS-TURKIYE PETROL RAFINE	Turkey	0	16993	2911
AMPOL LTD	Australia	1	16241	2911
PAO NOVATEK	Russia	1	14274	1311
YACIMIENTOS PETE FISCALES SA	Argentina	1	12381	2911
DEVON ENERGY CORP	United States	0	12206	1311
HELLENIQ ENERGY HOLDINGS SA	Greece	0	10907	2911
SARAS RAFFINERIE SARDE SPA	Italy	1	10125	2911
ALTAGAS LTD	Canada	1	8356	1311
HESS CORP	United States	0	7473	1311
WOODSIDE ENERGY GROUP LTD	Australia	1	6962	1311
DIAMONDBACK ENERGY INC	United States	0	6797	1311

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Table A3 – continued from previous page

Company Name	Country	High CC Exposure	Sales (USD)	SIC
CHESAPEAKE ENERGY CORP	United States	0	5792	1311
MARATHON OIL CORP	United States	0	5218	1311
SANTOS LTD	Australia	1	4837	1311
ANTERO RESOURCES CORP	United States	1	4619	1311
CHINA OILFIELD SERVICES LTD	China	1	4460	1381
WEATHERFORD INTL PLC	United States	0	3645	1381
COTERRA ENERGY INC	United States	1	3449	1311
MEG ENERGY CORP	Canada	1	3415	1311
TOURMALINE OIL CORP	Canada	0	3381	1311
RANGE RESOURCES CORP	United States	0	2930	1311
SM ENERGY CO	United States	0	2623	1311
TRANSOCEAN LTD	Switzerland	0	2556	1381
ORRON ENERGY AB (PUBL)	Sweden	0	2533	1311
MURPHY OIL CORP	United States	0	2275	1311
NABORS INDUSTRIES LTD	Bermuda	0	2018	1381
CALIFORNIA RESOURCES CORP	United States	1	1889	1311
CRESCENT POINT ENERGY CORP	Canada	1	1850	1311
VERMILION ENERGY INC	Canada	1	1613	1311
CHORD ENERGY CORP	United States	0	1580	1311
INTEROIL CORP	Singapore	1	1396	1311
PATTERSON-UTI ENERGY INC	United States	0	1357	1381
TULLOW OIL PLC	United Kingdom	0	1273	1311
ENQUEST PLC	United Kingdom	0	1266	1311
DENBURY INC	United States	0	1243	1311
VALARIS LTD	Bermuda	0	1232	1381
HELMERICH & PAYNE	United States	0	1219	1381
BAYTEX ENERGY CORP	Canada	0	1208	1311
ENERPLUS CORP	Canada	1	1208	1311
BEACH ENERGY LTD	Australia	1	1173	1311
SEADRILL LTD	Bermuda	0	1008	1381
DNO ASA	Norway	1	1004	1311
NOBLE CORP PLC	United States	0	848	1381
CALFRAC WELL SERVICES LTD	Canada	0	792	1381
ENSIGN ENERGY SERVICES INC	Canada	0	787	1381
PRECISION DRILLING CORP	Canada	0	780	1381
CNX RESOURCES CORPORATION	United States	1	751	1311
DIAMOND OFFSHRE DRILLING INC	United States	0	725	1381
ATHABASCA OIL CORP	Canada	1	658	1311
UNIT CORP	United States	0	639	1311
QUICKSILVER RESOURCES INC	United States	0	569	1311
W&T OFFSHORE INC	United States	0	558	1311
HUNTING PLC	United Kingdom	0	522	2911
PEYTO EXPLORATION & DEVELPMT	Canada	0	511	1311
PARKER DRILLING CO	United States	0	481	1381
GRAN TIERRA ENERGY INC	Canada	1	474	1311
ETABLISSEMENTS MAUREL & PROM	France	1	440	1311
KEY ENERGY SERVICES INC	United States	0	414	1381
SUMMIT MIDSTREAM PARTNERS LP	United States	0	401	1311

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Table A3 – continued from previous page

