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Public governance versus corporate governance: Evidence from oil drilling in forests[☆]

James Cust[a,b], Torfinn Harding[c,d,*], Hanna Krings[e], Alexis Rivera-Ballesteros[a]

[a] World Bank, United States of America
[b] OxCarre, University of Oxford, United Kingdom
[c] University of Stavanger Business School, Norway
[d] Norwegian School of Economics, Norway
[e] School of Business and Economics, RWTH Aachen University, Germany

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ABSTRACT

Petroleum companies look for oil and gas in some of the most remote and biodiverse forested areas on the planet. To study how local environmental footprints vary across countries and companies, we combine global company-level geo-coded data on oil drilling with high resolution data on forest loss. We find that oil wells drilled in countries with better public governance, measured by democracy scores, are associated with substantially lower forest loss in the period after drilling. In contrast, we do not find evidence of less forest clearance among companies with presumptively 'better' corporate governance practices, such as major international companies, publicly listed companies, or members of an industry association committed to high environmental standards. These results do not support a "pollution halo" effect, whereby companies might bring better environmental practices with them, exceeding domestic environmental standards.

1. Introduction

Natural environments are increasingly under pressure, amid population growth and economic expansion associated with rising prosperity. Public governance can help balance different interests and enforce regulations that reduce negative externalities on the environment. Corporate governance and self-regulation by companies can also play a role, with a growing emphasis placed by investors on ESG criteria

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* Corresponding author.
E-mail addresses: jimcust@gmail.com (J. Cust), torfinn.harding@uis.no (T. Harding), hanna.krings@rwth-aachen.de (H. Krings), alexis.rivera.b@gmail.com (A. Rivera-Ballesteros).

[1] What we call public governance, to separate it from corporate governance, is often referred to as just governance. Acemoglu (2008) describes it as follows: "governance refers to essential parts of the broad cluster of institutions. Particularly important elements of governance, defined as such, would include the political institutions of a society (the process of collective decision making and the checks on politicians, and on politically and economically powerful interest groups), state capacity (the capability of the state to provide public goods in diverse parts of the country), and regulation of economic institutions (how the state intervenes in encouraging or discouraging economic activity by various different actors)". Corporate governance or self-regulation of a company is often referred to as corporate social responsibility (CSR), which increasingly now considers environmental, social and governance related aspects of corporate activity and impact, commonly referred to as ESG. For theoretical work, see Coase (1960) on public regulation and Baron (2001, 2010) and Egorov and Harstad (2017) on private self-regulation.

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(environmental, social and governance) linked to responsible company practices. To date, little empirical work has examined the importance of public governance compared to corporate governance in reducing negative externalities on the local natural environment.[1]

In this paper, we study how forest loss around oil exploration wells vary with measures of public governance and corporate governance. We obtain variation in public governance by measures of institutional quality in all countries where oil exploration takes place in forested areas. To capture variation in corporate governance, we use measures such as public listing or membership in the International Petroleum Industry Environmental Conservation Association (IPIECA), and attach these company characteristics to each exploration well by using the identity of the operating company. The combination of global satellite data on forest loss (2001–2018) and the geo-coded well-level data on oil exploration with known drilling results in forests (2004–2010) covers 3,101 onshore oil exploration wells across 55 different countries and 396 different companies. Importantly, our measures of forest loss and oil exploration have the same accuracy across all these countries. This marks an advancement over previous work by allowing for globally comparable data on behavior related to a negative externality across a range of countries and companies.

To isolate from other potential explanations for forest loss beyond oil activities, we focus on areas in the immediate vicinity of the oil wells. We use a difference-in-differences design, where drilling sites receive drilling at different points in time. We are interested in heterogeneous effects in terms of public and private governance, and show that the forest loss around wells in high and low quality institution countries follow parallel trends before drilling. Also, the forest loss around wells drilled by different company types follow parallel trends before drilling. These pre-trend tests give support that our key identifying assumption in the difference-in-differences estimations is satisfied, which is that the forest loss would follow the same trends in the absence of drilling across the different countries or across the different companies. In addition, we present estimates based on the quasi-random event of oil discoveries.[2] The idea is that, conditional on drilling, striking oil is a random event. Again, we cannot reject that the pre-trends in forest loss are parallel and neither the measures of public nor private governance are associated with differential pre-trends. We observe commercially viable discoveries, a standard definition of discoveries in the industry, which allows us to obtain an estimate of the effect of likely continued presence of oil companies beyond the initial exploration effort.

We find that the presence of wells are associated with forest loss. Annual forest loss in percentage of a 5 km^2 circle around our wells is found to be on average 0.1 percentage points higher in the years after drilling compared to the years before drilling, summing up to an additional clearance of around 6 hectares over twelve years due to the drilling. Our results provide the first global estimates of this effect, which has previously been shown only for the U.S. and Canada by Allred et al. (2015). They find in their high-resolution analyses vegetation displacement of 5.7 hectares per well following well establishment, using the normalized difference vegetation index (NDVI). This is similar in magnitude to our average global finding for tree cover loss. On average, the area around drilled wells in our global sample experiences significant loss of forest cover.

The main finding of this paper is that wells in countries with better public governance are associated with lower forest loss in the period after drilling. We focus in our baseline results on public governance measured as the degree of democracy. In terms of magnitudes, wells drilled in countries with above median democracy scores see 20 hectares of forest lost over the following twelve years, compared to 30 hectares in countries with lower than median democracy scores. On the democracy scale that goes from 0 to 10, we find that going from a well drilled in Canada with a score of 10 to a well in Angola with a score of 1, sees a doubling of the forest loss; from about 20 hectares in Canada to about 40 hectares in Angola (see Fig. 1).

When a well successfully strikes oil, which happens on average about 75% of the time in our sample, the company will typically proceed with extracting the oil, with associated investment and construction activity around the well site. We find that a discovery leads to more forest loss in countries with lower democracy scores, solidifying the results from above.

Our results are qualitatively the same when we instead of democracy scores use alternative measures of public governance, such as polity scores and the six dimensions of public governance in The World Bank's Worldwide Governance Indicators (WGI): Voice and Accountability, Political Stability and Absence of Violence/Terrorism, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption. This suggests that our baseline measure picks up multiple aspects of public governance.

We interpret our results on public governance to reflect broad aspects of development. Better public governance might foster political competition, freedom of speech, and accountability of decision making; allowing citizens and organizations to voice environmental concerns and may spur the introduction and enforcement of policies to protect the environment. Better public governance may also have indirect effects. For example, Acemoglu et al. (2019) find that democracy has a positive effect on the likelihood of economic reforms, tax revenue as a percentage of GDP, and enrollment in primary and secondary education. More generally, the large literature on institutions and economic growth has shown that institutional quality matters for a host of outcomes related to economic development.[3] Economic policies, the capacity of the state, human capital, and various company investments can in turn affect environmental outcomes. In our setting, technology, information, workers' education, infrastructure, and the level of conflict are examples of potential mechanisms. In line with the idea that public governance can work via broad mechanisms, we show that the effect of public governance goes beyond environmental stringency, as measured by the World Economic Forum, and beyond GDP per capita.

When we augment the model with measures for corporate governance, the results for public governance are unaffected. We consider five measures associated with corporate governance: whether the operating company is nationally owned; whether it is one of the seven supermajor companies, excluding and including their subsidiaries; whether it is a member of IPIECA; and whether it is publicly listed. Consistently across these measures, we do not find that presumptively 'responsible' companies are associated with less forest loss from oil activities when we account for the public governance of the host country.[4]

Identification of the effects of public and corporate governance is challenging, as the measures we use may suffer from measurement error and they may be correlated with unaccounted-for differences across countries (e.g., Acemoglu et al., 2019). Within-country variation

[2] Oil discoveries have been used as natural experiments by Lei and Michaels (2014), Arezki et al. (2017), Harding et al. (2020) and Cust and Mihalyi (2017). We use "oil" and "oil and gas" interchangeably in this paper.

[3] See for example Acemoglu et al. (2005), Acemoglu et al. (2001), Acemoglu and Johnson (2005), Acemoglu et al. (2019), Bohn and Deacon (2000), Cust and Harding (2020), Dell (2010), Hall and Jones (1999), Michalopoulos and Papaioannou (2013), Papaioannou and Siourounis (2008) and Rodrik and Wacziarg (2005)

[4] The results regarding corporate governance hold when we include corporate governance measures only. Corporate governance measures are, in contrast to the public governance measures, not associated with overall lower forest loss. If anything, we find more forest loss around wells operated by companies classified as international oil companies (IOC) and companies being members of IPIECA. A well operated by an IOC sees on average about 60 hectares of forest loss after 12 years, whereas other wells see about 25 hectares. The differences associated with IPIECA membership are smaller, around 5–10 hectares after 12 years. We find little difference according to whether the operating company is a national oil company.

