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Beyond Greenwashing: Environmental Commitments and Gas Flaring in the African Oil Sector

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Abstract: Corporations follow through on their Zero Routine Flaring commitments globally, particularly in Africa where preexisting environmental standards are weak. Moreover, committers' flaring reductions on the continent are driven primarily by operational improvements rather than ownership changes. While flaring increases for assets divested to, or continuously operated by, non-committers, corporate actions to uphold commitments have resulted in a conservatively estimated 11% net reduction in flaring in Africa. Contrary to greenwashing concerns, our findings suggest that environmental commitments are backed by corporate policies akin to establishing a uniform cost of pollution across the firm. These policies incentivize substantial environmental improvements and may serve as a useful tool to address the challenges posed by globally fragmented regulation.

Keywords: Corporate commitments, sustainability, greenwashing, corporate social responsibility (CSR), environmental regulation, natural gas flaring, Africa.

JEL Codes: F18; K23; K32; L71; M14; M48; N57; O13; Q35; Q52; Q53; Q56

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I. INTRODUCTION

Though there is scientific consensus on the need to reduce global carbon emissions, many view existing government action as insufficient to achieve the necessary improvements. In light of this, sustainability-conscious stakeholders are increasingly pressuring corporations to voluntarily reduce their environmental impact (e.g., Cohen et al., 2023; Ilhan et al., 2023; Krueger et al., 2020). Many corporations have responded by signing standardized long-term environmental commitments that, while not legally binding, require periodic disclosure of progress toward a common goal (Bolton & Kacperczyk, 2024; Freiberg et al., 2021; Ioannou et al., 2016). These goals may be met by corporate actions to reduce emissions if stakeholders use commitments and associated disclosures to impose sufficient costs of noncompliance. However, corporations could also use commitments as a means of greenwashing, when firms' stated environmental goals are inconsistent with their actual implemented corporate actions (Raghunandan & Rajgopal, 2024; Friedman & Ormazabal, 2024; Abraham et al., 2024; Cohen et al., 2023; Kim & Yoon, 2023). Even if corporations do faithfully reduce their emissions within firm boundaries, they may do so in ways that do not benefit the environment, such as divesting dirty operations to less sustainable buyers (Duchin et al., 2024; Ecker & Keeve, 2023). To provide evidence on these issues, we examine whether oil extraction firms fulfill their Zero Routine Flaring (ZRF) commitments by reducing reported flaring (i.e., the burning of excess natural gas), how they do so—through operational changes, avoided investments, or divestitures—and the environmental consequences of these actions in the African oil and gas sector.

We focus on the World Bank's ZRF Initiative—a standardized commitment by which multinational oil and gas corporations responsible for 60% of global flaring have pledged to eliminate routine natural gas flaring by 2030 and provide periodic disclosures at the consolidated level. We focus on this commitment for several reasons. First, gas flaring releases air pollutants that endanger local health

and greenhouse gases that contribute to global warming, but it remains a common practice because the costs of collecting and transporting gas often exceed the proceeds from gas sales. Second, compliance is achievable through changes in real asset ownership that may not benefit the environment (e.g., divestitures of unclean assets) but are difficult for stakeholders to monitor. Third, committers operate extensively in Africa, where weak local environmental standards have allowed the highest pre-commitment flaring per unit production among global regions as well as making divestitures more appealing between committers and non-committers. Finally, gas flaring is measurable by oil block through satellite imaging, enabling us to measure environmental impact at a more granular level than often used firm-level measures. For these reasons, ZRF is a suitable setting to explore whether and how corporate actions to fulfill commitments can achieve environmental progress in regions with weak local environmental standards.

Importantly, the ZRF Initiative applies to a committer's global operations and progress is reported at the consolidated level, so corporate stakeholders that impose costs based on reported flaring can create a firm-wide cost of flaring irrespective of local costs imposed in each area of operation. This firm-wide "cost of carbon" should incentivize firms to first reduce reported flaring, whether by operational improvements or ownership changes, in areas with the lowest marginal abatement costs. This mechanism is central to the economic argument for stakeholder-enforced commitments because the uniform firm-wide cost acts as a global tax on externalities but is not subject to the political challenges of an actual global tax. Consistent with firm-level corporate actions, corporate disclosures through the Carbon Disclosure Project (CDP) and SEC filings, indicate that oil companies take costly abatement actions, like using spare natural gas to electrify operations, and implement firm-wide corporate policies around the time they commit to ZRF.

Our empirical evidence consists of three sets of analyses consistent with the three parts of our research question. Specifically, we examine (1) whether firms reduce reported flaring to follow through on ZRF (or alternatively use ZRF to greenwash); (2) how they follow through (i.e., through operational changes, reduced investments, or divestitures); and (3) whether these actions are net beneficial to the environment.

To assess whether firms reduce reported flaring after committing to ZRF, we use publicly available field-level World Bank data based on current ownership information, which stakeholders most likely use to assess compliance with ZRF. We first show that oil companies report a 22% reduction in worldwide flaring volumes by their third year after committing to ZRF. Consistent with both a lower cost of operational improvements and a greater scope to reduce ownership of unclean assets where local environmental standards are weak, our estimates of flaring reductions are larger in Africa (45%) compared to the rest of the world (16%). Reflecting the strong flaring reduction in Africa, we use more comprehensive nonpublic data in the remainder of the paper, which we only have access to for African oil blocks. This data includes information on historical block ownership that is likely inaccessible to most stakeholders but allows us to provide evidence of how companies meet their commitments and the aggregate environmental consequences.

To assess how firms follow through on ZRF in Africa, we first estimate the extent to which firms make operational changes to reduce flaring in their continuously operated blocks. Specifically, we examine block-level flaring dynamics in the years around operator commitment benchmarked against a within-country control sample of blocks operated by non-committers. We find a gradual decrease in flaring over a three-year period following commitment initiation, amounting to a 44% decline in flare volume. Importantly, we do not see differences in methane concentrations for committed and uncommitted blocks after

commitments are made—indicating that the change in flaring is unlikely to be driven by a shift toward venting, an environmentally disastrous but less observable alternative (McKinley, 2024). Overall, these results indicate that committers make operational improvements around commitments that decrease flaring.

Another way firms could fulfill commitments is through changes in real asset ownership. Given that non-committers do not incur similar costs and may have weaker "green" incentives, the asset reallocation could subvert the ostensible intent of the commitment by prompting an increase in flaring under non-committer ownership—a concern frequently expressed by media and NGOs in regions with low environmental standards such as Africa.[1] While not greenwashing, these changes could have negative environmental consequences. We explore this possibility by estimating the prevalence and consequences of both awards and divestitures of oil-producing blocks. In terms of prevalence, we find both a lower probability of awards for committers and higher frequency of divestitures from committers to non-committers. This reallocation is consistent with increased trade of oil assets due to differing corporate environmental policies between committers and non-committers, though these ownership changes make up only a modest proportion of the total blocks operated by committers.

To assess the environmental consequences of ownership changes, we compare block-level flaring dynamics in the years around awards and divestitures for committers and non-committers. We find that blocks awarded to committed (uncommitted) operators exhibit similar trends in flaring volumes as blocks continuously operated by committers (non-committers). Thus, we estimate that the reallocation of awards towards non-committers increases flaring by approximately 28%. Moreover, the blocks that are divested from committers to non-committers see a substantial 153% increase in flaring after divestiture. We do not find similar

[1] Notable examples documented by news media and NGOs include The New York Times, The Economist, The Washington Post, and the Environmental Defense Fund (Malek et al., 2022).

patterns for other types of divestitures. Taken together, these changes are consistent with environmental deterioration driven by a reallocation of assets from committers to non-committers.

To assess the aggregate environmental consequences of all corporate actions taken to fulfill the ZRF commitment, we perform a country-level analysis that also incorporates spillover effects to non-committers. One way that such spillover effects could occur is if limited gas transportation infrastructure or gas market capacity results in gas from committed fields displacing gas from uncommitted fields. The country level analysis also allows us to control for oil production that is not available at the field level. In this analysis, we regress aggregate country-level flaring on the fraction of fields owned by committers in a given year (determining ownership in 2012). We find a net 11% reduction in flaring. This is less than the reduction implied by aggregating the changes in flaring around actions by committers, consistent with spillover effects to non-committers counteracting approximately 75% of improvements by committers.

Importantly, we do not interpret our estimates as a causal effect of commitments, which only indicate a firm's intention to take some unspecified future actions to achieve a long-term goal (i.e., the commitment itself does not have an effect). In our definition of greenwashing, faithful reporting does not depend on whether the disclosure of a commitment causes a behavior change or whether a prior or intended behavior change leads to the disclosure of a commitment. So long as disclosures and actions are consistent, a firm is not greenwashing. Accordingly, our evidence does not show that ZRF commitments cause oil extraction firms to reduce flaring. Instead, we suggest that firms, on average, follow through on their commitments, notably also where local environmental standards are weak and corporate actions are most revealing about true intentions.

Our findings most directly contribute to the literature studying whether and how corporations fulfill sustainability commitments. The evidence on financial

fund commitments indicates that funds generally do not follow through on their commitments, and those that follow through do so primarily by selecting already cleaner firms rather than working toward environmental improvements in currently held firms (Heath et al., 2023; Kim & Yoon, 2023).[2] One likely reason is that there is a sufficient number of investors in public markets willing to hold brown firms without substantial price compensation (Broccardo et al., 2022).

The evidence on non-financial corporate commitments is less conclusive. Though vague commitments like signing on to the Business Roundtable's Purpose Statement are rarely associated with real corporate changes (Raghunandan & Rajgopal, 2024; Bebchuk & Tallarita, 2022), more specific commitments to reduce carbon emissions, especially ambitious ones or those associated with voluntary disclosures, are typically followed by reductions (Abraham et al., 2024; Bolton & Kacperczyk, 2024; Freiberg et al., 2021; Ioannou et al., 2016). Consistent with the findings on specific commitments, we also find that oil and gas firms generally follow through on their ZRF commitments.[3] However, we add to these findings by showing that follow-through also occur where baseline environmental standards are low (i.e., Africa), which suggests that commitments may provide a partial solution to weak local standards. More importantly, we also provide evidence on the environmental consequences of firms' actions to follow through on commitments.

[2] Contrary to this, Dai et al. (2023) find that funds do respond in ways that improve environmental outcomes in a European setting where securities regulators enforce disclosure rules for funds that commit to being socially responsible. However, the government enforcement makes it somewhat different from the stakeholder enforced voluntary commitments that we and other papers focus on.

[3] In environmental science, Liu et al. (2023) and Wen et al. (2023) have documented flaring reductions around country endorsements of the ZRF initiative. Contrary to both papers, we focus on firm-level ZRF commitments and flaring changes at the block level (controlling for country-year fixed effects) because we are interested in understanding whether multinational firms potentially alleviate the institutional challenges of implementing government regulation in much of the developing world. Country-level evidence does not speak to how flaring reductions occur at the firm-level (e.g., through investment policies) and whether firms are potentially part of a solution. Consistent with this, evidence in (Internet Appendix) Section IA4.6 shows that improvements after corporate ZRF commitments in fact are stronger in countries that have not committed to ZRF.

Prior evidence that firms follow through is indeed inconsistent with greenwashing but could still be due to divestments or reduced investments in brown assets or cause spillover effects to non-committers. Although we find that divestments, investment avoidance, and other spillover effects occur and are followed by deterioration in environmental outcomes, they are not frequent or large enough to offset the positive effects from operational changes for continuously owned assets.[4]

We also contribute to the literature on changes in real asset ownership to improve reported sustainability performance around increases in public pressure (Duchin et al., 2024), mandatory disclosure of ESG performance (Christensen et al., 2025; Ecker & Keeve, 2023; Rauter, 2020), and exposure to carbon pricing (Känzig et al., 2024). While Duchin et al. (2024) and Christensen et al. (2025) find that divestitures are common but followed by only minor deteriorations in sustainability performance, our findings suggest infrequent divestitures with substantial subsequent deterioration—likely reflecting two distinct forces. First, the market for oil assets in Africa is less liquid than most real asset markets, making the necessary price discount to divest assets high relative to the cost of investments to reduce flaring. Second, weak local environmental standards in Africa allow the discrepancy between committers and non-committers' behavior to have a greater impact on the environmental performance of assets.

Overall, despite the common intuition that multinational corporations are less conscious when operating in developing economies (e.g., Christensen, 2022; Cooney & Freslon, 2018), our study suggests that corporate sustainability initiatives may play a greater role where local environmental standards are weak (Lu, 2023). Plausibly, marginal improvements come at a lower cost in developing

[4] Whereas prior work on commitments often use performance benchmarks based on firms' own disclosures and judgments (e.g., voluntary emissions disclosures or ESG ratings), we leverage recent advances in remote sensing to establish a benchmark unaffected by firms reporting incentives (similar to Breuer et al., 2024 and following suggestions by Michelon et al., 2025).

nations where the local baseline for environmental performance imposed by regulators and stakeholders is low. This is exactly where uniform global commitments, which encourage stakeholder enforcement on firm-wide metrics, incentivize greater improvements if the commitments are not merely greenwashing. Essentially, this is the opposite effect of carbon taxes causing carbon leakage to less-regulated localities (Känzig et al., 2024) because stakeholders impose uniform costs everywhere a corporation operates.[5]

II. THEORY AND INSTITUTIONS

Government regulation—through taxes, subsidies, and penalties—is the standard response to externalities, but political differences across regions have hindered uniform global environmental regulation (Cao & Prakash, 2012; Fowlie, 2009; Langbein & Kerwin, 1985). With carbon externalities distributed globally but institutions unable to implement a uniform tax, nations and corporations often lack incentives for socially optimal long-term investments (Hazilla & Kopp, 1990; Markusen, 1975). Since many harmful consequences stem from corporate behavior, stakeholder pressure has become an alternative mechanism for internalizing externalities (Barzuza et al., 2022; Shive & Forster, 2020). This section explains the role of commitments in resolving environmental challenges, outlines institutional details about the ZRF relevant to our empirics, and documents costly corporate actions to fulfill ZRF disclosed by corporations.

[5] We also contribute to a broader literature in accounting and economics exploring how multinational corporate activity impacts communities in the Global South. For example, several studies explore how regulation imposed on US and European firms—such as tax law (Hoopes et al., 2023), carbon taxation (Känzig et al., 2024), extraterritorial corruption regulation (Christensen et al., 2024; Christensen et al., 2022), conflict mineral disclosures (Chang & Christensen, 2025; Baik et al., 2024), and local content requirements (Chang, 2025)—impact real outcomes in developing countries. Themes in our paper, such as the use of satellite data and the African extraction sector setting, also resonate with this recent work with the goal of shedding light on how global commerce affects economic development.

2.1 Corporate Commitments as a Solution to Environmental Challenges

In response to stakeholder pressure, corporations frequently sign standardized voluntary commitments (e.g., PRI, SBTi) that require periodic disclosure of company-wide progress toward a common goal. These commitments and disclosures are uniform, which can help stakeholders assess and compare corporations' improvement over time so that they can impose penalties for noncompliance (Fairfax, 2022; Bauer et al., 2021; Dimson et al., 2015). For instance, to punish a noncompliant firm, investors can require higher costs of capital (Pástor et al., 2022; Friedman & Heinle, 2016; Fama & French, 2007), customers can reduce demand (Hillman et al., 2025; Leonelli et al., 2025; Christensen et al., 2023; Darendeli et al., 2022; Dai et al., 2021), employees can require higher wages (Colonnelli et al., 2025; Choi et al., 2023; Novak & Bilinski, 2018; Dewatripont et al., 1999), and NGOs can exert political and social influence (Rauter, 2020; Arenas et al., 2009). If stakeholders impose sufficient penalties for noncompliance, firms have an incentive to make progress on their commitments.

Nevertheless, there are reasons to be skeptical that commitments convey information about corporations' real actions. First, although stakeholders often express concern about environmental and social issues, it is less obvious that they are willing to expend personal resources to inflict noncompliance penalties (e.g., Leonelli et al., 2025; Christensen et al., 2024; Jiang et al., 2024; Kim, 2024; Li et al., 2024; Larcker & Watts, 2020), especially for industries like oil extraction that inherently attract less responsible capital providers. Second, information asymmetry could result in an adverse selection problem if stakeholders are unable to differentiate between firms that are truly taking action to reduce externalities and those that are not, which could destroy the market for commitments (Smith, 2023; Akerlof, 1970). With these opposing arguments, it remains unclear whether corporate commitments are informative about corporations' real environmental improvements or simply a means of greenwashing.

Even if commitments are not greenwashing, it is unclear whether corporate actions to fulfill their commitment improve aggregate environmental outcomes. Suppose, optimistically, that stakeholders respond and firms report aggregate figures truthfully, it remains difficult for stakeholders to evaluate the corporate actions taken to achieve reported improvements (Atkeson et al., 2015). For instance, corporations could divest polluting assets that are costly to improve, lowering reported pollution numbers without reducing global emissions (e.g., Duchin et al., 2024; Ecker & Keeve, 2023). In fact, such divestitures of real assets could be followed by environmental deterioration if acquirers are technologically ill-equipped or subject to less stakeholder pressure.

Areas of the world with weak preexisting environmental standards are particularly suitable to explore both of these empirical questions. First, uniform firm-wide policies implemented by corporations are more likely to be binding in the presence of weak local environmental standards, where low-cost abatement options have not been previously mandated by local regulators and stakeholders, improving our ability to assess the extent of firms' greenwashing behavior independent of local external influence. Second, in the absence of external forces to constrain flaring, there is a larger scope for the trade of brown assets between firms subject to stakeholder pressure and those that are not because irresponsible firms can operate these assets in a more profitable but polluting fashion.

2.2 Institutional Details on ZRF Commitments and Committers

One prominent voluntary commitment is the World Bank's Zero Routine Flaring by 2030 (ZRF) Initiative (World Bank, 2024; Wen et al., 2023). Natural gas flaring is one of the most problematic practices in the oil and gas extraction process, causing both local health consequences and global climate concerns (Blundell & Kokoza, 2022).[6] However, the costs of reducing flaring through collecting and

[6] In (Internet Appendix) Section IA1.1, we provide specific details on natural gas flaring, concomitant regulation, and alternatives that operators can implement.

transporting natural gas often exceed the proceeds obtained from gas sales, especially in regions with low local demand for gas and weak infrastructure for transporting gas. This prompted the launching of the ZRF Initiative in 2015 and, as of 2024, signatories to the commitment account for approximately 60% of global flaring activity (World Bank, 2024).[7]

The World Bank reports global flaring activity in a database available on their website so that stakeholders can assess progress toward ending routine flaring at the corporate level based on current block operators and satellite estimates of flaring intensity. In fact, information about gas flaring intensity enters ESG rating methodologies (e.g., Refinitiv, S&P Global) both directly and through Scope 1 emissions, an additional channel through which stakeholders could consider such information.

The World Bank GFMR website reports data on 1,227 oil and gas companies around the world (as of March 29, 2024), of which 36 have committed to ZRF by 2022.[8] In Table 1 Panel A, we provide descriptive evidence comparing time-invariant characteristics of ZRF committers and non-committers. First, we focus on the intensity of stakeholder pressure that likely prompts firms to commit. Unsurprisingly, a majority of committers are publicly traded, as public firms are likely motivated by capital market pressure and heightened scrutiny from non-investor stakeholders. Similarly, committers are more likely to release annual sustainability reports, disclose to the carbon disclosure project (CDP), and have a S&P Global ESG rating, reflecting firms' responses to stakeholder demands for

[7] In (Internet Appendix) Section IA1.2, we provide institutional details on the World Bank's ZRF commitment, including a brief history, specific responsibilities for signatories, and reputational consequences for noncompliance.

[8] There are a total of 58 ZRF committers in the world (as of 2022) but only 45 have reported flaring estimates in the World Bank GFMR database (see Internet Appendix Section IA1.2 for a full listing). This is likely because of incomplete block ownership information, which prevents GFMR from capturing all blocks operated by all committers.

sustainability information. Moreover, they are also significantly more likely to be a signatory of other environmental commitments.[9]

Turning to the timing of commitment among committers, the main determinant of timing is the firm's headquarters location. In Figure 1, we plot each firm by headquarters location and their time of commitment. Notably, European and African oil firms commit early, most in the first year after ZRF was launched, while American firms commit later. This is likely because Europe had an earlier push towards methane reduction through targeted stakeholder pressure, strict regional regulation (e.g., in Norway), and the EU Emissions Trading Scheme, which likely flowed through to African firms through corporate connections. Many European oil firms were also founding members of the Oil & Gas Climate Initiative (OGCI) launched in 2014, which facilitated collaboration in reducing environmental impact. On the contrary, in the early years of ZRF, the US had uncertain flaring regulation, less intense stakeholder pressure, and many economic constraints such as negative gas prices. However, mounting political pressures from COP26 and increasing capital market attention in later years prompted most American oil majors to commit in 2021 and 2022. Consistent with sustainability pressure from capital markets mattering most in the commitment decisions of US firms, we show in Table 1 Panel B that the number of lead lenders committed to the Principles for Responsible Banking and large institutional investors that have committed to the Principles of Responsible Investing are significantly associated with US firms' timing of commitment.[10] Across the rest of the world, we observe no clear patterns in the timing of commitment.

[9] Unsurprisingly, the reduction in flaring after commitments that we find in Section 3 is also driven by firms under higher stakeholder pressure, as shown in (Internet Appendix) Section IA4.3.

[10] Lead lenders are those that *DealScan* classifies as lead arrangers or sole lenders. Large institutional investors are those with ownership exceeding US$10 million.

Importantly, the descriptive evidence presented in this section highlights that commitments occur jointly with other corporate influences, and it is important to note that we are not attempting to estimate the causal effect of commitments. At a conceptual level, commitments cannot be randomly assigned because they indicate a firm's intention to take some unspecified future action, such as inventing and implementing new technology, that works toward a long-term goal. Thus, changes in environmental performance would be caused by evolving corporate actions to fulfill commitments rather than the commitments themselves.

However, although reverse causality is not necessarily a concern for our definition of greenwashing, we would be concerned about an external factor that is not costly to the firm but causes both commitments and flaring reductions. For instance, if firms commit because local governments contemporaneously build infrastructure (e.g., pipelines), then the firm plays no role in reducing flaring. To alleviate such a concern, we include *Country* × *Year* fixed effects throughout our main analysis, and—in the next section—also provide evidence that firms take costly actions to reduce gas flaring around the time they commit to ZRF.

2.3 Corporate Disclosures on ZRF Commitments

To document costly actions that ZRF committers take to reduce flaring, we examine corporate carbon-reduction investments disclosed through the Carbon Disclosure Project (CDP) and SEC filings. In Figure 2 Panel A, we see a significant uptick in committers' flaring-reduction investments disclosed through the CDP around the signing of ZRF commitments. This suggests that firms do undertake intensive investments in flaring reduction during the years following ZRF commitment compared to other periods.

In an attempt to identify the investments that are related specifically to ZRF, we search SEC documents for the word "zero routine flaring." We find that 14 of the 18 SEC registrants discuss ZRF at least once in an SEC filing, and these ZRF discussions are most frequent in the two years immediately after firms commit (see

Figure 2 Panel B). Looking specifically at the filings that discuss ZRF, the most commonly discussed investments are related to reinjecting natural gas back into the ground or using gas to produce electricity for drilling operations, the latter of which replaces diesel generators, further lowering emissions. Moreover, we also find evidence consistent with firms implementing a firm-wide cost of carbon—either explicitly or in connection with executive compensation. We provide a more systematic documentation of these actions in (Internet Appendix) Section IA2.

Taken together, these disclosures indicate that oil companies do (1) take costly abatement actions connected to their ZRF commitment and (2) implement firm-wide policies that reduce flaring. Given that firms incur costs to fulfill the commitment, there must be some benefits from committing, such as a lower cost of capital. It is difficult to accurately estimate costs and benefits attributable to commitments because a firm-level analysis is too broad to reasonably identify the financial impacts of an improved environmental profile, especially among a subset of assets. However, given that ZRF commitments are discussed in 78% of the SEC filings of ZRF-committed SEC registrants, we argue that they are likely financially material, and theory suggests that disclosing material information reduces firms' cost of capital.

III. Reported Gas Flaring from World Bank Estimates

To answer the first part of our research question—assessing whether firms reduce reported flaring after committing to ZRF—we explore World Bank data on gas flaring volumes around ZRF commitments. The World Bank data covers global flaring activities and is publicly available on their website. However, historical asset ownership data is incomplete, and much of the reported flaring is based on asset ownership as of the latest data update (i.e., 2022 for our sample). Our objective is to assess whether committers reduce their reported flaring relative to

non-committers. Then, we compare flaring changes between African operations, where environmental standards are particularly weak, and elsewhere in the world.