Company Name	Country	High CC Exposure	Sales (USD)	SIC
EXCO RESOURCES INC	United States	0	394	1311
OBSIDIAN ENERGY LTD	Canada	0	357	1311
HERCULES OFFSHORE INC	United States	0	349	1381
GENEL ENERGY PLC	United Kingdom	0	335	1311
BATTALION OIL CORP	United States	0	285	1311
NACCO INDUSTRIES -CL A	United States	1	192	1221
SANDRIDGE ENERGY INC	United States	1	115	1311
HORIZON OIL LTD	Australia	0	64	1311
JKX OIL & GAS PLC	United Kingdom	0	56	1311
TOUCHSTONE EXPLORATION INC	Canada	1	20	1311

Table A4: Merging with Compustat NA + Global

	Comp WW	Comp WW + Trucost FF	Comp WW +Trucost FF +SvLVZ	Final Sample
No restrictions	56,894	9,970	4,703	
Sample Period 2010-2021	34,586	9,919	4,703	
thereof: fossil fuel firms	844	259	177	103
Fossil fuel coverage	1.00	0.89	0.80	0.78

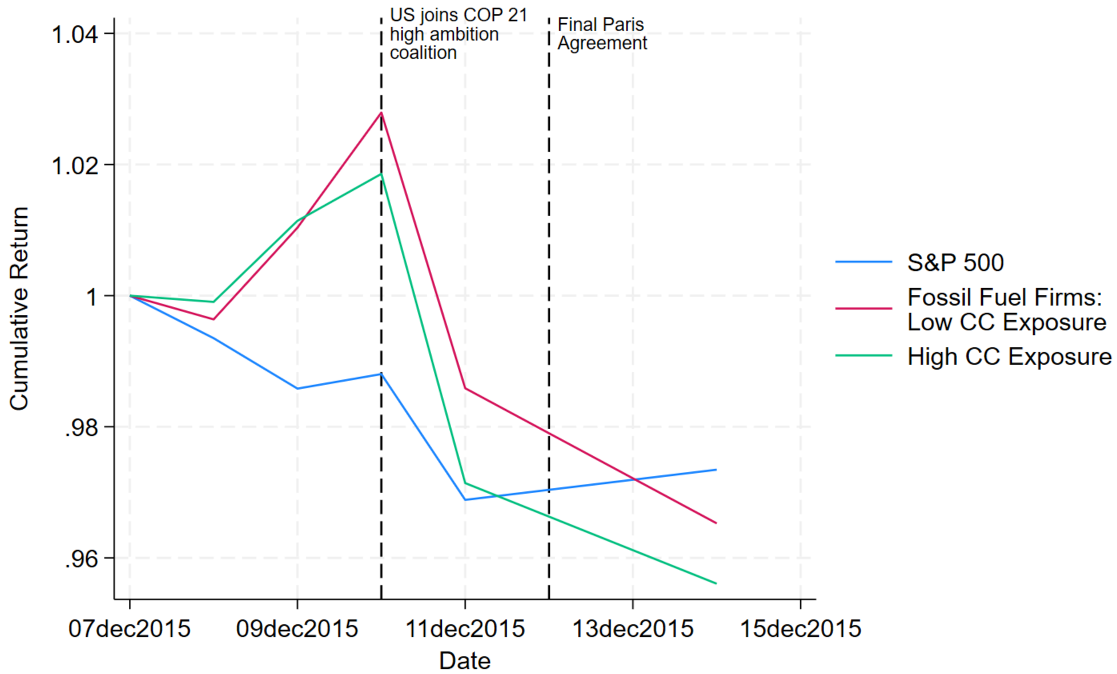
Note: Number of firms in different combined samples. SvLVZ refers to Sautner, Van Lent, Vilkov, and Zhang (2023). Fossil fuel coverage is the fraction of total sales in Compustat in the sample period that is accounted for in the subsample.

Table A5: Climate Exposure and Investment - Macro Controls

	(1)	(2)
High CC Exposure × Post-Paris	0.279***	0.279***
	(3.224)	(3.214)
Post-Paris		-0.371***
		(-4.925)
Log (Assets)	0.016	0.024
	(0.324)	(0.483)
RoA	1.705***	1.675***
	(8.183)	(8.190)
Debt-to-Equity	-0.048	-0.051
	(-1.392)	(-1.460)
Tangibility	-0.173	-0.081
	(-0.570)	(-0.267)
Oil WTI 1y Future		0.013***
		(5.803)
GDP Forecast t+1		-0.054*
		(-1.691)
GDP Forecast t+5		0.126**
		(2.259)
Firm FE	Yes	Yes
Year FE	Yes	No
R^2	0.649	0.643
N	1,147	1,147
Specification	Baseline	Macro controls

