Does Private Equity Ownership Make Firms Cleaner? The Role Of Environmental Liability Risks*

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Abstract

This paper studies how Private Equity (PE) firms affect firms' environmental outcomes in the oil and gas industry. On average PE ownership leads to a 70% reduction in the use of toxic chemicals and a 50% reduction in satellite-based measures of CO2 emissions. However, this average effect hides significant heterogeneities. PE-backed firms increase pollution in locations and periods where environmental liability risk is low, as shown by a novel natural experiment that reduced these risks for projects located on federal and Native American territories. Overall, high-powered incentives to maximize shareholder value may benefit environmental outcomes when the risk of environmental regulation is high.

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Whether PE ownership leads to more environmentally friendly policies is theoretically unclear and has been the subject of recent attention. In the United States, some members of Congress and the Senate have expressed concern that "the private equity industry poses significant threats to international environmental protections and efforts to combat global climate change."[1] At the core of these concerns is a characterizing feature of PE firms, namely their strong incentives to maximize the profit of their acquisition. Indeed, general partners are paid a fraction of the value of the company upon its sale, typically employ a large amount of leverage in their deals, and closely monitor the CEOs of their portfolio companies. As such, PE-backed firms could be incentivized to maximize profits by saving the cost of reducing pollution, thus harming local communities. Similar behaviors, where PE firms create value in a way that is detrimental to stakeholders, have been observed in the health care (Gupta et al. (2020)) and education (Eaton, Howell, and Yannelis (2019)) sectors, where the quality of services offered to consumers decreased following a PE buyout.

Despite these concerns, PE firms often present themselves as sustainable investors. The Blackstone Group, for instance, prominently hails their commitment to people and the planet, stating that "protecting the environment of the communities in which we operate is critically important."[2] This statement echoes a view advocated by both regulators and practitioners that adopting environmentally friendly policies is consistent with shareholders' interests, either as a way to implement non-pecuniary preferences or as a strategy to maximize risk-adjusted firms' returns. Conversely, non-PE-backed firms that face agency or financial frictions may not find it optimal to adopt environmentally friendly policies. Such frictions limit the investment in profitable abatement activities, such as energy efficiency projects with a long payback period. PE ownership, therefore, could diminish these frictions, as observed by Bernstein, Lerner, and Mezzanotti (2019) and Lerner, Sorensen, and Strömberg (2011), thus leading to more environmentally friendly policies.

To understand the role of PE ownership on pollution, this paper exploits novel high-frequency project-level data on environmental corporate policies from the oil and gas industry. Specifically, I look at two variables that give a novel picture of environmental corporate policies. The first variable is whether firms release toxic chemicals. I measure this by merging administrative data on the chemicals used in the production process for 139,809 US wells fracked between 2010 and 2019 with detailed information on the characteristics of each well. The second variable is whether

[1] Elizabeth Warren, Mark Pocan, Raúl M. Grijalva, Deb Haaland, Rashida Tlaib, Jesús G. "Chu" García, and Sheldon Whitehouse (December 16, 2019).

[2] See appendix 7 for additional citations of major PE firms.

firms engage in "flaring," which involves burning the gas contained in oil wells to save the fixed cost of connecting the well to a pipeline or to treat the gas (Elvidge et al. (2009)), remediations that cost several million dollars per well. I measure this by building on advances in satellite remote sensing (Elvidge et al. (2013)) to create and validate a database on whether firms practice flaring at the well level.

My analysis shows that PE ownership leads to a 70% reduction in the use of toxic chemicals and a 50% reduction in flaring compared to non-PE backed firms. To test for pre-trends and evaluate the immediacy of the effects, I present dynamic difference-in-differences event study plots around 110 PE acquisitions in a specification that includes firm fixed effects (FE), *hyper-local* area FE interacted with year FE, and a large set of well-level characteristics. This specification allows for a comparison of observationally equivalent projects completed in the same year and in the same *hyper-local* area within firms. Making the level of comparison at the *hyper-local* area is a notable advantage of my empirical setting, as it controls for salient differences between projects from PE-backed and non-PE-backed firms. For instance, projects that are near one another drill in the same rock formation, have the same distance to pipelines and local chemical suppliers, and the same exposure to the local population. All these variables drive the marginal cost and benefit of polluting and could also affect the acquisition decision of PE firms. These unobserved variables are mitigated by the geographical comparison at the *hyper-local* level.