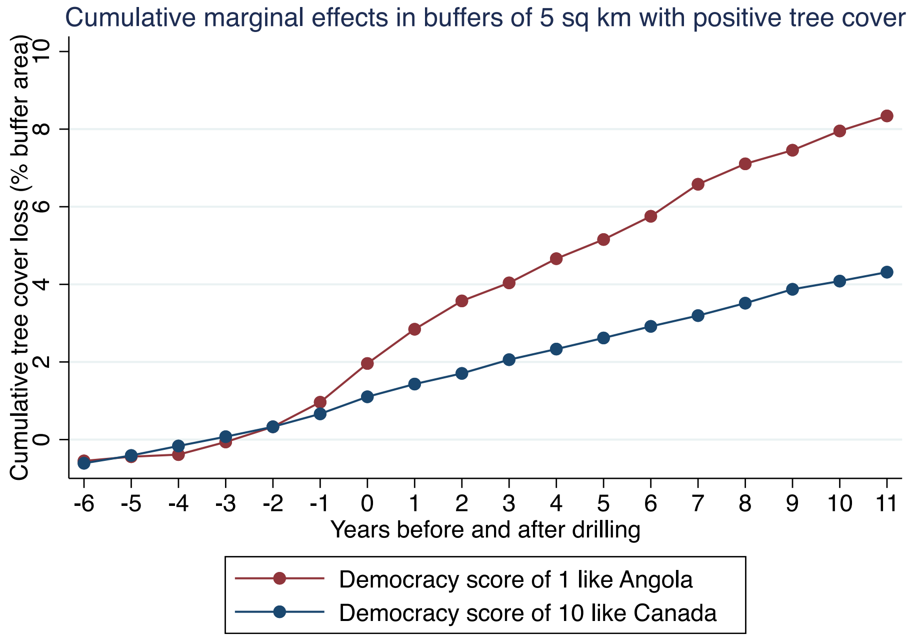

Fig. 1. Tree cover loss before and after exploration drilling in a circle of 5 km^2 around a well. Cumulative tree cover loss is measured in percent of a 5 km^2 ring area around a well. The starting year of exploration drilling is set to $t = -2$. Well and year fixed effects included. Using the *margins* function in Stata, we estimate marginal effects of each corporate governance measure on tree cover loss. This gives us the average effect per year across discovery results and institutional qualities. We compute the cumulative sum of the resulting marginal effects starting at $t = -2$, while we subtract those from $t = -3$ to $t = -6$.

in drilling, in the form of the precise location and timing of drilling and whether a discovery occurs or not, allows us to separate oil activities from general changes in the host countries. A further strength of our setting is that oil and gas is an international business, where many of the active companies operate in several countries. This allows us to include company fixed effects and estimate the effect of public governance within companies (see Section 5). This controls for the technology available at the company level, to the extent they use the same technology everywhere. We do also check robustness to the inclusion of company-year fixed effects, country-year fixed effects, a biomes-type control, an environmental stringency indicator, and GDP per capita.

To date, the largest share of investment in the global oil industry has gone to countries with ‘good governance’, such as those in the Organization for Economic Co-operation and Development (OECD) (Cust and Harding, 2020). Due to the gradual depletion of reserves and the opening up of new economies to investment, the global oil industry has more recently expanded its investments in developing countries (Arezki et al., 2019). This process may accelerate in the coming decades, especially if OECD-countries restrict new exploration for climate change reasons.[5] Developing countries tend to have weaker political institutions and studies suggest much of the untapped petroleum reserves in developing countries are likely to be located in areas with high biodiversity, such as tropical forests (Butt et al., 2013). The oil industry, the financial markets, and policy makers should be aware that the extent of local environmental externalities depend on the public governance, or otherwise will require more effective approaches to self-regulation or new forms of international scrutiny and standards.

The paper proceeds as follows. Section 2 explains this paper’s contributions to the literature. Section 3 describes the context, the data and the identification strategy. Section 4 presents the results. Section 5 deals with robustness checks and explains extra checks dealing with threats to identification. Section 6 concludes. An online appendix provides supplementary material.

2. Relation to the literature

This paper makes two principal contributions to the literature. The first lies in its study of the role of public governance in the context of local environmental footprints across countries. This compliments prominent studies based on within-country variation. Burgess et al. (2012) point to the importance of weak governance in exacerbating deforestation in Indonesia, Souza-Rodrigues (2015) shows that different policy choices by the government can have very different levels of efficacy in terms of avoided forest loss in the Amazon, and Lipscomb and Mobarak (2017) document how governance matters for river pollution in Brazil. Recent studies on petroleum extraction in the US have revealed associations with methane leakage, water contamination and deforestation (Allred et al., 2015; Muehlenbachs et al., 2015; Mason et al., 2015), as well as impairment of ecosystem services related to wildlife habitats, bio-diversity and landscape connectivity (Allred et al., 2015; Finer et al., 2008; Finer and Orta-Martínez, 2010; Rooney et al., 2012).[6] Aragón and Rud (2013) find a negative association between gold mining and the total factor productivity of local farmers in Ghana.[7]

[5] France, in 2017, was one of the first countries to announce it would halt all licensing of petroleum exploration within its territory: Oil&GasJournal, Dec20th,2017, accessed on August 13, 2019. Also Costa Rica, Denmark, Ireland, New Zealand and Spain have made commitments to limit future oil exploration.

[6] There is growing concern around the use of public policy to open up otherwise protected or environmentally precious public lands to oil and gas drilling and the impact this can have on forest cover and the local environment. See for example coverage in the US: https://westernlaw.org/defending-wildlands/protecting-public-lands/north-fork-valley-oil-gas-challenge-co/ Accessed: Sept 20, 2019.

[7] In terms of anecdotes, the Obama administration’s rejection of the Keystone XL pipeline exemplifies the role strong democratic institutions can play in limiting the environmental impacts of oil activities, as it was preceded by pressure from activists and politicians in Congress (Time Magazine, President Obama Announces Rejection of Keystone XL Pipeline, 2015). In contrast, Peru has been criticized for paying too little attention to its indigenous people and the local environment during expansions of oil exploration (The Economist, 2008; Finer et al., 2013). Indonesia grabbed international headlines due to alleged corruption in a project seeking to clean up toxic substances around wells drilled by Chevron (Financial Times, Chevron staff arrested in Indonesia,

Our global data allow us to investigate the role of cross-country differences in public governance, with forest loss being measurable and comparable across many countries. Our findings are in line with the existing literature, as we find substantial local environmental impacts of oil drilling. However, we also find that the extent of this negative externality varies significantly with the quality of public governance across countries. Our results are in line with a large economics literature that have found well-functioning and inclusive political institutions to be critical for economic development (Acemoglu et al., 2005).

The second principal contribution of this paper lies in its investigation of the role of company characteristics related to corporate governance and ESG. In spite of a growing theory literature on "private politics" and self-regulation by companies (Baron, 2001, 2010; Egorov and Harstad, 2017), there is surprisingly little empirical work that directly estimates the effect of (public) governance versus corporate governance on environmental outcomes.[8] Our analysis regarding ESG is also related to work that investigates the role of multinational corporations and foreign direct investment (FDI) into developing countries. The literature proposes two competing hypotheses. The "pollution haven" hypothesis suggests that investors are attracted to countries with lax environmental regulations (Javorcik and Wei, 2004; Wagner and Timmins, 2009). The "pollution halo" hypothesis states that foreign investors might bring universal environmental standards, as well as environmentally-friendly technology and management practices to their host countries (Birdsall and Wheeler, 1993; Zarsky, 1999). There is some evidence that stricter environmental safeguards deter investment (Chung, 2014; Hanna, 2010), while more lax domestic public regulation can lead FDI to have a greater environmental footprint (Zugravu-Soilita, 2017). On the other hand, stricter public regulation can bring benefits in terms of technological upgrading (Poelhekke and Van der Ploeg, 2015).

Our results do not provide support for the "pollution halo" hypothesis. Instead, we find that variation in company characteristics is not associated with better local environmental footprints. Our study thus offers historical evidence that goes against much of the rhetoric around ESG, which propose that companies might uphold higher environmental standards than laws and public regulations require. This finding has two, equally valid, interpretations: (i) presumptively 'responsible' companies do not deforest less than other companies, and/or (ii) the circumstances related to weak public governance in the drilling locations are hard to overcome even for such 'responsible' companies. In either case, our results recommend caution regarding the difference companies alone may achieve relying on historic approaches to self-regulation.[9]

3. Context, data and empirical strategy

3.1. Context

In this subsection we explain potential direct and indirect effects of oil drilling on deforestation. We also lay out some of the trade-offs that companies face, and discuss whether deforestation may be a good proxy for local environmental footprints more generally.

Direct impacts are those related to the drilling of the oil wells themselves, including clearing space for drilling platforms, oil derricks, holding tanks, base camps, sub-bases, and heliports. Seismic lines and detonation of seismic explosives, both needed to collect seismic data, require deforestation. The same is true for the clearing for access roads, transport routes and pipelines, including also their construction. A last type of direct impacts to mention is contamination from oil spills and wastewater discharges, which may have knock-on effects on forests. The clearing related to all the above can have consequences such as habitat loss and fragmentation. *Indirect impacts* include developments related to oil activities, such as roads and pipeline routes, that may cause better access to previously remote areas. In turn, such access can trigger, for example, logging, hunting, cattle farming, agricultural development, migration and urbanization.[10]

When developing oil fields in forests, companies are confronted with a series of *trade-offs*, as limiting the local environmental footprint typically will require extra costs and the use of advanced technology. For example, Finer et al. (2013) suggest best practices, which include the making of adequate development plans, the use of subsurface computer models and extended reach drilling (ERD), putting limits on road construction, camp sites, transportation, as well as cleaning-up of sites and considerations of ecological and social factors.

Avoiding degradation or facilitating restoration of the local environment can involve considerable costs. Alberta in Canada has introduced regulation to protect the caribou, a large reindeer, including provisions around deforestation. Bošković and Nøstbakken (2017) estimate that the total net present value cost of this regulation exceeded \$1.15 billion for oil leases sold between 2003 and 2012, as producers paid on average 24% less for regulated leases.[11] Canada has also introduced mandatory Environmental Impact Assessments (EIAs) to ensure that active mitigation plans are pursued, and oil companies have engaged in reforestation programs where more than 12 million trees have been planted (Poveda, 2015). Raimi et al. (2021) find considerable cleaning-up costs across 19,500 oil and gas wells in the U.S.. The median decommissioning costs for plugging was about \$20,000 per well, while median plugging and surface reclamation costs were about \$76,000 per well. They find costs of more than \$1 million per well in some rare cases. The examples above point to considerable costs in reducing the local environmental footprint. It is easy to imagine that strong public

2012; The Wall Street Journal, Murray Hiebert, Indonesia's Skewed Case Against Chevron, 2014).