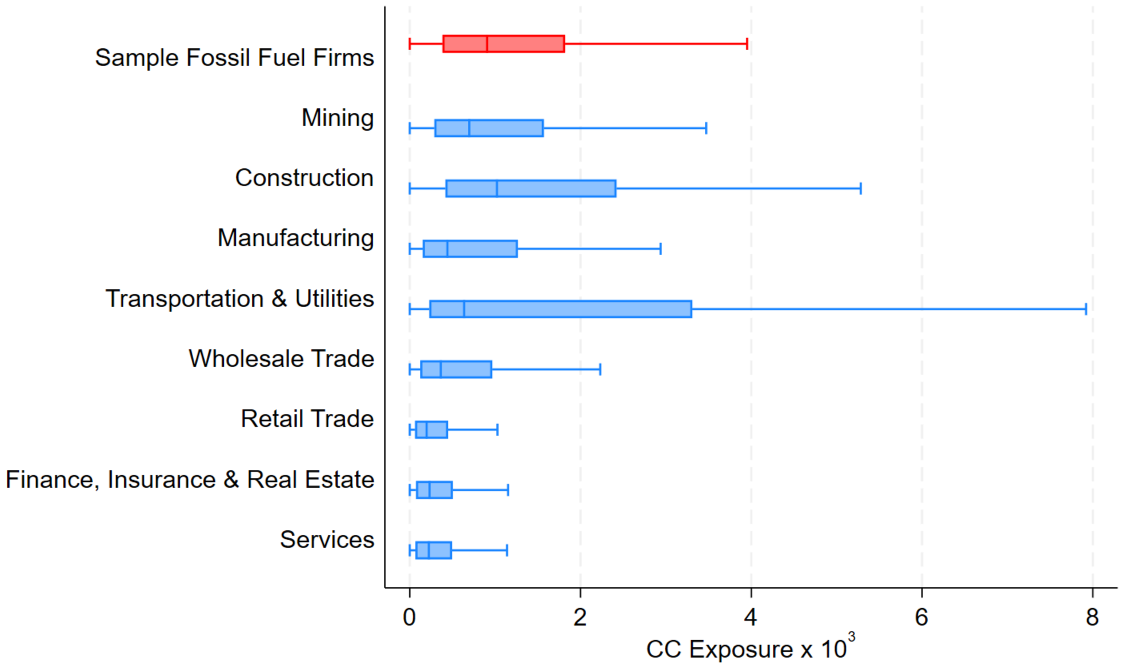
Note: Table reports results from a DiD framework around the 2015 Paris Agreement. Exposed firms have an average value of the exposure measure over time that is higher than the median value across all firms. Standard errors are clustered at firm level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, t-statistics in parentheses.