What are the economic channels driving the effect? I hypothesize that PE ownership confers strong incentive to maximize shareholders value[3], which leads to less pollution, when environmental regulation is likely to increase in the future. There are at least two non-mutually exclusive explanations for why abstaining from polluting is value maximizing where regulation risk is high in the context of the oil and gas industry. First, if regulation is more likely in the future, there is a benefit to over-comply now if the cost function of abatement exhibits dynamic increasing returns to scale, such as learning by doing effects. In the oil and gas industry, there is much evidence of learning effects, which makes this channel likely[4]. Second, the Comprehensive Environmental

[3] A PE sponsor provides a form of ownership that better aligns the incentives of owners with the corporate managers (Jensen (1989), Gompers, Kaplan, and Mukharlyamov (2016), Morris and Phalippou (2020)). The use of greater debt disciplines managers, and PE firms increase managerial incentives to maximize profit through performance-based pay or better management practices (Bloom, Sadun, and Van Reenen (2015)). General partners, on behalf of limited partners, control the board of their portfolio companies and actively monitor them. Moreover, general partners rarely have any personal connections with local communities that could interfere with pollution decisions.

[4] For instance, Kellogg (2011) shows that oil and gas firms gain learning experiences when working with the same contractors, which increases joint productivity and Covert (2015) shows that passive learning is a strong force in the fracking sector.

Response, Compensation and Liability Act imposes liabilities to oil and gas firms in case of a contamination if chemicals are used. A profit-maximizing agent decreases environmental risks when this enforcement risk is expected to become stronger in the future.

While this interpretation that PE-backed firms are more sensitive to environmental liability risks is broadly consistent with the institutional context of the oil and gas industry and provides a rational for the average reduction observed, I next exploit a natural experiment that plausibly exogenously changes environmental liability risks to better validate this interpretation.

Specifically, I exploit a succession of legal and political shocks that blocked the ability of the Bureau of Land Management (BLM) to regulate fracking on Native American reservations and federal lands between 2016 and 2018. Fracking has been exempt from federal environmental statutes since 2005. But in 2015, under the Obama Administration, the BLM passed a rule that would have imposed a comprehensive set of requirements aimed at curtailing fracking activity. The ruling never went into effect because it was challenged in court and blocked by a federal district court judge in Wyoming in 2016. The Trump administration then rescinded the rule completely in 2017. However, in 2018, environmental activists and the state of California challenged this decision, as the rescission was not economically motivated, contrary to the legal obligations of federal agencies. Therefore, between 2016 and 2018, the probability of having a new regulation in Native American reservations and federal lands was low.

This natural experiment offers two main advantages. First, it plausibly removes the endogeneity of PE acquisition by saturating the specifications with a firm interacted with a year fixed effect, which absorbs any unobserved and time-varying firm-level heterogeneity that could jointly affect the decision of the firm to pollute and the acquisition decision of PE firms. Second, the exogeneity assumption of the regulation shock to unobserved variables affecting the cost of pollution is credible. The boundaries of Native American reservations and federal lands were decided at the end of the nineteenth and the beginning of the twentieth centuries and overlap shale basins in a quasi-random way, as horizontal drilling and hydraulic fracturing were not widely used until the beginning of the twenty-first century. This quasi-random overlapping of shale boundaries and BLM areas is supported by the balance in characteristics before 2015 for projects around the borders of areas regulated by the BLM.

Using this empirical design, I show that projects from PE-backed firms in areas that faced lower regulation risks contained more toxic pollution than other projects from PE-backed firms in areas with no changes to regulation risks. The relative increase in pollution following the regulation shock is quantitatively large, equivalent to double the usage of pollution for the average firm in the sample. This within-firm increase in pollution among PE-backed firms is sufficient to slightly reverse the average reduction of PE ownership on pollution that was documented during the whole period. Back-of-the-envelope calculations suggest that this regulatory shock caused a net 30% increase in pollution in these areas between 2016 and 2018. However, this increase in pollution is highly localized for some specific areas and some specific time periods. This increase is not strong enough to reverse the average reduction in pollution following a PE acquisition, observed during the whole sample and across all shale basins. Thus, these results are consistent with the shareholder value maximization channel.