[8] Portney (2008) provides an overview of the literature on CSR. Despite little work exploring how corporate governance can alter environmental externalities, there is a large body of empirical work that has investigated the impacts of CSR on financial performance; Friede et al. (2015) review more than 2000 studies and Margolis et al. (2007) review 167 studies. Another branch of the literature has studied the origins of CSR. For example, Liang and Renneboog (2017) find that the CSR-ratings of companies and the legal origin of their home countries show strong correlations. In terms of market-based regulation, as an alternative to command and control policies, Bui and Mayer (2003) find little effect of the Toxics Release Inventory (TRI) in the US. TRI provides the public with a database on toxic emissions.

[9] As we study the environmental impact conditional on drilling taking place, our results are not informative about the "pollution haven" hypothesis.

[10] For more on direct impacts, see Allred et al. (2015), Bošković and Nøstbakken (2017), Butt et al. (2013), E&P Forum/UNEP (1997), Finer et al. (2008), Finer and Orta-Martínez (2010), Finer et al. (2013), Melstrom (2017), and references therein. For more on indirect impacts, see for example Finer and Orta-Martínez (2010), Finer et al. (2015), and references therein. In addition to the published paper we list above, there are plenty of anecdotes reported in news paper articles on these direct and indirect effects. For example, The Guardian, 2015, Roads are encroaching deeper into the Amazon rainforest: "Oil and gas access roads in western Amazon could open up 'Pandora's box' of environmental impacts" and "Oil and gas access roads, particularly in the Ecuadorian Amazon, cause both direct forest loss and indirect impacts from subsequent colonization, illegal logging, and over-hunting".

[11] Bošković and Nøstbakken (2017) explain the nature of the costs of protecting the local environment in the Alberta case:

> Operationally, the zones impose constraints on activities that support extraction, meaning that producers incur costs they would not incur outside the zones.[] Examples include limiting the clear cutting of forests, specifying how transport routes – such as roads and pipelines – must circumvent caribou migration routes and habitats, and limiting the seismic disturbances from drilling by restoring seismic lines and well sites to original conditions as soon as possible. All these costly activities come in addition to what the firms would do in the same situation but outside the caribou protection zone.

institutions may be needed to make companies incur such costs via regulation, rules or fees, but also their enforcement.

In this paper, we consider the size of *the local environmental footprint* around oil wells, measured in the form of deforestation. The motivation behind studying deforestation is twofold. First, deforestation is in itself an example of an environmental 'bad', whereby the social costs and private costs do not align.[12] Although deforestation at a large scale is not the focus of our paper, the scatter plot presented in the upper panel of Figure A.1 suggests a correlation between the *average forest loss per well* in our sample and the *Tree Cover Loss Index* from the *Environmental Performance Index* (EPI) of Yale University, both at the country-level. This suggests that what happens around each well may also be reflective of forest loss more generally at the country level.

The second part of the motivation for studying deforestation, is that deforestation may be a proxy for how governments and companies approach environmental externalities more generally. In contrast to other environmental hazards, deforestation comes with the major strength that we can observe it with the same high spatial resolution and quality across all countries. At the country-level, the *Environmental Performance Index* (EPI) of Yale University offers a ranking of countries according to their general environmental performance.[13] In the lower panel of Figure A.1, we plot the *average forest loss per well* in our sample against the EPI ranking in 2016. As expected, countries with good environmental performance, i.e. those located towards the left in the figure, typically have lower deforestation around the wells in our sample. If anything, this suggests that the deforestation we observe in our data may provide more general insights on environmental concerns.

3.2. Data

Data on oil and gas exploration drilling is provided by Wood Mackenzie Limited (Wood Mackenzie, 2011).[14] The data set distinguishes between wells that discover oil and/or gas, dry holes, and tight holes (where discovery information is kept secret). In our data set, a discovery is defined according to the industry standard: sufficient oil or gas for commercial production. 76% of the wells in our sample lead to discoveries (62% in the entire data set). Drilling an exploration well takes on average 47 days in our sample and in the entire data set. We do not observe extraction, but Arezki et al. (2017) report that the delay between giant oil discoveries and start of production on average is 4–6 years. We focus on oil exploration due to the benefits of data availability and the quasi-random nature of commercially viable discoveries.

Forest loss is detectable from satellites and therefore available globally. Data on global forest cover and forest change for the period 2001–2018 based on images of 30 m x 30 m resolution from the Landsat satellite is provided by Hansen et al. (2013). Forest loss is defined as a change from forest to non-forest state at the single pixel-level, recorded annually by a dummy variable. Forest state is defined as vegetation taller than 5 m. For each year, we calculate the percentage of the area surrounding a well that changes from forest state to non-forest state. This is our measure of annual forest loss.[15] We limit our analysis to the impact of oil drilling on forest loss, due to lack of global data on other environmental impacts such as oil spills, or the contamination of the ground water which has been found to be present in the context of shale gas in the U.S. (Muehlenbachs et al., 2015).

To measure public governance, we use as our benchmark measure the democracy scores from the Polity IV database (The Polity IV Project, Center for Systemic Peace, 2016). The democracy indicator ranges from 0 (low-measure) to 10 (high measure) and rates the presence and quality of institutions that enable citizens to express preferences about alternative policies, exercise constraints on the executive branch of government, and guarantee civil liberties to all citizens.

For our baseline estimates we use the average democracy score in the 1990s, the decade preceding our period of analysis. For illustration purposes in the graphs, we define "low" and "high" democracy scores as a score below and above the sample median, respectively. In our regression analysis we measure the democracy level as the deviation from the sample mean of 7.7, and the coefficients for the variables not interacted with democracy can then be interpreted to be the total effect for a country with a democracy score equal to the sample mean. See Table A.3 for the democracy scores across the countries in our sample.

As an alternative measure of public governance, we use the polity2 score (The Polity IV Project, Center for Systemic Peace, 2016). This score captures authority characteristics of states on a 21-point scale, where −10 is most autocratic (hereditary monarchy) and +10 is most democratic (consolidated democracy). The Polity scores are sometimes converted into three regime categories, i.e. "autocracie" (−10 to −6), "democracies" (+6 to +10), and "anocracies" for the remaining values (−5 to +5 and three special values: −66, −77 and −88). The Polity scores are based on underlying measures that record key qualities of executive recruitment, constraints on executive authority and political competition. The Polity data cover only the institutions of central government and political groups acting within that authority.[16] In addition, we also use the six WGI dimensions from the The World Bank (2020) that report aggregate and individual governance indicators for over 200 countries and territories over the period 1996–2019.

Our measures on public governance are broad and capture different aspects of institutions. The idea is that these measures are correlated with public governance and environmental protection. We have focused on democracy scores, because these arguably capture fundamental aspects of institutions, following North and Thomas (1973) and Acemoglu et al. (2005) in emphasizing fundamental versus proximate explanations. Aspects such as control of corruption may be seen as a result of a well-functioning democracy.

In two robustness exercises, we include GDP per capita from the World Bank or a measure of environmental stringency from the World Economic Forum (2016) alongside the measure of democracy. The latter runs from 1 (very lax) to 7 (very stringent), and we use both the value directly and the rank. The value is taken as an average of the available data sets, i.e. the years 2008, 2009, 2011 and 2013. The rank of each country is taken from the 139 countries comprised in the data set in ascending order, such that a lower number means more environmental stringency.

To capture variation in corporate governance, we consider the following categories of companies and drilling operations: (1) national oil companies (NOC); (2–3) the seven so-called international supermajors with and without their subsidiaries and acquisitions (IOC+ and IOC); (4) members of the global oil and gas industry association committed

[12] What is the value of deforestation? A technical background report for *The Changing Wealth of Nations 2021* publication by the World Bank explains the effects of forest degradation on ecosystem services in general. That paper estimates a loss of US$111 per ha deforestation per year.

[13] The EPI uses 40 performance indicators across 11 issue categories to rank countries within three policy areas: climate change, environmental health, and ecosystem vitality.

[14] The Pathfinder database from Wood Mackenzie Limited (Wood Mackenzie, 2011) that we use is considered to be the most comprehensive existing database on oil and gas exploration drilling, covering in total over 120,000 oil and gas exploration wells across 114 countries drilled in the period 1884–2010. For the United States, onshore wells are reported only for Alaska.

[15] Note that a switch from non-forest state to forest state is, however, not recorded as forest gain annually. The forest gain data from Hansen et al. (2013) is a dummy variable indicating whether a given pixel experienced forest gain in the period 2000–2018, which is used to construct the dependent variable. Hence, pixels can be "deforested" several times in our period.

[16] For further information, see https://www.systemicpeace.org/polityproject.html.

to high environmental standards (International Petroleum Industry Environmental Conservation Association or IPIECA); and (5) companies listed on a stock exchange (listed). These company characteristics are likely to be correlated with aspects of corporate governance that is relevant for the companies' attention to ESG, which we do not observe directly.[17] All these characteristics are measured as dummy variables taking one if the company belongs to the indicated group, and zero otherwise.[18]

Our corporate governance measures allow us to test a variety of forces beyond the profit motive. For nationally-owned companies (*NOC*), they may have strategic objectives, but are unlikely to face the same extent of shareholder or ESG pressures on environmental standards, compared to others. Our remaining measures are chosen as categories of presumptively more responsible corporate behavior. IOCs, IPIECA members, publicly listed companies, and companies with high ESG scores are all potentially more exposed to scrutiny and pressure from corporate boards, shareholders, regulators and the public, compared to companies not in each of these groups.