3.1 Data and Sample

We obtain global gas flaring data by oil field from the World Bank's *Global Flaring and Methane Reduction Partnership* (*GFMR*). The data provides information on the current operator's identity and annual flare volumes for each oil field. We limit our analysis to onshore fields (where flaring can be accurately measured via satellites, see Lu et al., 2020; Anejionu et al., 2015), actively operated fields (those that have a listed operator), fields where we can establish the operator's identity, and fields that exhibit any flaring throughout the sample period.[11] We then collapse to the field-operator-year level to ensure that fields are not repeated in the data. For each field, we identify whether the operator has committed to ZRF by matching the documented operator names to the World Bank's list of committers. Determining commitment status based on the operator is consistent with the World Bank's requirement that committers report "all flaring in fields that the company operate[s], irrespective of owner structure" (World Bank, 2024). Thus, the sample contains a balanced panel between 2012 and 2022 of oil fields that, as of 2022, are operated by either committers or non-committers.[12]

In Table 2, we present a temporal summary of commitment year for firms that have committed by 2022, showing that 56% (33%) of firms (fields) committed in the first two years. The 993 committed fields in our sample are spread across 43 countries, with 194 fields located across 9 African countries. Approximately 20% of fields in our sample are operated by committers. In addition, 47% of field-years contain flaring activity, indicating that flares are common but not ubiquitous across

[11] The World Bank GFMR dataset does not always include a unique operator name, which is likely because the dataset is not organized by unique field IDs. We infer the fields from the field name and country assigned by the World Bank, whenever we cannot establish the unique operator of a field, we exclude it from our analysis. See (Internet Appendix) Section IA3.2 for sample selection details.
[12] See (Internet Appendix) Section IA3.1 for a summary of variables and data sources.

all fields over time. The average (standard deviation of) flaring volume for each field-year in our sample is 17.6 (90.5) million cubic meters.[13]

3.2 Flaring Changes Around Commitments Globally

3.2.1 Gradual Change in Reported Flaring

To provide evidence on whether corporations follow through on ZRF commitments, we use a stacked difference-in-differences design that compares flaring volume in committed blocks to uncommitted blocks within the same country (Barrios, 2024; Goodman-Bacon, 2021; Cengiz et al., 2019). To capture the dynamics of flaring over time, we plot yearly coefficient estimates from the following OLS regression (expressed in unstacked form):

$$\text{asinh}(FlareVol_{d,t}) = \beta_0 + \beta_1 ZRF_f \times Year\ Relative\ to\ Commit_{f,t} + \alpha_d + \delta_{c,t} + \varepsilon_{d,t} \quad (1)$$

asinh(*FlareVol*) is the inverse hyperbolic sine of the flaring volume in millions of cubic meters within field *d* in year *t*.[14] *ZRF* is an indicator equal to one if a field is operated by a committer *f*. *Year Relative to Commit* is a set of indicators for each year defined relative to the year of commitment. We omit the indicator for the year before commitment, which serves as the benchmark period. To control for differences in flaring activity arising from time-invariant (or slow-moving) factors specific to each field (e.g., geographic location or extraction capacity), we include *Field* fixed effects. We also include *Country* × *Year* fixed effects to control for time-varying local policies or other institutional factors correlated with each host country—such as improvements in public infrastructure that reduce flaring at no cost to firms—to isolate firm-specific flaring changes for committers relative to non-committers. For instance, countries may build relevant infrastructure such as gas pipelines, and that could be a driver of firm commitments for Africa-

[13] See detailed descriptive statistics in (Internet Appendix) Section IA3.3.

[14] We use the inverse hyperbolic sine transformation of *FlareVol* because the variable is highly right-skewed (skewness of 14.53) with many zero values (53.6% of the sample) and several outliers (3.6% above 100 million cubic meters) even after excluding non-flaring fields. See the sensitivity tests for log and Poisson regressions. The same rationale applies for analyses in Section 4.

concentrated firms. To the extent that the infrastructure is equally beneficial to committers and non-committers, these fixed effects would alleviate this concern. We estimate standard errors clustered by operator.[15]

In Figure 3 Panel A, we graph the yearly *ZRF* × *Year Relative to Commit* coefficient estimates and their corresponding 95% confidence intervals. We observe that treated and control fields have very similar trends in flaring in years *t–3* to *t*. Consistent with changes in reported flaring after commitment, treated fields exhibit a gradually decreasing flare volume relative to control fields beginning the year after commitment. From about three years after commitment, the flaring volume stabilizes at an approximately 22% lower level, corresponding to approximately 5.15 million cubic meters per field-year.[16] The subsequent stabilization indicates that some flaring continues to occur, which need not be inconsistent with ZRF compliance because emergency flaring is allowed.

Next, to see whether the relative change is driven by committers or non-committers, we estimate the following equation:

$$\text{asinh}(FlareVol_{d,t}) = \beta_0 + \beta_1 \, Year\ Relative\ to\ Commit_{f,t} + \alpha_d + \varepsilon_{d,t} \qquad (2)$$

In Figure 3 Panel B, we graph the yearly *Year Relative to Commit* coefficient estimates and their corresponding 95% confidence intervals. We observe that treated and control fields have very similar trends in flaring in years *t–3* to *t*. Consistent with changes in reported flaring after commitment, treated fields

[15] In our setting, there are two concerns—correlations within firm (operator) or correlations within geography—that should be considered when clustering standard errors. Because our study focuses on corporate commitments and treatment is assigned at the operator level, we believe that clustering by operator is more suitable given that we expect there to be strong correlations in flaring behavior within the same firm over time (e.g., due to pervasive corporate strategies or historical investments in flaring reduction technology). Moreover, clustering by firm also allows us to control for geographical correlations to the extent that nearby blocks are operated by the same firm, which is often the case. However, given that geographic correlations are still a concern, see the sensitivity tests for clustering within 100km (Conley, 1999), within province, and within country.

[16] We calculate this as the percentage changes multiplied by the pre-commitment mean for committed blocks ($23.26 \times (e^{-0.250} - 1) = -5.15$).

exhibit a gradually decreasing flare volume relative to (stacked) control fields beginning in the year of commitment. From about three years after commitment, the flaring volume for treated fields stabilizes at a 22% lower level.[17]

3.2.2 Average Change in Flaring and Sensitivity Tests

To estimate the average change in reported flaring, we replace the individual *Year Relative to Commit* indicators in Eq. (1) with a single *PostCommit* indicator, which equals one for all years during or after the commitment year. In the first line of Figure 3 Panel C, we present the baseline average change in *FlareVol*. The *ZRF* × *PostCommit* coefficient estimate indicates a 11% average reduction in flaring volume after commitment.

Figure 3 Panel C also reports results from several sensitivity tests. Our first set of sensitivity tests changes sample restrictions to alleviate concerns that sample selection choices drive our results.[18] First, we exclude fields designated as gas-producing because those fields are less likely to flare gas as a byproduct.[19] Second, we include offshore fields, which represent an important part of oil production but where flaring is difficult to detect from satellite imagery. Third, we include fields with zero flaring throughout the sample period, in case these fields would have started flaring in the absence of the ZRF commitment. Fourth, we exclude observations after 2019 in case firms reduced operations during the COVID period. Fifth, we remove observations more than three years earlier or later than commitment for treated fields because these periods are not available for early and late committers.[20]

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[17] To interpret these and future coefficients as a percentage change, we take $e^{-0.250} - 1 = -22\%$.

[18] In (Internet Appendix) Sections IA4.1 and IA4.2, we estimate the main specification separately excluding each year of commitments and the main host countries, respectively. We find little evidence that commitments in any year or blocks in any host country drive our results.

[19] However, we know institutionally that even oil-focused blocks must dispose of gas byproducts. Thus, an oil-only designation does not necessarily indicate that the block does not flare gas.

[20] To mitigate selection concerns, we also employ a treated vs. not-yet-treated design in an untabulated analysis. However, since we expect that flaring declines around the time firms commit

Our second set of tests varies the empirical specification. First, we shift from *Country* × *Year* to *Province* × *Year* fixed effects to control for any time-varying trends by province that could impact flaring activity. Second, we replace the inverse hyperbolic sine (i.h.s.) with the natural logarithm of (1 + *FlareVol*) as the dependent variable given recent concerns with the i.h.s. transform (Chen & Roth, 2024; Mullahy & Norton, 2024; Aihounton & Henningsen, 2021). Third, we employ a standard DiD analysis without stacking by commitment year cohort. Fourth, we assess the sensitivity of our estimates to a violation of the parallel trends assumption using M values of 0.5 and 1.0 (Rambachan & Roth, 2023).[21] Fifth, we perform a geographic one-to-one matching, keeping only the single control field that is closest to each treated field to alleviate selection biases.

Our third set of tests varies standard error clustering. First, we estimate Conley (1999) standard errors that account for spatial correlation within a 100-kilometer radius and infinite serial correlation. Second, we cluster by field in case there is no correlation between fields operated by the same firm. Third, we cluster by province to account for within-province dependence across fields. Fourth, we cluster by country to account for within-country dependence across fields. Across all three sets of sensitivity tests, we find a negative but not always statistically significant coefficient with magnitude inside the 95% confidence interval of the baseline. Taken together, the results in this subsection show substantial reductions in reported flaring after commitments (based on current ownership data).

3.3 Flaring Changes for African vs. Non-African Countries

In Figure 4, we plot pre-ZRF (2012-2014) gas flaring scaled by oil production for countries around the world to assess the strength of anti-flaring

to ZRF and not necessarily strictly after commitment, this design may not be suitable for our setting. Consistent with this, our results become statistically insignificant in this specification.

[21] For this and all future uses of the Rambachan & Roth (2023) methodology, we estimate a single average post-period coefficient relative to separate coefficients for three periods before treatment.

standards in each host country. Africa overwhelmingly stands out as the continent with the highest per-unit flaring volumes among oil-producing countries, consistent with the general perception that environmental standards are weak in Africa. Moreover, this also necessarily indicates that actions to reduce flaring in African oil operations are higher-ranked on firms' marginal abatement cost curves (McKinsey & Company, 2007). In other words, the marginal cost per unit flaring reduction is likely among the lowest in the world. For this reason, profit-maximizing multinational corporations with a uniform global cost of flaring likely choose flaring reduction projects in Africa first.[22]

3.3.1 Gradual Change in Reported Flaring

In Figure 5 Panel A, we estimate Eq. (1) separately for oil fields in African and non-African countries. In the non-Africa group, we observe that treated and control fields have very similar trends in flaring in years *t–3* to *t*, but we do see a slight pre-trend in the Africa group. We emphasize that actions to reduce flaring in anticipation of the commitment do not imply that firms are not following through. Following commitments, there is a substantially larger decrease in flaring volumes for committed fields in Africa than outside of Africa. Specifically, about three years after commitment, the flaring volume in Africa (outside of Africa) stabilizes at a 45% (16%) lower level, corresponding to 24.1 (2.8) million cubic meters per field-year.[23] Based on a Z-test, the difference between flaring in African and non-African fields is statistically significant at the 10% or lower level at two years and after.

[22] In (Internet Appendix) Section IA4.5 and IA4.6, we also perform a sample split on the Yale Environmental Performance Index (EPI) and host country ZRF commitment, respectively, which yield results comparable to the Africa vs. non-Africa split. In (Internet Appendix) Section IA4.7, we also show that many committers own and operate assets in Africa, though it is not typically their dominant area of activity. Thus, firms are unlikely to make ZRF commitment decisions based on their African operations alone.

[23] We calculate this as the percentage changes multiplied by the pre-commitment mean for committed blocks. For Africa fields, this is $53.50 \times (e^{-0.602} - 1) = -24.08$. For non-Africa fields, this is $17.28 \times (e^{-0.177} - 1) = -2.76$.

3.3.2 Average Change in Flaring in Africa and Sensitivity Tests

In Figure 5 Panel B, we present the baseline average change in flaring volume for African oil fields and several sensitivity tests similar to those in Figure 3 Panel B.[24] The baseline estimate indicates a 40% average reduction in flaring volume after commitment. Across all three sets of sensitivity tests, we find a negative coefficient with magnitude inside a 95% confidence interval of the baseline (see Section 3.2.2 for details). Taken together, these findings suggest that committers reduce their reported flaring more where baseline environmental standards are low.[25]

IV. EXPLAINING THE FLARING REDUCTION IN AFRICA

To answer the second part of our research question—assessing the actions firms take to reduce reported flaring after committing to ZRF and the changes in flaring associated with each action—we use more detailed data that focus on the African oil sector.

4.1 Data and Sample

We obtain location, ownership, and buy/sell transaction details of oil and gas blocks in Northern and Western Africa, where most of Africa's oil and gas reserves are located, from *Enverus International* (*"Enverus"*) in November 2023. While we only have access to this data for African blocks, it is more comprehensive and higher quality than the publicly available World Bank data for Africa. Moreover, *Enverus* includes a current dataset of blocks with a snapshot of operator and owner details as well as a dataset on all historical block transactions, which together allow us to create a panel of block ownership through our sample period.[26]

[24] In (Internet Appendix) Sections IA4.4, we estimate the main specification separately excluding each African host country. We find little evidence that blocks in any host country drive our results.
[25] Tables for all analyses in Section 3 can be found in (Internet Appendix) Section IA4.8.
[26] The World Bank reports flaring data by field, which is a scientifically defined site where significant quantities of oil (and/or gas) have been discovered and can be extracted. *Enverus* reports

This would not be possible based on the World Bank dataset that stakeholders can use to assess progress on commitments but not sufficient to explore the distinct actions companies take to reduce reported flaring.

Using the *Enverus* dataset, we follow the sample selection choices made in the World Bank dataset as closely as possible. Specifically, we limit our sample to onshore blocks, actively operated blocks, and blocks that exhibit any flaring throughout the sample period. We then classify blocks into three groups by ownership status—continuously owned, awarded, and divested—and we consider the flaring implications for each. We display the locations of blocks by ownership status in Figure 6 Panel A. Our sample is concentrated in Algeria, Angola, Egypt, Gabon, Libya, Nigeria, and Tunisia where most African oil operations are located, but a total of 22 countries are represented in the sample. Specifically, 20% of blocks are continuously owned by committers, 33% of blocks are continuously owned by non-committers, 44% are awarded, and 3% are divested during the sample period.[27]

We obtain flaring data for 2012 through 2023 from the *Colorado School of Mines VIIRS Nightfire* dataset (Elvidge et al., 2013) versions 2.1 (through November 2017) and 3.0 (starting in December 2017). The data records one observation for each detected flare during every nightly satellite flyover.[28] We isolate flares as observations with a temperature above 1,400 kelvins, which other sources (e.g., forest fires) cannot reach. To calculate the flaring volume from radiant heat values, we use the Cedigaz constant, which is a value calibrated to

oil/gas operations by block, which is a legally defined site that the government designates to a firm for exploration and/or production of oil/gas (likely because *Enverus* is a commercial dataset primarily sold to firms that need info about economic assets). Large oil blocks can have several fields (in the case of Mali, Niger, and Namibia), or countries may divide fields into many blocks (in the case of Nigeria and Algeria).

[27] See (Internet Appendix) Section IA3.4 for sample selection details.

[28] While these nightly satellite images do not capture daytime flaring, it is unlikely that committed firms can strategically time emissions to avoid detection because gas flaring, unlike factory emissions, is not fully controllable by well operators. Gas and oil are extracted from a well at the same time, and it is not always predictable or controllable when gas reserves need to be flared.

linearly convert recorded radiant heat to flared gas volumes. Specifically, we divide the annual sum of radiant heat by 365 to get the daily average radiant heat, multiply by the Cedigaz constant of 0.0281 to convert to flare volume in billions of cubic meters, and finally multiply by 1000 to convert to millions of cubic meters.[29,30]

We display a heat map of flaring across African blocks in Figure 6 Panel B. This shows that 90% of documented flares (Panel B) occur in blocks labeled as actively operating (Panel A), confirming alignment between our data sources. In Table 3, we present a temporal summary of commitments for continuously owned blocks in Africa, showing that 82% (33%) of firms (blocks) committing in 2015 and 2016. The 194 committed blocks in our sample—which make up 39% of total continuously owned blocks—are spread across 9 African countries. In our total sample, 51% of block-years contain flaring activity, indicating that flares are common but not ubiquitous across all blocks over time. The average (standard deviation of) flaring volume for each block-year in our sample is 128.3 (813.9) million cubic meters.[31]

4.2 Analysis for Continuously Operated Blocks

4.2.1 Gradual Change in Gas Flaring

To provide evidence on whether corporations follow through on ZRF commitments in their continuously owned blocks, we employ a similar stacked difference-in-differences design as we did with World Bank data in Section 3, specifically estimating Eq. (1) for only continuously owned blocks in Africa. In Figure 7 Panel A, we graph the yearly *ZRF* × *Year Relative to Commit* coefficient estimates and their corresponding 95% confidence intervals. We observe that treated and control blocks have very similar trends in flaring in the years before

[29] This is consistent with the World Bank's methodology (see Internet Appendix Section IA5.11).
[30] See (Internet Appendix) Section IA3.1 for a summary of variables and data sources.
[31] Detailed descriptive statistics for each subsample can be found in (Internet Appendix) Section IA3.5. These flaring volumes are higher than the World Bank *GFMR* estimates because many *Enverus* blocks include several *GFMR*-defined fields.

commitment. Consistent with firms changing their flaring practices after commitment, treated blocks exhibit gradually decreasing flare volumes relative to control blocks beginning the year after commitment. From about three years after commitment, the flaring volume stabilizes at a 44% lower level, corresponding to approximately 116 million cubic meters per block-year.[32] The stabilization indicates that some flaring continues to occur, which need not be inconsistent with ZRF compliance due to the allowance of emergency flaring.

Next, we separately examine the changes in flaring volume around commitment for blocks continuously operated by committers and non-committers by estimating Eq. (2). In Figure 7 Panel B, we graph the yearly *Year Relative to Commit* coefficient estimates and their corresponding 95% confidence intervals. We observe that flaring volumes in treated blocks increased in the years leading up to the commitment but stopped increasing after commitment.[33] On the contrary, flaring volumes in control blocks were constant in the years leading up to the commitment (using a stacked sample) and increase after commitment. This is consistent with flaring spillovers from committers to non-committers, for example resulting from limited local capacity for gas consumption being reallocated to committers. However, it is unclear whether these spillovers account for all of the observed flaring reductions or whether there is some overall improvement, which we discuss in more detail using an aggregate country-level analysis in Section 5.

4.2.2 Average Change in Flaring and Sensitivity Tests

To estimate the average change, we replace the individual *Year Relative to Commit* indicators with a single *PostCommit* indicator, which equals one for all

[32] We calculate this as the percentage changes multiplied by the pre-commitment mean for committed blocks ($263.09 \times (e^{-0.583} - 1) = -116.23$).

[33] The reason that there is an upward flaring trend for treated blocks is due to a strong increase in Algeria for both committers and non-committers, but 78% of blocks are owned by committers, creating a difference in weighting. *Country* × *Year* fixed effects address this issue in Figure 7 Panel A, where no strong pre-trend remains.

years during or after the commitment year. In the first row of Figure 7 Panel C, we present the average change in flaring volumes. The baseline *ZRF* × *PostCommit* coefficient estimate indicates a 37% average reduction in flaring volumes after commitment.

Figure 7 Panel C also reports results from several sensitivity tests. Our first set of sensitivity tests changes sample restrictions to alleviate concerns that sample selection choices drive our results.[34] First, we exclude blocks designated as oil only in case those blocks produce less gas as a byproduct. Second, we include fields with zero flaring throughout the sample period, in case these fields would have started flaring in the absence of the ZRF commitment. Third, we exclude low-flaring blocks, defined as those with fewer than 10 flare-days throughout the sample period. Fourth, we exclude observations after 2019 in case firms reduced operations during the COVID period. Fifth, we remove observations more than three years earlier or later than commitment for treated fields because these periods are not available for early and late committers.

Our second set of tests varies the empirical specification. First, we control for *Well Count*, a count of newly opened wells representing highly active blocks, to control for shifts in operational intensity. Second, we shift from *Country* × *Year* to *Province* × *Year* fixed effects to control for any time-varying trends by province that could impact flaring activity. Third, we replace the inverse hyperbolic sine with the natural logarithm of (1 + *FlareVol*) as the dependent variable given recent concerns with the i.h.s. transform (Chen & Roth, 2024; Mullahy & Norton, 2024; Aihounton & Henningsen, 2021). Fourth, we estimate a Poisson Pseudo Maximum Likelihood model using the count of flares as the dependent variable. Fifth, we employ a standard DiD analysis without stacking by commitment year cohort. Sixth,

[34] In (Internet Appendix) Sections IA5.1 and IA5.2, we estimate the main specification separately excluding each year of commitments and each host country, respectively. We do not find evidence that commitments in any one year or blocks in any one host country drive our results.

we assess the sensitivity of our estimates to a violation of the parallel trends assumption using M values of 0.5 and 1.0 (Rambachan & Roth, 2023). Seventh, we perform a geographic one-to-one matching, keeping only the single control block that is closest to each treated block to alleviate selection biases.

Our third set of tests varies standard error clustering. First, we estimate Conley (1999) standard errors to account for spatial correlation within a 100-kilometer radius and infinite serial correlation. Second, we cluster by block in case there is no correlation between blocks operated by the same firm. Third, we cluster by province to account for within-province dependence. Fourth, we cluster by country to account for within-country dependence. Across all three sets of sensitivity tests, we find a negative but not always statistically significant coefficient with magnitude inside the 95% confidence interval of the baseline.

In a separate robustness test, we examine the possibility that committers reduce reported flaring by substituting toward venting of unburned methane—an environmentally harmful strategy given methane's substantially higher global warming potential. In (Internet Appendix) Section IA5.5, we use satellite-based methane estimates available between 2019 and 2023 to compare within-country methane concentrations across committed and uncommitted blocks. Across multiple specifications, we find no systematic differences in methane levels, suggesting that committers do not offset flaring reductions by increasing venting. Taken together, the results in this subsection indicate that firms indeed follow through on commitments by reducing flaring in continuously operated blocks.[35,36]

4.3 Analysis for Awarded and Divested Blocks

Another way committers could reduce reported flaring volumes is by

[35] In (Internet Appendix) Section IA5.3, we estimate the main specification around commitments of non-operator owners. Consistent with companies only being responsible for operated blocks under ZRF, we do not find evidence for any significant change in flaring after non-operator owners commit.
[36] Tables for analyses in Section 4.2 can be found in (Internet Appendix) Section IA5.4.

shifting their real asset ownership, specifically reducing acquisitions of new oil blocks or divesting existing oil blocks. It is likely that the blocks rejected by committers would ultimately be awarded or divested to non-committers, which could result in an overall flaring increase. In this section, we study the frequency of awards and divestitures and subsequent changes in gas flaring.

4.3.1 Frequency of Awards and Divestitures

We first explore whether committers change their propensity to make new investments in African oil blocks after commitment. Committers seeking to reduce reported flaring could foreseeably bid on fewer block licenses or make lower bids to compensate for the cost of reducing flaring, making them less likely to win awards. We use a dyadic difference-in-differences design that compares the probability of each block being awarded to a committer versus a non-committer. We consider operators awarded a block in a country over our sample period as potential bidders, and we include one observation for each block-bidder pair (Rauter, 2020). To capture the dynamics of award likelihood (i.e., successful bids) over time, we plot yearly coefficient estimates from the following OLS regression:

$$\mathbb{1}(Award_{b,f}) = \beta_0 + \beta_1 ZRF_f \times Year\ Relative\ to\ Commit_{b,f} + \alpha_b + \gamma_{c,f} + \delta_{c,t} + \varepsilon_{b,f} \quad (3)$$

$\mathbb{1}(Award)$ is an indicator equal to one if firm *f* is awarded block *b* at the most recent award. *ZRF* is an indicator equal to one if firm *f* is committed. *Year Relative to Commit* is a set of indicators for each award year defined relative to the year of commitment. We omit the indicator for the year before commitment, which serves as the benchmark period. To control for differences in award propensity arising from any factors specific to each award, we include *Block* fixed effects. We also include *Country* × *Firm* and *Country* × *Year* fixed effects to control for host country-specific corporate strategies and time-varying local policies, respectively, that could be connected to bid amount or award propensity. We estimate standard errors clustered at the block level.

In Figure 8 Panel A, we graph the yearly *ZRF* × *Year Relative to Commit* coefficient estimates and their corresponding 95% confidence intervals. We observe that blocks are more likely to be awarded to committers in two pre-period years. Then, the percentage of committed awards declines in the year after commitment, reaching an approximately 15% lower award probability for committers relative to non-committers by three years after commitment. There is a recovery after three years, but the award probability for committers remains lower than that for non-committers. Taken together, this evidence is consistent with committers contracting their new investments in African oil blocks around ZRF commitments, but the change is not sharp around the commitment, similar to the changes in corporate investment to reduce flaring discussed in Section 2.3.