The result of this natural experiment does not support several alternative explanations. According to the technological upgrade channel, the reduction in pollution could be generated by the adoption of a more productive technological process. More productive production processes are also cleaner, as they are often new and require fewer inputs to produce the same quantity (Shapiro and Walker (2018), Grinstein and Larkin (2020)). Further, private equity firms improve the productivity of their target companies (Acharya et al. (2013), Davis et al. (2014)). If the effect is fully driven by a technological upgrade channel, then we should observe a reduction in pollution that is independent of changes in regulatory risks on Native Americans and federal lands.

Similarly, the inverse relationship between environmental liability risks and PE-backed firms' pollution decisions is not consistent with a reduction driven by a non-pecuniary channel. If we view impact investing as a way to substitute for frictions that prevent governments from implementing environmentally friendly regulations as in Bénabou and Tirole (2010), then we should observe a decrease in pollution instead of an increase when regulatory risks become less important.

A financial constraint channel cannot explain that the marginal impact of PE ownership on pollution is a function of regulatory risks. PE firms reduce the financial constraint of their portfolio companies (Boucly, Sraer, and Thesmar (2011), Bernstein, Lerner, and Mezzanotti (2019)). As such, they are deep-pocket investors that typically have existing funds with undrawn capital (Gompers, Kaplan, and Mukharlyamov (2016)), and they are more likely to inject capital into their firms in case of financial distress (Hotchkiss, Strömberg, and Smith (2014)). Moreover, in theory, their reputation increases the pledgeable income of their portfolio companies (Malenko and Malenko (2015)). Financial constraint affects pollution decisions, either because it makes the investment in abatement technology more costly or because it makes survival less likely, creating an incentive for the firm to take more risks through greater pollution. According to this channel, we should observe an increase in pollution among firms that are not PE-backed and thus more financially constrained following lower environmental liability risks because financially constrained firms have a higher marginal gain of polluting. However, this prediction is the inverse of the effect we observe.

Returning to the shareholder value maximization channel, I then provide two stylized facts that are consistent with this interpretation and bring indirect evidence in favor of the shareholder value maximization view of PE ownership. First, we do not observe a reduction in pollution when the PE firm provides financing to a company without having the ability to control the management team. To show this result, I rely on a type of PE deal that exists only in the oil and gas industry: DrillCo contracts. This paper is the first, to my knowledge, to exploit and document this class of PE contracts. In such contracts, the PE firm provides capital for projects in exchange for cash flow rights from a project. Interestingly for my empirical design, the PE firm does not control the firm's management in a DrillCo. When comparing projects between firms with DrillCo contracts with their closest neighbors, I show that firms do not reduce pollution when the PE sponsor has no ability to control their portfolio companies – as when a DrillCo agreement is in place.

Second, I show that suppressing flaring has a high payback period; that is, not connecting the well to a pipeline saves several million dollars when the project begins.[5] However, the loss in earnings is diffuse in time and difficult to detect for shareholders with limited information. According to new data that I have collected from the Oil & Gas division of the North Dakota Department of Mineral Resources, on average, half of the production of gas that is flared is produced between the second and fifteenth year of the well. PE firms' monitoring of the company reduces the agency frictions between managers and shareholders that lead to short-term actions (as modeled in Stein (1989) and Grenadier and Malenko (2011)), creating greater long-term shareholder value.

This paper contributes to several literatures. One core question in sustainable finance is to understand whether the adoption of better Environmental, Social, and Governance (henceforth, ESG) practices leads to higher firm profits or higher portfolio returns (Brest, Gilson, and Wolfson (2018),

[5] Most of the costs to reduce flaring are paid at the beginning of the project. First, on-site facilities and equipment, such as dehydrators and compressors need to be installed close to the well. According to the Interstate Natural Gas Association of America (INGAA), such costs averaged $210,000 per well in the Bakken. Then, the well needs to be connected to a pipeline, the pricing of which is a function of the distance between the well and the pipeline and the diameter of the connecting facility. According to the INGAA, the prices in 2017 range from $29,000 to $167,000 per mile for a diameter ranged between 2 and 22 inches.

