Financing and the Green Paradox

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Abstract

We study the investment decisions of polluting firms in response to changes in climate regulation risks. We build a model of firm financing and investment that predicts higher investment prior to the regulatory shock for firms more exposed to the shock, and higher borrowing costs after the regulatory shock. In our empirical analysis, using the Paris Climate Accords as a shock to future climate regulation, we find evidence consistent with the model. High-emissions intensity firms issue shorter-maturity bonds post Paris, experience a drop in capital expenditures and investment rates, and see an increase in pollution rates. Our findings show that high-emissions intensity firms that expect financing frictions to intensify under climate regulatory shocks can exhibit behavior consistent with a "green paradox," where polluting firms increase ex ante investment in the expectation of future climate regulation. We discuss the possibility of multiple equilibria in the model where the expectation of increased future regulation drives the investment that eventually validates the increased regulation likelihood.

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1 Introduction

The green paradox refers to increases in emissions due to actions that firms take in anticipation of a policy intervention aimed at reducing carbon emissions (Sinclair, 1992; Sinn, 2008). This paper studies the corporate bond issuance and investment decisions of firms ahead of a shock to the saliency of climate risks and of increased future regulation. We develop a model of firm investment and financing where firms behave according to the green paradox and test its predictions in our empirical analysis. The model reconciles the evidence on financing decisions from the corporate bond market with observed investment and emissions decisions.

We model a firm that can take an investment option at a cost and needs financing for it. The investment is sensitive to (climate) regulation: the period the firm is deciding over the investment option coincides with the possibility of a regulatory shock on emissions that increases the project's operating costs. The firm can contribute financing toward the cost of the project at the time of taking the option or prior to it. If the borrowing rate is the same prior to the option exercise and at the time of the option exercise, the firm would not borrow earlier, because the option may never materialize and all of the early investment would have been for nought. However, if the regulatory shock increases the expected financing cost for the polluting firm, then the higher future cost creates an incentive to invest earlier. By investing earlier the firm benefits from cost savings as more of the financing of the cost of the investment is done at the lower rate.

The model delivers several predictions. First, the model predicts that a higher probability of climate regulation affecting the firm leads the firm to borrow and invest more earlier on, akin to the green paradox. Importantly, this result only applies if

borrowing costs are contingent on the passing of the regulation. If instead borrowing costs are higher in the future independently of whether the regulation shock realizes, then the firm will still want to do some early investment, but will do *less* of it if the probability of climate regulation increases. Second, the earlier investment by the firm is associated with a higher probability of completing the investment project, and with more pollution. Third, if the regulatory event carries increased costs to the firm, then the firm faces higher borrowing costs in that state of nature. Fourth, firms in industries with better abatement technologies or with projects with higher cash flow volatility are predicted to invest more earlier on.

When we introduce a regulatory body to the model, we show that the regulation equilibrium may exhibit multiple equilibria. In the spirit of Glazer and McMillan (1992) and others, the regulatory body is modeled to increase the probability of regulation when it sees higher investment earlier on by polluting firms. We show that this threat strategy coupled with the green paradox result can produce multiple equilibria: an equilibrium with low risk of regulation and low investment earlier on and an equilibrium with high risk of regulation and high investment earlier on. In the high investment equilibrium, the industry's expectation of the likelihood of the regulator's action drives investment up by polluting firms (i.e., the model's green paradox effect), and the increased investment leads to a higher probability of regulation, thus validating those expectations. The green paradox can therefore be the result of a self-fulfilling prophecy by polluting firms over the actions of the regulator. An immediate consequence of the multiplicity of equilibrium is that small changes in expectations can drive the industry to the high pollution equilibrium. Second, the very actions of the regulator aimed at curbing firm investment in polluting technologies can be counterproductive. At the

same time, and because of the symmetry of our results, a shift in policy that may signal a reduced likelihood of regulation leads to less investment by polluting firms. Third, different industries or different groups of firms, such as private versus public, subject to different regulatory bodies may experience different outcomes. This result may explain the differential investment patterns across private and public US firms (e.g. Duchin, Gao, and Xu 2022).

To empirically analyze how the risk of climate regulation affects financing and investment decisions, we consider the 2015 Paris Climate Accords as a shock to future regulatory risk (Ilhan, Sautner, and Vilkov, 2021; Bolton and Kacperczyk, 2021, 2023; Seltzer, Starks, and Zhu, 2024).[1] We estimate difference-in-difference equations describing financing, investment and emissions pre- and post-Paris Accords. We use two variables to indicate treatment: a continuous variable equal to the lagged value of firm GHG-emissions intensity and an indicator variable equal to 1 if the firm lagged emissions intensity is above the sample median.

We analyze firm financing decisions in the corporate bond market. The corporate bond market offers two unmodeled dimensions that are of interest in our analysis. Our model emphasizes the increased bankruptcy cost associated with regulation as the incentive for firms to invest earlier. There are two more reasons why the cost of financing in the bond market may increase post regulation. First, the bond market is a natural way to segment investors by investor horizon (Vayanos and Vila, 2021) and recent evidence suggests that there is a segment of the investor population that has longer-term investment horizon and non-pecuniary preferences toward the environment, social and governance (ESG) performance of firms (e.g. Starks, Venkat, and Zhu

[1]The Paris Climate Accords is an international treaty on climate change whose signatories committed to tight climate policy objectives.

(2017)). The Paris Accords may induce a shift of these investors to less polluting firms, increasing the cost of borrowing to more polluting firms. Second, cash flows of bonds of longer maturity may be more sensitive to the uncertainty of future regulation. This added sensitivity may reflect in an higher borrowing cost for longer term bonds that forces polluting firms to consider shorter term debt. Empirically, the corporate bond market data allow us to study investment and financing of public and private companies and prior evidence has shown that private firms have higher GHG emissions intensity than public firms (Ivanov, Kruttli, and Watugala, 2024).

We use data on facility-level greenhouse gas emissions from the US Environmental Protection Agency (EPA) and combine these data with corporate bond data from Mergent and balance sheet data from Capital IQ. The mapping between the EPA data and the other two datasets is based on name and address of the respective parent companies. The EPA data have detailed information on a facility's parent companies, their names, addresses, and ownership stakes in a given year, which we use to assign emissions levels to parent companies. We aggregate bond issues by the same firm in a given year to a single observation. Our data range from 2010 to 2020, with the merged EPA and Capital IQ sample, and merged EPA, Capital IQ, and Mergent sample comprising about 3,000 firm-year observations each.

We first consider how bond characteristics, offering yield, maturity and amount vary with firm emissions. We find that firms with more GHG-emissions intensity offer bonds with shorter maturity in the post Paris period, controlling for common firm determinants. For the firms with above median GHG-emissions intensity, the offering maturity of new corporate debt issues drops by about 1.8 years on average. This result is consistent with the finding in Seltzer, Starks, and Zhu (2024) regarding insurance

companies' behavior around the Paris Accords. We do not find any statistically significant effect on offering amounts or yields. One interpretation of the result on yields is that firms adjust to an upward shift of their yield curve post Paris (see Seltzer, Starks, and Zhu 2024 and others for additional evidence of tightening of financing costs for emissions inefficient firms post Paris) by borrowing more short term, which typically carries lower yields. Arguably, with an upward sloped yield curve, they would be paying higher yields had they continued borrowing at similar maturities as before.

We then analyze whether a firm's emissions intensity has a corresponding effect in its investment policy, as predicted by the model, by studying changes in firm capital expenditures (CAPEX) in the period following the passage of the Paris Accords. We find that the ratio of CAPEX to assets is lower for high-emissionss intensity firms in the post-period. The effect we find is sizable. For the firms with above median emissions intensity, the investment rate is 1 percentage point smaller than for other firms, all else equal, in the post-Paris period. When we repeat the regressions using the level of CAPEX as the outcome, we again find a significant decrease in CAPEX for high-emissions intensity firms in the post period.