Another way committers can fulfill ZRF commitments is by divesting high-flaring blocks, allowing them to disclaim responsibility for continued flaring in those blocks. Poor local standards result in a wide discrepancy in environmental requirements, creating potential economic scope for the sale of assets from committers under home-country stakeholder pressure to non-committers subject to less scrutiny (Duchin et al., 2024). These sales could result in further increases in flaring and deterioration in the local and global environment if buyers are less able or willing to limit their environmental impact.

Thus, we explore the ownership flows of divested blocks between committers and non-committers. Numerous NGO reports (e.g., Malek et al., 2022), news articles (e.g., The New York Times and The Economist), and academic studies (e.g., Duchin et al., 2024) make the argument that unclean assets are flowing from companies committed to sustainability to those under less sustainability pressure. To assess the extent to which this is systematically occurring, we display ownership flows between committers and non-committers in Figure 8 Panel B.[37]

[37] We define a committer as only those *after* commitment. Thus, firms that are not yet committed at the time of the award or divestiture are considered non-committers.

Consistent with anecdotal evidence from the media, we observe 30 divested blocks, 11 of which are sold from committers to non-committers. Moreover, the flow from committed sellers (11) to uncommitted buyers is larger than the flow from uncommitted sellers to committed buyers (1) and committed sellers to committed buyers (4), indicating that committers are more likely to sell and less likely to buy blocks. However, relative to the total number of blocks continuously operated by committers (194), only 8% are divested and 6% are sold to non-committers. Thus, divestitures in our setting are not as prevalent as often emphasized and do not seem to be a common strategy companies use to fulfill their ZRF commitments in Africa.

4.3.2 Change in Gas Flaring Around Awards

We next examine flaring around awards. In the awards sample, we only include those blocks awarded during our sample period (i.e., after 2011). It is important to note that the awards in our sample do not necessarily mark the historical start of production for each block, as licenses could be renewed by the current holder or relinquished at the termination of a previous license period and re-awarded to another operator. In our data, we only observe the most recent award date, but multiple awards per block after 2012 is unlikely because licenses often last for a decade or more. In our sample, 7% of the awarded blocks are awarded to committers (after commitment) while the remaining 93% are awarded to non-committers (including committers before their commitment).

To provide evidence on changes in flaring around new block awards, we employ a stacked difference-in-differences design that separately assesses changes in flare volumes before and after new block awards to committers and non-committers. We separately compare these two treated groups with two distinct control groups—blocks continuously operated by committers and non-committers—resulting in four regression specifications across two panels. To clarify our empirical design, Figure 9 Panel A provides a 2x2 DiD matrix, where

the colors represent the choice of treatment group and the panels represent the choice of control group.

To capture the dynamics of flaring over time, we plot yearly coefficient estimates from the following OLS regression:

$$\text{asinh}(FlareVol_{b,t}) = \beta_0 + \beta_1 Award_b \times Year\ Relative\ to\ Award_{b,t} + \alpha_b + \delta_{c,t} + \varepsilon_{b,t} \quad (4)$$

asinh(*FlareVol*) is the inverse hyperbolic sine of the flaring volume within block *b* in year *t*. *Award* is an indicator equal to one if block *b* is awarded during the sample period. *Year Relative to Award* is a set of indicators for each year defined relative to the year of award. We omit the indicator for the year before award, which serves as the benchmark period. To control for differences in flaring activity arising from time-invariant (or slow-moving) factors specific to each block (e.g., geographic location or extraction capacity), we include *Block* fixed effects. We also include *Country* × *Year* fixed effects to control for time-varying local policies or other institutional factors correlated with each African host country. We estimate standard errors clustered at the block level.

In Figure 9 Panel B (Panel C), we graph the *Year Relative to Award* coefficient estimates and their corresponding 95% confidence intervals from estimating Eq. (4) separately for committed and uncommitted awards against a control group of blocks continuously operated by non-committers (committers). We observe that blocks awarded to non-committers (committers) exhibit almost identical flaring behavior to blocks continuously operated by non-committers (committers), which suggests that investments in flaring reduction are similar for newly awarded and continuously operated blocks.[38] At three years after the award, the difference between the committed award change (–33%) and the uncommitted award change (+7%) indicates a net difference in flaring of approximately 40%, representing the estimated damage resulting from each new asset acquisition

[38] In (Internet Appendix) Section IA5.6, we estimate the main specification separately excluding each host country. We do not find evidence that blocks in any one host country drive our results.

forfeited by ZRF committers. Relative to the pre-award mean for committed awards, this magnitude corresponds to a flaring increase of 30.5 million cubic meters per block-year.[39]

4.3.3 Change in Gas Flaring Around Divestitures

We now examine flaring around divestitures. In the divestiture sample, we only include those blocks that change ownership during our sample period (i.e., after 2011). Further, we remove divestitures that do not result in an operator change because commitments apply to operated blocks. If a block is divested multiple times, we take the first divestiture of a block during our sample period as the treatment date. In our sample, half of the divested blocks are sold by committers (after commitment) while the remaining half are sold by non-committers (including committers before their commitment).

To provide evidence on changes in flaring after divestitures, we employ a stacked difference-in-differences design that separately assesses changes in flare volumes before and after block divestitures from committers to non-committers and other divestitures. Similar to the award analysis, we separately compare these two treated groups with two distinct control groups—blocks continuously operated by committers and non-committers—resulting in four regression specifications across two panels. To clarify our empirical design, Figure 10 Panel A provides a 2x2 DiD matrix, where the colors represent the choice of treatment group and the panels represent the choice of control group.

To capture the dynamics of flaring over time, we plot yearly coefficient estimates from the following OLS regression:

$$\text{asinh}(FlareVol_{b,t}) = \beta_0 + \beta_1 \, Divest_b \times Year\ Relative\ to\ Sale_{b,t} + \alpha_b + \delta_{c,t} + \varepsilon_{b,t} \quad (5)$$

[39] To interpret the coefficient as a percentage change, we take $e^{-0.403} - 1 = -33\%$ for committed awards and $e^{0.071} - 1 = +7\%$ for uncommitted awards. Then, we multiply the difference by the pre-award mean for blocks awarded to committers ($81.10 \times 0.40 = 32.4$).

asinh(*FlareVol*) is the inverse hyperbolic sine of the flaring volume within block *b* in year *t*. *Divest* is an indicator equal to one if a block is divested. *Year Relative to Sale* is a set of indicators for each year defined relative to the year of divestiture. We omit the indicator for the year before divestiture, which serves as the benchmark period. To control for differences in flaring activity arising from time-invariant (or slow-moving) factors specific to each block (e.g., geographic location or extraction capacity), we include *Block* fixed effects. We also include *Country* × *Year* fixed effects to control for time-varying local policies or other institutional factors correlated with each African host country. Standard errors are clustered at the block level because divestitures occur by block.

In Figure 10 Panel B (Panel C), we graph the yearly *ZRF* × *Year Relative to Sale* coefficient estimates and their corresponding 95% confidence intervals from estimating Eq. (5) separately for committed-to-uncommitted and other divestitures against a control group of blocks continuously operated by non-committers (committers).[40] In Panel B, we observe a salient decline in flaring before committed-to-uncommitted divestitures, consistent with committers reducing flaring, but this immediately reverses after divestiture. When using a committer control group in Panel C, we instead see an uptick in the pre-period for other divestitures—consistent with the committer control group reducing flaring while most other divested blocks are previously owned by non-committers. Then, we observe a salient rise in flaring immediately after committed-to-uncommitted divestitures. Interestingly, the effect attenuates around the third year after divestiture, indicating that the differential may only be temporary.[41] At about three years after divestiture, the flaring volume reaches an approximately 153% higher

[40] In (Internet Appendix) Section IA5.8, we perform a placebo test for divestitures without operator changes. Consistent with ZRF applying only to operated blocks, we observe an insignificant and small change in flaring following these divestitures.

[41] In (Internet Appendix) Section IA5.7, we estimate the main specification separately excluding each host country. We do not find evidence that blocks in any one host country drive our results.

level for blocks divested from committers to non-committers, corresponding to approximately 26.2 million cubic meters per block-year.[42] With either control group, flaring does not seem to increase immediately after other divestitures, indicating that the increase in flaring is driven by ownership transfers to firms under less scrutiny rather than the act of divestiture itself.[43]

V. Country-Level Analysis of Net Aggregate Changes in Flaring

To answer the third part of our research question—assessing the overall environmental consequences of actions taken to fulfill the ZRF commitment—we aggregate our analysis to the country-level, allowing us to observe aggregate changes in flaring around commitments. On the one hand, the country-level analysis takes into account potential flaring spillovers from committers to non-committers, for example those arising from equilibrium effects in the natural gas market. Specifically, if committers are willing to accept an increasingly lower price for gas due to their zero routine flaring goal, this could lower the local market price for gas and reallocate gas sales from committers to non-committers. This may then increase flaring for non-committers for whom it is no longer economically feasible to capture the gas and, in the extreme scenario, result in minimal net reductions in flaring. On the other hand, the country-level analysis does not allow us to control for unobserved confounders using *Block* or *Country* × *Year* fixed effects and ignores the gradual change in flaring that we find in earlier sections.

To estimate country-wide flaring reductions, we aggregate flaring to the country-year level and use the fraction of blocks in each country that are owned by committers as the treatment variable. We fix ownership before the first divestiture

[42] To interpret the coefficient as a percentage change, we take $e^{0.927} - 1 = +153\%$. Then, we multiply this by the pre-divestiture mean for blocks divested from committers to non-committers ($17.13 \times 1.53 = 26.2$).
[43] Tables for analyses in Section 4.3 can be found in (Internet Appendix) Section IA5.9.

(i.e., in 2012) for each divested block to ensure we capture increased flaring from divested blocks. We control for oil production volumes at the country-year level and, alternatively, weight the regression by oil production volume and the count of blocks to capture the intensity of flaring per barrel or per block. Specifically, we plot yearly coefficient estimates from the following OLS regression:

$$\text{asinh}(FlareVol_{c,t}) = \beta_0 + \beta_1 \%Commit_{c,t} + \beta_2 \text{asinh}(OilProd_{c,t}) + \alpha_c + \delta_t + \varepsilon_{c,t} \quad (6)$$

asinh(*FlareVol*) is the inverse hyperbolic sine of the flaring volume within country *c* in year *t*. *%Commit* is the proportion of blocks operated by committers in country *c* in year *t* (based on prior ownership). asinh(*OilProd*) is the inverse hyperbolic sine of the oil production (in barrels) within country *c* in year *t*. To control for differences in flaring activity arising from time-invariant (or slow-moving) factors specific to each, we include *Country* fixed effects. We also include *Year* fixed effects to control for global trends in the oil market. Standard errors are clustered at the country level.

In Table 4, we show the coefficient estimates and their corresponding standard errors from estimating several different specifications of Eq. (6). Across all columns, we observe a large and statistically significant reduction in aggregate flaring. We present an unweighted specification in Column (1) and add a control for country-level crude oil production in Column (2). The magnitudes are nearly identical, making it unlikely that changes in production volumes drive the flaring changes we observe. In Columns (3) and (4), we then present specifications weighted by crude oil production and the count of blocks, respectively. We interpret the magnitude from Column (4), which is the most comparable to the block-level main analysis. Specifically, we multiply the final-year average of *%Commit* (0.281) with the transformed coefficient to get an average flaring reduction of 11.4%.[44]

[44] To interpret the coefficient as a percentage change, we take $1 - e^{-0.521} = 40.6\%$. Then, we multiply by 0.281 (the average fraction of committed blocks in the year 2023) to get the average reduction.

In (Internet Appendix) Section IA5.10, we perform an alternative calculation that aggregates the within-country flaring changes for continuously operated, awarded, and divested blocks in Africa, but this calculation ignores spillover effects. Comparing the country-level aggregate flaring reduction of 11.4% to the calculation ignoring spillovers that yields a 44.4% reduction.[45] This difference between these two estimates suggests that three-quarters of the reduction is driven by within-country spillovers to non-committers while the remaining portion is the overall decline in flaring in Africa, but it is important to note that this is a conservative estimate because it ignores the fact that flaring changes occur gradually over three years after commitment.[46] Our finding that there is an aggregate reduction in flaring is consistent with the evidence in Section 2.3 that committers invest in flaring reduction activities that do not result in spillovers to nearby non-committers (e.g., reinjection).

VI. Conclusion

Recognizing that many environmental consequences of corporate actions remain insufficiently addressed by government regulation, stakeholders have turned to private enforcement mechanisms to incentivize corporate responsibility. Corporations have responded with long-term environmental commitments, such as the World Bank's Zero Routine Flaring by 2030 Initiative. We provide evidence of changes in investments and flaring activity after corporate ZRF commitments. We find that reported flaring decreases for committers around the world after

[45] We calculate the 44.4% reduction as the continuously operated and divested flaring changes ($-115.76 \times 194 + 26.21 \times 11$) divided by the continuously operated and divested pre-treatment mean flaring volumes ($263.09 \times 194 + 17.13 \times 11$) from the aggregate calculation in (Internet Appendix) Section IA5.10. We exclude new awards because most are not operated at the baseline year (2012).
[46] If we also ignored the gradual effect in the alternative calculation in (Internet Appendix) Section IA5.10, we would arrive at an estimate of 35.7% rather than 44.4%, which would suggest that spillovers account for about two-thirds of the change.

commitment, and this change in flaring is particularly strong for African oil blocks, which are subject to weaker environmental standards.

Decomposing the change in Africa between continuously operated, awarded, and divested blocks indicates that committers are primarily making operational improvements to reduce flaring rather than disclaiming responsibility through forfeiting awards and divesting assets, inconsistent with concerns that stakeholder pressure results in a net aggravation of pollution by inducing corporations to divest dirty assets. Our aggregate calculations indicate a net reduction of 11%.

Overall, the evidence suggests that corporate actions to follow through on commitments can alleviate challenges associated with weak and heterogeneous environmental standards across jurisdictions, as most commitments are based on company-wide measures—such as total carbon emissions—that transcend individual jurisdictions. Because these measures aggregate activity across a company's global operations, harm done in any host country contributes equally to a company's consolidated metric. Then, stakeholders using company-level reporting to enforce commitments essentially impose uniform costs on global corporate conduct. This contrasts with government regulations such as carbon taxes or subsidies that are generally limited to specific countries and create cross-border cost differences that may result in regulatory leakage (e.g., Känzig et al., 2024).

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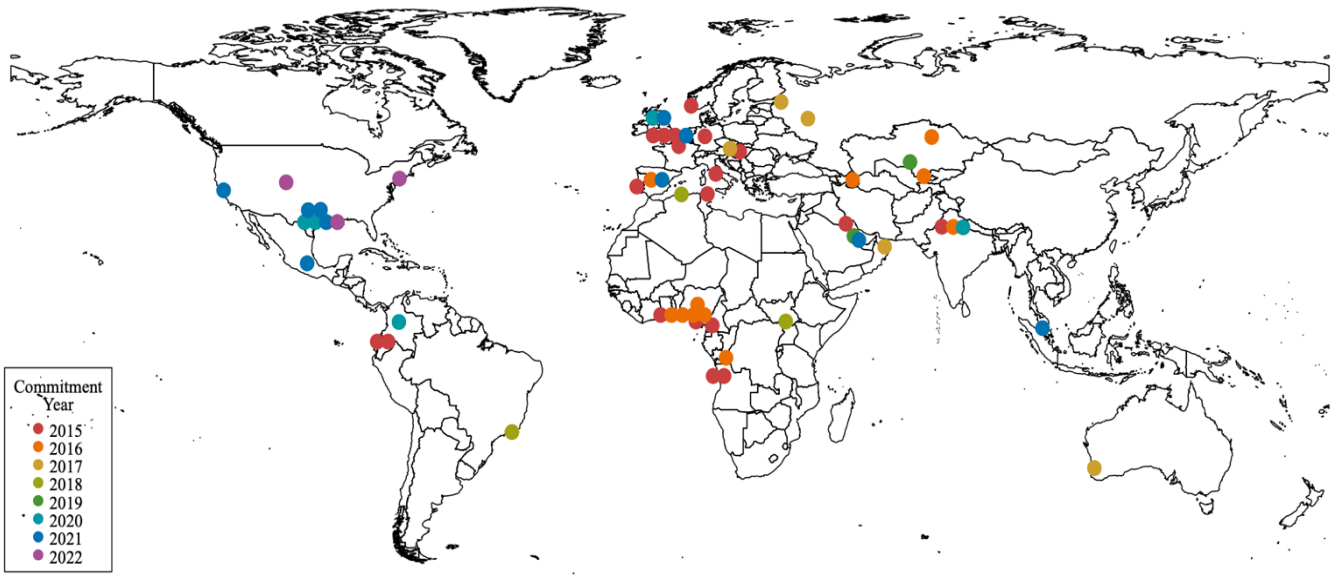
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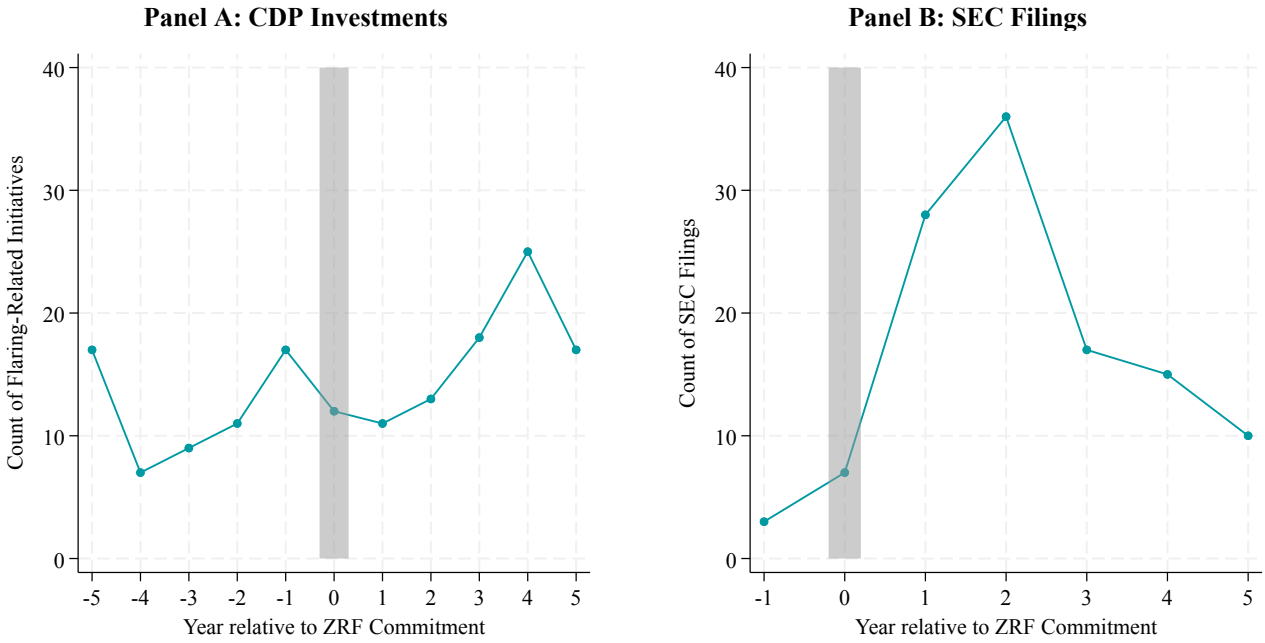
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Figure 1. Map of Committer HQs



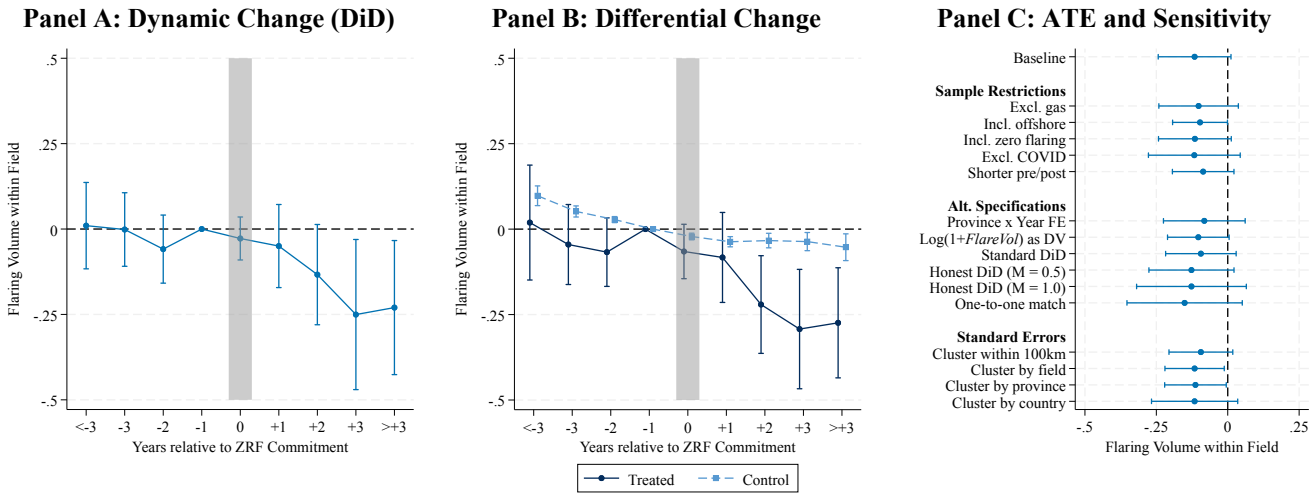
Notes: This figure shows the geographic distribution of committer headquarter locations by year of commitment. If one city contains several committer headquarters, the dots are spaced out slightly, showing earlier committers to the left.

Figure 2. Costly Actions to Reduce Flaring



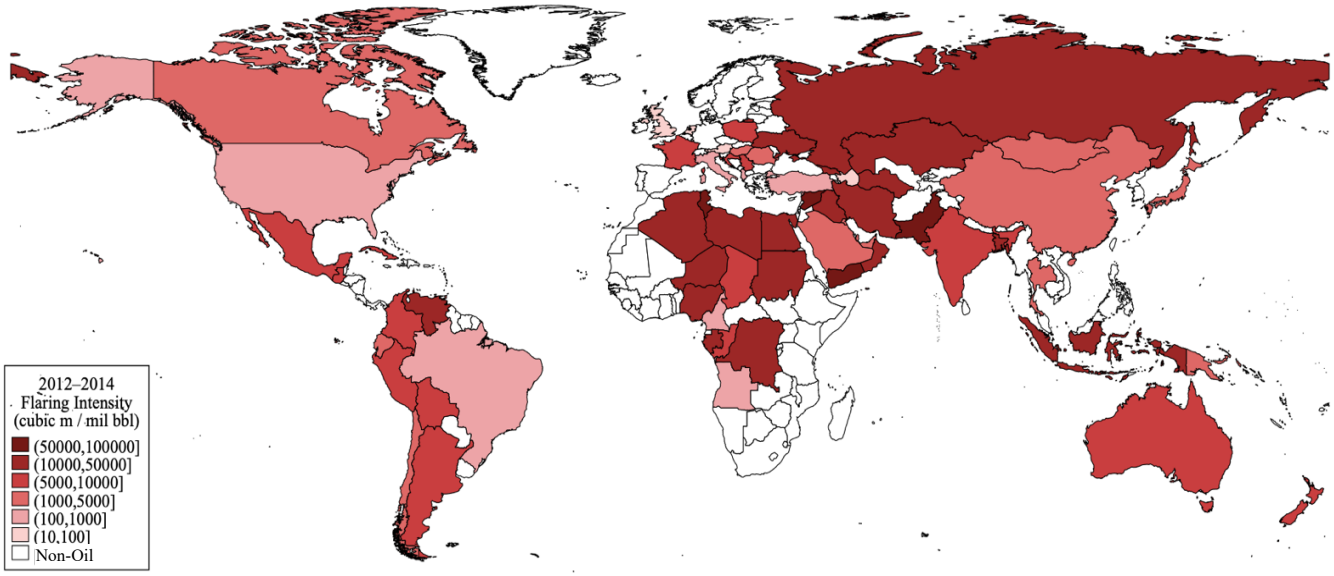
Notes: This figure shows the count of CDP investments and SEC filings that discuss ZRF over time. Panel A plots the count of internal corporate initiatives discussing "flaring" or "methane" reported by oil and gas firms to the Carbon Disclosure Project (CDP) relative to the time of ZRF commitment. Panel B plots the count of SEC filings of oil and gas firms that discuss "zero routine flaring" relative to the time of ZRF commitment. The year of ZRF commitment is shaded in gray.