Zerbib (2019), Cole et al. (2020), Larcker and Watts (2020), Gibson et al. (2020), Hartzmark and Sussman (2019), Pástor, Stambaugh, and Taylor (2020), Barber, Morse, and Yasuda (2021), Pastor, Stambaugh, and Taylor (2021), Jeffers, Lyu, and Posenau (2021)). If sustainable corporate policies maximize firms' expected profits, then PE-backed firms should adopt them, given the strong incentives that general partners have to increase firms' pecuniary value. The reduction that we observe speaks in favor of the idea that both social and financial expected returns can be improved simultaneously.

This paper complements survey-level evidence in understanding why financial investors engage with their portfolio companies on corporate environmental policies. Publicly listed firms that have high ESG performance are less exposed to risks (Godfrey, Merrill, and Hansen (2009), Oikonomou, Brooks, and Pavelin (2012), Jo and Na (2012), Kim, Li, and Li (2014), Hoepner et al. (2018), Ilhan, Sautner, and Vilkov (2021), Albuquerque, Koskinen, and Zhang (2019)). Krueger, Sautner, and Starks (2020) show in a survey that institutional investors report that managing environmental risks is the main reason they engage with the firms they invest in. My paper complements this literature by focusing on another class of investors, namely private equity firms, and shows that PE investors negatively affect environmental outcomes when environmental regulation risk is low.

Finally, this paper also contributes to the literature on the externalities of private equity ownership. The channel I found in this paper offers a way to unify the a priori conflicting results of this literature. PE ownership benefits other stakeholders for tasks or industries with large liability risks that are highly regulated and has led to better outcomes in other industries, including a reduction in food poisoning (Bernstein and Sheen (2016)) and worker hazards (Cohn, Nestoriak, and Wardlaw (2019)) and better operational outcomes in the banking industry (Johnston-Ross, Ma, and Puri (2021)). The results of this paper suggest that these forces are less prevalent in historically non-profit and opaque industries, such as the health care (Gupta et al. (2020)) or education (Eaton, Howell, and Yannelis (2019)) sectors, where PE ownership leads to worse consumer outcomes.

This paper also contributes to the literature on the externalities of private equity ownership by studying the impact of PE ownership on the persons incurring the cost of pollution[6], whereas

[6]Other factors affecting pollution decisions include other financial investors (Akey and Appel (2019), Dyck et al. (2019), Naaraayanan, Sachdeva, and Sharma (2019), Chu and Zhao (2019)), supply chains (Schiller (2018)), CEO preferences (Di Giuli and Kostovetsky (2014), Li, Xu, and Zhu (2021)), financial constraints (Kim and Xu (2017), Cohn and Deryugina (2018), Bartram, Hou, and Kim (2019), De Haas and Popov (2019), Levine et al. (2019), Bartram, Hou, and Kim (2019)), and competition (Grinstein and Larkin (2020)).

most previous papers focus exclusively on consumers, workers, and governments. The exception is Shive and Forster (2019), who study the impact of listing status on environmental externalities, albeit in an empirical setting that is different from this paper, and show that PE ownership is associated with an increase or no effect on pollution, while this paper documents a decrease when regulation risk is high. The advantage of my empirical setting that could explain the difference in results is the ability to control almost perfectly for production and technology, to conduct the econometric analysis at a high-frequency and highly disaggregated level, and to observe pollution decisions for all firms in my sample. However, interpreting their results with the mechanism in this paper suggests that in the US during the timeframe of their study environmental regulation risk was not prevalent.

The remainder of the paper is organized as follows. Section 1 provides the institutional background of the empirical setting and section 2 describes and validates the datasets used. Section 3 details the main result that PE ownership causes a reduction of pollution, but not for DrillCo contracts. Section 4 shows that the impact of PE ownership on pollution is inversely related to environmental liability risks. Section 5 discusses the results. Section 6 performs several sensitivity analyses to test the robustness of the findings. Finally, section 7 concludes.