The seven supermajor international oil companies, comprising our *IOC* category, have widely-recognized brands and are often seen as leaders in technology, innovation and standard setting. They may therefore be more sensitive to improving their environmental practices, seeking to protect their reputation and adopting ESG criteria throughout their corporate decision-making earlier than smaller, less prominent companies.

Listed companies may similarly face reputational risks associated with shareholder and customer scrutiny. Additionally, they may also be subject to extra regulatory checks and disclosure requirements, compared to non-listed entities.

IPIECA is an association dedicated to advancing social and environmental performance in the global oil and gas sector by advancing climate action, environmental responsibility and social performance. IPIECA has membership principles to which corporate and associate members have to abide. Within its set of goals, IPIECA is explicitly targeting forests. Members have to "support the aims of the UN Convention for Biological Diversity" and manage responsibly "operational impacts on the natural environment and ecosystem services". We interpret this to include limiting deforestation. Only a subset of the companies in our sample are members of this global oil and gas industry association (see footnote 18). Given the voluntary nature of such membership, we expect those companies to be associated with corporate practices that lead to lower levels of deforestation around drilling sites.[19]

We do not observe companies' efforts in protecting the environment directly. Instead, we follow the approach we used above for public governance, and estimate the heterogeneity in forest loss related to oil exploration with respect to the different company characteristics listed above.

Data not described in this section is described in the table note of the relevant tables.

Our sample includes all wells with positive tree cover in their 1 km^2 vicinity (a radius of about 564 meters around each well) in 2000, the starting year of the forest loss data.[20] In our main analysis, we focus on forest loss within a buffer of 5 km^2 around each well. We show robustness checks varying this down to 1 km^2, like Allred et al. (2015), 2 km^2 and up to 10 km^2. We use forest loss data for the period 2001–2018 and limit the sample to wells that were drilled in the period 2004–2010. Thus, the forest loss around each well can be observed for a minimum of three years, and a maximum of nine years, before drilling. We obtain a balanced dataset with at least three years of pre-drilling tree cover loss data, to test for parallel pre-trends. We end up with a maximum of 55 countries, 3,101 onshore oil wells and 51,061 well–year observations in our sample, with positive tree cover in a 1 km^2 buffer area, with known drilling results and non-missing democracy scores. We observe 396 different operating companies in our sample. Table A.3 in the appendix lists the countries, the number of wells per country, and their average democracy scores in the 1990s.

Fig. 2 illustrates an example of drilling around a well located in the western Amazon Basin using satellite data. This animation shows the deforestation derived from the construction of infrastructure around exploration wells drilled in this area of the Amazon between 1985 and 2016. In the appendix, we include four maps to provide examples of the wells we observe in the data and to illustrate the buffer size that we use (see Figures A.2–A.5). There is one example from each of the regions Africa, South America, Southeast Asia, and Oceania.

3.3. Identification

We seek to estimate the local environmental footprint of forest loss from oil activities, and in particular test whether the footprint varies depending on the public governance in the host country and the corporate governance of the operating company.

We study annual forest loss in a 5 km^2 circle around each well, which are often drilled in the deep forest. This allows us to focus on the local environmental effects and abstract from possible indirect effects, such as from forest clearance along roads, from urbanization, or from the potential Dutch disease effects discussed by Wunder and Sunderlin (2004).[21]

The principal treatment we consider is oil drilling and its outcomes. All the sites we include receive drilling at some point, but *when* the drilling occurs vary across sites. This means that drilling in itself allows for difference-in-differences estimation, where the sites yet to receive drilling act as control group for the sites that have already received drilling. Our data start in 2001, no sites receive drilling before 2004 and all sites have received drilling by 2010.

[17] We define company categories as follows: Nationally-owned companies (NOCs) includes companies with a state ownership stake exceeding fifty percent. IOCs includes the seven supermajor companies and their subsidiaries–BP, Shell, ExxonMobil, Chevron, ENI, Total and ConocoPhillips. IOC+ includes in addition also companies owned or acquired by the supermajors. The IPIECA category includes all companies in our data that are currently members of IPIECA: Anadarko, BP, BHP Billiton, Chevron, CNOOC Ltd, ConocoPhillips, Eni, ExxonMobil, Hess Corporation, Hunt Oil, Husky Energy, Marathon, Nexen, OMV, Occidental, Pemex, Petrobras, Petronas Carigali, PTTEP, Repsol YPF, Santos, Shell, Total, Tullow Oil. IPIECA is a non-profit oil and gas industry association for environmental and social issues established in 1974: www.ipieca.org We define "local" and "large" based on the entire data set on exploration drilling.

[18] We define the company categories in the following way: For nationally-owned companies (NOCs) we include companies with a state ownership stake exceeding fifty percent. For IOCs we include the seven supermajor companies with their subsidiaries–BP, Shell, ExxonMobil, Chevron, ENI, Total and ConocoPhillips. For our IOC+ category we also include companies acquired by the supermajors. Our IPIECA category includes 24 companies currently members of IPIECA in our database: Anadarko, BP, BHP Billiton, Chevron, CNOOC Ltd, ConocoPhillips, Eni, ExxonMobil, Hess Corporation, Hunt Oil, Husky Energy, Marathon, Nexen, OMV, Occidental, Pemex, Petrobras, Petronas Carigali, PTTEP, Repsol YPF, Santos, Shell, Total, Tullow Oil.

[19] Based on the sustainability reports of the IPIECA members in our dataset, Appendix Table A.1 lists very briefly different IPIECA members' respective explicitly stated commitments to preserving forests. Appendix Table A.2 provides two concrete examples of IPIECA members' commitment to preserving forests.

[20] Figure A.6 presents a histogram of the tree cover in a 1 km^2 area around wells in our sample in the year 2000 where we include all wells with positive tree cover. In Table A.25 we run a robustness check where we instead limit the sample to wells with positive forest loss in their 1 km^2 vicinity in our sample period, and our findings hold.

[21] Recent work has shown that major new road building can lead to significant indirect forest loss along the highway routes (Asher et al., 2018).

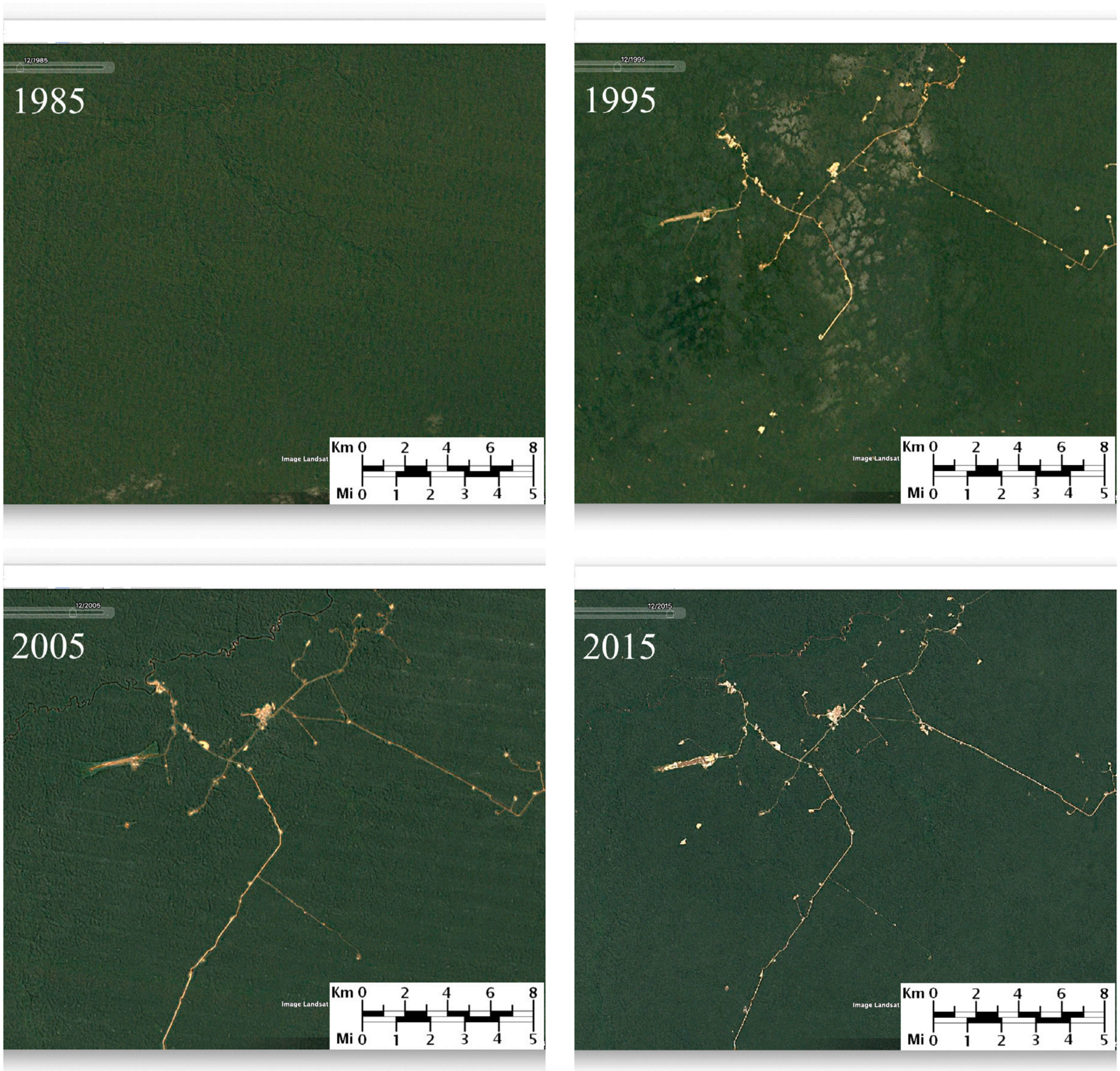

Fig. 2. Satellite picture of oil drilling area in Brazil 1985–2015 (3BRSA-0670-AM well, lat:-4.8794, long:-65.2894).
Source: Credit: Made with animation and Landsat satellite images via EarthTime.org, courtesy of the U.S. Geological Survey and EarthTime.org.