Figure 3. ZRF Commitments and Reported Gas Flaring



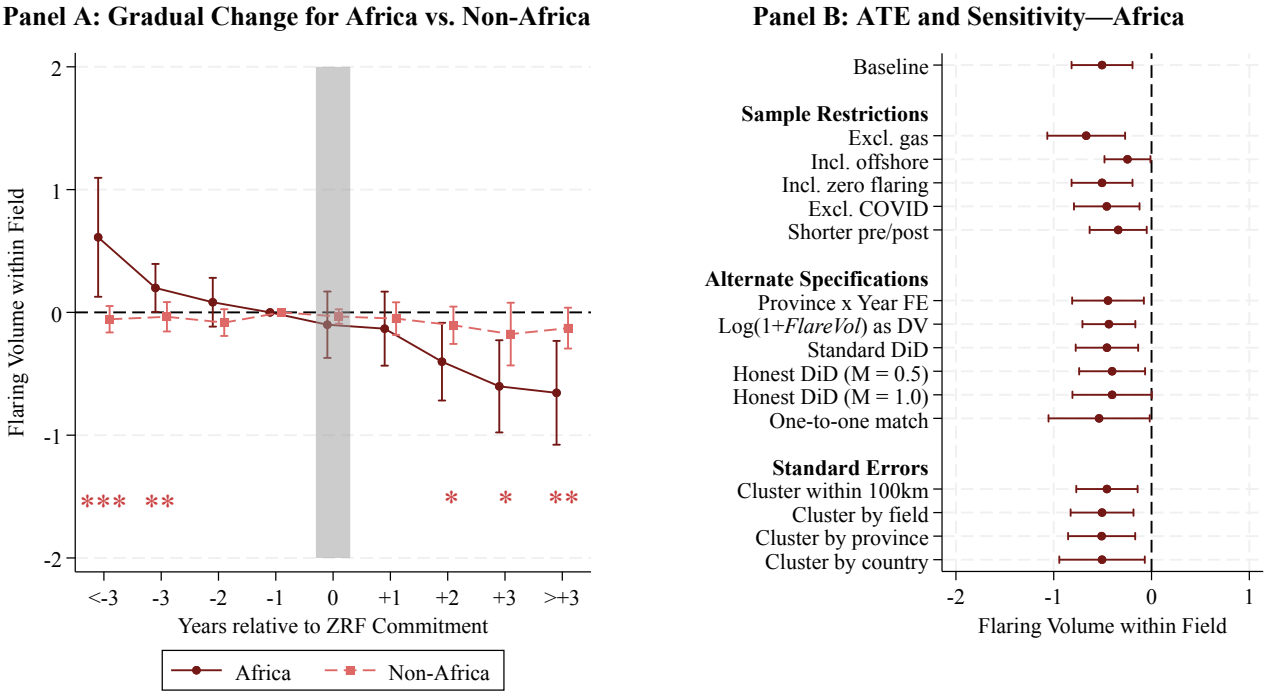
Notes: This figure shows coefficient estimates and 95% confidence intervals for OLS regressions estimating changes in natural gas flaring around corporate commitments across the whole world. Panel A estimates the model from Eq. (1), which compares flaring volumes in oil fields operated by committers and non-committers around the time of commitment. Panel B estimates the model from Eq. (2), which separately plots flaring volumes in oil fields operated by committers and (stacked) non-committers around the time of commitment. Panel C replaces the *Year Relative to Commit* indicators with a single *PostCommit* indicator to estimate the average change at the year of commitment and several alternative specifications. The sample selection is described in Section IA3.2 of the Internet Appendix, and singletons are further dropped corresponding to the fixed-effect structure if necessary. The baseline sample is a balanced panel of oil fields from 2012 to 2022. Standard errors are clustered at the operator level unless otherwise specified.

Figure 4. Average Flaring Intensity Around the World Before ZRF



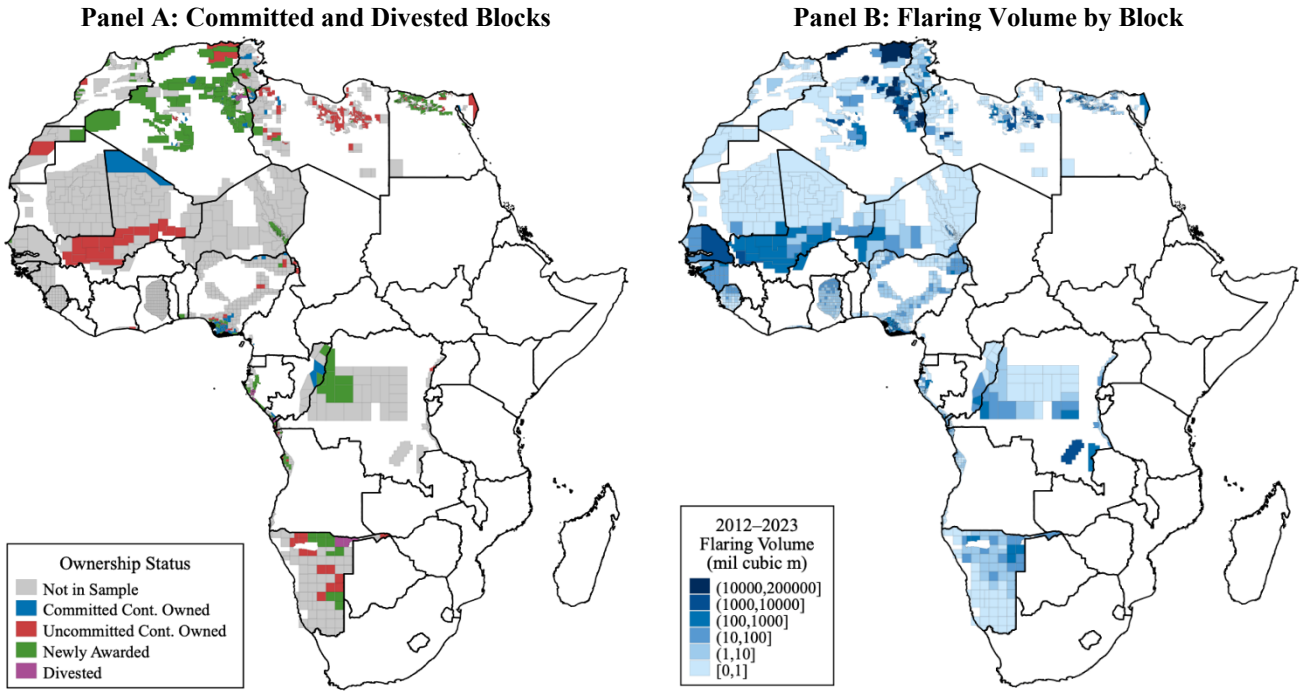
Notes: This figure shows total flaring volumes (in cubic meters) divided by total oil production (in millions of barrels) for oil-producing countries around the world between 2012 and 2014 (before ZRF commitments began). Country-level flaring volumes are collected from the World Bank *GFMR* dataset, and country-level oil production is collected from *Our World in Data* at https://ourworldindata.org/grapher/oil-production-by-country.

Figure 5. ZRF Commitments and Reported Gas Flaring by Region



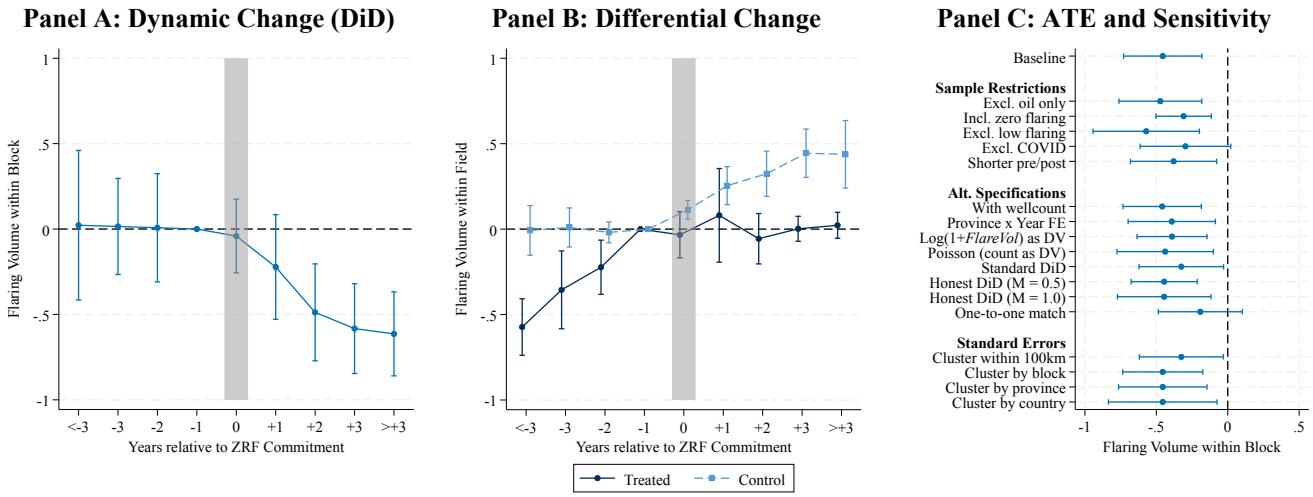
Notes: This figure shows coefficient estimates and 95% confidence intervals for OLS regressions estimating changes in natural gas flaring around corporate commitments. Panel A separately estimates the model from Eq. (1) for African and non-African oil fields. *, **, and *** indicate that the difference between the coefficient for Africa and non-Africa is statistically significant at the 10%, 5%, and 1% level, respectively, using a one-tailed two-sample Z-test. Panel B replaces the *Year Relative to Commit* indicators with a single *PostCommit* indicator to estimate the interaction effect for Africa, the average change at the year of commitment for African oil fields, and several alternative specifications. The sample selection is described in Section IA3.2 of the Internet Appendix, and singletons are further dropped corresponding to the fixed-effect structure if necessary. The baseline sample is a balanced panel of oil fields from 2012 to 2022. Standard errors are clustered at the operator level unless otherwise specified.

Figure 6. Blocks and Gas Flaring in Africa



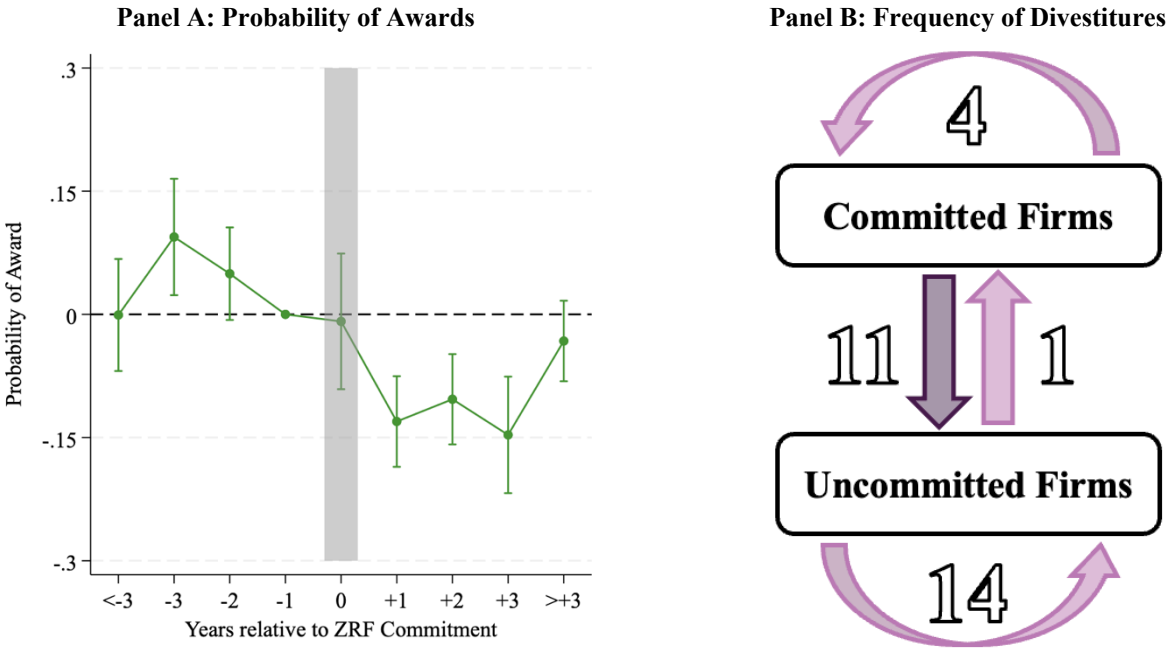
Notes: This figure shows the geographical distribution of oil-producing blocks and gas flaring in Africa. Panel A separates blocks by ownership status, classifying blocks as continuously operated by a committer, continuously operated by an non-committer, awarded, or divested during our sample period (2012–2023). Panel B is a heat map showing the total flaring volume (in million cubic meters) in each block across our sample period (2012–2023).

Figure 7. Gas Flaring for Continuous Operators



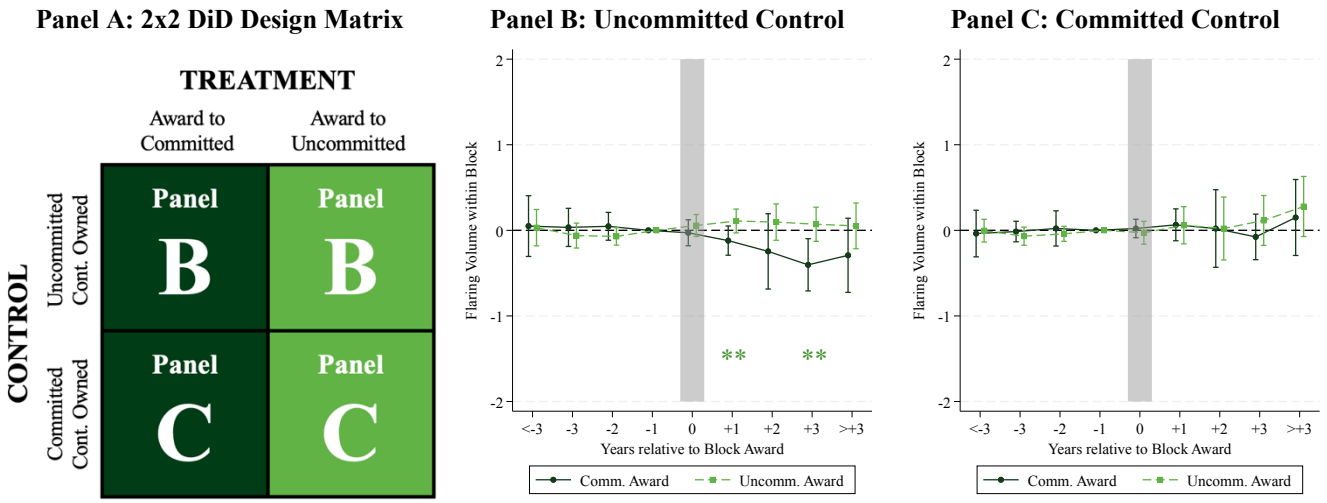
Notes: This figure shows coefficient estimates and 95% confidence intervals for OLS regressions estimating changes in natural gas flaring for continuously operated blocks in Africa around corporate commitments. Panel A estimates the model from Eq. (1), which compares flaring volumes in oil blocks continuously operated by committers and non-committers around the time of commitment. Panel B estimates the model from Eq. (2), which separately plots flaring volumes in oil blocks operated by committers and (stacked) non-committers around the time of commitment. Panel C replaces the *Year Relative to Commit* indicators with a single *PostCommit* indicator to estimate the average change at the year of commitment and several alternative specifications. The sample selection is described in Section IA3.4 of the Internet Appendix, and singletons are further dropped corresponding to the fixed-effect structure if necessary. The baseline sample is a balanced panel of oil blocks from 2012 to 2023. Standard errors are clustered at the operator level unless otherwise specified.

Figure 8. Commitments and Ownership Flows



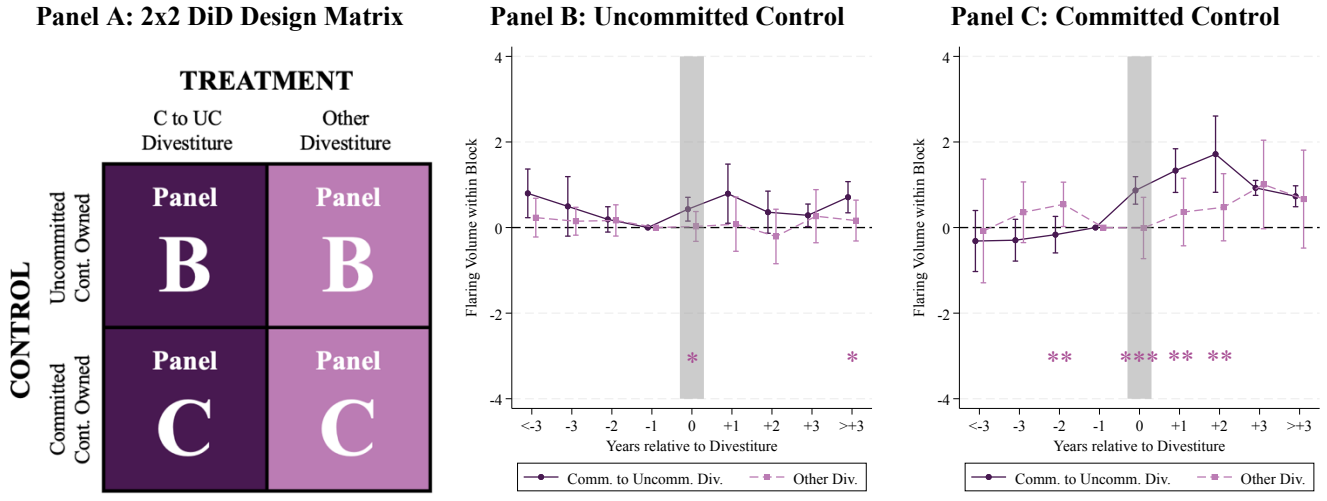
Notes: This figure shows coefficient estimates and 95% confidence intervals for OLS regressions estimating the probability of awards around corporate commitments and changes in natural gas flaring around awards in Africa. Panel A estimates the dyadic regression model from Eq. (3), which compares the probability that committed and uncommitted bidders within the same country win the award for each block around the time of commitment. Panel B provides a decomposition of the asset sales to and from committers and non-committers in our sample. The sample in Panel A is a dyadic panel of oil blocks awarded between 2012 and 2023. Standard errors are clustered at the block level.

Figure 9. Awards and Gas Flaring



Notes: This figure shows coefficient estimates and 95% confidence intervals for OLS regressions estimating changes in natural gas flaring around awards in Africa. Panel A shows a DiD design matrix to clearly specify the treatment and control groups in the estimated models. Panel B (C) estimates the model from Eq. (4), which separately compares flaring volumes in oil blocks awarded to committers and non-committers against a control group of blocks continuously operated by non-committers (committers). *, **, and *** indicate that the difference between the coefficient for committed and uncommitted awards is statistically significant at the 10%, 5%, and 1% level, respectively, using a one-tailed two-sample Z-test. The sample selection is described in Section IA3.4 of the Internet Appendix, and singletons are further dropped corresponding to the fixed-effect structure if necessary. The samples are balanced panels of oil blocks from 2012 to 2023. Standard errors are clustered at the block level.

Figure 10. Divestitures and Gas Flaring



Notes: This figure shows coefficient estimates and 95% confidence intervals for OLS regressions estimating changes in natural gas flaring around divestitures in Africa. Panel A shows a DiD design matrix to clearly specify the treatment and control groups in the estimated models. Panel B (C) estimates the model from Eq. (5), which separately compares flaring volumes in oil blocks divested from committers and non-committers and between other combinations of firms against a control group of blocks continuously operated by non-committers (committers). *, **, and *** indicate that the difference between the coefficient for committed-to-uncommitted and other divestitures is statistically significant at the 10%, 5%, and 1% level, respectively, using a one-tailed two-sample Z-test. The sample selection is described in Section IA3.4 of the Internet Appendix, and singletons are further dropped corresponding to the fixed-effect structure if necessary. The samples are balanced panels of oil blocks from 2012 to 2023. Standard errors are clustered at the block level.

Table 1. Determinants of ZRF Commitment

Panel A: Comparison of Firms by Stakeholder Pressure

Indicator	Committers (all)		Non-committers (in GFMR)	
	# Firms	% of total	# Firms	% of total
Firm Stakeholder Pressure				
Publicly Traded Firm	33	56.9%	148	12.4%
Firm Releases ESG Report	24	41.4%	87	7.3%
Firm Responded to CDP	15	25.9%	34	2.9%
Firm Has ESG Score (S&P Global)	26	44.8%	94	7.9%
State-Owned Firm	25	43.1%	181	15.2%
Other Commitments/Memberships				
OGCI	11	19.0%	5	0.4%
OGMP	25	43.1%	18	1.5%
IPIECA	21	36.2%	16	1.3%
IOGP	29	50.0%	32	2.7%
MGP	13	22.4%	3	0.3%
Net Zero Pledge	31	53.4%	83	7.0%
UNGC	18	31.0%	26	2.2%
Total # Firms	58		1190	

Panel B: Survival Model of Commitment Timing

Dep. Var.: *Time to Commitment*	Baseline	Lender PRB	Investor PRI
	(1)	(2)	(3)
US	0.976***	1.029***	2.313***
	(0.208)	(0.204)	(0.534)
US x *LeadLenderPRB*		-1.882***	
		(0.700)	
NonUS x *LeadLenderPRB*		0.495	
		(0.312)	
US x *BigInvestorPRI*			-1.788***
			(0.427)
NonUS x *BigInvestorPRI*			-0.625
			(0.394)
NumFields	0.002	0.000	0.018*
	(0.006)	(0.009)	(0.010)
Constant	0.820***	0.809***	1.187***
	(0.221)	(0.222)	(0.321)
Model	Lognormal	Lognormal	Lognormal
Observations (Company-Year)	144	112	84

Notes: This table presents a determinants model of ZRF commitments based on private stakeholder pressure. Panel A shows the number and percentage of committers and non-committers that show various indicators of private stakeholder pressure. Panel B presents a survival model of time to commitment for committers based on capital market pressures (i.e., debt and equity). We use *DealScan* to identify PRB-committed lenders and *CRSP Mutual Funds* to identify PRI-committed institutional owners. *US*, *Europe*, and *NonUSEurope* are indicators for the company's headquarters location. *LeadLenderPRB* is an indicator equal to one if any of the firm's lead debt arrangers are committed to the UN Principles for Responsible Banking (PRB). *BigInvestorPRI* is an indicator equal to one if any of the firm's large institutional owners (above $10 million in holdings) are committed to the UN Principles for Responsible Investment (PRI). The lognormal survival model is used in all specifications. Standard errors are clustered at the country level.

Table 2. Committed Firms and Fields by Commitment Year (World Bank Sample)

Commit Year	Companies in Sample		Reported Fields	
	# Firms	%	# Fields	%
	(1)	(2)	(3)	(4)
2015	16	35.56	214	21.55
2016	9	20.00	113	11.38
2017	3	6.67	253	25.48
2018	2	4.44	100	10.07
2019	2	4.44	44	4.43
2020	4	8.89	122	12.29
2021	7	15.56	89	8.96
2022	2	4.44	58	5.84
Total	45	100.00	993	100.00

Notes: This table separates committed companies and oil fields across the world by year and displays the temporal distribution of commitments for companies and fields. Columns (1) and (2) describe companies within our World Bank sample. Columns (3) and (4) describe oil fields within our World Bank sample.

Table 3. Committed Firms and Continuously Owned African Blocks by Commitment Year (*Enverus* Sample)

Commit Year	Companies in Sample		Cont. Operated Blocks	
	# Firms	%	# Blocks	%
	(1)	(2)	(3)	(4)
2015	9	52.94	47	24.23
2016	5	29.41	17	8.76
2017	1	5.88	4	2.06
2018	1	5.88	125	64.43
2019	0	0.00	0	0.00
2020	0	0.00	0	0.00
2021	1	5.88	1	5.15
2022	0	0.00	0	0.00
Total	17	100.00	194	100.00

Notes: This table separates committed companies and continuously operated oil blocks in Africa by year and displays the temporal distribution of commitments for companies and blocks. Columns (1) and (2) describe companies within our *Enverus* sample. Columns (3) and (4) describe continuously operated oil blocks within our *Enverus* sample.

Table 4. Country-Level Changes in Flaring

Dep. Var.: asinh(*FlareVol*)	Unweighted		Weighted	
			By Prod. Vol.	By Count
	(1)	(2)	(3)	(4)
%Commit	-0.661*	-0.671*	-0.487***	-0.521*
	(0.360)	(0.327)	(0.159)	(0.270)
asinh(*OilProd*)		0.563		
		(0.357)		
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
R-squared	0.986	0.987	0.976	0.983
Observations (Country-Year)	156	156	156	156

Notes: This table presents the computation of country-level changes in flaring for blocks where ownership is defined at the beginning of the sample (2012). *%Commit* is the percentage of blocks in a country that is operated by ZRF committers. asinh(*OilProd*) is the inverse hyperbolic sine of annual oil production (in millions of barrels). Columns (1) and (2) are unweighted regressions while Columns (3) and (4) are weighted by raw production volume and count of blocks, respectively. Standard errors are clustered at the country level.