1 Institutional Background

This section presents the specificities of the oil and gas industry that are important to understand for the empirical design. Namely, subsection 1.1 shows how shale gas and oil operators produce pollution and why this pollution is important for regulators and for firms. Then subsection 1.2 describes the regulation of the fracking industry. Finally, subsection 1.3 exposes the type and nature of PE contracts specific to the oil and gas industry.

1.1 Shale oil and gas drilling and pollution

The production of natural gas in the United States increased by more than 25% from 2007 to 2013, and the production of oil nearly doubled between 2009 (5.4 Mb/d million barrels of oil per day) and 2014 (9.4 Mb/d at year-end 2014), following the discovery of hydraulic fracturing and horizontal drilling.[7] Horizontal drilling allows the exploitation of reserves located in a horizontal

[7]Oil production from fracked wells accounts for nearly half of US production (EIA (2017)).

reservoir and that could not be exploited with a traditional vertical well. Hydraulic fracturing is the practice of creating cracks in the rock so that gas and oil can circulate to the well for subsequent extraction. These cracks are made by injecting high-pressure water mixed with different chemical components, technologies that enable the exploitation of large, untapped reserves of hydrocarbons captured in porous and low-permeability rocks.

1.1.1 Different ways of polluting

There are multiples ways through which the extraction of oil and gas, especially through hydraulic fracturing, generates pollution. The fracturing process is conducted using chemicals that can be highly toxic for humans. For instance, proppants are injected to ensure that the fractures remain open and to create a high-conductivity pathway so that the hydrocarbons can easily reach the surface. Anti-bacterial agents are included in the fracking mix to reduce bioclogging and corrosion. A clay stabilizer is added so that the clay does not swell. Other toxic chemicals can be included depending on the situation. These components can come into contact with humans, either by groundwater contamination or leaks from storage tanks.

Oil and gas activities also generate pollution by flaring, which consists of burning the gas contained in oil wells instead of recovering it. The gas that is burnt allows the firm to avoid investing in infrastructure —such as connecting the well to a pipeline— that would allow its exploitation. The burnt gas can disperse toxic chemicals to the neighborhood, thus contaminating the air.

1.1.2 Cost for firms and local communities

Toxic chemicals used by fracking firms affect the welfare of local residents. A wealth of evidence suggests that this pollution affects the health of people living close to wells, which is reflected in the reduced demand for houses close to fracking areas. To date, these toxic pollutants have been exposed to 18 million households that live at least one mile from a well (Konkel (2017)). This number will grow as US onshore production expands. According to the 2010 decennial census, more than 55 million households live in a shale basin and thus risk exposure to toxic chemicals.

In table A.1 of the online appendix, I provide an analysis of the costs and benefits of reducing flaring. Connecting the well to a pipeline has two components: first, on-site facilities and equipment, such as dehydrators and compressors, need to be installed close to the well; second, the well needs to be connected to a pipeline. These components cost several millions dollars at time 0 of the project. However, the benefits are not all reaped at time 0 because reducing flaring causes an increase in gas production during the whole life of the well.

The pollution that flaring generates is quantitatively significant. Flaring is also an important contributor to global warming, although estimates are hard to find. Worldwide flaring burnt 145 billion cubic meters of gas in 2018, which is equivalent to the total annual gas consumption of Central and South America.[8] In the US, each day of flaring in the shale oil fields of North Dakota and South Texas burns 1.15 billion cubic feet of natural gas, which could provide power for 4 million homes or driving nearly 5 million cars for one day.[9] Certain oil and natural gas-rich nations like Yemen, Algeria, and Iraq could meet their national CO2 reduction targets under the UN Paris Agreement just by eliminating flaring (Elvidge et al. (2018)). Given the importance of such pollution, the World Bank has launched the Zero Routine Flaring initiative, aimed at suppressing routine flaring by 2030 (Bank (2015)).