Finally, we report results on changes to firm emissions in the post-Paris period. Recall that the model predicts that by investing more earlier, the more emissions inefficient firms have a greater likelihood of completing the investment and hence of polluting if the regulatory shock materializes. We find that emissions intensity is not very persistence, suggesting it displays mean reversion. For the high-emissions intensity firms, we find an increase in persistence in the post-Paris Accords sample that is consistent with the model. In other words, firms with high-emissions intensity tend to have relatively *higher* emissions intensity in subsequent years in the post-Paris

period.

Our findings are consistent with the Green Paradox hypothesis acting through a financing channel. Evidence in Norman and Schlenker (2024) show that oil futures prices decreased with increases in the daily change in the prediction market's expectations that the Waxman-Markey bill would pass, a bill aimed at promoting investments in renewable energy sources and reducing carbon emissions. Unlike in our paper, they do not study quantities directly. Still, they estimate that the lowering of oil prices would boost contemporaneous oil consumption by $2\% - 4\%$. Lemoine (2017) finds that the U.S. Senate breakdown in negotiations of the Waxman-Markey bill lead to an increase in coal futures prices and in coal storage as predicted by the Green Paradox hypothesis. None of these papers looks at actual emissions as we do. Sinn (2015) argues forcefully that the failure of policies to both curb CO2 emissions and generate a significant increase in carbon prices is itself evidence of the green paradox. Jensen, Mohlin, Pittel, and Sterner (2015) study within the context of a model of the green paradox the effect that several factors may have in attenuating the green paradox but does not consider the role of finance.

The next section offers a brief review of the related literature. Section 3 presents the model and its main predictions. Section 4 discusses the data sources and the empirical strategy and Section 5 presents the results. Section 6 concludes.

2 Related literature

Seltzer, Starks, and Zhu (2024) find that shortly after the Paris Accords credit ratings go down and corporate bond yields increase for high emissions public firms, and also

that insurance companies (mutual funds) reduce (increase) their exposure to high emission firms. Also using the Paris Accord as a shock to the risk of regulation, Cao, Li, Zhan, Zhang, and Zhou (2023) find that liquidity deteriorates in bonds of high carbon-intensive public firms post Paris. Several papers find changes to firm risk in the public equity and options markets for high emissions firms in the post-Paris Accords period. Seltzer, Starks, and Zhu (2024) find evidence of increased asset volatility which they back out using equity values pre- and post-Paris periods. Ilhan, Sautner, and Vilkov (2021) find that carbon tail risk is priced in stock options and that it increases post Paris for firms with carbon-intense business models. Bolton and Kacperczyk (2021) find a carbon risk premium in the cross section of U.S. stocks that also increases post-Paris. Ehlers, Packer, and de Greiff (2022) find a loan carbon premium after the Paris Accords. Our paper provides further evidence on the effects of the Paris Accords by looking at the patterns linked to private and public firms in the bond market, and in studying changes in the investment policy of firms post-Paris.

Beyene, De Greiff, Delis, and Ongena (2021) focus on a cross-country sample of fossil fuel firms and find those facing higher climate risk, using a climate change policy index, pay higher bond spreads but not higher syndicated loan spreads. They find no difference on the maturity of bonds and loans. Duan, Li, and Wen (2023) find that the bonds of carbon intensive firms earn a negative return, which is consistent with being too high priced and having low yields. Kacperczyk and Peydro (2022) find that banks with carbon commitments restrict loan supply to carbon intensive industries. Ivanov, Kruttli, and Watugala (2024) find that the passing in Congress of climate related policies is associated with shorter loan maturities and higher loan interest rates for treated firms.

Several papers study the bond market and Environmental and Social (ES) and Environmental, Social and Governance (ESG) indices. Amiraslani, Lins, Servaes, and Tamayo (2023) find no relation between ES and bond yields except for the period 2008-2009 where they argue investors were more sensitive to trust issues and firms with high ES were viewed as more trustworthy by the market. de Xavier, Sansi, and Chidambaran (2021) find that firms with high ESG rating have lower yields. Both these papers use KLD scores but the former ignores the G component. Goss and Roberts (2011) find that firms with high levels of concerns regarding their Corporate Social Responsibility pay more for their loans than socially responsible firms.

There is a literature on the differential behaviors in terms of emissions by private and public firms. Duchin, Gao, and Xu (2022) find that polluting chemical plants are sold by public firms to private firms, but there is no reduction in pollution, though the stock returns of the public firms selling go up. Im (2023) shows that there is also no reduction in carbon dioxide emissions when public firms sell assets to private firms, but does not find an increase in stock prices for the sellers. Hartzmark and Shue (2023) show that an increase in borrowing costs to brown firms make them pollute more whereas a decrease in borrowing costs to green firms do not make them be greener. Our finding that the prospect of climate regulation is associated with both higher borrowing costs and increased emissions intensity is in line with their findings. Korganbekova (2023) finds positive spillovers across facilities in different states owned by the same firm from state-level climate regulation.

Landeri and Rampini (2023) study the adoption of newer, clean technologies when firms are heterogeneously financially constrained. They find that if clean and brown technologies exist in equilibrium, than the clean technology requires larger downpay-

ment and financially constrained firms invest in the brown technology. Bellon and Boualam (2024) argue that climate regulation risk makes dirty technologies more interesting to firms in distress, akin to a risk-shifting argument. van der Ploeg and Withagen (2012) discuss welfare implications of backstops, renewable resources that substitute perfectly for fossil fuels, and when a green paradox exists depending on the costs associated with the backstop technology. Acharya, Giglio, Pastore, Stroebel, and Tan (2024) study climate risk that arises from the arrival of breakthrough technologies in the renewable energy sector and from taxes on carbon emissions and restrictions on drilling. Engle (2024) suggests that the risk of stranded assets can lead polluting firms to underinvest, reducing the overall supply of fossil fuels. Chen (2023) provides a model of the interaction between quality of ESG disclosure and ESG policies. When investors have greater preference for ESG, the firm may decrease ESG investments if it cannot disclose well and investors discount firm statements of being green. Piccolo, Schneemeier, and Bisceglia (2022) argue that concentration of ESG-oriented investors on a small set of green firms may discourage green investments by excluded firms. Acemoglu, Akcigit, Hanley, and Kerr (2016) study taxation and technology adoption when there is climate-related transition risk and the dirty technology is more advanced.

3 A model of financing and investment and the green paradox

Consider the investment and borrowing decisions of a firm that faces the prospect of climate-related regulatory risk. There are three periods indexed by $0, 1, 2$. The firm has an investment option in a polluting asset (e.g., drill oil from a new well) at time

1 that requires an investment of I. At time 2, the investment returns an operating profit of $\tilde{\pi}$, with continuous cdf $F(\tilde{\pi})$. Also at time 1, there is a shock to climate regulation that occurs with probability λ. This shock affects the operating profit from the investment opportunity reducing it by the constant κ. We view κ as the cost that results from having to adapt the investment opportunity to meet the new regulations, which includes any pollution-abatement actions by the firm, or carbon credits that need to be purchased.[2]

At time $t = 0$, the firm can borrow an amount $I_0 \leq I$. The borrowed amount I_0 is used to partially fund the investment needed at $t = 1$ to exercise the option. If the option is taken at time $t = 1$, then the additional borrowing of $I_1 = I - I_0 \geq 0$ is needed to undertake the investment. There is a convex cost to investing earlier of $\psi I_0^2/2$. This cost is motivated by the agency conflicts that may arise from an empire building motive or the lack of commitment not to invest the money in some other way.

We assume that the firm can issue one-period bonds at the gross interest rate R in both periods 0 and 1, unless the regulatory risk materializes in which case the investors enter a new status quo of penalizing polluting firms and the borrowing cost goes up to R_λ. For now, we take these rates to be exogenous. Below, we show that $R_\lambda > R$ if the firm faces a higher probability of default at time 2 in the event of a regulatory shock. For simplicity, the firm's rate of time preference is set to zero.