Online Appendix to

Beyond Greenwashing: Environmental Commitments and Gas Flaring in the African Oil Sector

SAMUEL CHANG, HANS B. CHRISTENSEN, and ANDREW MCKINLEY

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Section IA1. Additional Institutional Details

IA1.1 Natural Gas Flaring

Natural gas flaring is one of the most problematic practices in the oil and gas extraction process, causing both local health consequences and global climate concerns (Motte et al., 2021).[1] Crude oil is both significantly more valuable and easier to transport than natural gas. However, crude oil reservoirs typically also contain large volumes of natural gas, and it is infeasible to extract one fuel while leaving the other in place. Thus, well operators must either capture and sell the natural gas or dispose of it. Historically, the most common ways to dispose of the gas were by flaring and/or venting. Capturing and transporting the gas requires specialized equipment and infrastructure, including a pipeline to transport it to a processing facility. However, this is not economically viable if the cost to collect and transport gas exceeds the profit from its sale.[2] Additionally, much of the gas must be exhausted early in the life of a well, precisely when infrastructure is unlikely to be available.

Given these constraints, operators typically chose to either vent the gas, directly releasing it into the atmosphere, or flare the gas, burning it as it is released. Venting is undesirable as it directly emits methane among other chemical compounds, which has 28 times the global warming potential of carbon dioxide (World Bank, 2024). However, venting is largely unobservable because methane is colorless, making monitoring challenging. Flaring, on the other hand, is easily observable, as burning natural gas near the well pad produces bright flames readily captured by satellite imaging. Flaring also contributes to climate damage, with estimates suggesting it is responsible for producing over 350 million tons of carbon dioxide equivalents annually (World Bank, 2024). However, unlike venting, environmental damage from flaring is not limited to greenhouse gas emissions. While pure natural gas is a clean burning fuel,[3] unprocessed natural gas contains numerous hydrocarbons in addition to methane. Burning these gases can release sulfur dioxide, nitrogen oxides, carbon monoxide, volatile organic compounds, black soot, and particulate matter which each have varying levels of human toxicity.

[1] See Figure IA1.1 for a graphical representation of the discussion in this section.
[2] This is a much more salient concern after the fracking boom, which caused global natural gas prices to plummet.
[3] Burning pure methane releases only carbon dioxide and water in the following chemical reaction:
$CH_4 + 2O_2 \Rightarrow CO_2 + 2H_2O$.

There is considerable evidence that these substances are detrimental to human health. For example, Moretti and Neidell (2011) find that volatile organic compounds and nitrogen oxides interact to form ozone, which entails significant health costs. There is also an extensive body of work documenting that nitrous oxide, carbon monoxide, and particulate emissions induce adverse health outcomes, including increased mortality, particularly among infants and the elderly (e.g., Cushing et al., 2021; Anderson, 2020; Knittel et al., 2016; Currie & Walker, 2011; Currie et al., 2009; Chay & Greenstone, 2005).

Blundell and Kokoza (2022) demonstrate a causal link between flaring and health outcomes. Using an instrumental variable strategy and plausibly exogenous variation in wind patterns, they find that a one percent increase in upwind flaring causes 0.73% more respiratory-related hospitalizations and is present up to 60 miles from the flaring site. In dollar terms, the health damages from flaring are roughly equivalent to its climate costs.

Of course, another issue with flaring is that it is wasteful because the associated gases are burnt without being utilized in a productive process or being reinjected back underground. For example, the World Bank estimates that enough gas is flared each year to power all of sub-Saharan Africa.[4] This waste was particularly salient during disruptions in natural gas markets following the invasion of Ukraine. Unsurprisingly, oil and gas companies face increasing pressure to reduce their flaring from governments and the private sector. There has been an increased push for companies to capture gas for utilization. North Dakota have recently set targets for gas capture by operators while New Mexico and Colorado banned routine flaring.[5] Internationally, flaring has largely been regulated by governments with relatively high state capacity, such as Norway and Colombia.

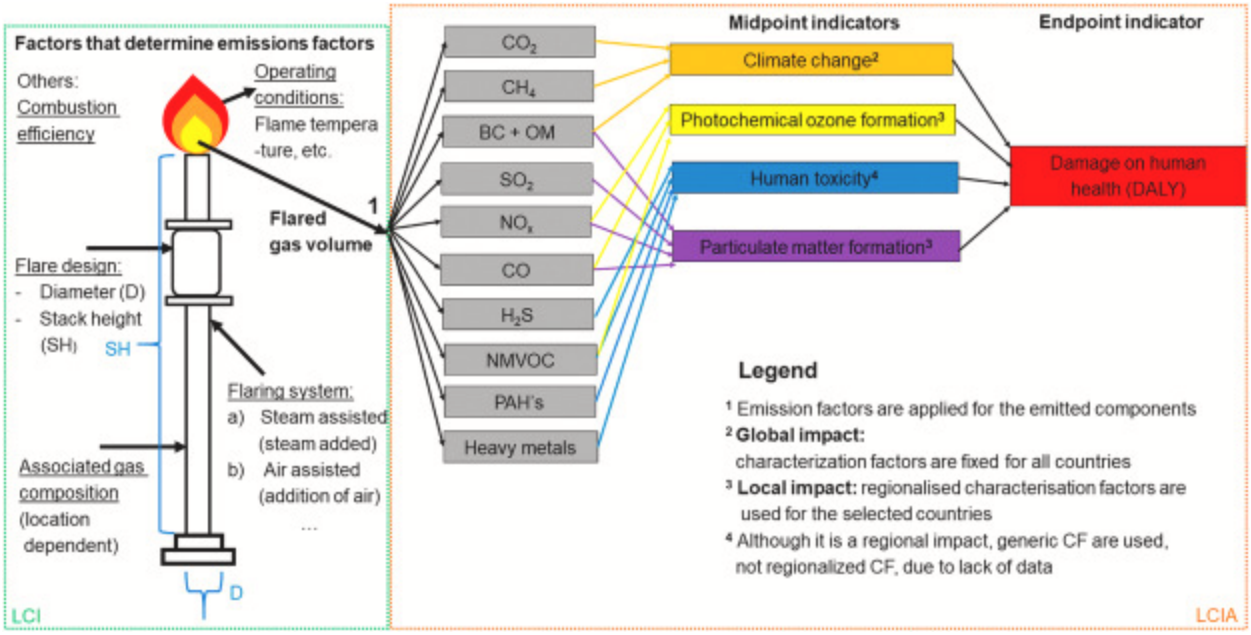
To achieve these policy goals, oil and gas operators have several options. The most straightforward is to capture the gas and feed it into a pipeline. However, this solution can be expensive and requires the pipeline infrastructure to be in place at the time of drilling, which may not be feasible. Recently, there has been an increase in smaller-scale solutions to reduce flaring. Green completions are one such possibility.[6] When drilling a well, there is a period of flowback of various liquids as well as gases. In a green completion, portable equipment is brought in via

[4] https://www.worldbank.org/en/programs/gasflaringreduction/gas-flaring-explained
[5] https://www.iea.org/policies/8888-north-dakota-industrial-commission-order-24665; https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/natural-gas/032621-new-mexico-regulator-puts-in-place-rule-requiring-operators-to-eliminate-gas-flaring; https://www.iea.org/policies/8859-colorado-senate-bill-19-181
[6] https://www.epa.gov/natural-gas-star-program/reduced-emission-well-completions-and-workovers

truck to separate the gas from the liquids and capture the gas. At this point, the gas can be further processed for sale. This approach can generate revenue from gas sales and reduce flaring but is only feasible at the time a well is drilled or worked over. Another option is the usage of spare natural gas to generate electricity near the drill site.[7] This electricity can then be used to power drilling equipment in the area. Overall, the estimated costs of eliminating routine flaring are estimated at around $100 billion, so providing economic opportunities to collect the associated gas remains a pressing climate and health challenge.

[7] https://www.wsj.com/business/energy-oil/oil-frackers-electric-power-grid-03f52767?mod=Searchresults_pos2&page=1

Figure IA1.1. Gas Flaring and Health Consequences



Notes: This figure, taken from Motte et al. (2021), provides a graphical representation of the determinants, substances released, and health consequences of gas flaring.

IA1.2 World Bank Zero Routine Flaring Initiative

Considering the extensive evidence that flaring causes both local and global environmental harm, the World Bank established the Zero Routine Flaring by 2030 (ZRF) Initiative as a potential solution. The ZRF commitment was launched in 2015 with both countries and oil companies as founding signatories and sits within the Global Flaring and Methane Reduction Partnership (GFMR). The GFMR is a trust fund created in collaboration with governments, oil companies, and nongovernmental organizations. The fund provides grant funding, technical assistance, policy advising, and institutional capacity building and seeks to increase access to fund infrastructure that would reduce flaring. Table IA1.2 provides details including the home country and year of commitment for each committed firm as of March 2024 (when we downloaded the GFMR dataset).

The responsibilities of ZRF endorsing members can vary by the type of institution. For example, endorsing countries and oil companies must comprehensively report their flaring activities so that stakeholders may assess their progress towards ending routine flaring while development institutions are not required to do so. Endorsing countries that do not self-report are monitored by the World Bank using satellite instruments, and their failure to self-report is disclosed on the ZRF's website. Countries also have additional responsibilities under the commitment to "provide a legal, regulatory, investment, and operating environment that is conducive to upstream investments and to the development of viable markets for utilization of the gas and the infrastructure necessary to deliver the gas to these markets."[8] These commitments ensure that the requisite infrastructure exists such that companies can feasibly meet their obligations.

Though ZRF is a voluntary commitment, signatories include all US and European oil majors and account for approximately 60% of global flaring activity (World Bank, 2024). Thus, the commitment plausibly mandates the disclosure of flaring activity for signatories, but is not legally binding and, thus, misreporting is not enforced through regulatory penalties.[9] Similar to

[8] See https://unece.org/fileadmin/DAM/energy/se/pdfs/comm_consult/Astana_2017/World_Bank_-_ZRF_Initiative_text_list_map.pdf for additional details.

[9] We asked the World Bank how they facilitated the verification of self-reports. Their answer was as follows: "Governments and oil companies that have endorsed the ZRF commit to annually reporting their flaring data and their progress in ending the practice. The ZRF Initiative is a voluntary and public commitment, not a legally binding document, but commitments are monitored, through both government and company reports and satellite-based estimates of gas flaring. The ZRF establishes a clear public commitment that, through the reporting hosted on the ZRF website, can be monitored by civil society through a variety of means, including by comparing the reporting to government and company reports and satellite observations, including those published by GFMR as part of our Global Gas Flaring Tracker Report."

mandatory CSR disclosures, the ZRF commitment acts primarily by providing accurate performance metrics to stakeholders, who are then better able to impose reputational costs on firms that do not show significant progress in reducing flaring. Even though flaring reductions are costly for firms to implement, they are socially desirable changes because of dire local and global externalities that are mitigated. However, as discussed before, most local African firms are not signatories to the ZRF, similar to firms outside the jurisdiction of CSR reporting mandates (Christensen et al., 2021). Thus, committed firms have the incentive to sell blocks in which flaring reductions are the most costly, reallocating flaring activity to less transparent, competent, and regulated firms. In our study, we attempt to quantify the net impact of operational improvements and divestitures on aggregate gas flaring to assess whether CSR initiatives such as the ZRF commitment are successful in reducing societal externalities.

Table IA1.2. Distribution of Committed Firms

Company Name	HQ Country	Sample Details		ZRF Commitment	
		# Fields	# Blocks	Commit Year	Self-Report?
Azule	Angola	0	0	2015	1
BP	United Kingdom	1	0	2015	1
Cairn	India	0	0	2020	1
Capricorn	United Kingdom	0	0	2020	1
CEPSA	Spain	7	1	2021	1
Chevron	United States	16	0	2021	0
Civitas	United States	0	0	2022	0
ConocoPhillips	United States	7	0	2020	1
Ecopetrol	Colombia	40	0	2020	1
Eni	Italy	44	13	2015	1
ETAP	Tunisia	1	4	2015	0
EOG Resources	United States	1	0	2021	1
Equinor	Norway	9	12	2015	1
ExxonMobil	United States	8	0	2022	0
Frontier	Nigeria	1	1	2016	1
Galp	Portugal	0	0	2015	1
Gazprom	Russia	5	0	2017	0
Harbour	United Kingdom	0	0	2021	1
Hess	United States	0	0	2022	1
KazMunayGaz	Kazakhstan	0	0	2016	1
KazPetrol Group	Kazakhstan	0	0	2019	0
KPC	Kuwait	0	0	2015	1
Lukoil	Russia	0	0	2017	1
MOL	Hungary	15	0	2015	1
Neptune	United Kingdom	4	0	2021	1
Niger Delta	Nigeria	1	0	2015	1
NNPC	Nigeria	0	9	2016	0
Nile	South Sudan	0	0	2018	0
Oando	Nigeria	0	1	2016	0
Oxy	United States	0	0	2020	1
OIL	India	0	0	2016	1
OMV	Austria	12	4	2017	1
ONGC	India	52	1	2015	0
Pan Ocean	Nigeria	1	0	2016	0
Petroamazonas	Ecuador	6	0	2015	1
Petroecuador	Ecuador	2	0	2015	1
Petrobras	Brazil	20	0	2018	1
PDO	Oman	0	0	2017	1
PETRONAS	Malaysia	2	0	2021	1
Pioneer	United States	0	0	2021	1
QatarEnergy	Qatar	1	0	2021	1
Range Resources	United States	0	0	2021	1
Repsol	Spain	5	0	2016	1

(continued)

Table IA1.2. Distribution of Committed Firms (continued)

Company Name	HQ Country	Sample Details		ZRF Commitment	
		# Fields	# Blocks	Commit Year	Self-Report?
Saudi Aramco	Saudi Arabia	41	0	2019	1
Seplat	Nigeria	5	4	2016	1
Savannah	United Kingdom	1	0	2015	0
Seven	Nigeria	0	3	2015	0
Shell	United Kingdom	44	10	2015	1
SOCAR	Azerbaijan	1	0	2016	0
SNH	Cameroon	1	1	2015	0
SNPC	Rep. Congo	2	2	2016	0
Sonangol	Angola	1	0	2015	1
Sonatrach	Algeria	80	125	2018	1
TotalEnergies	France	18	2	2015	1
Uzbekneftegaz	Uzbekistan	67	0	2016	0
Vista	Mexico	0	0	2021	1
Wintershall DEA	Germany	2	1	2015	1
Woodside	Australia	0	0	2017	1
Total		524	194		

Notes: This table presents details on each firm that was committed as of March 2024, when we downloaded the World Bank database. We include committed firms regardless of whether they are included in our sample, but we identify how many fields (World Bank sample) and blocks (*Enverus* sample) each firm operates. We also document the HQ country of each firm, the year of commitment, and whether or not each firm self-reports flaring data.

Section IA2. SEC Filings on Gas Flaring

To provide additional detail on the relevance of the World Bank's Zero Routine Flaring (ZRF) commitment to firms' business strategies, we study how firms discuss the ZRF commitment in their U.S. securities filings. To do so, we parse through all filings on the SEC's EDGAR web platform containing the phrase "zero routine flaring" between January 1, 2010, to December 31, 2024, which returns 307 results. After screening for duplicate filings, we are left with 274 filings that mention "zero routine flaring." For each filing, we record whether it refers to the World Bank's commitment, what investments firms report undertaking, if any, and whether the firm mentions company-wide initiatives that help prioritize flaring reductions. Table IA2.1 contains the results for committed SEC registrants in our sample. Note that many non-US firms in our sample also file disclosures (e.g., 20-Fs) with the SEC.

The first set of columns provides a count of the mentions of ZRF by company and filing type. It highlights the wide variety of filing types that firms use to disclose activities related to the commitment (e.g., sustainability reports, annual reports, and proxy statements), and that this disclosure is frequent. The next column provides examples of the types of investments that firms voluntarily disclose in their filings that mention ZRF—electrification and reinjection are the most common, but firms also report joint ventures with governments and other large capital investments to meet their flaring targets. The last column highlights some of the firm-wide initiatives mentioned in SEC filings that incentivize emissions reductions. While ESG compensation is the most widespread—including explicit flaring reduction targets—we do see evidence of firms utilizing an internal cost of carbon and considering region-specific costs. The use of regional costs of carbon alongside marginal abatement cost curves are consistent with our conjecture that firms reduce emissions by region and select the cheapest abatement options first. Finally, at least one firm reports that committing allowed them to reduce their cost of debt.

Table IA2.1. SEC Filings Related to Zero Routine Flaring (ZRF)

Firm Name	Forms					Flaring Reduction Investments	Firm-Wide Policies
	10-K	10-Q	20-F	8-K	Other		
BP	0	0	3	0	0		
Chevron	3	0	0	0	8	Flare detection	Marginal abatement cost curves
Civitas	0	0	0	0	3	Electrification	
ConocoPhillips	3	8	0	0	7	Enhanced vapor recovery; Recovery for sales	Regional GHG prices; ESG compensation; Marginal abatement cost curves
Ecopetrol	0	0	1	0	5		
Eni	0	0	2	0	3	Reinjection; Gas power plants; Infrastructure in Nigeria and Egypt	
EOG Resources	0	0	0	0	5		
Equinor	0	0	6	0	0	New fields require investments to have zero flaring	
ExxonMobil	2	6	0	9	13	Electrification	
Hess	1	0	0	1	6	Expanded infrastructure	Compensation tied to flaring
Oxy	3	0	0	0	6	Add storage; Add pipelines; Electrification	Lowered borrowing costs tied to GHG reductions
Petrobras	0	0	6	0	8	New platforms have anti-flaring technology	
Pioneer	0	0	0	0	1		ESG Compensation
Range Res.	0	0	0	0	0		
Shell	0	0	7	0	6	Reinjection; Gas gathering JVs with Iraq and Nigeria	
TotalEnergies	0	0	11	0	17	Reinjection; Electrification; Tech transfers	Firm-wide cost of carbon
Vista	0	0	0	0	0		
Woodside	0	0	0	0	3		

Notes: This table provides a summary of SEC filings discussing flaring reduction investments and firm-wide flaring reduction policies for ZRF-committed firms since their commitment year.

Section IA3. Sample Selection and Composition

IA3.1 Data Sources and Variables

In this section, we provide details on each dataset we use in our analyses, whether it is publicly available, where it can be found, and definitions of each variable derived from the dataset. While individual variable definitions can be found in the paper text and the table notes, Table IA3.1 can be referred to for a comprehensive overview of all data used in the study.

Table IA3.1. Data Sources and Variables

Dataset and Source	Variables
LSEG Dealscan Available through WRDS (used in Section 2.2)	*LeadLenderPRB*: an indicator for whether any of the firm's lead debt arrangers are committed to the UN Principles for Responsible Banking (PRB)
CRSP Mutual Funds (Quarterly) Available through WRDS (used in Section 2.2)	*BigInvestorPRI*: an indicator for whether any of the firm's large institutional owners (above $10 million in holdings) are committed to the UN Principles for Responsible Investment (PRI)
World Bank ZRF Website Publicly available at https://www.worldbank.org/en/programs/zero-routine-flaring-by-2030/endorsers (used in Sections 3, 4, and 5)	*ZRF*: indicator equal to one if a field is operated by a committed firm *Year Relative to Commit*: set of indicators for each year defined relative to the year of commitment *%Commit*: proportion of blocks operated by committed firms in one country in one year (based on prior ownership)
World Bank GFMR Publicly available at https://www.worldbank.org/en/programs/gasflaringreduction/global-flaring-data (used in Section 3)	*FlareVol*: flaring volume in millions of cubic meters within one field (or country) in one year
Enverus Oil and Gas (Africa) Available for purchase at: https://www.enverus.com/solutions/energy-analytics/ep/prism/global/ (used in Sections 4 and 5)	*Operator*: identity of operator used to link with ZRF commitments $\mathbb{1}$(*Award*): indicator equal to one if a company is awarded a block at the most recent award *Award:* indicator equal to one a block is awarded during the sample period *Year Relative to Award*: set of indicators for each year defined relative to the year of award *Divest*: indicator equal to one if a block is divested *Year Relative to Sale*: set of indicators for each year defined relative to the year of divestiture
VIIRS Nightfire Publicly available at: https://eogdata.mines.edu/products/vnf/ (used in Sections 4 and 5)	*FlareVol*: flaring volume in millions of cubic meters within one block in one year (imputed using the World Bank methodology for conversion detailed in Section IA5.9 and 5.10)
Sentinel-5P Methane Publicly available at: https://sentinels.copernicus.eu/data-products/-/asset_publisher/fp37fc19FN8F/content/tropomi-level-2-methane (used in Section IA5.5)	*Methane*: average methane concentration in parts per billion (ppb) within one block in one year
EIA International Publicly available at: https://www.eia.gov/international/data/world/petroleum-and-other-liquids/annual-petroleum-and-other-liquids-production (used in Section 5)	*OilProd*: oil production (in barrels) within one country in one year

Notes: This table provides a comprehensive overview of each dataset we use in our analyses, whether it is publicly available, where it can be found, and definitions of each variable derived from the dataset.

IA3.2 Sample Selection for World Bank Analysis

This section provides additional details on sample selection for the global World Bank sample, which specifies empirical choices made in forming the final sample for analysis. Table IA3.2 delineates the overall sample selection process for each portion of data cleaning. This can be referred to in the replication process.

Table IA3.2. Sample Selection Criteria for World Bank Analysis

Selection Criterion		Observation Count
World Bank *GFMR* Dataset (field-year panel) – downloaded March 29, 2024		136,291
Less:	Offshore fields	(10,878)
Less:	Missing operator name	(17,934)
Collapse:	Duplicate fields	(65,003)
Less:	Fields with multiple operators	(14,045)
More:	Expand to balance panel	26,756
Less:	Never-flaring fields	(638)
Total sample of field-years		54,549

Notes: This table describes the sample selection process for our World Bank analyses. The observation counts in the analyses do not match the numbers in this table because we further drop singleton observations for various fixed effect structures.

IA3.3 Descriptive Statistics for World Bank Analysis

This section provides a detailed sample description for the World Bank sample used in Section 3 of the paper. As mentioned throughout the paper, Table IA3.3a presents the distribution of each variable used in the analyses. In addition, Table IA3.3b tabulates the distribution of fields across countries and years of commitment.

Table IA3.3a. Descriptive Statistics for World Bank Analysis

	N	Mean	SD	P1	P25	Median	P75	P99
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ZRF	54549	0.200		0	0	0	0	1
ZRF x *PostCommit*	54549	0.097		0	0	0	0	1
FlareVol	54549	17.631	90.459	0	0	0	4.731	313.372

Notes: This table provides detailed descriptive statistics for the World Bank sample at the field-year level. Variables are defined in the paper.