1.2 The regulation of pollution in the US oil and gas industry

The release of toxic components in natural surface waters —such as lakes, rivers, streams, wetlands, and coastal areas— is controlled in the United States by the Clean Water Act (CWA) and the Safe Drinking Water Act (SDWA). Among other federal statutes, the practice of hydraulic fracturing has been exempt from the SDWA and from important permitting and pollution control requirements included in the CWA since the Energy Policy Act of 2005.[10]

The highly controversial exemption is based on the idea that fracking does not affect local communities.[11] I exploit these exemptions in my empirical analysis to define a variable of over-compliance. I select chemicals that are reported as toxic and hazardous for human health, in the United States House of Representatives Committee on Energy and Commerce report from April

[8] https://www.worldbank.org/en/news/press-release/2019/06/12/increased-shale-oil-production-and-political-conflict-contribute-to-increase-in-global-gas-flaring.

[9] https://www.rystadenergy.com/newsevents/news/press-releases/Permian-natural-gas-flaring-and-venting-reaching-all-time-high/.

[10] This exemption does not apply to diesel fuels from hydraulic fracturing.

[11] In 1997, the Environmental Protection Agency (EPA) was ordered by a decision from the US Court of Appeals of the 11th Circuit to include hydraulic fracturing in the SDWA. In 2001, a special task force led by Vice President Dick Cheney asked that Congress exempt hydraulic fracturing from the SDWA. Then, the EPA released a controversial report in 2004 claiming that hydraulic fracturing "poses little or no threat" to drinking water. As a result, the 2005 energy bill withdrew the ability of the EPA to regulate hydraulic fracturing activities. This exemption was highly controversial. In March of 2005, evidence of potential mishandling in the EPA study of 2004 was officially found. Moreover, the Oil and Gas Accountability Project (OGAP) organized a review of the 2004 report and found proof that the EPA removed from the initial drafts any section that suggested unregulated fracturing could be detrimental to human health.

2011. Health scientists agree on the high degree of toxicity of these chemicals, and anecdotal stories of local contamination due to these components have been reported. As a result, these chemicals have a high media exposure and have been reported by several environmental organizations as threatening human health. With one exception, all these chemicals are all regulated by the SDWA and CAA but subject to the fracking industry exemption. Table 1 reports the names of all the chemicals used in the analysis, as well as their CASN number and whether they are regulated by SDWA and CAA.

The extent to which this exemption applies to the Bureau of land management (BLM) has been the subject of an ongoing legal dispute. The BLM, a federal agency within the US Department of the Interior, is responsible for the environmental regulation of federal land and Native American reservations and oversees one-eighth of the land in the continental United States. Its core mission is "to sustain the health, diversity, and productivity of the public lands for the use and enjoyment of present and future generations." Within its scope of work, the BLM supervises the leasing of oil and gas reserves and provides technical advice for drilling operations on Native American reservations.

In appendix 7, I provide more additional details on the legal dispute regarding the ability of the BLM to regulate fracking, which I summarize here. In 2012, the BLM started drafting a regulation to reduce the negative externalities caused by hydraulic fracturing. The regulation was supposed to go into effect on June 24, 2015. On March 20, 2015, various petitioners filed a motion for a preliminary injunction to challenge the fracking rule.[12] The preliminary injunction was granted by the Federal Court of the 10th Circuit, which found that "BLM did not have the authority to regulate fracking" (Williams (2015)). The rule was abrogated in 2016 by the District of Wyoming.

On January 20, 2017, former-President Donald Trump was inaugurated and changed the political orientation of the BLM, which withdrew its support for the fracking rule. An Interior Department Assistant Secretary stated that an "initial review has revealed that the 2015 Rule does not reflect... the current Administration's policies and priorities concerning the regulation of hydraulic fracturing on Federal and Indian lands."

Following this rescission, the state of California and a group of environmental activists sued the BLM on January 24, 2018, for voiding the fracking rule, because the Administrative Procedure Act requires that any agency that decides to change its policy should explain why the new policy is

[12] The petitioners included the Independent Petroleum Association of America (IPAA), the Western Energy Alliance ("Alliance"), the states of Utah, North Dakota, Wyoming, and Colorado, and the Ute Indian Tribe.

better. These details were absent from the decision. As a result, it was highly likely that the BLM could not regulate fracking between 2016 and 2018.