[2]The effects of regulation do not have to come through the supply side via κ. Demand side regulation, captured by a reduction in the mean of π, is isomorphic in our model. Also, scaling the cost by the investment size does not change the main results.

The firm's profit maximizing problem at time 0 is

$$\begin{aligned}\max_{0\leq I_0\leq I} &= (1-\lambda)E\left[\max_{I_1\in\{I-I_0,0\}}(\tilde{\pi}-RI_1,0)\right] \\ &+ \lambda E\left[\max_{I_1\in\{I-I_0,0\}}(\tilde{\pi}-\kappa-R_\lambda I_1,0)\right]-RI_0-\frac{\psi}{2}I_0^2. \qquad (1)\end{aligned}$$

In the regulatory state the investment option is less valuable for two reasons, the abatement cost κ and the higher financing cost R_λ. Rewrite the problem as

$$\begin{aligned}\max_{0\leq I_0\leq I} &= (1-\lambda)\int_{R(I-I_0)}^{\infty}(\tilde{\pi}-R(I-I_0))\,dF(\tilde{\pi}) \\ &+ \lambda\int_{\kappa+R_\lambda(I-I_0)}^{\infty}(\tilde{\pi}-\kappa-R_\lambda(I-I_0))\,dF(\tilde{\pi})-RI_0-\frac{\psi}{2}I_0^2.\end{aligned}$$

The first order condition with respect to I_0 yields:

$$(1-\lambda)\left[1-F(R(I-I_0))\right]R+\lambda\left[1-F(\kappa+R_\lambda(I-I_0))\right]R_\lambda-R-\psi I_0\leq 0. \qquad (2)$$

The optimal choice of I_0 equates the marginal borrowing cost at time 0 plus the cost of investing early to the marginal benefit at time 1. The marginal borrowing cost at time 0 is R and the marginal cost of early investment is ψI_0. The marginal benefit at time 1 is the cost savings from having invested earlier: these are the weighted average of R times the expected option exercise $(1-F(R(I-I_0))$ if there is no regulatory shock, and R_λ times the expected option exercise $(1-F(\kappa+R_\lambda(I-I_0))$ if there is a regulatory shock. The cost savings occur only if there is a regulatory shock and the option is exercised.

The second order condition for a maximum is:

$$(1-\lambda)f(R(I-I_0))R_0^2 + \lambda f(\kappa + R_\lambda(I-I_0))R_1^2 - \psi \leq 0.$$

The second order condition compares the slope of the marginal benefit curve with that of the marginal cost curve. Both slopes are positive. The reason the marginal benefit is increasing with I_0 is that the more the firm invests earlier (and ignoring its cost), the higher the exercise probabilities. Assume that the second order condition is satisfied at the corner solution $I_0 = I$. This can be satisfied by picking a high enough slope of the marginal cost curve, ψ. Then the slope of the marginal benefit is lower than the slope of the marginal cost at $I_0 = I$. Because the marginal cost curve has constant positive slope, to ensure that the two lines cross to get an interior solution, we require that the left hand side of equation (2) is positive at $I_0 = 0$ and that it is negative at $I_0 = I$. These two assumptions can be met by appropriately choosing a high R_λ for the first restriction, and for any given R_λ, choose a high enough ψ for the second restriction. At the optimum the second order condition is also met because the slope of the marginal cost curve must be higher than that of the marginal benefit curve when they cross.[3]

If $\psi = 0$, then the marginal cost of investing at time 0 is constant (equal to R). Because the marginal benefit of investing early is increasing in I_0, then the optimal is either to have no early investment, or to make all the investment early on. If R_λ is sufficiently large relative to R, a high enough probability of exercising the option conditional on the regulatory shock occurring will generate savings that will make the firm take the corner solution of investing all at time 0. Otherwise, $I_0^* = 0$.

[3]We further assume that the mean of $\tilde{\pi}$ is high enough such that the expected value of the objective function at the optimal I_0^* is positive.

When $\psi > 0$, the marginal cost of early investment is increasing in I_0. If ψ is sufficiently large, then the slope of the marginal cost is higher than that of the marginal benefit and there can be an interior solution to I_0 as discussed.

3.1 Model predictions

Here we highlight several model properties (for which we assume that an interior optimum exists, $0 < I_0^* < I$). First, $dI_0^*/d\lambda > 0$, that is a firm facing higher regulatory risk at time 1 (i.e., higher λ), invests relatively more at time 0. To see the intuition for this result note that in the state of the world where the regulatory shock occurs the likelihood of exercising the option is lower because of κ and the higher borrowing cost, i.e., $\kappa + R_\lambda(I - I_0) > R(I - I_0)$. Thus, a firm that faces a higher λ has a lower overall probability of exercising the investment option, which discourages early investment. However, the state where there is regulatory risk is also the state of cost savings, and an increase in λ increases the likelihood of cost savings and encourages early investment. At the optimum, under the conditions that guarantee an interior solution, the second effect dominates and I_0^* increases with λ.

Importantly this result is not due to having higher borrowing rates unconditionally in period 1: if at time 1 the cost of borrowing is R_λ across all states, then a higher λ puts more weight on the state of the world where the probability of exercising the option is lower and the marginal benefit of investing earlier declines, leading to lower I_0^*. In this sense, the result has the flavor of the 'green paradox' (Sinn, 2008): the higher cost faced by the firm in the state where regulatory risk occurs generates an incentive to invest early in the potentially polluting technology, which itself counteracts the efforts of the regulation.

A consequence of the previous result is that the probability of exercising the option at time 1 is higher for a firm with higher regulatory risk (i.e., higher λ). Hence, firms with higher regulatory risk are more likely to see increases in pollution. The proposition collects these results.

Proposition 1. *A firm with higher λ:*

- *invests relatively more (less) in the period prior to (after) the regulatory shock;*
- *experiences a larger increase in pollution in the period after the regulatory shock.*

The model offers a prediction on abatement technologies via the cost parameter κ. A firm with better abatement technology (i.e., lower κ) invests more earlier on, that is $dI_0^*/d\kappa < 0$. The intuition for this result is the marginal benefit of early investment increases all else equal because with a lower κ the probability of exercising the option in the state of increased climate regulation increases and thus the expected cost savings from early investing.

For the next result, let $\tilde{\pi} \sim \mathcal{N}(\mu, \sigma^2)$. Then, $dI_0^*/d\sigma > 0$. Intuitively, higher volatility of firm cash flows increases the value of the investment option by increasing the probability of exercising the option, thus increasing the cost savings from early investment.

Since these results apply for firms with $\lambda > 0$, we have:

Proposition 2. *A firm facing regulatory risk (i.e., $\lambda > 0$), invests more in the period before the regulatory shock if*

- *it has better abatement possibilities (i.e., lower κ);*
- *it has a higher volatility of cash flows (i.e., higher σ).*

3.2 Cost of financing in the event of a regulatory shock

In this section we endogenize the value of R_λ. We argue that one reason for a higher interest rate when the regulatory event occurs at time 1 is intrinsically linked to the regulatory event itself through a higher probability of bankruptcy.

We assume that R is the risk free rate. We assume that the firm has ongoing projects that payout at time 1 that guarantee a time 0 loan. The remaining cash flows at time 1 are paid out to investors. At time 1, if the regulatory shock does not occur, then the project is undertaken only if the firm's shareholders get some income from it, which implies that bondholders are fully repaid, so the borrowing at time 1 in the event of no regulatory risk is also risk free in the model.