Table IA3.3b. Distribution of Fields (World Bank Sample)

Country	Committed (by Year of Commitment)								Uncommitted	Total
	2015	2016	2017	2018	2019	2020	2021	2022		
Albania	0	0	0	0	0	0	0	0	1	1
Algeria	23	0	1	79	0	0	6	0	17	126
Angola	0	0	0	0	0	0	1	0	7	8
Argentina	15	0	0	0	0	0	14	5	141	175
Australia	4	0	0	0	0	0	1	0	77	82
Austria	0	0	1	0	0	0	0	0	0	1
Azerbaijan	0	1	0	0	0	0	0	0	2	3
Bahrain	0	0	0	0	0	0	0	0	2	2
Bangladesh	0	0	0	0	0	0	2	0	4	6
Belize	0	0	0	0	0	0	0	0	1	1
Bolivia	2	3	0	3	0	1	0	0	16	25
Brazil	0	0	0	17	0	0	0	0	17	34
Brunei	2	0	0	0	0	0	0	0	0	2
Cameroon	1	0	0	0	0	0	0	0	0	1
Canada	7	1	0	0	0	1	3	4	356	372
Chad	0	0	0	0	0	0	0	0	6	6
Chile	0	0	0	0	0	0	0	0	6	6
China	0	0	0	0	0	0	0	0	183	183
Colombia	2	0	0	0	0	42	3	0	57	104
Congo	2	2	0	0	0	0	0	0	2	6
Croatia	0	0	0	0	0	0	0	0	14	14
Cuba	0	0	0	0	0	0	0	0	6	6
DRC	0	0	0	0	0	0	0	0	5	5
Ecuador	6	0	0	0	0	0	0	0	24	30
Egypt	2	0	0	0	0	0	0	0	187	189
Ethiopia	0	0	0	0	0	0	0	0	1	1
France	0	0	0	0	0	0	0	0	5	5
Gabon	1	0	0	0	0	0	0	0	28	29
Georgia	0	0	0	0	0	0	0	0	3	3
Germany	0	0	0	0	0	0	2	0	1	3
Guatemala	0	0	0	0	0	0	0	0	2	2
Hungary	9	0	0	0	0	0	0	0	7	16
India	50	23	0	0	0	8	0	0	7	88
Indonesia	0	0	0	0	0	4	1	1	159	165
Iran	0	0	0	0	0	0	0	0	79	79
Iraq	2	1	4	0	0	0	1	1	58	67
Italy	1	0	0	0	0	0	0	0	2	3
Japan	0	0	0	0	0	0	0	0	1	1
Kazakhstan	2	9	0	0	3	0	0	0	80	94
Kuwait	10	0	0	0	0	0	0	0	3	13
Libya	1	0	1	1	0	0	0	0	75	78
Mexico	1	0	1	0	0	0	0	0	115	117
Mongolia	0	0	0	0	0	0	0	0	1	1
Mozambique	0	0	0	0	0	0	0	0	3	3
Netherlands	0	0	0	0	0	0	0	0	1	1
New Zealand	0	0	0	0	0	0	0	0	12	12
Niger	0	0	0	0	0	0	0	0	2	2
Nigeria	44	7	0	0	0	0	6	0	50	107
Oman	1	0	0	0	0	20	0	0	93	114

(continued)

Table IA3.3b. Distribution of Fields (World Bank Sample, continued)

Country	Committed (by Year of Commitment)								Uncommitted	Total
	2015	2016	2017	2018	2019	2020	2021	2022		
Pakistan	8	0	0	0	0	0	0	0	91	99
Papua New Guinea	0	0	0	0	0	0	0	1	3	4
Peru	0	1	0	0	0	0	0	0	17	18
Poland	0	0	0	0	0	0	0	0	12	12
Qatar	0	0	0	0	0	0	3	0	0	3
Romania	0	0	9	0	0	0	0	0	6	15
Russia	0	0	216	0	0	0	0	0	718	934
Saudi Arabia	4	0	0	0	41	0	3	0	0	48
Serbia	0	0	0	0	0	0	0	0	4	4
Sudan	0	0	0	0	0	0	0	0	8	8
Syria	0	0	0	0	0	0	0	0	58	58
Thailand	0	0	0	0	0	0	0	0	19	19
Trinidad and Tobago	1	0	0	0	0	0	0	0	2	3
Tunisia	8	0	8	0	0	0	0	0	15	31
Turkey	0	0	0	0	0	0	0	0	3	3
Turkmenistan	1	1	0	0	0	0	0	0	56	58
Ukraine	0	0	0	0	0	0	0	0	79	79
UAE	1	0	0	0	0	0	0	0	15	16
United Kingdom	0	0	0	0	0	0	0	0	2	2
United States	3	0	0	0	0	46	43	46	813	951
Uzbekistan	0	64	11	0	0	0	0	0	14	89
Venezuela	0	0	0	0	0	0	0	0	88	88
West Bank and Gaza	0	0	0	0	0	0	0	0	1	1
Yemen	0	0	1	0	0	0	0	0	23	24
Total	214	113	253	100	44	122	89	58	3,966	4,959

Notes: This table presents the distribution of global fields by country and commitment year in the World Bank sample. Sample selection is detailed in Section IA3.2.

IA3.4 Sample Selection for Africa Analysis

This section provides additional details on sample selection for the Africa *Enverus* sample, which specifies empirical choices made in forming the final sample for analysis. Table IA3.4 delineates the overall sample selection process for each portion of data cleaning. This can be referred to in the replication process.

Table IA3.4. Sample Selection Criteria for Africa Analysis

Panel A: Total Block-Level Sample

Selection Criterion		Unique Block Count
Enverus Oil Blocks Dataset		3,907
Less:	Offshore blocks	(1,615)
Less:	Non-operated blocks	(749)
Less:	Non-flaring blocks	(594)
Total sample of blocks throughout all analyses		949

Panel B: Individual Sample Decomposition

Blocks with Ownership Changes	Unique Block Count
New Awards (only)	416
Both Awarded and Divested	15
Divestitures (only)	15
Blocks without Ownership Changes	
Continuously Operated by Committed	194
Continuously Operated by Uncommitted	309
Total Sample	949

Notes: This table describes the sample selection process for our commitment and divestiture analyses. The observation counts in the analyses do not match the numbers in this table because we form a panel over 12 years and further drop singleton observations for various fixed effect structures. Panel A describes the selection for our total sample of blocks. Panel B decomposes the sample into the individual groups used in each analysis.

IA3.5 Descriptive Statistics for Africa Analysis

This section provides detailed descriptive statistics for the sample of African blocks used in Sections 4 and 5 of the paper. As mentioned throughout the paper, Table IA3.5a presents the distribution of each variable used in the analyses. In addition, Table IA3.5b tabulates the distribution of continuously operated blocks across countries and years of commitment.

Table IA3.5a. Descriptive Statistics for Africa Analysis

Panel A: Continuous Ownership Sample

	N	Mean	SD	P1	P25	Median	P75	P99
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ZRF	6036	0.386		0	0	0	1	1
ZRF x *PostCommit*	6036	0.222		0	0	0	0	1
FlareVol	6036	150.434	750.514	0	0	0.108	29.240	2389.521

Panel B: New Awards Sample (Committed Control)

	N	Mean	SD	P1	P25	Median	P75	P99
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Award	7500	0.690		0	0	1	1	1
Award x *PostAward*	7500	0.306		0	0	0	1	1
FlareVol	7500	151.233	958.118	0	0	0	8.168	2393.588

Panel C: Divestitures Sample (Committed Control)

	N	Mean	SD	P1	P25	Median	P75	P99
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Divest	2688	0.134		0	0	0	0	1
Divest x *PostSale*	2688	0.057		0	0	0	0	1
FlareVol	2688	228.510	1015.696	0	0	0.415	97.945	3026.303

Notes: This table provides detailed descriptive statistics for the Africa sample at the block-year level. Variables are defined in the paper.

Table IA3.5b. Distribution of Continuously Operated Blocks (*Enverus* Sample)

	Committed (by Year of Commitment)					Uncommitted	Total
Country	2015	2016	2017	2018	2021		
Algeria	14	0	0	122	1	41	178
Angola	0	0	0	0	0	11	11
Cameroon	1	0	0	0	0	3	4
Congo	2	2	0	0	0	0	4
Côte d'Ivoire	0	0	0	0	0	2	2
DRC	0	0	0	0	0	6	6
Egypt	2	0	0	0	0	82	84
Gabon	1	0	0	0	0	11	12
Ghana	0	0	0	0	0	1	1
Libya	3	0	1	2	0	81	87
Mali	0	0	0	1	0	13	14
Morocco	0	0	0	0	0	3	3
Namibia	0	0	0	0	0	14	14
Nigeria	17	15	0	0	0	29	61
Senegal	0	0	0	0	0	1	1
Tunisia	7	0	3	0	0	11	21
Total	47	17	4	125	1	309	503

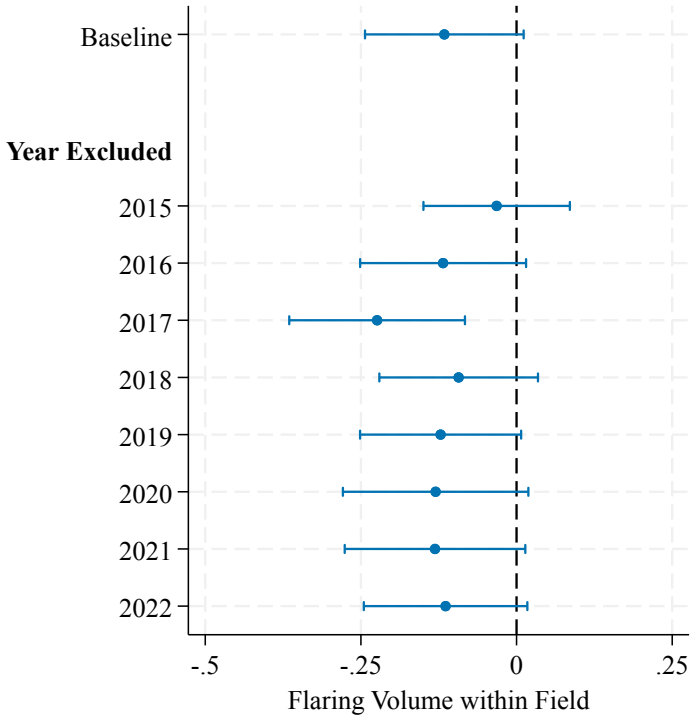
Notes: This table presents the distribution of continuously operated African blocks by country and commitment year in the *Enverus* sample. Sample selection is detailed in Section IA3.4.

Section IA4. Supplementary Tests for World Bank Analysis

IA4.1 Jackknife Excluding Commitment Years

In Figure IA4.1 below, we present results dropping each commitment year from the World Bank sample in turn. We start with the baseline specification in Figure 3 Panel C, from which we drew our main inferences. The results are weaker after removing firms committing in 2015, consistent with early committers being mostly European firms under heavier political and stakeholder pressure. Moreover, the results seem to be stronger after removing firms committing in 2017, as these are mostly Russian firms (i.e., Lukoil and Gazprom) under less pressure. Removing both of these groups (untabulated) yields a coefficient similar to the baseline. Otherwise, the remaining specifications yield results of similar magnitude to the baseline.

Figure IA4.1. Jackknife Excluding Commitment Years

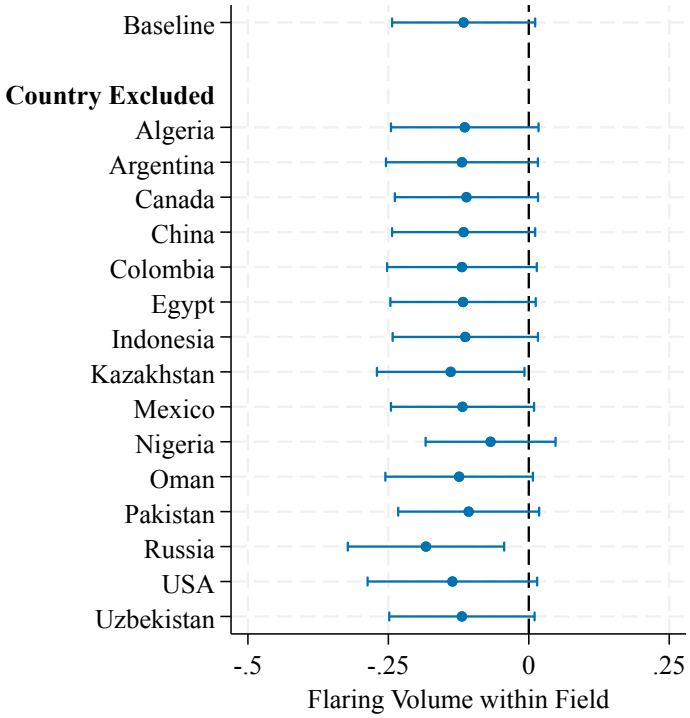


Notes: This figure shows coefficient estimates and 95% confidence intervals for OLS regressions estimating annual changes in natural gas flaring around corporate commitments. We estimate the model from Figure 3 Panel C in the paper as the baseline but separately exclude operators committing in each year.

IA4.2 Jackknife Excluding Host Countries Around the World

In Figure IA4.2 below, we present results dropping blocks in the most frequent host countries from the World Bank sample in turn. We use the specification in Figure 3 Panel C, from which we drew our main inferences. Similar to what we find in Section IA4.1, removing Russian blocks from the sample significantly increases the magnitude of the estimate, consistent with Russian firms (operating in Russia) being under less pressure. Also consistent with our findings in Section 3.3 of the paper that lower environmental standards are associated with larger flaring reductions, removing Nigerian blocks from the sample significantly decreases the magnitude of the estimate because Nigeria has relatively low *ex ante* environmental standards. Otherwise, the remaining specifications yield results of similar magnitude to the baseline.

Figure IA4.2. Jackknife Excluding Countries



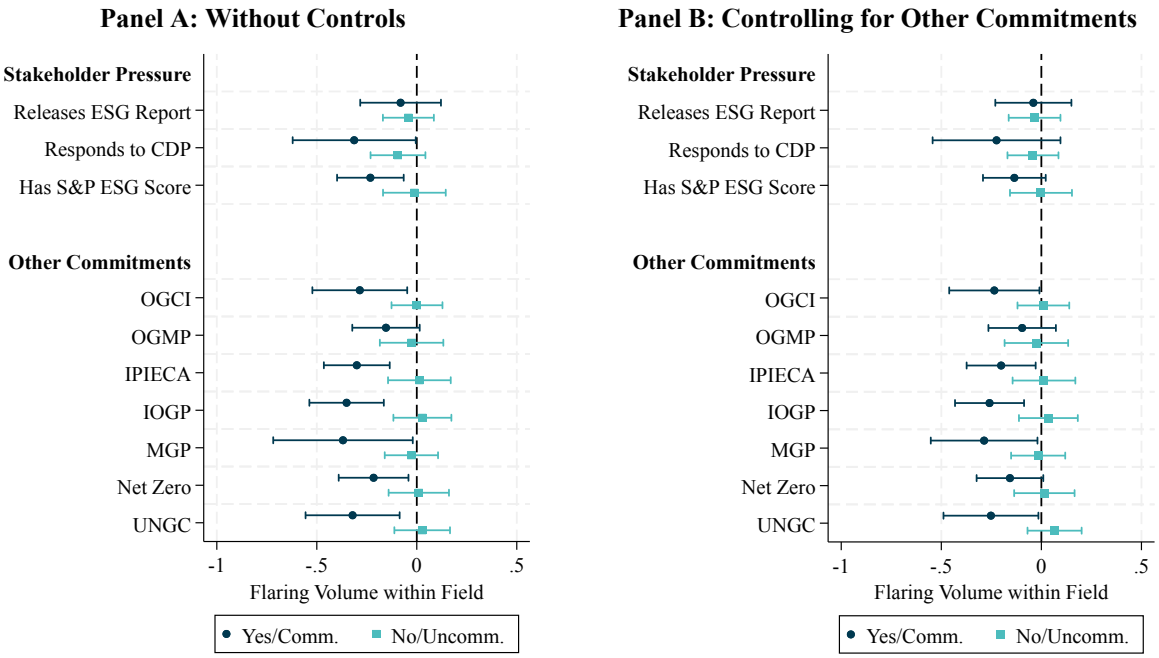
Notes: This figure shows coefficient estimates and 95% confidence intervals for OLS regressions estimating annual changes in natural gas flaring around corporate commitments. We estimate the model from Figure 3 Panel C in the paper as the baseline but separately exclude blocks in each host country.

IA4.3 Splits on Stakeholder Pressure and Other Commitments

In Figure IA4.3 below, we present results interacting with firm-level proxies for stakeholder pressure and other firm-level climate commitments. ZRF-committed firms tend to be under heavier stakeholder pressure as proxied by releasing ESG reports, responding to CDP, and possessing an S&P Global ESG score. Moreover, 44 out of 58 committed firms are also committed to or members of other environmental initiatives including the Oil and Gas Climate Initiative (OGCI), Oil and Gas Methane Partnership (OGMP), International Petroleum Industry Environmental Conservation Association (IPIECA), International Association of Oil and Gas Producers (IOGP), Methane Guiding Principles (MGP), Net Zero Pledges, and United Nations Global Compact (UNGC). We are unable to split the sample as in prior tests because few uncommitted firms have high stakeholder pressure or other commitments. We use the specification in Figure 3 Panel C and add interaction terms for both firms with and without the specified criteria. For completeness, we also include each criteria interacted with year fixed effects.

In Panel A, we only see a decline in flaring after ZRF for firms under higher stakeholder pressure and those committed to other firm-level commitments, suggesting that stakeholder pressure plays a major role in firms' decisions on whether to follow through on their ZRF commitments. However, after controlling for time-varying post-commitment indicators for OGCI, OGMP, MGP, Net Zero, and UNGC in Panel B, we do not observe much variation in the coefficient magnitudes, indicating that firms committed to other environmental initiatives still show an incremental decrease in flaring after committing to ZRF.

Figure IA4.3. Commitments and Reported Gas Flaring by Stakeholder Pressure

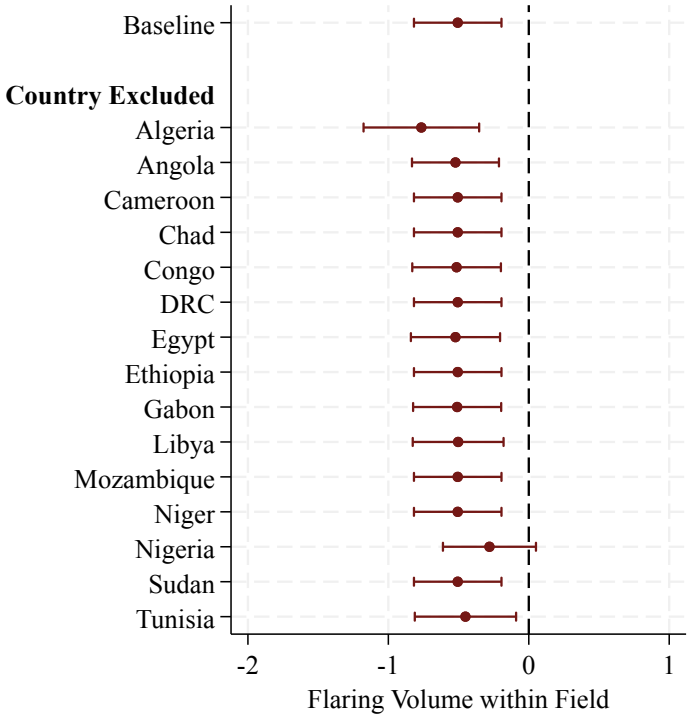


Notes: This figure shows coefficient estimates and 95% confidence intervals for OLS regressions estimating annual changes in natural gas flaring around corporate commitments. We estimate the model from Figure 3 Panel C in the paper but add interaction terms for proxies of stakeholder pressure and other climate-related commitments. Panel A presents specifications without controls. Panel B controls for time-varying post-commitment indicators for OGCI, OGMP, MGP, Net Zero, and UNGC. We are unable to obtain data on year of joining for IPIECA and IOGP.

IA4.4 Jackknife Excluding Host Countries in Africa

In Figure IA4.4 below, we present results dropping blocks in each host country in Africa from the World Bank Africa-only sample in turn. We use the specification in Figure 5 Panel B, from which we drew our main inferences. Our results remain similar in magnitude and statistically significant across most rows, which indicates that the treatment effect is not driven by commitment in any given country. The two exceptions are Algerian blocks, which seem to see a much smaller change after commitments, and Nigerian blocks, which seem to see a much larger change. This is likely because most Algerian blocks are operated by state-owned Sonatrach, which is already under strict government regulation, while most Nigerian blocks are operated by Western-owned big oil companies, which are subject to stronger home-country stakeholder pressure. Moreover, this is consistent with our hypothesis because Algeria has higher *ex ante* environmental standards than Nigeria, so Algerian blocks should show a smaller change than Nigerian blocks.

Figure IA4.4. Jackknife Excluding Countries (Africa)



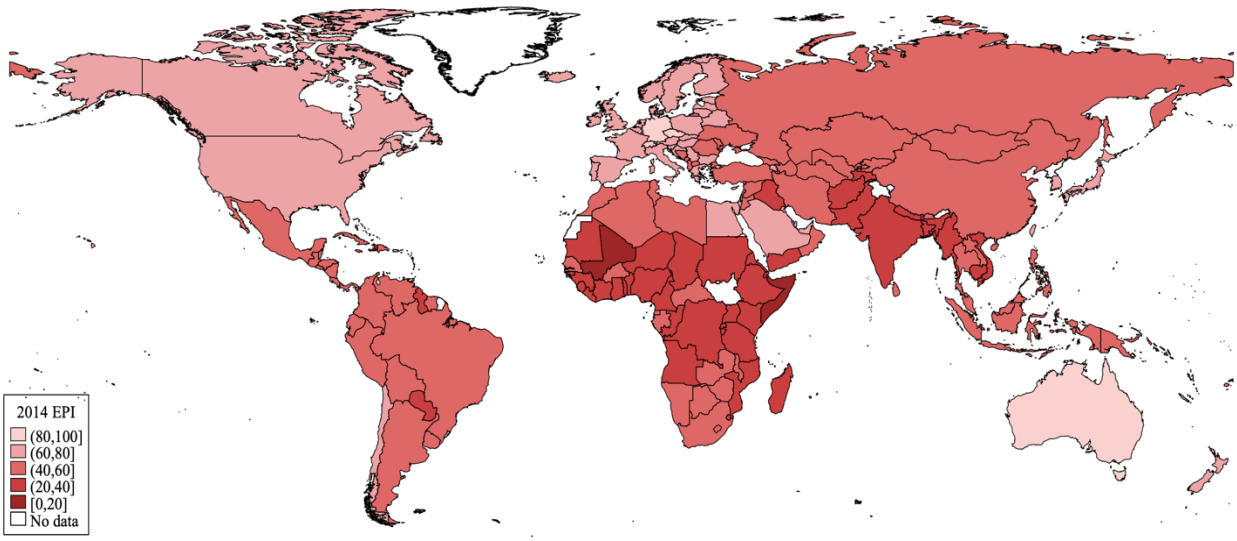
Notes: This figure shows coefficient estimates and 95% confidence intervals for OLS regressions estimating annual changes in natural gas flaring around corporate commitments. We estimate the model from Figure 5 Panel B in the paper as the baseline but separately exclude blocks in each host country.

IA4.5 Split on Environmental Performance

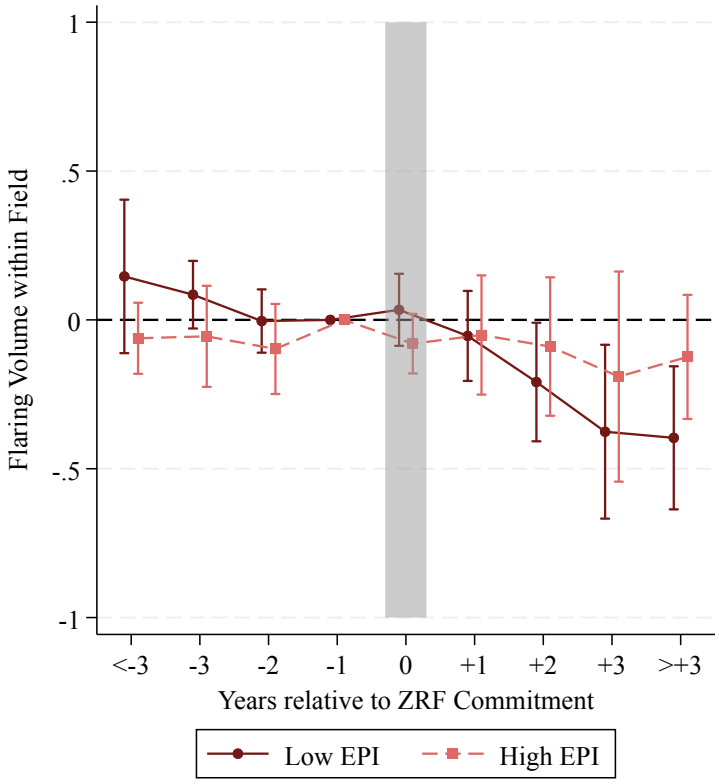
In this section, we perform a split on the 2014 Yale Environmental Performance Index (EPI)—a proxy for pre-period environmental standards—rather than Africa vs. non-Africa. In Figure IA4.5 Panel A below, we show a map with each country's average EPI value, demonstrating that Africa indeed has many countries with the poorest environmental performance in the world. In Figure IA4.5 Panel B below, we present results splitting between host countries with lowest-tercile EPI and higher-tercile EPI from the World Bank sample. We use the specification in Figure 5 Panel A, and our results are similar, indicating a stronger change in flaring for countries with lower environmental standards.

Figure IA4.5. Commitments and Reported Gas Flaring by Environmental Performance

Panel A: Pre-Period Environmental Performance Around the World



Panel B: World Bank Analysis

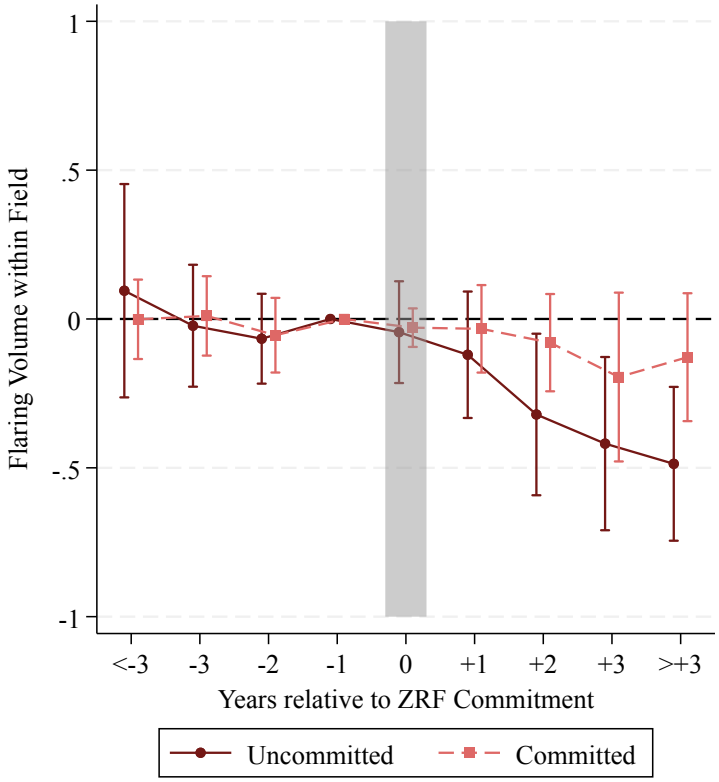


Notes: Panel A shows average values from the Yale Environmental Performance Index (EPI) in 2014 around the world. Panel B shows coefficient estimates and 95% confidence intervals for OLS regressions estimating annual changes in natural gas flaring around corporate commitments. We estimate the model from Figure 5 Panel A in the paper but separate countries by EPI rather than geographic location.