To estimate the effect of drilling, we estimate the following simple difference-in-differences model:

$$df_{ijkt} = \beta_1 post_{ijkt} + \alpha_i + \vartheta_t + u_{ijkt} \tag{1}$$

where i indicates the well, j indicates the country where the well is drilled, k indicates the operating company of the well and t indicates the year when the well was drilled. Note that j nests i, but we include it for clarity. df is measured in percent of the 5 km^2 circle surrounding the well. To allow for drilling preparations, the *post* dummy takes value one in the year before the drilling is recorded and in all succeeding year. α_i represents well fixed effects, which control for unobserved time-invariant characteristics that vary at the well or country level, such as geographic location. ϑ_t represents time fixed effects, which control for common time-varying shocks across wells, such as global changes in technology and prices.

Drilling decisions and forest loss may both be affected by unobservable factors, which would bias our estimates. For example, the choice to drill in a particular country may be affected by the relative stringency of domestic regulations, which are correlated both with institutional quality and forest loss. For example, the "pollution haven" hypothesis posits that investors may be drawn to countries with weaker environmental rules (Javorcik and Wei, 2004). A recent paper finds that oil drilling responds to institutional quality (Cust and Harding, 2020). On the company side, the quality of corporate governance may be correlated with factors affecting forest loss through the selection of drilling sites within countries, such as remoteness or population density.

To break the correlation between potential omitted factors in our error term and our explanatory variables of interest, we utilize the natural experiment of whether an exploration well yields a discovery or not. Conditional on drilling a well, there is in our data a likelihood of about 3/4 of discovering oil. As we observe commercially viable discoveries, striking oil will mean a high likelihood of continued presence of oil companies. In other words, whether a well will lead to a discovery is ex-ante uncertain and there is therefore an element of randomness shifting a site into one of two groups: the group of sites receiving continued presence of oil companies in a development phase and then an extraction phase, or the group of sites that will be abandoned by the oil industry. As such, discovery status provides us with quasi-random variation in the likelihood of oil activities in the years after drilling.

This helps us separate out oil activities from other potential factors driving forest loss around the drilling sites. To this end, we estimate the following difference-in-differences model:

$$df_{ijkt} = \beta_1 post_{ijkt} + \beta_2 post_{ijkt} disc_{ijkt} + \alpha_i + \vartheta_t + u_{ijkt} \quad (2)$$

where membership in the treatment group is defined by $disc_{ijkt}$, which is a dummy taking 1 if the well leads to a economically viable discovery, as reported in our drilling data. Note that the effect of the discovery dummy itself is captured by the well fixed effect. β_2 gives the effect on forest loss of the oil activities associated with striking oil compared to having drilled a well but not striking oil. The identifying assumption for β_2 in Eq. (2) is that the trend in forest loss around discovery sites would be parallel to the forest loss around non-discovery sites in absence of discoveries.

We investigate the role of public and corporate governance by allowing for heterogeneity in the effect of oil activities:

$$\begin{aligned} df_{ijkt} =& \beta_I post_{ijkt} disc_{ijkt} inst_j + \beta_K post_{ijkt} disc_{ijkt} comp_k \\ &+ \beta_1 post_{ijkt} + \beta_2 post_{ijkt} disc_{ijt} + \beta_3 post_{ijt} inst_j + \beta_4 post_{ijt} comp_j \\ &+ \beta_5 comp_k + \alpha_i + \vartheta_t + u_{ijkt} \end{aligned} \quad (3)$$

$inst_j$ is democracy score for the 1990s, prior to the period in which the drilling we study took place to avoid any reverse causality. It is measured as the difference to the sample mean. $comp_k$ is one of the measures of the corporate governance of the operating company, as discussed in Section 3.2. We use values observed in 2016, due to data limitations. Note that the effect of the institutions measure is captured by the well fixed effect, while this is not the case for the company characteristic and we therefore include it separately. In robustness checks, we show that our results are robust also to the inclusion of company fixed effects, allowing us to estimate the effect of public governance within companies, as well as to company-year and country-year fixed effects.

The coefficients β_I and β_K are coefficients of interest, showing the heterogeneity in the effect of oil activities on forest loss related to public and corporate governance, respectively. The identifying assumption is that these measures would not be related to differential trends in forest loss around discovery and non-discovery wells in absence of the discoveries. We will first present estimates where we allow for heterogeneity in terms of public governance (we set $\beta_K = 0$), and then present estimates where we allow for heterogeneity in terms of both public and private governance.

In all our regressions, standard errors are clustered at the country level to take into account potential spatial and temporal correlation in the error term u_{ijkt}.

3.4. Testing for parallel pre-trends

To test for pre-trends, we estimate Eqs. (2) and (3), exchanging the variable *post* for a trend variable, coded as 1 in 2001, 2 in 2002, and so on. We include only observations for the pre-drilling years.[22] We include observations from $t = -2$ and backwards, as $t = -1$ is likely to have been used for drilling preparations. This is consistent with our definition of the post dummy, which takes 1 from $t = -1$ and onwards.

Table A.4 presents the results. In the upper panel, we include interactions between trend and democracy, or trend and corporate governance measures or trend and the discovery dummy. All but one of these interaction terms are statistically insignificant, suggesting that the forest loss around drilling sites in low democracy score countries as well as drilling sites where companies with low corporate governance scores would later drill does not follow different trends than other drilling sites. The one exception is the drilling sites where NOCs will drill later on, which see a steeper trend in forest loss than other drilling sites.

The lower panel brings in discoveries and corresponds to Eq. (3), our equation of main interest. It includes triple interaction terms for democracy and company characteristics. All the coefficients on the triple interaction terms are statistically insignificant, indicating no heterogeneity in pre-trends across discovery and non-discovery sites depending on public or corporate governance.

The lack of different pre-trends with respect to the variables of interest, in particular the triple interactions in the lower part of Table A.4, supports that our identifying assumption is satisfied.

[22] These pre-trend tests follows Muralidharan and Prakash (2017). Pre-drilling forest loss is the closest we get to observe what would have happened in absence of drilling. In addition, we present accumulated marginal effects across the different types of drilling sites, which confirms parallel developments in forest loss before drilling (see Figs. 3–5).

Table 1
Drilling and discoveries.

	(1) All	(2) Result = 1	(3) Result = 0	(4) Dpost*Result
post = 1	0.107**	0.0848	0.0769	0.0844*
	(0.021)	(0.193)	(0.499)	(0.096)
post = 1 × disc = 1				0.0292
				(0.714)
N	51 061	38 807	12 254	51 061
Wells	3101	2360	741	3101
Adj.R2	0.00143	0.00173	0.00144	0.00141

Notes: Tree cover loss before and after exploration drilling in a circle of 5 km^2 around a well. Annual tree cover loss is measured in percent of a 5 km^2 ring around a well. The starting year of exploration drilling is set to $t = -2$. Estimates based on Eqs. (1) and (2); well and year fixed effects included and standard errors clustered at the country level. p-values in parentheses *($p < 0.1$), **($p < 0.05$), ***($p < 0.01$).

4. Results

4.1. Oil activities and forest loss

In Table 1, we present in column 1 the estimate of β_1 in Eq. (1), i.e. the forest loss post drilling compared to pre-drilling around all wells in our sample. On average, a forest cover corresponding to 0.107 percentage points of the 5 km^2 circle around the drilling site is lost every year from the drilling preparations begin. Columns 2 and 3 present the corresponding estimates for discovery wells and non-discovery wells separately. 24% of our sample is non-discovery wells. The coefficients on the post dummy have similar magnitudes in the two samples, but none of them are statistically significant. Column 4 brings in discovery status and presents the estimate of Eq. (2). The coefficient on the interaction term between post and discovery status, β_2, is insignificant, which is unsurprising given the results of column 2 and 3. Thus, surprisingly, there is, on average, no significant difference between the forest loss around discovery wells and non-discovery wells. Even though discovery sites are likely to receive more oil activities in terms of further investments and extraction, the forest is just as intact as if oil had not been found.

4.2. The role of public governance

In Table 2, we expand the analysis of Table 1 by allowing for heterogeneity with respect to the democracy score in the country where the drilling takes place. In column 1, we find that the general increase in forest loss post drilling is higher in countries with low democracy scores. Column 2 and 3 show that this effect is driven by discovery wells only. Column 4 confirms this result as the heterogeneity with respect to the democracy score appears in the triple interaction term. In other words, the lower the democracy scores, the higher the forest loss around discovery wells.

Table 2
Public governance.