Suppose the additional cost the firm faces upon the regulatory event is a random variable, $\tilde{\kappa}$ with cdf $G(\tilde{\kappa})$. In addition, suppose the realization of the random variable $\tilde{\kappa}$ occurs only after the decision to invest in the technology at time 1 is made. Then the expected time 1 payout for the firm in the event of regulation is

$$E_{\tilde{\pi}}\left[\max_{I_1\in\{I-I_0,0\}}\left[E_{\tilde{\kappa}}\max_{eqty,noeqty}\left(\tilde{\pi}-\tilde{\kappa}-R_\lambda I_1,0\right),0\right]\right], \tag{3}$$

where *eqty* and *noeqty* identify states of the world where equity holders get paid: if the option is undertaken, but the cost ends up larger than $\pi - R_\lambda I_1$ (which occurs with probability $1 - G(\pi - R_\lambda I_1)$), then equity holders get zero and lenders get only a fraction of their investment, or possibly nothing if the cost is high enough.

We assume lenders are risk neutral. Lenders break even on average across realiza-

tions of $\tilde{\pi}$, assuming a borrowed amount of $I_1 = I$. The interest rate R_λ solves:

$$RI = \int G\left(\tilde{\pi} - R_\lambda I\right) dF(\tilde{\pi}) R_\lambda I + \int \int_{\tilde{\pi} - R_\lambda I}^{\tilde{\pi}} (\tilde{\pi} - \tilde{\kappa}) dG(\tilde{\kappa}) dF(\tilde{\pi}). \tag{4}$$

Note that R_λ does not actually depend on the value of λ, contrary to what the subscript might suggest. The subscript merely indicates the states of the world where the cost of borrowing R_λ applies.

Lenders are fully paid for values $\tilde{\kappa} < \tilde{\pi} - R_\lambda I$. For intermediate values of the cost, $\tilde{\pi} - R_\lambda I < \tilde{\kappa} < \tilde{\pi}$, lenders get a decreasing amount $\tilde{\pi} - \tilde{\kappa}$, and for values $\tilde{\kappa} > \tilde{\pi}$, lenders get zero. Because $\int_{\tilde{\pi} - R_\lambda I}^{\tilde{\pi}} (\tilde{\pi} - \tilde{\kappa}) dG(\tilde{\kappa}) < \left[G(\tilde{\pi}) - G\left(\tilde{\pi} - R_\lambda I\right)\right] R_\lambda I$, then $R < \int G(\tilde{\pi}) dF(\tilde{\pi}) R_\lambda \leq R_\lambda$. The result that $R_\lambda > R$ is the critical assumption we had made earlier on and that comes through in the model with a higher probability of default in the event of the regulatory shock.[4] The increased risk of bankruptcy in the event the regulatory risk is realized gives rise to the testable hypothesis:

Proposition 3. *A firm exposed to regulatory risk (i.e., with $\lambda > 0$) has higher interest rate at time 1 in the state of the world where the regulatory shock is realized compared to the interest rate it faces at time 0.*

[4] An alternative to close the model is to assume that lenders break even for every π and $I_1 > 0$. In this case lenders are paid a rate of return that equals R on average

$$RI_1 = G\left(\pi - R_\lambda I_1\right) R_\lambda I_1 + \int_{\pi - R_\lambda I_1}^{\pi} (\pi - \tilde{\kappa}) dG(\tilde{\kappa}). \tag{5}$$

The interest rate R_λ that solves this equation is contingent on the realization of π and I_1 since the shareholder makes the investment decision knowing how much investment is still needed and what π is. Here too, it can be shown that $R_\lambda > R$. We opted for a different pricing model because in reality interest rates do not vary continuously with operating profits and borrowing amounts.

3.3 Equilibrium regulation

We introduce a concerned regulator that determines the likelihood of the regulatory shock based on the level of investment made by the firms in the industry at time 0. We are motivated by the notion that regulators often use the threat of regulation to affect firm behavior (for early work see Glazer and McMillan 1992, and Erfle and McMillan 1990).

Let m be the measure of ex ante identical firms in the industry and mI_0 be the industry's investment at time 0. We model regulation as a binary random variable whose probability distribution is determined by industry investment in the polluting technology. Specifically, let $\lambda = \Lambda(mI_0)$ where $\Lambda(.)$ is an increasing function: the regulator increases the probability of the regulatory shock as firms invest more in period 0.

In this model extension, λ is a firm's conditional probability that the regulator will initiate regulatory action. Each firm is assumed atomistic with regard to the equilibrium probability of regulation. An equilibrium in regulation, λ^*, is a fixed point of the equation $\lambda^* = \Lambda(mI_0^*(\lambda^*))$. Figure 1 illustrates the regulation equilibrium. The solid line depicts the function $I_0^*(.)$ (plotted on the y-axis) against values of λ. There is no investment at time 0 for low enough λ, after which I_0^* increases with λ as shown in Proposition 1. The dashed line depicts the function $\Lambda(.)$ (plotted on the x-axis) against values of I_0 (plotted on the y-axis). Points where the two curves intersect are equilibrium points.

[Insert Figure 1 here]

The figure illustrates a case of multiple equilibria. Depending on the curvatures of

the functions $\Lambda(.)$ and $I_0^*(.)$, there could be multiple equilibria: an equilibrium with high regulatory risk and high investment at time 0, and an equilibrium with low regulatory risk and low investment at time 0 (there is an equilibrium with $(\lambda^*, I_0^*) = (0, 0)$ if $\Lambda(0) = 0$). With multiple equilibria the risk of regulation becomes self fulfilling: if firms anticipate high regulatory risk (i.e., a high λ), then it is advantageous for each of the firms to invest more at time 0. In other words, the industry's expectation of the likelihood of the regulator's action leads to increased investment, which then validates the original expectations.

There are three main reasons for the possibility of multiple equilibria. First, we assume that firms take the probability of regulation as given, which leads to an externality. Firms do not incorporate the fact that as each of them invests more, the regulator increases the probability of the regulatory shock. Second, in our model, the benefit of investing early (through the borrowing-cost savings) accrues because of the possibility of future regulation, a feature that is absent in models of the threat of regulation and that is the source of the green paradox result in the model. Third, in the illustrated equilibrium, the regulatory function $\Lambda(.)$ penalizes industry investment sufficiently aggressively in order to intersect with $I_0^*(.)$.

The self fulfilling nature of the equilibria suggests that the green paradox can manifest itself differently in different industries (or different groups of firms, such as private versus public, or financial sector versus manufacturing) subject to different regulatory bodies, and exposed to different public pressure. In an industry where firms believe that the regulatory event is less likely, say because it has been under significant regulatory pressure already, the expected cost savings are small, there is less investment earlier on, and the regulator keeps a low probability of a regulatory shock in equilibrium.

In contrast, in industries where firms believe that the regulatory event is more likely, the very actions of the regulator aimed at curbing firm investment lead to increased investment in the polluting technology in equilibrium.

Another prediction from the self fulfilling expectation nature of multiple equilibria is that small changes in agents' expectations can lead everyone to coordinate in a different equilibrium. Finally, the existence of multiple equilibria suggests that the (threat of) regulatory action can be counterproductive, though not because the regulator is subject to the efforts of powerful lobbies in the way discussed in Stigler (1971) and Peltzman (1976). However, the symmetric nature of our predictions yields that changes in policy stance that suggest less future regulation, may actually result in less pollution.

4 Empirical methodology

4.1 Data

Our empirical analysis uses data from multiple sources. We obtain the sample of U.S. corporate bond issuances from 2010-2020 from Mergent Fixed Income Securities Database (FISD) using standard processing based on Adrian, Boyarchenko, and Shachar (2017) and others. We obtain balance sheet data of U.S. public and private firms from S&P Capital IQ. Capital IQ collates data on private firms through publicly available disclosures, for example, private and public firms face SEC disclosure requirement when issuing publicly traded debt like corporate bonds. We merge Mergent FISD and Capital IQ data based on bond issuer-level CUSIP. The matched data are aggregated to the parent level to ensure a Mergent parent corresponds to an ultimate parent firm in Capital IQ. We use 2-digit SIC industry codes to filter out firms in financial

(60-67), government (91-97) and "nonclassifiable" (99) industries.