Figure A1: Stock Returns Around the Paris Agreement



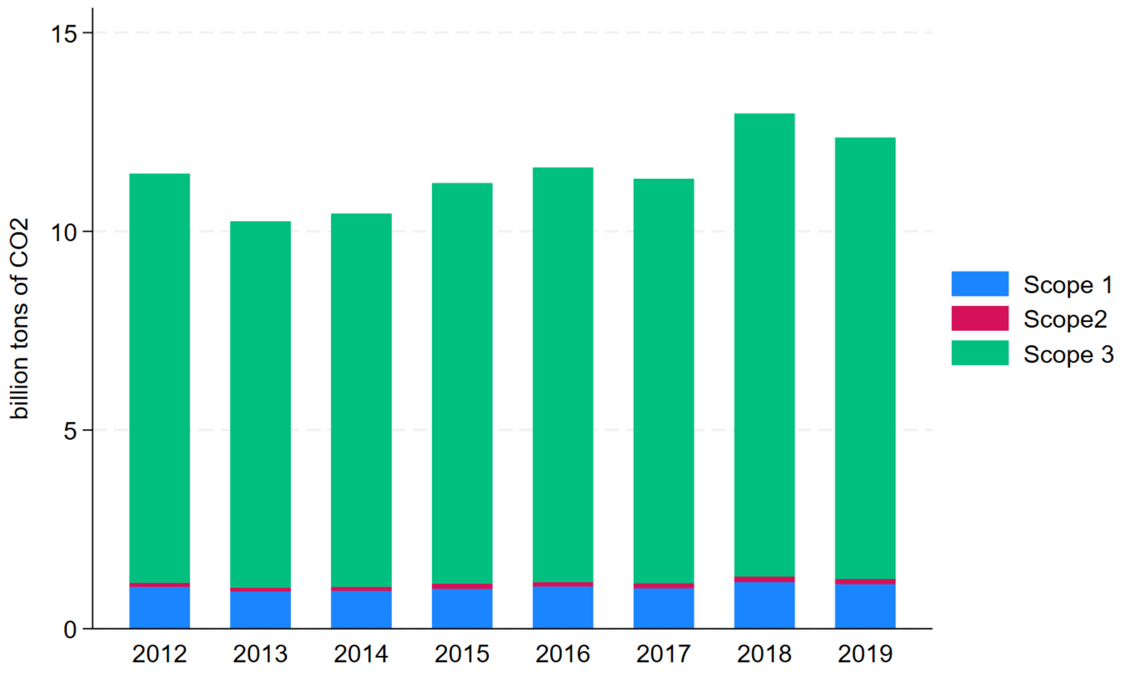
Note: Cumulative stock returns for low/high climate change exposure firms around the Paris Agreement. Media reports suggest that the public announcement on December 10 by the US to join a coalition of countries willing to negotiate an ambitious climate pact was an important milestone in the COP21 meetings (e.g.: https://www.bbc.com/news/science-environment-35057282).

Figure A2: Climate Change Exposure by Sector



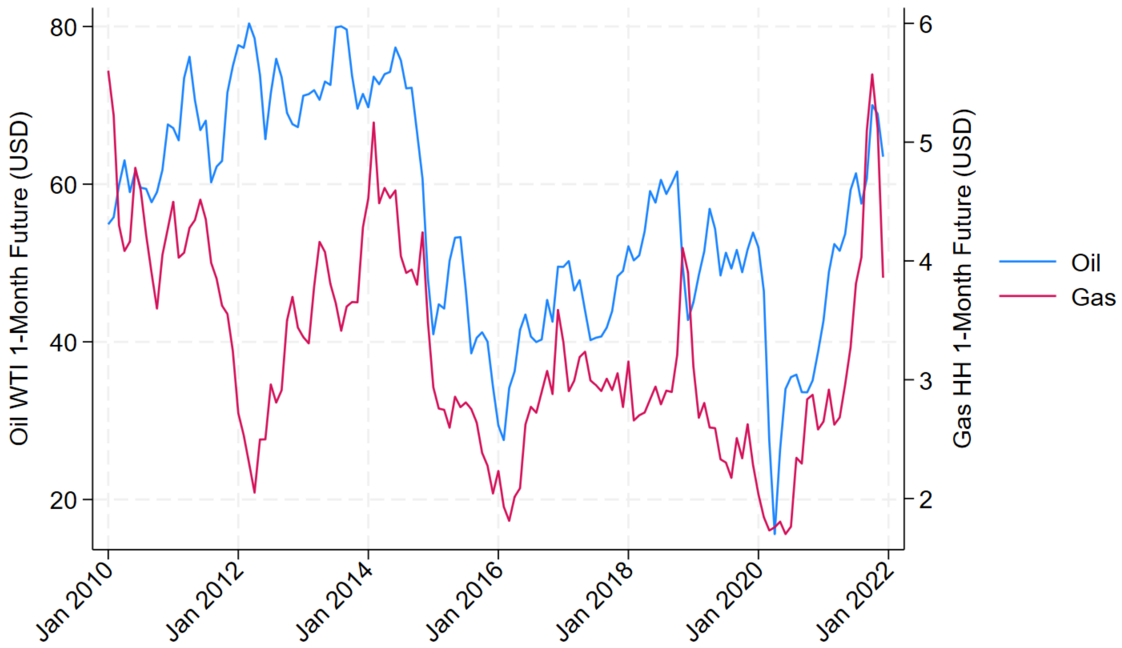
Note: Distribution of Sautner et al. (2023) measure of general climate exposure for firms by sector between 2010-2021.