	(1) All	(2) Result = 1	(3) Result = 0	(4) Dpost*Result
post = 1	0.113*** (0.001)	0.0984** (0.029)	0.0804 (0.451)	0.0857** (0.041)
post = 1 × inst	−0.0213*** (0.001)	−0.0351*** (0.004)	0.0245 (0.137)	0.0249 (0.124)
post = 1 × disc = 1				0.0418 (0.405)
post = 1 × disc = 1 × inst				−0.0600** (0.029)
N	51 061	38 807	12 254	51 061
Wells	3101	2360	741	3101
Adj.R2	0.00163	0.00229	0.00166	0.00190

Notes: Tree cover loss before and after exploration drilling in a circle of 5 km^2 around a well. Annual tree cover loss is measured in percent of a 5 km^2 ring around a well. $inst$ is a continuous variable that measures the democracy score difference from the sample average democracy score in the 1990s. $disc$ dummy takes the value of 1 if the well leads to a economically viable discovery, as reported in our drilling data. The starting year of exploration drilling is set to $t = -2$. Estimates based on Eq. (3) with $\beta_K = 0$; well and year fixed effects included and standard errors clustered at the country level. p-values in parentheses *($p < 0.1$), **($p < 0.05$), ***($p < 0.01$).

4.3. Public governance vs. corporate governance

In Table 3, we allow for heterogeneity in the effect of oil discoveries both with respect to the democracy score and in terms of measures of corporate governance of the operating company. The idea is to run a 'horse race' between the two types of governance. The first column simply repeats our estimate when we include heterogeneity in terms of democracy score only. In columns 2–6, we allow for heterogeneity in terms of the five proxies for corporate governance described in Section 3.2. We find mixed evidence on the role of the various company characteristics. For example, IOC-status shows some tendency to amplify the forest loss around discoveries, whereas listed status show some tendency to dampen the forest loss.

Across all columns in Table 3, we estimate a stable and statistically significant negative association between democracy and forest loss. Furthermore, this finding turns out to be robust across all measures of public governance that we consider; see Tables A.5 – A.11 for the seven other measures. It also turns out to be robust across the many other robustness checks we do in Section 5. In contrast, we do not find robust evidence that 'better' corporate governance reduce forest loss.

For completeness, we allow in Table 4 for additional interactions between democracy and the corporate governance measures. The finding that countries with lower democracy scores see higher forest loss comes through also in this more flexible model, as seen from the triple interaction term in row 4. From the quadruple interaction term in row 8, we see that IOC status amplifies the role of democracy; these companies are more sensitive to the level of democracy. This surprising result implies relatively more forest loss around wells operated by IOCs in countries with low democracy scores.

In conclusion, presumptively more responsible company types are not found to overcome the influence of domestic governance, or, put another way, we find insufficient evidence to conclude there is a 'pollution halo' effect associated with their presence. Instead our results imply that presumptively more responsible companies are not consistently associated with better environmental outcomes than other companies.

4.4. Magnitudes

In Fig. 3, we present the key finding of this paper: the local environmental footprint due to oil activities, measured as forest loss around drilling sites, vary crucially with the institutional quality of the host country. The figure corresponds to Table 2. The upper left chart shows accumulated estimated marginal effects of drilling for countries with above median democracy scores ($Dhigh = 1$) vs for countries with below median democracy scores ($Dhigh = 0$). Countries like Australia, Brazil and Chile would be in the former group, while countries like Angola, Mexico and Mozambique would be in the latter group. In the upper right chart, we show the estimated marginal effects for two specific values of the democracy scores. A country with democracy scores like Angola has twice as much forest loss around drilling sites as a country with democracy scores like Canada. The two lower panels split the effects according to discovery status and show that the difference with respect to democracy scores is much more pronounced for discovery wells.

In terms of magnitudes, Fig. 3 shows that an oil discovery in a country with high democracy score leads to a forest loss of about 4% over the period, whereas non-discovery wells and discovery wells in countries with low democracy scores lead to forest loss of about 6% over the period. Our 5 km^2 circle around each drilling site covers an area of about 1,000 American football fields. The difference between the groups is thus about 20 football fields over 12 years.

Fig. 4 shows accumulated estimated marginal effects split according to our measures of corporate governance, corresponding to Table 3. Across IOCs and non-IOCs, we see large differences in the accumulated forest loss, with IOCs clearing at 15% after 13 years and non-IOCs at 5%. A difference of 8% corresponds to about 80 American football fields. The differences with respect to IPIECA membership and listed status are smaller, but go in the same direction: the companies with presumptively better corporate governance clear more of the forest.

Finally, we present in Fig. 5 results for forest loss around wells drilled by IOCs, corresponding to the estimates in the table including also the quadruple interaction (Table 4). The left panel presents the results for wells drilled by IOCs, with and without discoveries and in countries with high and low democracy scores. Wells drilled by IOCs in countries with low democracy scores lead to much forest loss, with 10% for non-discovery wells and 25% for discovery wells in the course of 12 years. In comparison, wells drilled by IOCs in high democracy countries and wells drilled by non-IOCs lead to about 4%–5% forest loss in the same period.

The graphs in this section communicate the two principal insights of this paper. First, public governance affects forest loss as expected, the better the institutional quality the lower the forest loss. Second, there is no evidence of less forest loss around drilling sites operated by companies with presumptively better corporate governance. If anything, drilling sites operated by such companies see more rather than less forest loss due to oil drilling, in line with our earlier conclusion that we fail to find support for a 'pollution halo' effect in the data.

5. Threats to identification and robustness checks

5.1. Alternative measures of public governance

In Tables A.5–A.11 in the online appendix we present results supporting our baseline finding across alternative measures of institutional quality. In Table A.5 we investigate the role of polity, where −10 means autocratic ('low quality') and 10 means democratic ('high quality'). Tables A.6–A.11 use The Worldwide Governance Indicators, which provide measures on six different dimensions of governance: Voice and Accountability (VA), Political Stability and Absence of Violence (PV), Government Effectiveness (GE), Regulatory Quality (RQ), Rule of Law (RL) and Control of Corruption (CC) (The World Bank, 2020). All six measures run from −2.5 to 2.5, with higher values indicating a better quality of governance. For all seven indicators, the result support our findings in the baseline model: an oil discovery leads to higher forest loss in countries with lower quality of their public governance. It follows that disentangling which aspects of institutions that matter most is not an easy task, and we leave this for future research.

Table 3
Public governance vs. corporate governance.

	(1) All	(2) NOC	(3) IOC	(4) IOCplus	(5) IPIECA	(6) listed
post = 1	0.0857**	0.113***	0.106*	0.0948*	0.0486	0.0293
	(0.041)	(0.005)	(0.063)	(0.056)	(0.249)	(0.585)
post = 1 × disc = 1	0.0418	0.0595	0.0248	0.0251	0.0555	0.0690
	(0.405)	(0.375)	(0.590)	(0.590)	(0.198)	(0.192)
post = 1 × inst	0.0249	0.0256*	0.0264	0.0266	0.0223	0.0225
	(0.124)	(0.099)	(0.118)	(0.118)	(0.134)	(0.143)
post = 1 × disc = 1 × inst	−0.0600**	−0.0654**	−0.0568**	−0.0575**	−0.0577**	−0.0598**
	(0.029)	(0.047)	(0.016)	(0.019)	(0.033)	(0.031)
post = 1 × c.comp		−0.0170	0.175	0.176	0.134***	0.175**
		(0.844)	(0.481)	(0.459)	(0.006)	(0.040)
post = 1 × disc = 1 × c.comp		−0.131	0.790*	0.622	−0.0307	−0.0788*
		(0.331)	(0.075)	(0.123)	(0.613)	(0.087)
N	51 061	50 337	50 337	50 465	51 061	51 061
Wells	3101	3057	3057	3065	3101	3101
Adj.R2	0.00190	0.00196	0.00236	0.00221	0.00199	0.00203

Notes: Tree cover loss before and after exploration drilling in a circle of 5 km^2 around a well. Annual tree cover loss is measured in percent of a 5 km^2 ring around a well. *inst* is a continuous variable that measures the democracy score difference from the sample average democracy score in the 1990s. *disc* dummy takes the value of 1 if the well leads to a economically viable discovery, as reported in our drilling data. *comp* dummy takes the value of 1 if the company belongs to the group indicated in the column heading. The starting year of exploration drilling is set to $t = -2$. Estimates based on Eq. (3); well and year fixed effects included and standard errors clustered at the country level. p-values in parentheses *($p < 0.1$), **($p < 0.05$), ***($p < 0.01$).

Table 4
Public and corporate governance interaction.