The emissions data measured in CO2 equivalents (CO2e) are from the U.S. Environmental Protection Agency (EPA). Starting in 2010, the EPA requires that each production facility with more than 25,000 metric tons of CO2e emissions per year reports their emissions. This regulation covers carbon dioxide, methane, nitrous oxide, and fluorinated GHGs. These data are publicly available (https://www.epa.gov/ghgreporting), cover a wide range of industries, account for a substantial share of total U.S. emissions, and have been used in other studies (e.g., Shive and Forster (2020); Bartram, Hou, and Kim (2022); Ivanov, Kruttli, and Watugala (2024)). Firms are required to report direct and indirect GHG emissions. Direct CO2e emissions are those emitted from the facility itself, for example, through the combustion of fossil fuels by equipment owned by the facility and emissions from industrial processes. Indirect emissions are the emissions from the combustion of fuels produced by the facility, which is particularly relevant for firms in the oil and gas sector.

We match parent firms in the EPA data to parent firms in the Capital IQ and Mergent datasets, respectively, using the name and ZIP code of the parent company of each GHG-emitting facility. We first conduct a fuzzy name match and then verify each potential match manually. In Figure 2, we show the county-level distribution of high GHG-emitting firms as of 2015 for EPA facilities that are mapped to Capital IQ firms. In the figure, we sum up the GHG emissions of all facilities in a given county. Emissions are then aggregated to parent level for the empirical analysis.

The summary statistics for the variables used in our empirical analysis are reported in Table 1 Panels A (EPA sample) and B (Mergent sample). We reproduce descriptive stats for balance sheet information under both samples. Table A1 presents the variable

definitions.

We take the log of emissions and of emissions intensity (emissions divided by revenues). This reduces the skewness of the two variables and the resulting means (medians) are 11.0 and 5.6 (11.2 and 5.9), respectively. For the capital expenditures, we also either take the log of the variable or divide by the firm's assets. The average (median) capital expenditures of a firm in our sample is 7.1% (5.1%) of assets. The additional balance sheet variables debt, net property plant and equipment, and cash are also divided by the respective firm's assets.

For the Mergent sample, shown in Table 1 Panel B, we have data on the total offering amount, yields, and time-to-maturity (TTM) of the issued bonds. Further, we have the same balance sheet variables as in Panel A.

4.2 Regression specifications

We analyze the effects of a shock to climate regulation risk using the following panel regression specification:

$$\begin{aligned} y_{i,t} = {} & \beta_0 EmissionsIntensity_{i,t-1} + \beta_1 EmissionsIntensity_{i,t-1} \times PostParis_t \\ & + \gamma Z_{i,t-1} + \theta_{i,t} + \epsilon_{i,t}, \end{aligned} \tag{6}$$

where i denotes the firm and t the current year. The sample period is from 2010 to 2020. We estimate multiple empirical specifications, where the dependent variables of interest, $y_{i,t}$, are bond market variables—offering amount of corporate bonds issued by the firm, time-to-maturity of the issued bonds, and offering yield—firm emissions intensities and changes in emissions, and firm annual capital expenditures and investment

rate, or capital expenditures normalized by assets. The main independent variables are the dummy variable $PostParis$ that captures the period following the Climate Paris Accords, 2016 through 2020, the lagged value of emissions intensity (or a dummy that classifies firms above median emissions intensity), and the interaction between the two. We also control for lagged firm-level controls, $Z_{i,t-1}$, which capture observed variation at the firm level of determinants of spreads and investment policy. Specifications include firm fixed effects and time fixed effects to control for unobserved time-invariant and firm characteristics, but we also consider industry times year fixed effects as a way to account for industry-wide shocks that affect firm decisions. Any lower order terms that are not shown are absorbed by the fixed effects. The standard errors are clustered at the firm level.

The specification in equation 6 allows us to test the model predictions implied by propositions 1 and 3. We view the parameter λ, used to generate these propositions, as the firm's likelihood of being affected by the regulatory event, which depends on the firm's pollution intensity. Thus, we capture λ in the data via the interaction $EmissionsIntensity_{i,t-1} \times PostParis_t$. The reasoning is that the Paris Accord delivered country-wide commitments to act to keep global warming at most at 2 degrees Celsius above pre-industrial temperatures. These commitments and the regulatory changes that they entail are likely to impact more acutely more polluting firms. Proposition 3 predicts borrowing frictions tighten following the climate regulation shock. We thus hypothesize that the coefficient on the interaction term $EmissionsIntensity_{i,t-1} \times PostParis_t$ is positive for the dependent variable offering yield and negative for time to maturity. Proposition 1 predicts that investment is relatively lower to more polluting firms following the regulatory shock,

which we test with the hypothesis of a negative coefficient on the interaction term $EmissionsIntensity_{i,t-1} \times PostParis_t$ when the dependent variable is the log of capital expenditures or capital expenditures to assets. Proposition 1 also predicts that emissions increase following the regulatory shock. We therefore hypothesize a positive sign on the coefficient on the interaction $EmissionsIntensity_{i,t-1} \times PostParis_t$ when the dependent variable is either log emissions or changes in log emissions.

We capture firm exposure to regulation through their emissions intensity. We are motivated by evidence that in some industries institutional investors base their exclusionary screening on emissions intensity. In addition, the 2010 Waxman-Markey bill that never passed the Senate, selected firms to be included using energy intensity (a normalized measure of scope 2 emissions). Also, if emissions intensity is a technology feature (with some technologies being more polluting than others) then targeting with regulation technologies (and industries) that generate high revenues and have high emissions intensity is likely to yield the greatest benefit in emissions reduction.

5 Results

This section displays the results when empirically testing the model-implied hypotheses discussed in Section 3. We center this empirical analysis around the Paris Agreement and examine its impact on corporate decisions along multiple dimensions.

5.1 Corporate bond issuance

Table 2 shows results from estimating the regression specification in equation (6) when the dependent variable is one of four bond market variables, annual amount offered,

average offered yield weighed by issued amount, average offered yield weighed by maturity, and average time to maturity weighed by amount issued. For each dependent variable we present two regressions, each with a different metric for emissions, a continuous proxy, the logarithm of emissions to revenue, and a discrete proxy, a dummy that takes the value of one when a firm's emissions are above median emission intensity that year. All regressions include the following control variables: firm size (the logarithm of assets), leverage (debt to assets ratio), fraction of tangible assets (property plant and equipment to assets), fraction of liquid assets (cash to assets), and firm and year fixed effects.

In columns (1) and (2), the dependent variable is the offering amount. The coefficient on the logarithm of Emissions/Revenue is positive but statistically insignificant. Same applies to the coefficient on the dummy High Emissions/Revenue. The interactions with $PostParis$ are also insignificant suggesting that firms with higher emissions intensity do not issue larger corporate bond notional amounts relative to firms that are less emissions inefficient, before and after the Paris Accords. In columns (3) and (4), the dependent variable is the average offering yield weighed by issued amount, and in columns (5) and (6), the dependent variable is the average offering yield weighed by time to maturity. We make this distinction because firms that shift to lower maturity bonds may benefit from lower yields due to the slope of the yield curve (e.g., a firm that issues two bonds with two years apart in offered maturity and shifts to lower maturities puts greater weight on the longer maturity bond). In fact, column (3) shows that more emissions inefficient firms experienced lower yields in the post Paris period of our sample, but this effect disappears when we weigh offered yields by the offered bonds' time to maturity. Lastly, columns (7) and (8) show results for time to

maturity. The coefficient on lagged logarithm of Emissions/Revenue is positive but insignificant. The coefficient of emissions intensity interacted with $PostParis$ is negative and significant at 1% level. The estimated coefficient suggests that an increase in firm emissions intensity by one standard deviation is associated with a decrease in bond maturity issuance of 1.2 years (-0.475×2.511 years). We find a quantitatively slightly larger result in column (8). In the post Paris period, a firm with above median emissions intensity issued bonds with 1.8 years shorter maturity than more emissions efficient firms. These decreases in maturity are economically significant as the average (median) maturity of bonds in our sample is 10.2 (8.2) years.