IA4.6 Split on Host Country Commitment

In Figure IA4.6 below, we present results splitting between host countries committed and uncommitted to ZRF at the country level. We use the specification in Figure 5 Panel A, and our results are similar for blocks located in committed and uncommitted countries. If anything, we see a stronger decline in uncommitted countries, consistent with our findings in Section IA4.5 that committed firms tend to make greater improvements in countries with lower *ex ante* environmental standards, assuming these countries are also less likely to commit to ZRF.

Figure IA4.6. Commitments and Reported Gas Flaring by Host Country Commitment



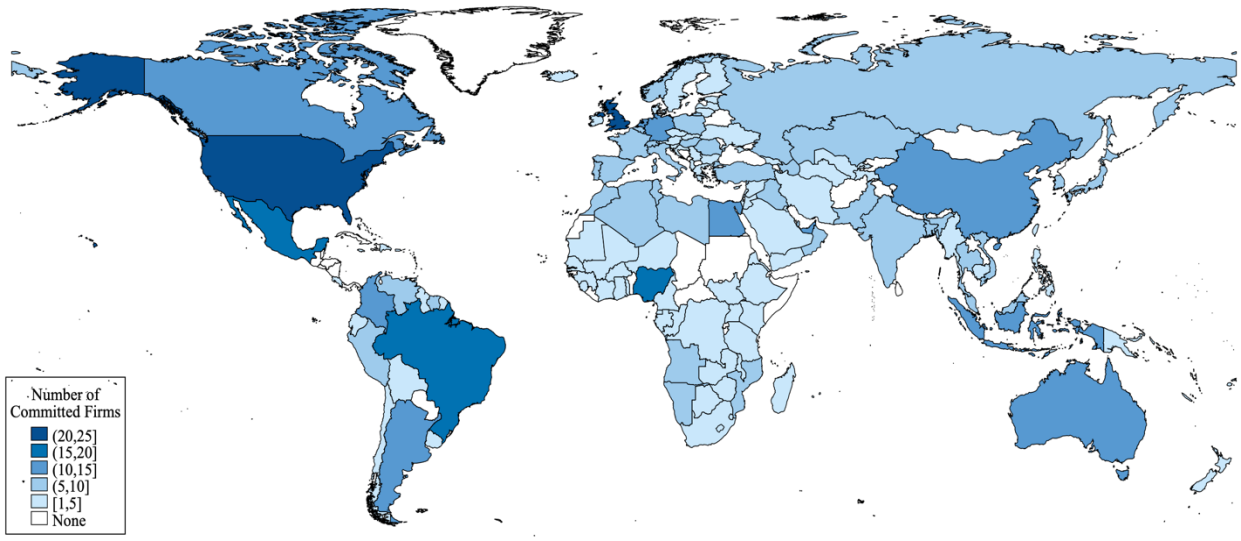
Notes: This figure shows coefficient estimates and 95% confidence intervals for OLS regressions estimating annual changes in natural gas flaring around corporate commitments. We estimate the model from Figure 5 Panel A in the paper but separate countries by host country ZRF commitment.

IA4.7 Spatial Distribution of Committed Firm Operations

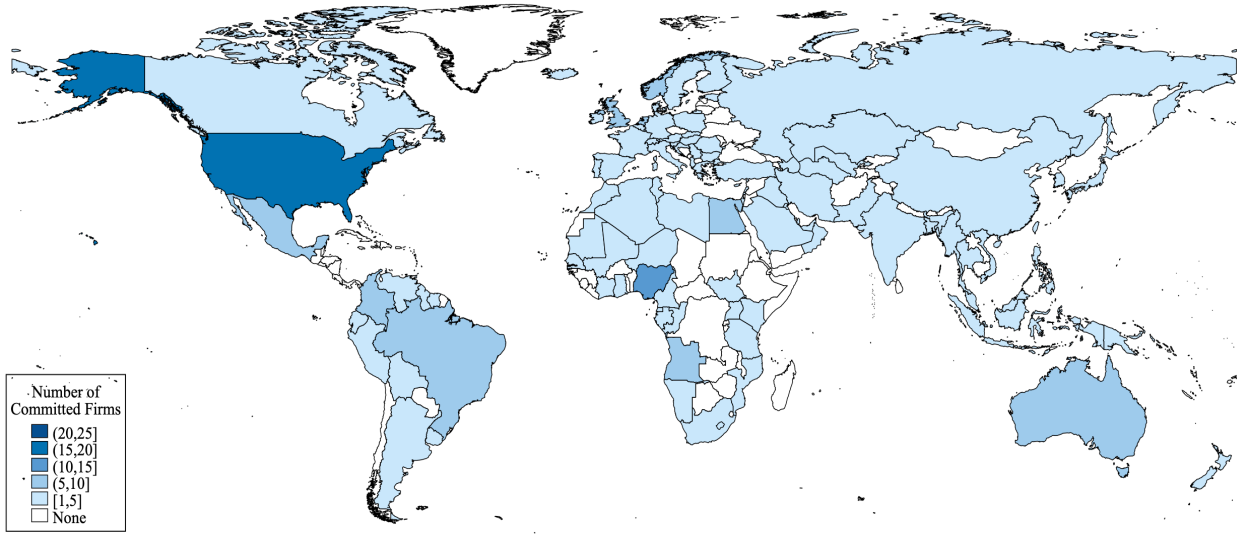
In this section, we illustrate the spatial distribution of committed firm operations around the world. We collect each committed firm's areas of operation from its most recent annual report. In Figure IA4.7 Panel A (Panel B), we show a map with the number of committed firms owning (operating) assets in each country, demonstrating that a substantial number of firms operate in Africa, but Africa is generally not their dominant geographical area of activity. This also demonstrates that firms are unlikely to make ZRF commitment decisions based on their African operations alone.

Figure IA4.7. Committed Firm Areas of Operation

Panel A: All Owned Assets



Panel B: Assets Operated by Firm



Notes: This figure shows the number of committed firms that operate in each country based on their most recent financial statement disclosures. Panel A documents all assets owned by firms. Panel B documents only assets operated by firms.

IA4.8 Tables for World Bank Analysis

In this section, we tabulate both the average change and dynamic change for the main World Bank analysis and the Africa cross-sectional test. In Table IA4.8 Columns (1) and (4), we estimate Eq. (1) in both average change and dynamic change form for the full World Bank sample. In Table IA4.8 Columns (2)–(3) and (5)–(6), we perform the same specifications separately for African and non-African countries and also conduct a one-sided two-sample Z-test of the difference in the coefficients. The table corresponds to Figures 3 and 5 in the main text.

Table IA4.8. ZRF Commitments and Reported Gas Flaring

Dep. Var.: asinh(*FlareVol*)	Average Effect				Dynamic Effect			
	Full Sample	Africa	Non-Africa	*Difference*	Full Sample	Africa	Non-Africa	*Difference*
	(1)	(2)	(3)	(2) – (3)	(4)	(5)	(6)	(5) – (6)
ZRF x *PostCommit*	-0.116***	-0.506***	-0.043*	-0.463***				
	(0.065)	(0.159)	(0.059)	Z = -2.73				
ZRF x *BeforePre3*					0.010	0.612**	-0.056	0.668***
					(0.064)	(0.244)	(0.055)	Z = 2.67
ZRF x *Pre3*					-0.001	0.199**	-0.036	0.235**
					(0.055)	(0.099)	(0.061)	Z = 2.02
ZRF x *Pre2*					-0.059	0.083	-0.083	0.166
					(0.051)	(0.100)	(0.055)	Z = 1.45
ZRF x *Pre1*					0.000	0.000	0.000	
					–	–	–	
ZRF x *Pre0*					-0.028	-0.100	-0.034	-0.066
					(0.032)	(0.136)	(0.030)	Z = -0.47
ZRF x *Post1*					-0.050	-0.133	-0.051	-0.082
					(0.062)	(0.152)	(0.068)	Z = -0.49
ZRF x *Post2*					-0.133*	-0.401**	-0.105	-0.296*
					(0.075)	(0.160)	(0.077)	Z = -1.67
ZRF x *Post3*					-0.250**	-0.602***	-0.177	-0.425*
					(0.112)	(0.189)	(0.130)	Z = -1.85
ZRF x *AfterPost3*					-0.230**	-0.655***	-0.128	-0.527**
					(0.100)	(0.213)	(0.085)	Z = -2.30
Block FE	Yes	Yes	Yes		Yes	Yes	Yes	
Country x Year FE	Yes	Yes	Yes		Yes	Yes	Yes	
R-squared	0.766	0.763	0.759		0.766	0.765	0.759	
Observations (Block-Year)	398,591	28,102	354,346		398,591	28,102	354,346	

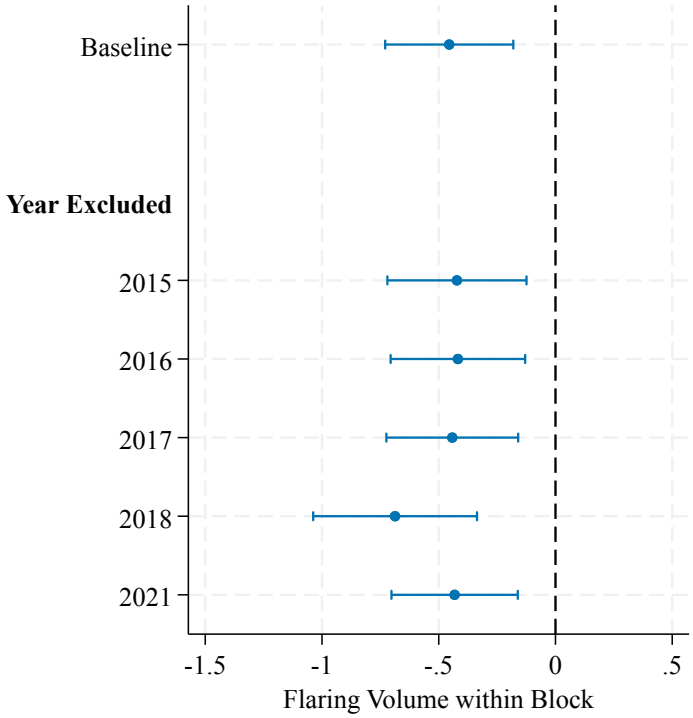
Notes: This table shows coefficient estimates and standard errors for OLS regressions estimating changes in natural gas flaring around corporate commitments. Columns (1)–(3) estimate the average effect while Columns (4)–(6) estimate the dynamic effect. We also perform one-tailed two-sample Z test of the difference between the coefficient for African and non-African countries. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. The sample selection is described in Section IA3.2 of the Internet Appendix, and singletons are further dropped corresponding to the fixed-effect structure if necessary. The sample is a balanced panel of oil fields from 2012 to 2022. Standard errors are clustered at the operator level.

Section IA5. Supplementary Tests for Africa Analysis

IA5.1 Jackknife Excluding Commitment Years for Continuously Operated Blocks

In Figure IA5.1 below, we present results dropping each commitment year from the continuously operated sample in turn. We start with the baseline specification in Figure 7 Panel C, from which we drew our main inferences. Our results remain similar in magnitude and statistically significant across all rows, which indicates that the treatment effect is not driven by commitments in any given year. The one exception is excluding 2018, which excludes Sonatrach (discussed in Section IA4.4).

Figure IA5.1. Jackknife Excluding Commitment Years (Continuously Operated)

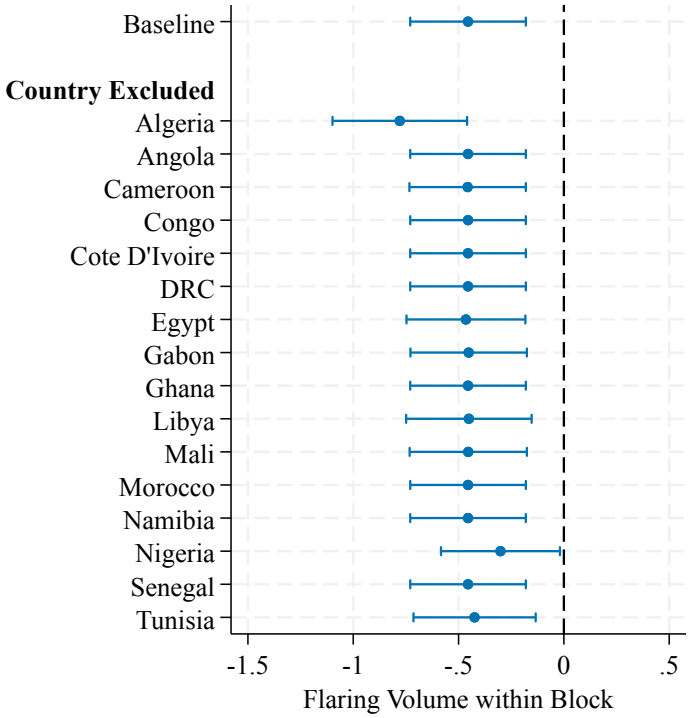


Notes: This figure shows coefficient estimates and 95% confidence intervals for OLS regressions estimating annual changes in natural gas flaring around corporate commitments. We estimate the model from Figure 7 Panel C in the paper as the baseline but separately exclude each commitment year.

IA5.2 Jackknife Excluding Host Countries for Continuously Operated Blocks

In Figure IA5.2 below, we present results dropping blocks in each host country from the continuously operated sample in turn. We use the specification in Figure 7 Panel C, from which we drew our main inferences. Our results remain similar in magnitude and statistically significant across most rows, which indicates that the treatment effect is not driven by commitment in any given country. The two exceptions are Algerian blocks, which seem to see a much smaller change after commitments, and Nigerian blocks, which seem to see a much larger change. As discussed in Section IA4.4, this is likely because most Algerian blocks are operated by state-owned Sonatrach, which is already under strict government regulation, while most Nigerian blocks are operated by Western-owned big oil companies, which are subject to stronger home-country stakeholder pressure.

Figure IA5.2. Jackknife Excluding Countries (Continuously Operated)

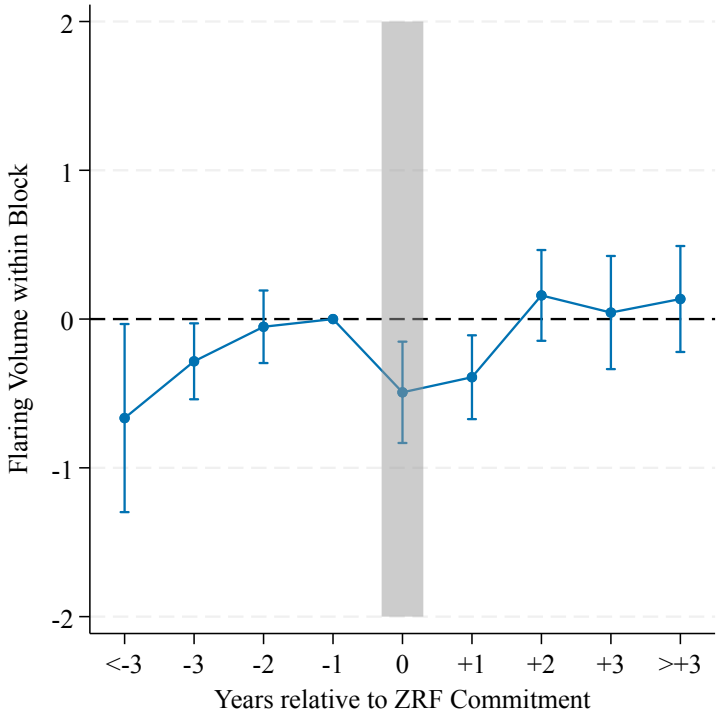


Notes: This figure shows coefficient estimates and 95% confidence intervals for OLS regressions estimating annual changes in natural gas flaring around corporate commitments. We estimate the model from Figure 7 Panel C in the paper as the baseline but separately exclude blocks in each host country.

IA5.3 Placebo Test for Non-Operator Owners of Continuously Operated Blocks

In Figure IA5.3 below, we present analyses around commitments of non-operator owners for blocks operated by uncommitted firms. Since the World Bank ZRF commitment does not cover blocks that signatories own but do not operate, there should not be a significant change in flaring after a non-operator owner commits. We modify the treatment period to be the first year that any owner commits to ZRF, but we keep constant all other empirical choices. Our results indicate, if anything, a temporary reduction in flaring that reverts by the second year after commitment. This may be due to committed operators attempting to reduce flaring immediately after committing but soon transferring operation rights to an uncommitted partner (who returns to original flaring volumes) while retaining their ownership stake. Thus, these blocks still show little to no environmental improvement in the long run. Taken together, it is reassuring that companies do not exhibit a long-term reduction in flaring for the blocks they are not held responsible for under ZRF guidelines.

Figure IA5.3. Gas Flaring for Continuous Non-Operator Owners



Notes: This figure shows coefficient estimates and 95% confidence intervals for OLS regressions estimating annual changes in natural gas flaring around corporate commitments. We estimate the model from Figure 7 Panel A but defines treatment at the time non-operator owners commit to ZRF.

IA5.4 Tables for Continuously Operated Analysis

In this section, we tabulate both the average change and dynamic change for the continuously operated blocks analysis in Africa. In Table IA5.4 Columns (1) and (2), we estimate Eq. (1) in both average change and dynamic change form for the continuously operated sample. The table corresponds to Figure 7 in the main text.

Table IA5.4. Gas Flaring for Continuous Operators

Dep. Var.: asinh(*FlareVol*)	(1)	(2)
ZRF x *PostCommit*	-0.455***	
	(0.140)	
ZRF x *BeforePre3*		0.022
		(0.221)
ZRF x *Pre3*		0.015
		(0.142)
ZRF x *Pre2*		0.007
		(0.160)
ZRF x *Pre1*		0.000
		–
ZRF x *Pre0*		-0.041
		(0.109)
ZRF x *Post1*		-0.222
		(0.155)
ZRF x *Post2*		-0.488***
		(0.143)
ZRF x *Post3*		-0.583***
		(0.133)
ZRF x *AfterPost3*		-0.614***
		(0.124)
Block FE	Yes	Yes
Country x Year FE	Yes	Yes
R-squared	0.866	0.866
Observations (Block-Year)	24,700	24,700

Notes: This table shows coefficient estimates and standard errors for OLS regressions estimating changes in natural gas flaring for continuously operated blocks in Africa around corporate commitments. Column (1) estimates the average effect while Column (2) estimates the dynamic effect. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. The sample selection is described in Section IA3.4 of the Internet Appendix, and singletons are further dropped corresponding to the fixed-effect structure if necessary. The sample is a balanced panel of oil blocks from 2012 to 2023. Standard errors are clustered at the operator level.

IA5.5 Venting as an Alternative to Flaring

To reduce reported flaring volumes, committers could substitute flaring, which releases carbon dioxide after burning gas, with venting, which directly releases methane into the environment. Since methane is 25 times more potent than carbon dioxide as a greenhouse gas, the net environmental impact of substituting from flaring to venting is severe. On the one hand, venting is a plausible avoidance strategy because methane is an odorless and colorless gas, making it harder to observe than large, bright gas flares. This is especially true early in our sample period when satellite technology was less sophisticated. On the other hand, it is unlikely that committed multinationals would establish a corporate policy to replace flaring with venting because such a policy would be an egregious violation of the ZRF commitment, is observable to many internal parties (e.g., workers or suppliers), and public revelation could entail major reputational costs.

In this section, we use recent advances in satellite technology to gauge whether committers substitute from flaring to venting to evade commitments. If this is the case, we should see greater methane concentrations for committed blocks relative to uncommitted blocks. To explore this possibility, we gather methane data from the European Space Agency's Sentinel-5P satellite and form a panel of within-block methane emissions in the desert areas of Algeria, Egypt, Libya, and Tunisia—where methane estimates are more reliable—for the years 2019 through 2023.[10] Because the data is only available after 2019, we cannot perform a difference-in-differences analysis around commitments. Instead, we compare the annual methane concentration for committed and uncommitted blocks by plotting coefficient estimates by year and country from the following OLS regressions:

$$\text{asinh}(Methane_{b,t}) = \beta_0 + \beta_1 ZRF_f \times Year_t + FEs + \varepsilon_{b,t} \quad (1)$$

$$\text{asinh}(Methane_{b,t}) = \beta_0 + \beta_1 ZRF_f \times Country_c + FEs + \varepsilon_{b,t} \quad (2)$$

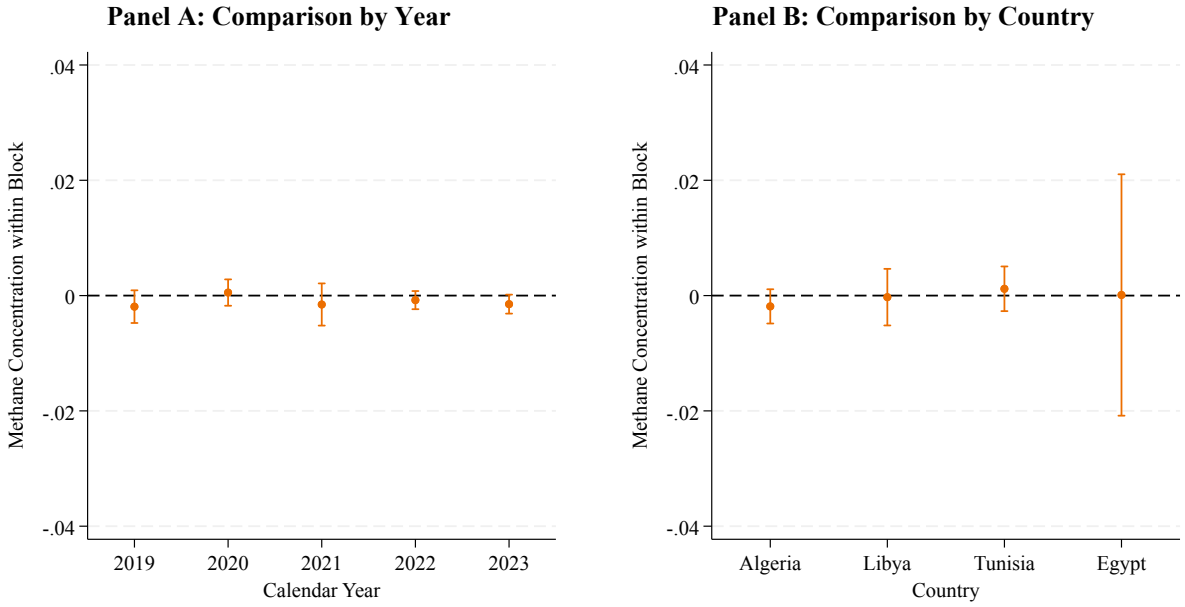
asinh(*Methane*) is the inverse hyperbolic sine of the methane concentration in parts per billion (ppb) within block *b* in year *t*. *ZRF* is an indicator equal to one if a block is operated by a committer *c*. *Year* (*Country*) is a set of indicators for each calendar year (host country). In both equations, we include *Country* × *Year* fixed effects to perform within-country comparisons of committed and

[10] Sentinel-5P captures data across the light spectrum including, crucially, short-wave infrared (SWIR) wavelengths. Methane absorbs light in the SWIR spectrum, allowing us to measure methane concentrations by comparing the amount of light absorbed in the wavelengths sensitive to methane to the amount of light absorbed in wavelengths just below that threshold. This method is most reliable in areas without excess vegetation, so we restrict the sample to countries in relatively arid regions (Ayasse et al., 2018). Sentinel-5P makes daily passes over most of the globe, capturing images with a resolution of approximately one square kilometer.

uncommitted blocks. We estimate standard errors clustered at the operator level since commitments are assigned by operator.

In Figure IA5.5 Panel A, we plot the yearly *ZRF* × *Year* coefficient estimates and their corresponding 95% confidence intervals for Eq. (1). The coefficients indicate that, on average, committed blocks have statistically insignificant but lower methane concentrations than uncommitted blocks, and this difference does not seem to change over time. In Figure IA5.5 Panel B, we plot the yearly *ZRF* × *Country* coefficient estimates and their corresponding 95% confidence intervals for Eq. (2). We also find insignificant differences in methane concentrations between committed and uncommitted blocks in each country. Overall, these results are inconsistent with a substantial shift from flaring to venting after commitments. The evidence that multinational companies that commit to ZRF do not respond with increased venting is also consistent with evidence in the US showing that corporate stakeholder pressure limits substitution to venting (McKinley, 2024).