	(1) NOC	(2) IOC	(3) IOCplus	(4) IPIECA	(5) listed
post = 1	0.115***	0.105*	0.0944*	0.0505	0.0312
	(0.003)	(0.060)	(0.054)	(0.191)	(0.520)
post = 1 × disc = 1	0.0695	0.0224	0.0227	0.0503	0.0657
	(0.330)	(0.627)	(0.628)	(0.249)	(0.234)
post = 1 × inst	0.00639	0.0298	0.0300	0.0277	0.0320
	(0.221)	(0.108)	(0.106)	(0.130)	(0.197)
post = 1 × disc = 1 × inst	−0.0646*	−0.0549**	−0.0552**	−0.0519**	−0.0530*
	(0.065)	(0.021)	(0.022)	(0.020)	(0.066)
post = 1 × c.comp	0.0129	0.0912	0.0666	0.163***	0.191**
	(0.685)	(0.471)	(0.564)	(0.005)	(0.011)
post = 1 × disc = 1 × c.comp	−0.0801	0.255**	0.307***	−0.0293	−0.0140
	(0.288)	(0.022)	(0.005)	(0.647)	(0.760)
post = 1 × inst × c.comp	0.0747***	−0.0933	−0.0739	−0.0569	−0.0627
	(0.003)	(0.133)	(0.187)	(0.225)	(0.223)
post = 1 × disc = 1 × inst × c.comp	0.0222	−0.138***	−0.113***	−0.00839	−0.0312
	(0.331)	(0.000)	(0.004)	(0.827)	(0.239)
N	50 337	50 337	50 465	51 061	51 061
Wells	3057	3057	3065	3101	3101
Adj.R2	0.00254	0.00280	0.00259	0.00220	0.00251

Notes: Tree cover loss before and after exploration drilling in a circle of 5 km^2 around a well. Annual tree cover loss is measured in percent of a 5 km^2 ring around a well. *inst* is a continuous variable that measures the democracy score difference from the sample average democracy score in the 1990s. *disc* dummy takes the value of 1 if the well leads to a economically viable discovery, as reported in our drilling data. *comp* dummy takes the value of 1 if the company belongs to the group indicated in the column heading. The starting year of exploration drilling is set to $t = -2$. Estimates based on Eq. (3) expanded with interaction between public and corporate governance; well and year fixed effects included and standard errors clustered at the country level. p-values in parentheses *($p < 0.1$), **($p < 0.05$), ***($p < 0.01$).

5.2. Alternative measure of corporate governance

To complement the measures of corporate governance used above, we bring in an *ESG* measure from CSRHub. The measure seeks to capture the environmental, social, and governance performance of a given company. It runs from 0 to 100, reflecting ranking-percentiles, where the value of 100 is the most positive ESG score. Thus, the measure allows for comparisons within the same industry. We obtain the CSRHub ESG score for 109 of the 396 companies in our sample and 90% of the IPIECA companies.[23] We include it in the form of a dummy

[23] In the analysis, we use the latest ESG value that is available by typing the company's name in their advanced search engine. As this value corresponds to the 2022 ranking, there is an obvious potential weakness of the performance being measured after our sample ends. The score may not be representative for the company's ESG performance in our sample-period as the company may have changed. There may also be reverse causality, where low deforestation results in a high ESG score. We still choose to use this measure as ESG measurement seems to be rapidly developing and historical ESG data with the same quality and coverage are hard to come by. Table A.30 provides more information on the ESG measure.

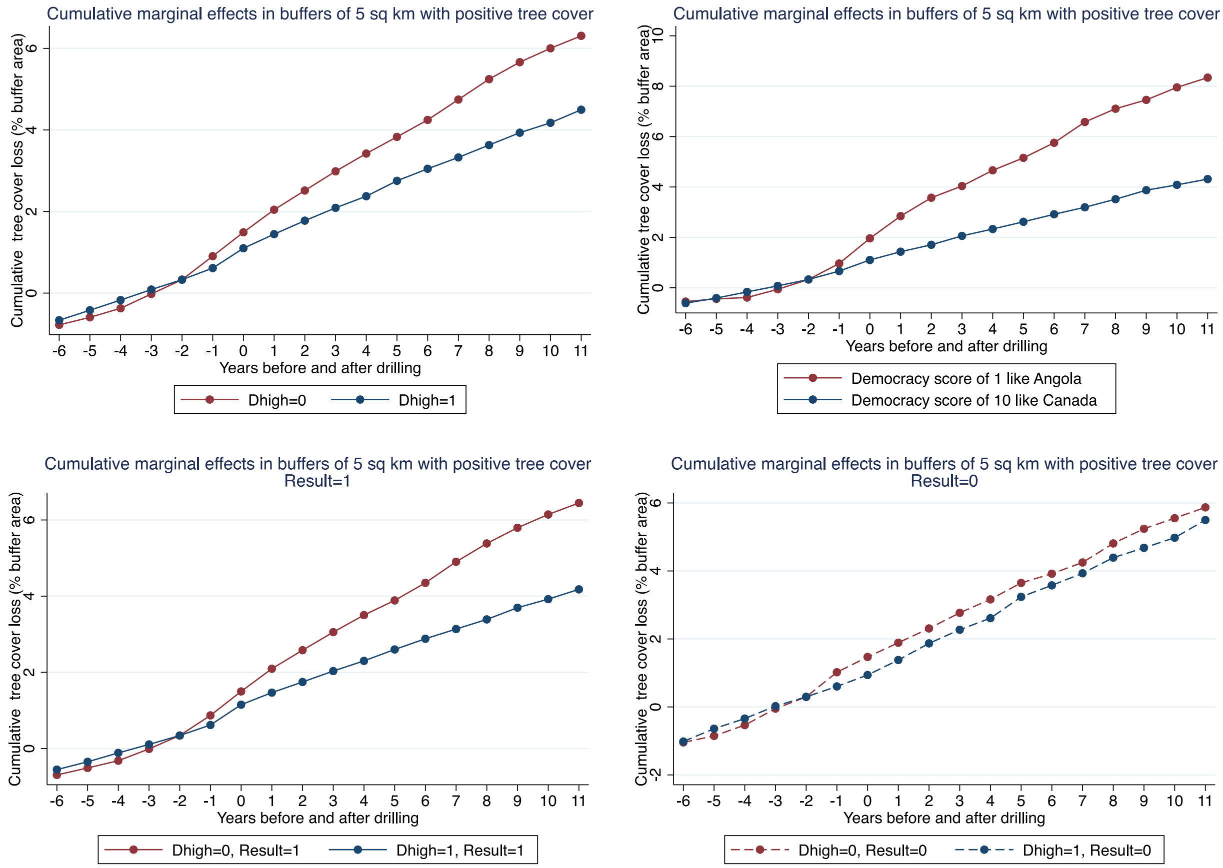

Fig. 3. Tree cover loss before and after exploration drilling in a circle of 5 km^2 around a well. Cumulative tree cover loss is measured in percent of a 5 km^2 ring area around a well. The starting year of exploration drilling is set to $t = -2$. "Dhigh" refers to countries with a democracy score above median. *Result* dummy (indicated *disc* in tables) takes the value of 1 if the well leads to a economically viable discovery, as reported in our drilling data. Well and year fixed effects included. Using the *margins* function in Stata, we estimate marginal effects of each corporate governance measure on tree cover loss. This gives us the average effect per year across discovery results and institutional qualities. We compute the cumulative sum of the resulting marginal effects starting at $t = -2$, while we subtract those from $t = -3$ to $t = -6$. This figure corresponds to Table 2.

variable, taking one if the company's score is above the median score in our sample (72), and zero otherwise.

In Table A.31, we present our baseline model with the CSRHub ESG dummy as the measure of corporate governance (column 1).[24] We find that the interaction between the discovery dummy and the democracy score is negative and significant as usual, and the coefficient is in magnitude also quite similar to our other results. The coefficients on the ESG interaction with the discovery dummy is negative and non-significant. We then undertake all the robustness checks we do in this paper (column 2–11), and the results are robust. We conclude that our results are robust to using CSRHub's ESG measure to measure corporate governance.

5.3. On potential omitted variable bias

In this section we discuss potential threats to our identification and how we have sought to deal with them. We control for cross sectional heterogeneity, including country specific factors not varying over time, by the inclusion of well fixed effects. We take out common global shocks, like the oil price, by the inclusion of year fixed effects. One remaining concern could be that country specific changes over time are correlated with both forest loss and drilling, for example specific policy reforms. To deal with this, we include in Tables A.12–A.13 country-specific time-trends in addition to the well and year fixed effects. In Tables A.14–A.15 we include country-year fixed effects, which take out the effect of any country-specific shocks varying from year to year.

We might further worry that company characteristics and country characteristics are conflated. This is addressed directly by our estimates presented in Section 4.3, where we investigate the importance of different company characteristics and do not find robust heterogeneous effects, as we do for the quality of democracy. Furthermore, we control for unobservable characteristics of companies by including company and company year-fixed effects in Tables A.16–A.19.

We might also worry that natural geography correlates with either public governance measures or corporate governance measures. For example, many countries in the tropics may have both different types of forest and weaker democratic institutions. We might then conflate the two and wrongly assign differences due to characteristics of tropical forest to the quality of institutions. Similarly, different companies may systematically operate in different geographical environments depending on for example their technology and expertise, which may again correlate with our measures of corporate governance. Finally, as we use discoveries for identification in this paper, another worry is that the natural geography around the wells is correlated with both discoveries and forest loss. To deal with these concerns, we include in Tables A.20–A.21 interactions with a dummy taking 1 for all wells located in biomes classified as "wild woodlands" according to the Socioeconomic Data and Applications Center (Ellis et al., 2013), and zero for all other wells. Our results hold up. In fact, it turns out that the correlation between biomes and democracy scores is negligible and we observe a large spread of democracy scores across all biomes (supporting graphs available at request from the authors).

As noted earlier, focusing on areas in the immediate vicinity of the wells should also reduce the scope for omitted variable bias. In Tables A.22–A.24, we show that our results are robust to decreasing the buffer

[24] Table A.32 presents the pre-trend test for the baseline model of Table A.31, showing no evidence of differential pre-trends.