Overall, the results indicate that bonds are offered at shorter maturity to more inefficient firms following the Paris Accords consistent with a tightening of financing conditions as predicted in Proposition 3. We find no statistically significant change in offered yields in the post Paris period for the high polluters viz-a-viz the less polluting firms. One possible interpretation of this result is that firms adjusted to an upward shift of their yield curve post Paris (see Seltzer, Starks, and Zhu 2024 and others for additional evidence of tightening of financing costs for emissions inefficient firms post Paris) by borrowing more short term. Despite this shift in maturity, firms were not able to lower their overall issuance yield.

The control variables in these regressions offer what are usual results. Firms with higher leverage then to issue less and at higher yields and firms with more tangible assets (i.e., higher NPPE to assets) tend to issue larger amounts. Larger firms tend to pay lower yields but also borrow at shorter maturities.

5.2 Corporate investment

The empirical results on borrowing conditions suggest a tightening of financial conditions for emissions inefficient firms following the Paris climate regulatory shock. The decrease in issued maturities also suggests that firms funded fewer long term investments or that they funded these investments with short term debt, which may keep financing costs lower but adds refinancing risk. Proposition 1 suggests that with higher financing costs in the regulation state, firms with higher emissions intensity invest relatively more in the pre-Paris period and less in the post-Paris period.

Table 3 presents results from estimating the regression specifications in equation (6) with capital expenditures and capital expenditures to assets as the dependent variables. The right hand side variables are the same as those used in Table 2. The results indicate that high-emissions intensity firms invest more in the pre-Paris period, though none of the estimated coefficients are statistically significant (columns (4) through (6)). In the post-Paris period, firms that increase their emissions intensity see an associated reduction in their subsequent capital expenditures. The results are particularly strong for the regression specifications with firm and industry times year fixed effects. In column (5), firm-years with above median emissions intensity experience an investment rate in the following year that is 1.1% lower than firms that are less emissions inefficient in the post-Paris. This effect corresponds to 19% (1.1/5.9) of the average investment rate for the issuing firms in our sample. When the dependent variable is the change in log capital expenditures (columns (1) to (3)) the results are qualitatively similar with decreases of around 10%.

Regarding the control variables, larger firms tend to invest more in dollar terms, but have a lower investment rate, suggestive of decreasing returns to scale. Firms

with higher Property Plant and Equipment in place also have lower investment and investment rates. More leveraged firms have lower investment, which could be an indication of many things, including possible debt overhang. Firms with more cash to assets have higher investment in our sample of issuing firms.

5.3 Emissions intensity

Table 4 presents the results with firm emissions intensity as the dependent variable. In columns (1) to (3), the treatment variable is lagged log emissions intensity and in columns (4) to (6) the treatment variable is the dummy for emissions intensity above the median of the sample. The control variables are the same as those used in Table 3, including firm, industry and year fixed effects.

In columns (1) to (3) we see that the past level of emissions intensity is associated with future values of the variable, but with a low degree of persistence, especially in columns (2) and (3). The interaction term of emissions intensity with the $PostParis$ dummy in, say, column (3) suggests that firms that see an increase in their emissions in the post-Paris period face relatively greater persistence in emissions intensity than firms with lower emissions inefficiencies. This result is consistent with Proposition 1 that predicts higher emissions following the shock to regulatory risk.

Of the control variables, we do not find that firm size affects the future level of emissions intensity. However, the share of property, plant, and equipment in total assets and the share of cash in assets are both positively related to emissions, suggesting that asset tangibility and asset liquidity are both linked to firm emissions.

6 Conclusion

We show how financing can interact with firm policies inducing firms to exhibit behavior consistent with a "green paradox," where polluting firms increase ex ante investment and eventually pollution in the expectation of future climate regulation.

We develop a simple model of firm financing and investment that predicts higher investment prior to the regulatory shock and a worsening of credit terms after the regulatory shock for firms more exposed to the shock. In our empirical analysis, using the Paris Climate Accords as a shock to future climate regulation and transition risk, we find evidence consistent with the model. High-emissions firms issue shorter-maturity bonds post-Paris without any significant decrease in yields at issuance. Further, these high-emissions firms decrease capital expenditures and investment rates after the Paris Climate Accords but see an increase in emissions intensity.

We allow for a regulatory decision maker in the model and consider the implications of a regulation equilibrium. We show that there can be multiple equilibria and the reason for the multiplicity of equilibria is tied directly to the existence of a green paradox. This is because the model predicts an increase in pollution when the regulatory state becomes more likely, and we assume that the regulator is more likely to initiate regulation if it observes increased investment by polluting firms. The multiplicity of equilibria suggests that small changes in firms' expectation of regulation can trigger an escalade of investment by polluting firms. At the same time, the symmetry of the results in the model suggests that a reduction in the perception that climate regulation will occur can dramatically reduce investment by polluting firms. These predictions are worth further study.

Our findings show that high-emissions firms that expect financing frictions to in-

tensify under future climate regulatory shocks may in fact initiate investments that eventually lead to increased pollution. As such, the Green Paradox hypothesis suggests that long periods where the threat of climate regulation remains high without the actual passage and implementation of binding regulation that puts a price on GHG emissions may have counterproductive effects. The model suggests that these unintended effects of delay in regulation could be reversed if the capital market were to move to penalize polluting firms before the regulatory shock takes place, but it is yet unclear in the literature what financial trade-off are investors willing to accept to do so.

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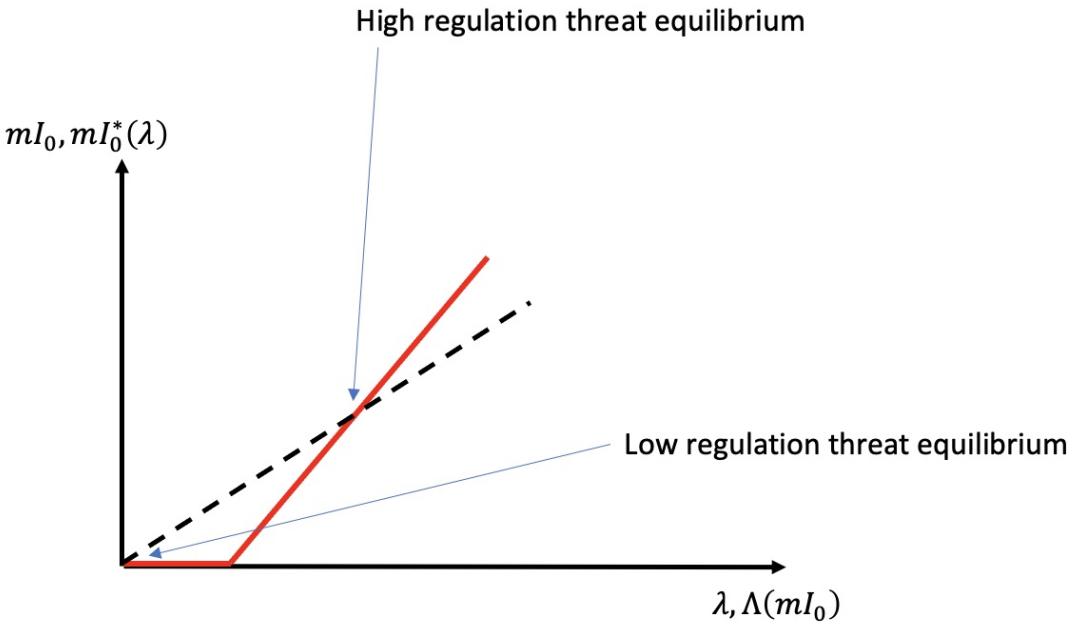


Figure 1: Equilibrium regulation levels and industry investment.