Figure IA5.5. Methane Emissions for Continuous Operators

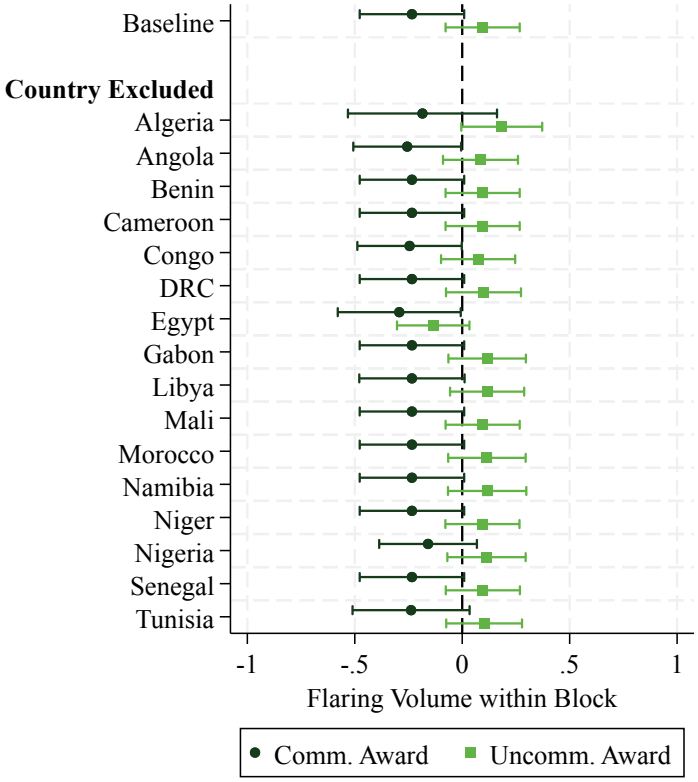


Notes: This figure shows coefficient estimates and 95% confidence intervals for OLS regressions estimating differences in methane concentrations between committed and uncommitted blocks in Northern Africa. Panel A estimates the model from Eq. (1), which compares methane concentrations separately for each year. Panel B estimates the model from Eq. (2), which compares methane concentrations separately for each country. The sample is a subset of the one described in Section IA2 of the Internet Appendix, including only blocks located in Algeria, Libya, Tunisia, and Egypt. The sample is a panel of oil blocks from 2012 to 2023. Standard errors are clustered at the operator level.

IA5.6 Jackknife Excluding Host Countries for Newly Awarded Blocks

In Figure IA5.6 below, we present results dropping each host country from the new awards sample in turn. We use the specifications in Figure 9 Panel B, from which we drew our main inferences. Our results for uncommitted awards remain similar in magnitude and statistically significant across most rows. Our results for committed awards also remain insignificant and close to zero across most rows.

Figure IA5.6. Jackknife Excluding Countries (Newly Awarded)

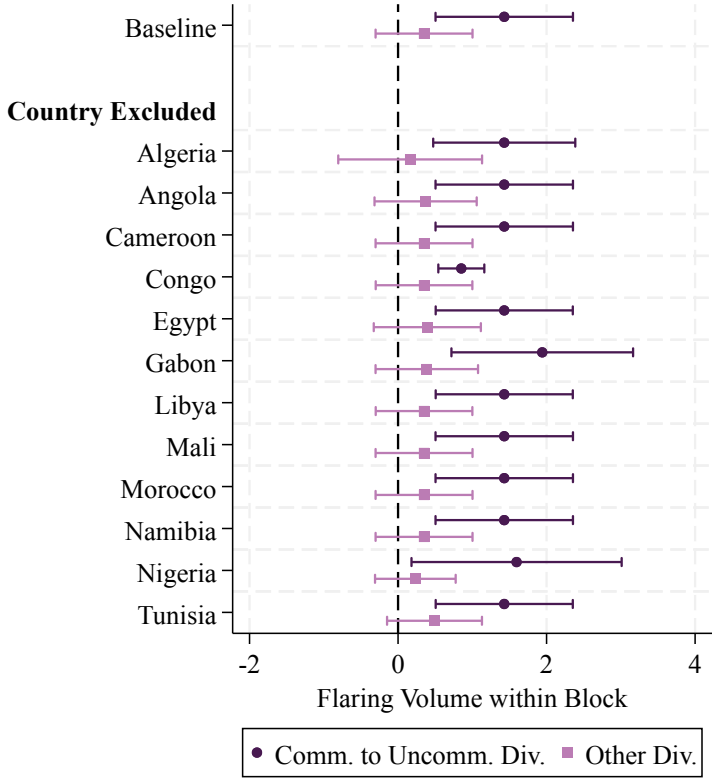


Notes: This figure shows coefficient estimates and 95% confidence intervals for OLS regressions estimating annual changes in natural gas flaring around new awards. We estimate the model from Figure 9 Panel B in the paper as the baseline but separately exclude blocks in each host country.

IA5.7 Jackknife Excluding Host Countries for Divested Blocks

In Figure IA5.7 below, we present results dropping each host country from the divestiture sample in turn. We use the specifications in Figure 10 Panel C, from which we drew our main inferences. Our results for committed-to-uncommitted divestitures remain similar in magnitude and statistically significant across all rows. Our results for other divestitures remain insignificant and close to zero across all rows.

Figure IA5.7. Jackknife Excluding Countries (Divested)

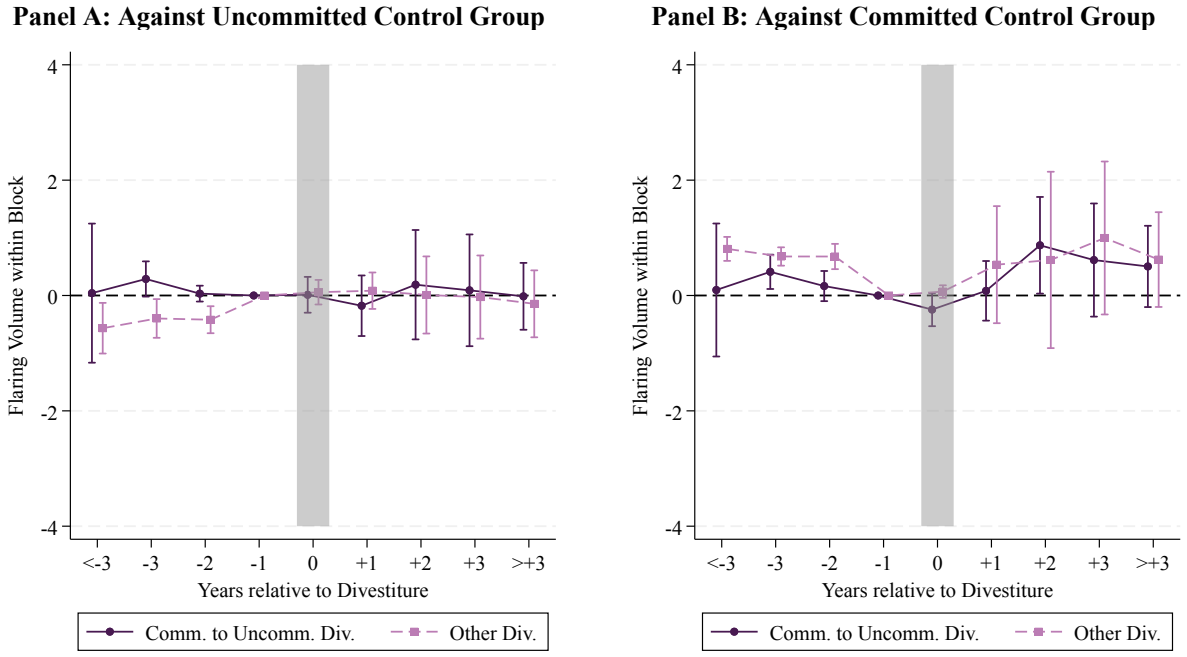


Notes: This figure shows coefficient estimates and 95% confidence intervals for OLS regressions estimating annual changes in natural gas flaring around divestitures. We estimate the model from Figure 10 Panel C in the paper as the baseline but separately exclude blocks in each host country.

IA5.8 Placebo Test for Divestitures without Operator Change

In Figure IA5.8 below, we present results for divestitures without operator changes. We use the specifications in Figure 10 Panels B and C, from which we drew our main inferences. Since the World Bank's ZRF does not cover blocks that signatories own but do not operate, blocks sold but not operationally transferred should not experience a significant change in flaring. Consistently, we see a path that looks similar for committed-to-uncommitted and other divestitures.

Figure IA5.8. Placebo Test for Non-Operator Divestitures



Notes: This figure shows coefficient estimates and 95% confidence intervals for OLS regressions estimating annual changes in natural gas flaring around divestitures that do not result in operator changes. We estimate the models from Figure 10 Panels B and C but define treatment as non-operator divestitures.

IA5.9 Tables for Awards and Divestitures Analysis

In this section, we tabulate both the average change and dynamic change for the awards and divestitures analysis in Africa. In Table IA5.9a Panel A (Panel B), we estimate Eq. (4) in both average change and dynamic change form for the newly awarded sample against a control group of uncommitted (committed) continuously operated blocks. This table corresponds to Figure 10 in the main text. In Table IA5.9b Panel A (Panel B), we estimate Eq. (5) in both average change and dynamic change form for the divested sample against a control group of uncommitted (committed) continuously operated blocks. This table corresponds to Figure 10 in the main text.

Table IA5.9a. Gas Flaring for Newly Awarded Blocks

Panel A: Uncommitted Control Group

Dep. Var.: asinh(*FlareVol*)	Average Effect			Dynamic Effect		
	C Award	UC Award	*Difference*	C Award	UC Award	*Difference*
	(1)	(2)	(1) – (2)	(3)	(4)	(3) – (4)
Award x *PostAward*	-0.234*	0.095	-0.329**			
	(0.124)	(0.088)	Z = -2.16			
Award x *BeforePre3*				0.050	0.031	0.019
				(0.179)	(0.108)	Z = 0.09
Award x *Pre3*				0.034	-0.061	0.095
				(0.113)	(0.074)	Z = 0.70
Award x *Pre2*				0.047	-0.071	0.118
				(0.082)	(0.052)	Z = 1.22
Award x *Pre1*				0.000	0.000	
				–	–	
Award x *Pre0*				-0.029	0.056	-0.085
				(0.077)	(0.065)	Z = -0.84
Award x *Post1*				-0.120	0.109	-0.229**
				(0.086)	(0.070)	Z = -2.07
Award x *Post2*				-0.246	0.096	-0.342
				(0.222)	(0.108)	Z = -1.39
Award x *Post3*				-0.403**	0.071	-0.474**
				(0.154)	(0.101)	Z = -2.57
Award x *AfterPost3*				-0.292	0.052	-0.344
				(0.219)	(0.135)	Z = -1.34
Block FE	Yes	Yes		Yes	Yes	
Country x Year FE	Yes	Yes		Yes	Yes	
R-squared	0.838	0.841		0.838	0.841	
Observations (Block-Year)	36,760	69,639		36,760	69,639	

Panel B: Committed Control Group

Dep. Var.: asinh(*FlareVol*)	Average Effect			Dynamic Effect		
	C Award	UC Award	*Difference*	C Award	UC Award	*Difference*
	(1)	(2)	(1) – (2)	(3)	(4)	(3) – (4)
Award x *PostAward*	0.058	0.129	-0.071			
	(0.075)	(0.104)	Z = -0.55			
Award x *BeforePre3*				-0.038	-0.004	-0.034
				(0.131)	(0.067)	Z = -0.23
Award x *Pre3*				-0.014	-0.069	0.055
				(0.057)	(0.053)	Z = 0.71
Award x *Pre2*				0.022	-0.041	0.063
				(0.099)	(0.044)	Z = 0.58
Award x *Pre1*				0.000	0.000	
				–	–	
Award x *Pre0*				0.021	-0.028	0.049
				(0.052)	(0.067)	Z = 0.58
Award x *Post1*				0.064	0.059	0.005
				(0.089)	(0.109)	Z = 0.04
Award x *Post2*				0.021	0.021	0.000
				(0.217)	(0.186)	Z = 0.00
Award x *Post3*				-0.077	0.116	-0.193
				(0.127)	(0.147)	Z = -0.99
Award x *AfterPost3*				0.150	0.278	-0.128
				(0.213)	(0.177)	Z = -0.46
Block FE	Yes	Yes		Yes	Yes	
Country x Year FE	Yes	Yes		Yes	Yes	
R-squared	0.904	0.897		0.904	0.897	
Observations (Block-Year)	24,235	54,379		24,235	54,379	

Notes: This figure shows coefficient estimates and standard errors for OLS regressions estimating changes in natural gas flaring around awards in Africa. Panel A (B) estimates the model from Eq. (4), which separately compares flaring volumes in oil blocks awarded to committed and uncommitted firms against a control group of blocks continuously operated by uncommitted (committed) firms. Columns (1)–(2) estimate the average effect while Columns (3)–(4) estimate the dynamic effect. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. The sample selection is described in Section IA3.4 of the Internet Appendix, and singletons are further dropped corresponding to the fixed-effect structure if necessary. The samples are balanced panels of oil blocks from 2012 to 2023. Standard errors are clustered at the block level.

Table IA5.9b. Gas Flaring for Divested Blocks

Panel A: Uncommitted Control Group

Dep. Var.: asinh(*FlareVol*)	Average Effect			Dynamic Effect		
	C to UC Div	Other Div	*Difference*	C to UC Div	Other Div	*Difference*
	(1)	(2)	(1) – (2)	(3)	(4)	(3) – (4)
Divest x *PostSale*	0.088	-0.103	0.191			
	(0.160)	(0.179)	Z = 0.80			
Divest x *BeforePre3*				0.799***	0.232	0.567
				(0.287)	(0.229)	Z = 1.54
Divest x *Pre3*				0.495	0.148	0.347
				(0.351)	(0.165)	Z = 0.90
Divest x *Pre2*				0.190	0.166	0.024
				(0.149)	(0.184)	Z = 0.10
Divest x *Pre1*				0.000	0.000	
				–	–	
Divest x *Pre0*				0.429***	0.026	0.403*
				(0.140)	(0.176)	Z = 1.79
Divest x *Post1*				0.792**	0.080	0.712
				(0.349)	(0.320)	Z = 1.50
Divest x *Post2*				0.359	-0.208	0.567
				(0.248)	(0.322)	Z = 1.40
Divest x *Post3*				0.286**	0.265	0.021
				(0.133)	(0.313)	Z = 0.06
Divest x *AfterPost3*				0.709***	0.163	0.546*
				(0.184)	(0.241)	Z = 1.80
Block FE	Yes	Yes		Yes	Yes	
Country x Year FE	Yes	Yes		Yes	Yes	
R-squared	0.828	0.832		0.829	0.832	
Observations (Block-Year)	7,542	23,052		7,542	23,052	

Panel B: Committed Control Group

Dep. Var.: asinh(*FlareVol*)	Average Effect			Dynamic Effect		
	C to UC Div	Other Div	*Difference*	C to UC Div	Other Div	*Difference*
	(1)	(2)	(1) – (2)	(3)	(4)	(3) – (4)
Divest x *PostSale*	1.430***	0.350	1.080*			
	(0.472)	(0.333)	Z = 1.87			
Divest x *BeforePre3*				-0.272	-0.137	-0.135
				(0.332)	(0.555)	Z = -0.209
Divest x *Pre3*				-0.296	0.293	-0.589
				(0.233)	(0.326)	Z = -1.470
Divest x *Pre2*				-0.166	0.524**	-0.690**
				(0.204)	(0.232)	Z = -2.233
Divest x *Pre1*				0.000	0.000	
				–	–	
Divest x *Pre0*				0.893***	-0.046	0.939***
				(0.157)	(0.329)	Z = 2.576
Divest x *Post1*				1.356***	0.345	1.011**
				(0.249)	(0.351)	Z = 2.349
Divest x *Post2*				1.740***	0.398	1.342**
				(0.423)	(0.365)	Z = 2.402
Divest x *Post3*				0.947***	0.994**	-0.047
				(0.076)	(0.454)	Z = -0.102
Divest x *AfterPost3*				0.751***	0.599	0.152
				(0.112)	(0.486)	Z = 0.305
Block FE	Yes	Yes		Yes	Yes	
Country x Year FE	Yes	Yes		Yes	Yes	
R-squared	0.899	0.901		0.899	0.901	
Observations (Block-Year)	4,796	14,683		4,796	14,683	

Notes: This figure shows coefficient estimates and standard errors for OLS regressions estimating changes in natural gas flaring around divestitures in Africa. Panel A (B) estimates the model from Eq. (5), which separately compares flaring volumes in oil blocks divested from committed to uncommitted firms and between other combinations of firms against a control group of blocks continuously operated by uncommitted (committed) firms. Columns (1)–(2) estimate the average effect while Columns (3)–(4) estimate the dynamic effect. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. The sample selection is described in Section IA3.4 of the Internet Appendix, and singletons are further dropped corresponding to the fixed-effect structure if necessary. The samples are balanced panels of oil blocks from 2012 to 2023. Standard errors are clustered at the block level.

IA5.10 Alternate Aggregate Calculation

In this section, we detail the calculations for aggregating the flaring changes in continuously operated, awarded, and divested blocks in Africa based on estimates in Section 4. This calculation serves as an alternative to the country-level analysis in Section 5 that excludes spillovers to the control group. Though we observe a relatively strong increase in gas flaring after committed-to-uncommitted divestitures, such divestitures are infrequent. As discussed in Section 4.3, only 6% of blocks owned by committed firms are divested to uncommitted firms during the sample period, while the remaining continuously owned blocks show a significant decrease in flaring activity. Thus, in the aggregate, we observe a clear net decrease in flaring following ZRF commitments.[11]

As shown in Table IA5.10 Panel A, the first step is to multiply the pre-treatment mean for each sample by the percent change calculated in each analysis to arrive at the change in flare volume after commitments, awards, and divestitures of –115, +32, and +26 million cubic meters per block-year, respectively. Then, as shown in Panel B, the second step is converting the change in gas volume flared into CO_2-equivalent emissions and aggregating across total blocks in each sample. We follow the World Bank's methodology in assuming that flaring converts 98% of natural gas into CO_2 and releases the remaining 2% as methane, so we use a conversion factor of 2.8 kilograms of CO_2-equivalent emissions per cubic meter of natural gas flared. Multiplying the per-block changes by the conversion factor yields an average change in CO_2-equivalent emissions after commitments for continuously operated blocks, awards, and divestitures of –324, +91, and +73 thousand metric tons per block, respectively. Finally, we multiply these changes by the count of blocks continuously owned by committed firms, committed awards forfeited, and committed-to-uncommitted divestitures to obtain continent-wide changes in CO_2-equivalent emissions.[12] These changes come out to –62.9, +1.3, and +0.8 million metric tons for continuously owned, awarded, and divested, respectively. Note that we calculate the number of committed awards forfeited as the decline in award probability after commitment multiplied by the number of pre-

[11] In (Internet Appendix) Section IA5.11, we provide a technical discussion of specific computations, including justifications for the assumptions we make.

[12] We calculate the number of committed awards forfeited as the total number of awards to committed firms before commitment (93) multiplied by the decline in award probability (14.7%) from Figure 9 Panel A to arrive at approximately 14 blocks.

commitment awards to committed firms.[13] Combining these changes equates to a net reduction of approximately 60.8 million metric tons.

In summary, while awards are forfeited and divestitures do occur after commitments, these are relatively rare events and largely immaterial to the total flaring reductions observed after oil and gas firms commit to zero routine flaring. Firms appear to follow through on commitments primarily through operational improvements rather than disclaiming responsibility by forfeiting and divesting assets.

Table IA5.10. Aggregate Change in Flaring

Panel A: Changes in Flare Volume

Corporate Action	**Pre-Treat Mean Flare Vol.** (mln m^3)	**Percent Change** (from figures)	**Flare Vol. Change** (mln m^3)
Continuously Operated	263.09	-44%	-115.76
Awarded	81.10	40%	32.44
Divested (to UC)	17.13	153%	26.21

Panel B: Changes in CO_2-Equivalent Emissions

Corporate Action	**Flare Vol. Change** (mln m^3)	**WB Conv. Factor** (kg/m^3)	**CO_2-equivalent per block** (thousand metric tons)	**Number of Blocks**	**Total CO2e Change** (mln metric tons)
Continuously Operated	-115.76	2.8	-324.13	194	-62.88
Awarded	32.44	2.8	90.83	14	1.27
Divested (to UC)	26.21	2.8	73.38	11	0.81
Net Change	Continuously Operated + Awarded + Divested (to UC)				-60.80

Notes: This table presents the computation of net changes in carbon-equivalent emissions following commitments for continuously operated blocks, awards, and divestitures in Africa. Panel A presents the computation of flare volume changes corresponding to several coefficients in the analyses. Panel B presents the computation of CO_2-equivalent emission changes corresponding to previously computed flare volume changes, the World Bank conversion factor, and the number of treated blocks in each sample.

[13] Because most commitments occur approximately halfway through our sample (between 2015 and 2018), it is reasonable to assume that the quantity of pre-period awards would approximately equal the quantity of post-period awards in the absence of commitment.

IA5.11 Calculation Details for Carbon Emissions

In 2011, the National Oceanic and Atmospheric Association (NOAA) launched a suite of satellite-mounted detectors called the Visual and Infrared Radiometer Suite (VIIRS).[14] VIIRS is capable of detecting multiple wavelengths of infrared radiation, which at nighttime respond only to heat emissions with high spatial resolution. VIIRS' ability to record radiation across wavelengths allows us to determine the temperature of a heat source using Wein's Displacement Law, which states that different temperatures peak at different wavelengths and provides a constant that enables one to convert between the two. Conveniently, natural gas flaring tends to occur at temperatures above those of naturally occurring sources such as wildfires or volcanoes. We use a threshold of 1,400 Kelvin to ensure that we are isolating only natural gas sources and follow the World Bank (2024) methodology to estimate the carbon emissions from flaring.[15]

After we identify the flares and their temperature, we must convert these observations into an amount of energy. That is accomplished by first applying the Stefan-Boltzman law to calculate the amount of energy generated per unit of area, in this case, watts per meter squared. However, we need the total amount of energy produced in order to calculate the amount of natural gas required to generate that energy. This means we need to calculate the surface area of the flare. Surface area is calculated by comparing the observed size of the flare divided by the size of a flare that would fill the entire VIIRS image; by multiplying that ratio times the area of the VIIRS image, which is known, we get an estimated size. Multiplying the size times the energy per unit of area then gives a flare's total radiant heat (energy), which is then converted to megawatts. These steps are already completed in the flaring dataset we obtain from the Colorado School of Mines (Elvidge et al., 2013).

With the total radiant heat from the dataset, we can estimate the volume of natural gas that would need to be combusted to generate the observed amount of energy. Cedigaz, an oil and gas consultant, estimates a linear relationship between radiant heat and flare volume by comparing known volumes to VIIRS satellite estimates. This linear relationship is captured by the estimated constant (0.0281 billion cubic meters per megawatt-year), which can then be applied to estimate the annual volume for each flare (Elvidge et al., 2016). We show these computations for our sample

[14] https://ncc.nesdis.noaa.gov/VIIRS/
[15] https://pubdocs.worldbank.org/en/853661587048977000/Estimation-of-flare-gas-volumes-from-satellite-data-002.pdf

in Table IA5.10 Panel A. Specifically, we multiply daily radiant heat values by the coefficient (percent change) from our main analyses and the Cedigaz constant, yielding the change in flaring volume for continuously owned and committed-to-uncommitted divestitures.

Finally, we need to convert flare volumes into carbon emissions. The World Bank assumes a flare efficiency of 98%, meaning that 98% of the flared gas combusts to produce carbon dioxide (CO_2), with the remaining 2% being methane directly released into the atmosphere. Methane has twenty-five times the warming potential of carbon dioxide, so any failures in combustion can drastically increase the warming impact of flaring. Under these assumptions, a cubic meter of flared gas equates to 2.8 kilograms of CO_2 (World Bank, 2024). In the last step, we multiply the 2.8 kilograms times the amount of gas flared to arrive at our estimates of changes in CO_2-equivalents, which we convert into metric tons. We show these computations for our sample in Table IA5.10 Panel B. Specifically, we multiply the volume changes from Table IA5.10 Panel A by the conversion factor and the total number of treated blocks to get the total change in CO_2-equivalent emissions. Finally, we net the decrease from continuously owned blocks and the increase from divested blocks to arrive at a final estimate that flaring is reduced by approximately 38 million metric tons per year.

In terms of magnitude, the World Bank estimates annual flaring volumes in Africa to be slightly less than 100 million metric tons of CO_2-equivalent emissions while they estimate worldwide volumes to be around 400 million metric tons. Thus, our results suggest a reduction of around 60% of African flaring and 15% of worldwide flaring from African oil operations after corporate commitments.

Section IA6. References

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