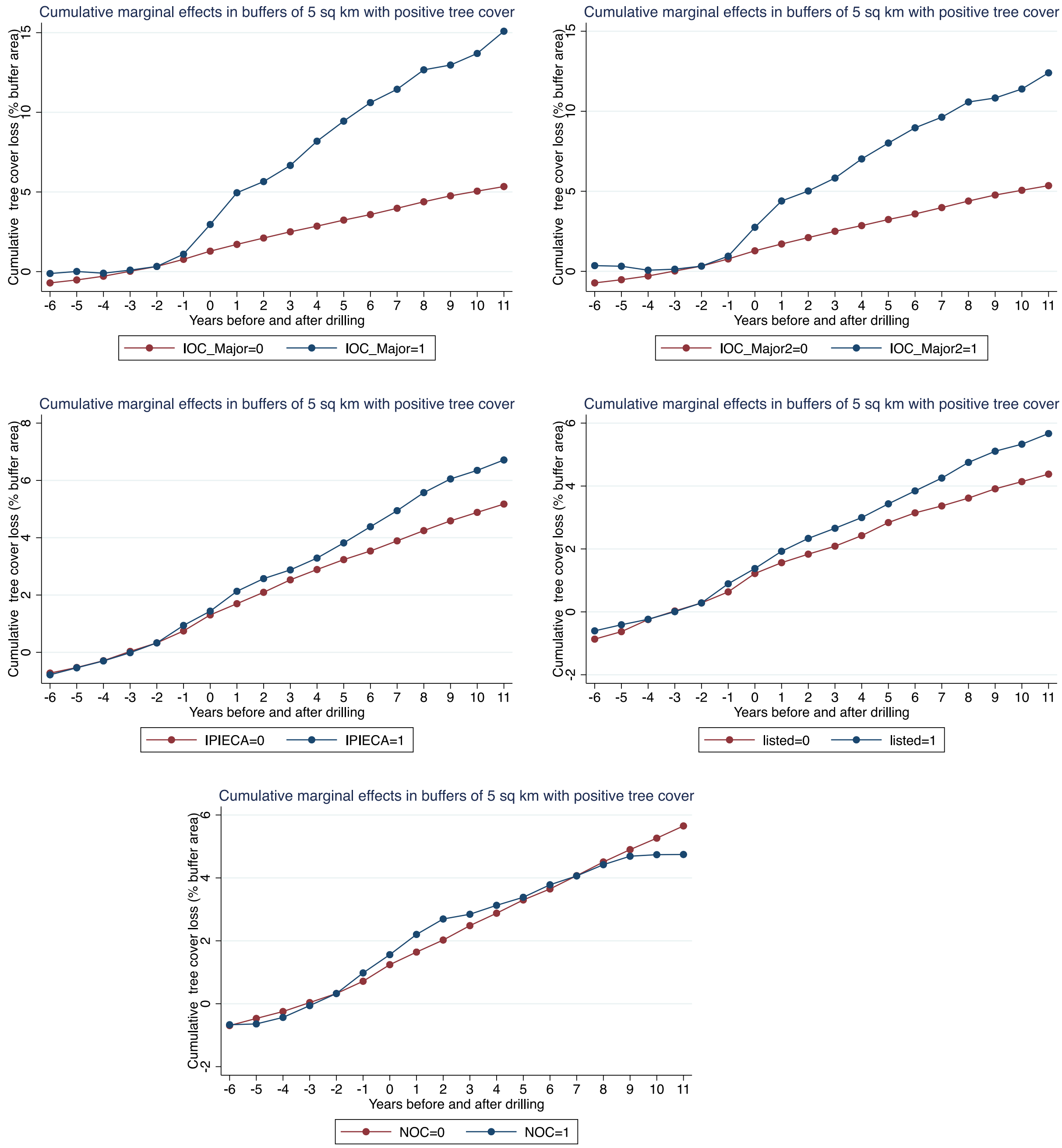

Fig. 4. Tree cover loss before and after exploration drilling in a circle of 5 km^2 around a well. Cumulative tree cover loss is measured in percent of a 5 km^2 ring area around a well. The starting year of exploration drilling is set to $t = -2$. IOC_Major = super major international oil companies (IOC), IOC_Major2 = super major international oil companies including susidiaries and acquisitions (IOC+), $IPIECA$ = companies currently members of IPIECA, $listed$ = companies listed on a stock exchange and NOC = national oil companies. Well and year fixed effects included. Using the *margins* function, we estimate marginal effects of each corporate governance measure on tree cover loss. We compute the cumulative sum of the resulting marginal effects starting at $t = -2$, while we subtract those from $t = -3$ to $t = -6$. This figure corresponds to Table 3.

size around each well to 1 km^2 and 2 km^2 and increasing it to 10 km^2. In Table A.25, we use the 5 km^2 buffers, but include only sites that have experienced some deforestation.

Finally, we investigate whether clustering of wells affect our results. In our baseline regressions, we include areas covering 5 km^2 around each well. This corresponds to a radius of 1.26 km ($\sqrt{\frac{5km^2}{3.14}}$). In Table A.26 we exclude all wells that have 5 km^2 buffers that intersect with the buffers of other wells. In Table A.27, we double the radius to 2.52 km, and thus drop all wells with overlap for 20 km^2 buffers.

Our results do not change by the modifications described above. This supports that our results are not driven by unobservable characteristics or shocks across countries or companies.

5.4. Public governance vs. competing factors

Having scrutinized our results on public versus corporate governance above, we have found robust results on public governance across a large set of measures for both public governance and corporate governance. We will now scrutinize our public governance finding by testing for robustness to the inclusion of factors that are potentially correlated with public governance.

In Table A.28, we include interactions with GDP per capita alongside our interactions with democracy. The interaction terms with democracy take similar coefficients as in the baseline model, whereas the interaction terms with GDP per capita are all insignificant.

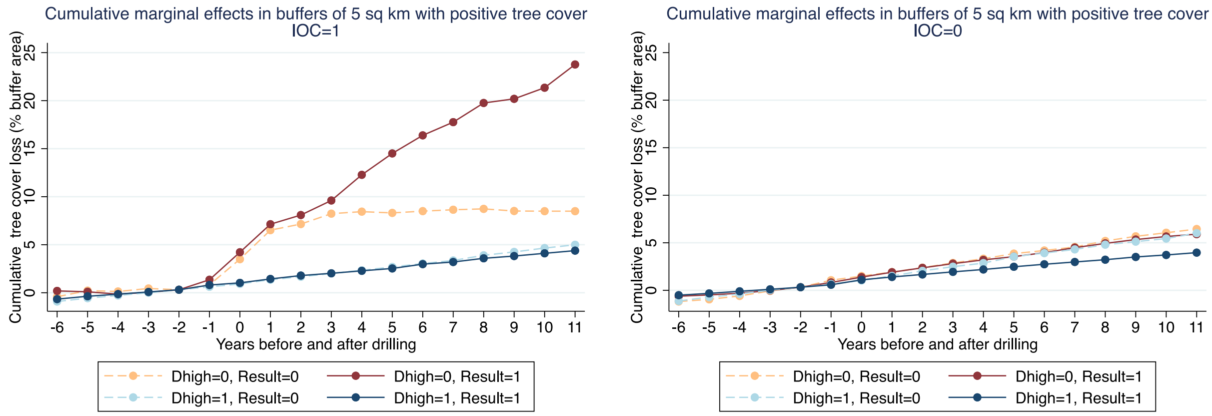

Fig. 5. Tree cover loss before and after exploration drilling in a circle of 5 km^2 around wells drilled by IOC+s (IOCs including subsidiaries and acquisitions), with and without discoveries (left panel) and around wells drilled by the remaining non-IOCs (right panel). Cumulative tree cover loss is measured in percent of a 5 km^2 ring area around a well. The starting year of exploration drilling is set to $t = -2$. "Dhigh" refers to countries with a democracy score above median. *Result* dummy (indicated *disc* in tables) takes the value of 1 if the well leads to a economically viable discovery, as reported in our drilling data. Well and year fixed effects included. Using the *margins* function, we estimate marginal effects of each corporate governance measure on tree cover loss. We compute the cumulative sum of the resulting marginal effects starting at $t = -2$, while we subtract those from $t = -3$ to $t = -6$. This figure corresponds to Table 4.

Table A.29 repeats the exercise but with measures of Environmental Stringency instead of GDP per capita. Environmental stringency is measured by the World Economic Forum. The first four columns use stringency rank and the four last columns use stringency value, measured on a scale from 1 (very lax) to 7 (very stringent). Again, the coefficients on the interaction terms with democracy are similar to before, whereas the interaction terms with the stringency measures take insignificant coefficients.

Based on these results, we conclude that our finding of lower forest loss related to oil drilling in democratic countries reflect more than the level of development or the stringency of environmental regulation.

6. Concluding remarks

In this study, we provide the first global estimates of forest loss associated with oil drilling. To identify the effect of oil drilling on forest loss, we focus on areas in the immediate vicinity of oil wells and make use of the quasi-random event of an oil discovery at exploration wells as a natural experiment. We exploit the global dimension of our dataset with 3,101 oil wells in 55 countries ranging in the entire spectrum of institutional quality and drilled by 396 different companies.

We present evidence that in the wake of an oil discovery, the rate of forest loss is twice as high in undemocratic countries as in democratic countries. The evidence is similar for other measures of public governance. This result points to the importance of public governance in limiting the environmental footprint of resource extraction in forests. The large variation in public governance across countries reflects broad aspects of development. Fundamental aspects include varying degrees of constraints on the executive branch of government, political competition, freedom of speech and accountability of decision making.

A striking result in our study is that the forest loss in the wake of an oil discovery does not improve (i.e. lead to less forest loss) when the well is operated by a presumptively more environmentally responsible company. This stands in contrast to the "pollution halo" hypothesis, which proposes that foreign investors might bring universal environmental standards or environmentally-friendly production methods with them when operating abroad. The current ESG focus at many companies, and among investors, may thus prove insufficient to address negative environmental externalities, especially in the presence of weak public governance.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

Appendix A. Supplementary tables, figures and maps

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jdeveco.2023.103070.

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