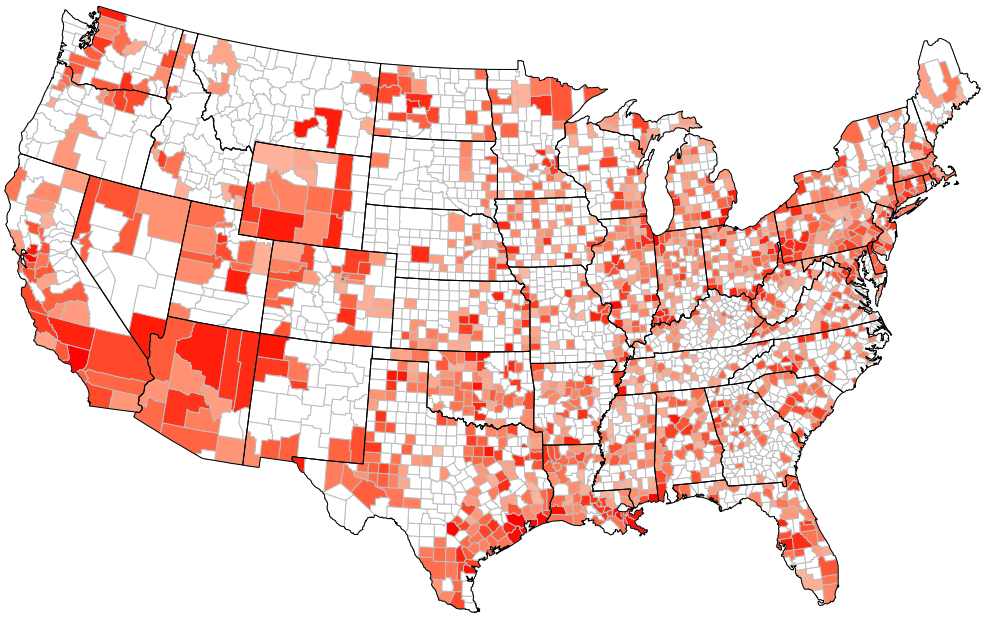


Figure 2: County-Level Emissions Based on EPA Facilities

This figure shows county-level emissions based on the EPA facilities located in a given county for public and private firms. Only facilities of EPA firms that are also in the Capital IQ data are included. The data illustrated in the figure are for 2015. Our analysis uses the time series.

Table 1: Summary Statistics

This table shows the summary statistics for the main variables used in the analysis. The data are annual from 2010 to 2020. Table A1 presents all variable definitions. Panel A presents summary statistics for the sample of EPA firms. Panel B gives summary statistics for the sample of Mergent firms. The N column shows the number of observations used to calculate the statistics in a particular row. The last four columns show percentiles.

Panel A: Firm emissions and balance sheet information (EPA sample)

	N	Mean	Median	Stdev	25th	75th	10th	90th
$log(Emissions)$	35,337	10.959	11.217	3.458	10.277	12.592	7.771	14.464
$log(\frac{Emissions}{Revenue})$	2,993	5.552	5.935	2.511	3.67	7.654	1.899	8.662
$log(CAPEX)$	2,967	5.594	5.700	1.993	4.418	7.100	2.984	8.084
$\Delta log(CAPEX)$	2,937	0.029	0.037	0.537	-0.183	0.256	-0.527	0.563
$\frac{CAPEX}{Assets}$	2,954	0.071	0.051	0.069	0.030	0.082	0.018	0.142
$log(TotalAssets)$	3,014	8.510	8.573	1.847	7.342	9.929	6.062	10.829
$\frac{Debt}{Assets}$	3,014	0.355	0.334	0.208	0.225	0.456	0.116	0.611
$\frac{NPPE}{Assets}$	3,008	0.506	0.526	0.244	0.306	0.717	0.152	0.813
$\frac{Cash}{Assets}$	2,980	0.06	0.037	0.068	0.011	0.086	0.003	0.149

Panel B: Bond offerings information (Mergent sample)

	N	Mean	Median	Stdev	25th	75th	10th	90th
log(Total Offering Amount)	6,687	13.615	13.459	1.035	12.899	14.221	12.429	15.595
Amount-Weighted Offering Yield (%)	6,015	5.450	4.969	2.370	3.690	6.771	2.830	10.000
Maturity-Weighted Offering Yield (%)	6,015	5.551	5.001	2.297	3.909	6.772	3.086	10.000
TTM (in Years)	6,687	10.208	8.178	5.981	7.038	10.238	5.097	24.160
$log(CAPEX)$	2,978	5.912	5.956	1.755	4.680	7.232	3.678	8.651
$\frac{CAPEX}{Assets}$	2,971	0.059	0.038	0.068	0.020	0.070	0.010	0.194
$log(Assets)$	2,996	9.092	9.053	1.500	8.008	10.219	7.176	11.573
$\frac{Debt}{Assets}$	2,996	0.383	0.349	0.211	0.248	0.483	0.155	0.780
$\frac{NPPE}{Assets}$	2,986	0.373	0.307	0.276	0.123	0.616	0.058	0.858
$\frac{Cash}{Assets}$	2,972	0.066	0.043	0.069	0.014	0.094	0.004	0.208

Table 2: Firm Corporate Bond Issuance - Post-Paris Agreement

This table presents results of the panel regression model given in equation (6). The data are annual from 2010 to 2020. The dependent variables are log(offering amount) in Columns (1) - (2), amount-weighted yield (in %) in Columns (3) - (4), maturity-weighted yield (in %) in Columns (5) - (6), and time to maturity in Columns (7) - (8). All specifications include year fixed effects and firm fixed effects. The standard errors are clustered at the firm level. t-statistics are shown below the corresponding coefficient estimates. The significance of the coefficient estimate is indicated by * for $p < 0.10$, ** for $p < 0.05$, and *** for $p < 0.01$.

	log(Total Offering Amount)		Amount-Weighted Offering Yield (%)		Maturity-Weighted Offering Yield (%)		TTM	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$log(\frac{Emissions_{i,t-1}}{Revenue_{i,t-1}}) \times PostParis_t$	0.005		-0.047*		-0.028		-0.475***	
	0.238		-1.759		-1.080		-3.126	
$IsHighEOR_{i,t-1} \times PostParis_t$		0.065		-0.163		-0.058		-1.783**
		0.592		-1.043		-0.378		-2.078
$log(\frac{Emissions_{i,t-1}}{Revenue_{i,t-1}})$	0.013		0.062		0.046		0.033	
	0.209		1.221		0.874		0.118	
$IsHighEOR_{i,t-1}$		0.186		0.129		0.020		0.053
		1.379		0.580		0.092		0.056
$log(Assets)_{i,t-1}$	-0.002	-0.000	-0.079	-0.094**	-0.091*	-0.106**	-0.379**	-0.279*
	-0.046	-0.010	-1.631	-2.156	-1.906	-2.495	-2.054	-1.820
$\frac{Debt_{i,t-1}}{Assets_{i,t-1}}$	-0.640**	-0.626*	1.553***	1.594***	1.430***	1.464***	0.083	0.364
	-1.989	-1.959	3.265	3.504	3.117	3.327	0.045	0.207
$\frac{NPPE_{i,t-1}}{Assets_{i,t-1}}$	0.820***	0.810***	-0.185	-0.175	-0.138	-0.136	-1.301	-1.883
	3.038	3.046	-0.373	-0.346	-0.286	-0.277	-0.896	-1.316
$\frac{Cash_{i,t-1}}{Assets_{i,t-1}}$	0.770	0.713	-0.187	-0.235	-0.208	-0.257	-0.979	-0.925
	1.027	0.966	-0.140	-0.172	-0.158	-0.193	-0.262	-0.250
Observations	1,200	1,202	1,105	1,107	1,105	1,107	1,200	1,202
Adjusted R^2	0.572	0.573	0.716	0.716	0.708	0.708	0.432	0.426
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y

Table 3: Firm Capital Expenditure - Post-Paris Agreement

This table presents results of the panel regression model given in equation (6). The data are annual from 2010 to 2020. The dependent variables are $\Delta log(CAPEX_{i,t})$ in Columns (1) - (3), and $\frac{CAPEX_{i,t}}{Assets_{i,t}}$ in Columns (4) - (6). The specifications include a combination of year, industry, firm, and industry-year fixed effects as indicated. The standard errors are clustered at the firm level. t-statistics are shown below the corresponding coefficient estimates. The significance of the coefficient estimate is indicated by * for $p < 0.10$, ** for $p < 0.05$, and *** for $p < 0.01$.