1.3 Private equity in the oil and gas industry

Several features of the oil and gas industry make it attractive for PE investment. First, this industry is a capital-intensive sector. For instance, in 2009, the median well cost was above $4 million (Gilje and Taillard (2015)), and the average cost for a proposed onshore US gas pipeline was $7.65 million per mile in 2015-2016. Second, the oil and gas industry is risky, as the sector is highly cyclical and vulnerable to changes in oil and gas prices. Third, there is ample asymmetric information regarding the investment opportunity set of oil and gas companies, as it is difficult to observe the quality of their reserves. Adverse selection is so pervasive that oil and gas firms make inefficient production decisions to prove the quality of their reserves (Gilje, Loutskina, and Murphy (2020)). The presence of risk and asymmetric information, which deter classical bank lending, and the high demand for capital make the industry attractive to PE firms. Figure 1.B shows that the oil and gas industry has concentrated more than 8% of transactions for deals that involve a transfer of control rights in the United States since 2010, according to Preqin. This is quantitatively significant, as the equivalent number for the health care, insurance, or retail sector is lower. The software industry is the only sector that has a larger number of deals in dollar value than the oil and gas industry.

ESG concerns are prevalent among the main PE firms, as shown in the citations of appendix 7, although I lack comprehensive detailed data on ESG commitments by PE funds. A common theme of these citations is that reducing pollution and increasing the quality of life for the local population allow PE firms to earn extra risk-adjusted returns.

Another unique feature of the oil and gas sector is the presence of DrillCo contracts, a joint venture between a financial investor and an exploration and production (E&P) company. They do not imply the creation of a new firm, contrary to what the name suggests. There is a large variety of DrillCo contracts, and their features are only limited by the creativity of the contracting parties. In its basic form, an investor provides cash in exchange for a working interest in a group of wells drilled and operated by the E&P company. Most of the time, a DrillCo contract contains three main components. In each tranche,[13] the investor provides a capital commitment. This capital commitment is used to pay the development costs of the well(s) and part of the E&P working

[13] In this case, a tranche is a group of oil and gas wells.

interests as a form of a carry ("carried amount"). In exchange for the capital commitment, the investors acquire a working interest in each tranche. This working interest can be subject to partial reversion once pre-determined IRR hurdles are met. More complexity among DrillCo contracts can then be found. For example, the location of the acreage can be made confidential to avoid direct competition with potential competitors. The DrillCo contract can also contain an alternative plan in case the initial wells are dry. The working interest is defined at the wellbore, but can be depth limited. Another important source of heterogeneity in DrillCo contracts is the timing of the payment, regarding both the moment when the investor transfers the funds and when the operator pays back the investors. The development costs of the well(s) can have a specific limit or, for some deals, a budget can be agreed upon.

DrillCo transactions differ in several ways from a traditional PE acquisition. They imply less control from the investors than when an acquisition is made. Most of the operational decisions are undertaken by the E&P company. As Tim Murray from Benefit Street Partners[14] explained: "We don't micro-manage operational details about how you're fracking the wells." Another difference is that there is no change in capital structure, contrary to a leveraged buyout. Finally, in a DrillCo, all the income made by PE investors comes from the working interest in a tranche of wells, and does not come from the exit value of the deal. Therefore, DrillCo contracts are financed from PE funds but without any transfers of control rights, change in capital structure, or pressure to exit the investment.

2 Data, Validation and Summary Statistics

2.1 Data

2.1.1 Oil and gas datasets

The Ground Water Protection Council and the Interstate Oil and Gas Compact Commission launched FracFocus in April 2011, a repository of chemicals used during the fracking process. This repository was first a voluntary disclosure database to report the chemicals used for each well, but states slowly began to impose mandatory reporting to this database. Figure A.1 reports the year in which each state mandated reporting. By 2013, 75% of 28 oil and gas-producing states had instituted

[14] Nissa Darbonne, "The DrillCo," in Oil and Gas Investor, Money Redefined: Capital Formation, June 2016.

mandatory reporting to FracFocus. In 2015, the latest states (Kentucky and North Carolina) had a mandatory reporting to FracFocus.