Figure A3: Total Sample Firm Emissions



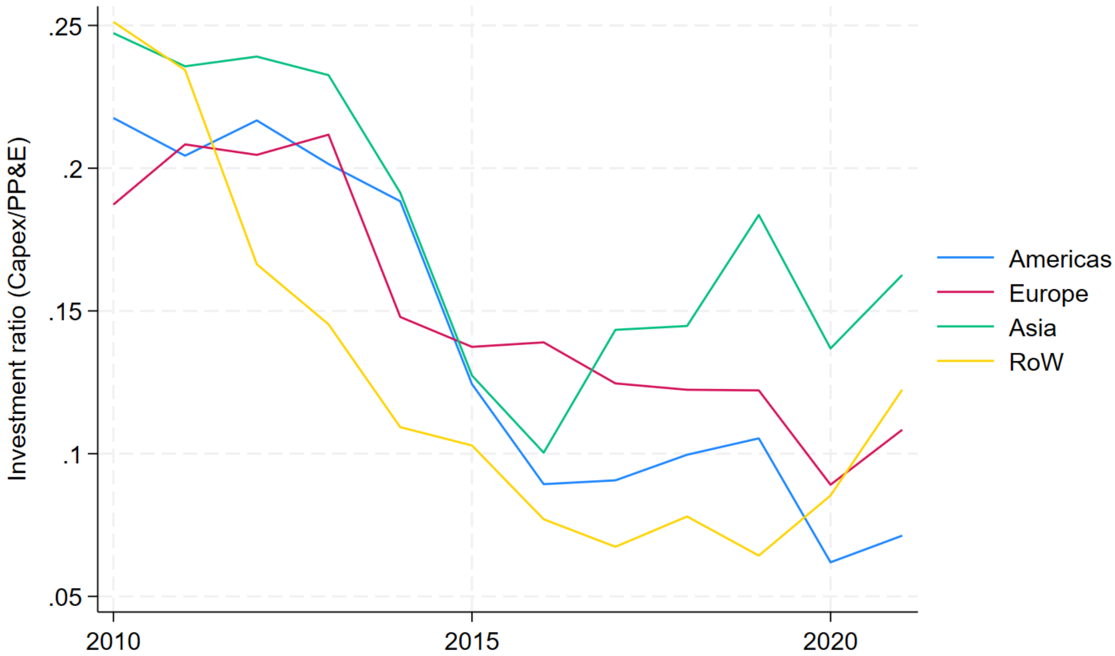
Note: Total scope 1, 2 and 3 emissions by the fossil fuel firms with non-missing emissions data in the sample. Emissions data is obtained from ISS.

Figure A4: Oil and Gas 1-month Futures



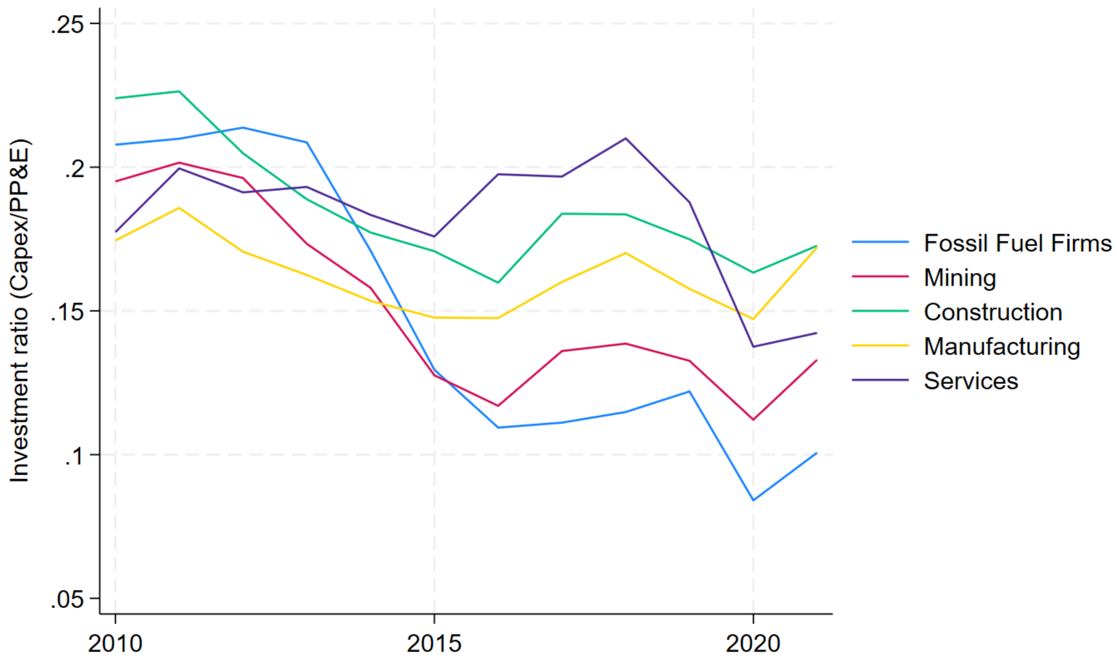
Note: Data on futures prices comes from Bloomberg. Sample period 01/2010 until 12/2021.