	$\Delta log(CAPEX_{i,t})$			$\frac{CAPEX_{i,t}}{Assets_{i,t}}$		
	(1)	(2)	(3)	(4)	(5)	(6)
$IsHighEOR_{i,t-1} \times PostParis_t$	-0.032	-0.093**	-0.126**	-0.004	-0.011***	-0.010**
	-0.910	-2.198	-2.382	-1.494	-3.375	-2.340
$IsHighEOR_{i,t-1}$	-0.003	-0.027	0.015	0.002	0.006	0.008
	-0.081	-0.414	0.238	0.708	1.060	1.491
$log(Assets)_{i,t-1}$	-0.024***	-0.287***	-0.320***	-0.001*	-0.007	-0.011***
	-3.813	-4.575	-6.096	-1.650	-1.466	-2.762
$\frac{Debt_{i,t-1}}{Assets_{i,t-1}}$	-0.212**	-0.595***	-0.442***	-0.016***	-0.069***	-0.056***
	-2.431	-3.995	-2.839	-3.253	-4.232	-3.490
$\frac{NPPE_{i,t-1}}{Assets_{i,t-1}}$	-0.064	-1.342***	-1.311***	0.011	-0.106***	-0.112***
	-0.718	-5.312	-5.194	1.435	-5.202	-5.218
$\frac{Cash_{i,t-1}}{Assets_{i,t-1}}$	0.987***	1.076***	1.096***	0.073***	0.077***	0.084***
	4.213	3.646	3.645	3.600	3.180	3.453
$\frac{CAPEX_{i,t-1}}{Assets_{i,t-1}}$	-2.265***	-4.243***	-4.784***	0.639***	0.385***	0.328***
	-7.112	-10.069	-12.492	24.674	9.100	6.534
Observations	2,567	2,567	2,567	2,569	2,569	2,569
Adjusted R^2	0.138	0.236	0.295	0.691	0.750	0.765
Year FE	Y	Y	N	Y	Y	N
Industry FE	Y	N	N	Y	N	N
Firm FE	N	Y	Y	N	Y	Y
Industry × Year FE	N	N	Y	N	N	Y

Table 4: Firm Greenhouse Gas Emissions

This table presents results of the panel regression model given in equation (6). The data are annual from 2010 to 2020. The dependent variable is $log(\frac{Emissions_{i,t}}{Revenue_{i,t}})$. The specifications include a combination of year, industry, firm, and industry-year fixed effects as indicated. The standard errors are clustered at the firm level. t-statistics are shown below the corresponding coefficient estimates. The significance of the coefficient estimate is indicated by * for $p < 0.10$, ** for $p < 0.05$, and *** for $p < 0.01$.

	(1)	(2)	(3)	(4)	(5)	(6)
$log(\frac{Emissions_{i,t-1}}{Revenue_{i,t-1}}) \times PostParis_t$	0.028***	0.017**	0.034*			
	3.351	2.033	1.723			
$log(\frac{Emissions_{i,t-1}}{Revenue_{i,t-1}})$	0.880***	0.470***	0.428***			
	45.043	9.599	7.513			
$IsHighEOR_{i,t-1} \times PostParis_t$				0.316***	0.177***	0.231**
				3.095	2.908	2.088
$IsHighEOR_{i,t-1}$				2.210***	0.689***	0.568***
				14.437	4.245	3.711
$log(Assets)_{i,t-1}$	-0.000	-0.017	0.016	-0.125***	-0.094	-0.055
	-0.012	-0.338	0.313	-3.554	-1.246	-0.794
$\frac{Debt_{i,t-1}}{Assets_{i,t-1}}$	-0.004	-0.287**	-0.240*	0.134	-0.305**	-0.290**
	-0.056	-2.278	-1.906	0.549	-2.205	-2.061
$\frac{NPPE_{i,t-1}}{Assets_{i,t-1}}$	0.677***	0.702***	0.699**	2.200***	0.670**	0.640**
	5.565	2.652	2.402	5.779	2.136	2.005
$\frac{Cash_{i,t-1}}{Assets_{i,t-1}}$	0.211	0.709**	0.998***	0.912	0.765**	0.941**
	0.847	2.246	2.789	1.302	2.043	2.298
$\frac{CAPEX_{i,t-1}}{Assets_{i,t-1}}$	-0.054	-0.077	-0.024	-0.308	-0.123	-0.060
	-0.206	-0.213	-0.063	-0.384	-0.295	-0.136
Observations	2,562	2,562	2,562	2,564	2,564	2,564
Adjusted R^2	0.946	0.958	0.959	0.815	0.948	0.950
Year FE	Y	Y	N	Y	Y	N
Industry FE	Y	N	N	Y	N	N
Firm FE	N	Y	Y	N	Y	Y
Industry × Year FE	N	N	Y	N	N	Y

Appendix

Table A1: Variable Definitions

This table presents definitions of the main variables. The first column gives the variable name. The second column includes a short description. The last column gives the reference to the raw data source. Detailed descriptions and summary statistics of these variables are in Section 4.

Variable	Description	Source
log(Total Offering Amount)	Natural log of total notional amount of all bonds issued by a parent firm in a year	Mergent FISD
Amount-Weighted Offering Yield (%)	Average offering yield weighted by the offering amount of the bonds issued by a parent firm in a year	Mergent FISD
Maturity-Weighted Offering Yield (%)	Average offering yield weighted by the time-to-maturity of the bonds issued by a parent firm in a year	Mergent FISD
TTM	Average time-to-maturity (in years) weighted by the offering amount of the bonds issued by a parent firm in a year	Mergent FISD
$log(\frac{Emissions_{i,t}}{Revenue_{i,t}})$	Natural log of emissions over revenue (i.e., emission intensity)	EPA, S&P Capital IQ
$\Delta log(\frac{Emissions_{i,t}}{Revenue_{i,t}})$	Change in the natural logarithm of emissions to revenue	EPA, S&P Capital IQ
$\Delta log(Emissions_{i,t})$	Change in the natural log of emissions level	EPA
$IsHighEOR_{i,t}$	Indicator variable that takes value one if the firm-year emissions to revenue are above the sample median of emissions to revenue	EPA, S&P Capital IQ
$log(CAPEX_{i,t})$	Natural logarithm of firm capital expenditures	S&P Capital IQ
$\frac{CAPEX_{i,t}}{Assets_{i,t}}$	Ratio of firm capital expenditures to total assets	S&P Capital IQ
$log(Assets_{i,t})$	Natural logarithm of firm total assets.	S&P Capital IQ
$\frac{Debt_{i,t}}{Assets_{i,t}}$	Ratio of firm total debt to total assets	S&P Capital IQ
$\frac{NPPE_{i,t}}{Assets_{i,t}}$	Ratio of firm net property plant and equipment to total assets. A measure of asset tangibility (Lemmon, Roberts, and Zender, 2008).	S&P Capital IQ
$\frac{Cash_{i,t}}{Assets_{i,t}}$	Ratio of firm cash to total assets	S&P Capital IQ
PostParis_t	Indicator variable that equals one if the year is after the passage of the Paris Accords	