Figure A5: Investment Ratio by Region



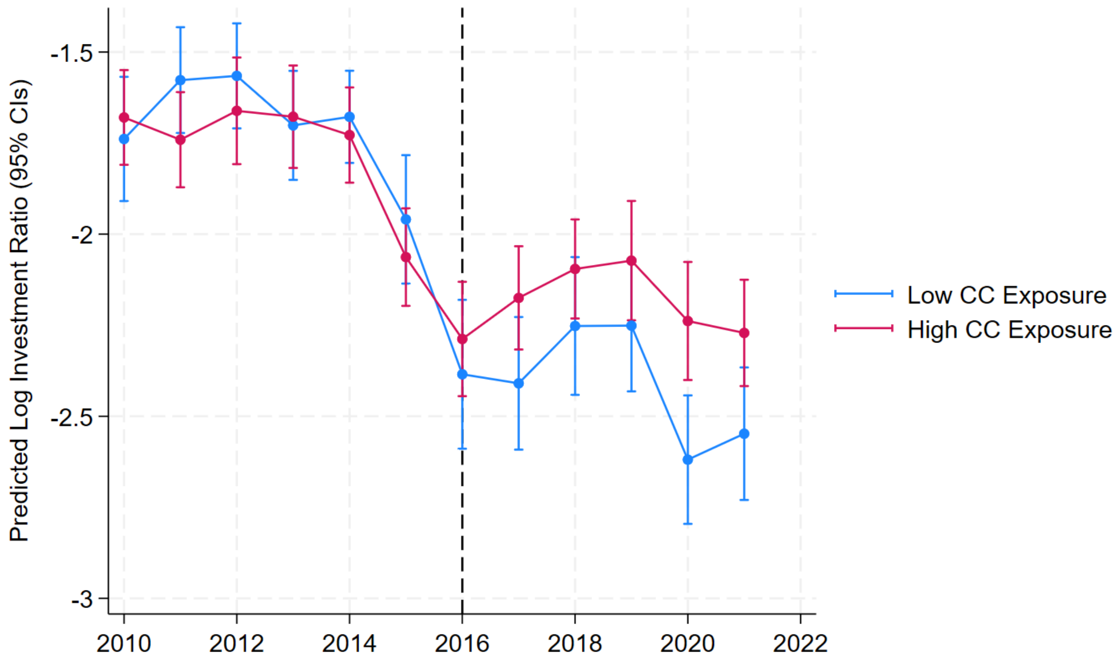
Note: Average ratio of capital expenditures to property, plant and equipment by fossil fuel firms in different regions over the sample period from 2010 - 2021.

Figure A6: Investment in Other Sectors



Note: Average ratio of capital expenditures to property, plant and equipment by firms in different sectors over the sample period from 2010 - 2021. Industry classification determined by SIC codes.
The decrease in the investment ratio of the Services sector between 2018 and 2020 is partially due to a change in IFRS 16 - Leasing - that became effective in 2019. The change requires lessees to recognize lease liabilities and right-of-use assets on balance sheet. (IFRS, 2019)

Figure A7: Climate Change Exposure and Log Investment - Parallel Trends



Note: This Figure depicts predicted values for low versus high climate change exposure firms from the following regression:
$\log(\text{Inv. Ratio}_{f,t}) = \beta_1 \times \text{High CC Exposure}_f \times \text{Year}_t + \beta_3 \times \text{High CC Exposure}_f + \gamma F_{f,t} + \alpha_t + \epsilon_{f,t}$.