This administrative dataset allows us to investigate the input used during the production process with an extremely fine degree of granularity. The data report information at the well level, such as longitude and latitude, the API14 number (the regulatory ID of the well), the dates upon which the well job started and was completed, and the name of the operator. The dataset also contains the total number of chemicals used with their CAS number, which allows us to perfectly identify the presence of a toxic chemical. Operators can report a chemical as confidential, and, in this case, the CAS number will be hidden.

I merge the API14 number with detailed data from the private vendor Enverus, which provides information on production (for the first six months of oil and gas extraction), the horizontal length, the vertical depth, and the basin in which the well is drilled. These variables are essential because the first six months of production predict overall future well production with great accuracy. Once the well starts producing, it follows a stable and predictable decline curve.[15] The horizontal and vertical size of the well captures the type of technology used (whether it is a horizontal well) and the cost required during the drilling process (as larger wells are more costly). Moreover, knowing the basin in which the well is located allows us to define an important layer of comparison among wells, as they are more likely to be established within the same infrastructure and rock formation. I drop 30 observations that are not located in the United States onshore because they contain mistakes in the latitude or longitude or because they are offshore projects. I chose to drop offshore projects because they are usually more capital intensive and require specific infrastructures, although all the results remain the same when they are included.

2.1.2 Satellite datasets and a new flaring measure

I construct the measure of flaring using satellite data from the NASA IR public files. I rely on the approach of Elvidge et al. (2013), which can be summarized as follows. First, a satellite pyrometer —NASA/NOAA Visible Infrared Imaging Radiometer Suite (VIIRS)— is used to measure the radiation emitted by hot sources on the earth. Then, I exploit the fact that we can recover the temperature using the Max Planck equation, which relates the spectral radiance to the wavelength and the temperature of the material, and the Wien's displacement law, which states that the wavelength

[15] For instance, in the ARPS model, there is a stable linear relationship between the log production of the month and the log of the month.

of maximum spectral radiant emittance shifts to a shorter wavelength as the temperature increases (Elvidge et al. (2009, 2013)).

I identify the practice of flaring using the fact that it emits a temperature between 1600º C and 2000º C, not to be mistaken with forest fires, which generally reach about 800º C. The FracFocus data contain the longitude and latitude of each well. I use this information to investigate whether the temperature is between 1600º C and 2000º C at a point within 500 meters around the location of the well. One main limitation of this dataset is that if the wells are too close to each other, then we cannot disentangle which one is flaring with a high degree of precision. Therefore, I create a variable to distinguish the cases in which such a situation occurs. I validate the quality of the satellite data in several ways. First, as shown by figure A.2, the spatial detection of flaring is consistent with the geographical distribution of oil and gas basins. Second, the probability of observing a flare before the completion of the well is extremely low. After the well is completed, this probability surges and starts decreasing, consistent with observed practices. Figure A.3 shows that the non-parametric probability of observing flaring equal 3% before the well is completed; this probability rises to 15% within 90 days following well completion.

2.1.3 Data on private equity

I use several distinct sources to construct a database of PE deals that result in a transfer of ownership. I download all "add-on," "buyout," and "growth capital" deals and exits from Preqin that I manually match to the oil and gas dataset using the operator name. The results remain robust if I focus only on buyout deals. Consequently, I am able to match a total of 146 deals. I cross-check the accuracy of the date of the deal, the type, and the firm identity using both Pitchbook and Enverus market intelligence. I drop the observation if one of the source documents shows no transfer of ownership (such as mezzanine debt) or if I observe that the add-on relates to only part of the assets of the target firm and not the total assets of the firm. I also drop an observation if the acquirer is not a PE or VC firm but rather a hedge fund or other investment structure. This process results in 110 firm-deal observations made by 55 different financial sponsors.

2.2 Summary statistics

2.2.1 Sample

My sample includes 139,809 US wells fracked between 2010 and 2019. On average, firms use 0.3 toxic components per well and flare 21% of their wells. A sample-average firm has a total of 100 projects scattered among 11 different locations in 1.37 states. Table 2 the reports the additional basic descriptive statistics of the sample.

2.2.2 Pre-acquisition

Panel A of table 3 reports the raw differences at the firm-level between PE target firms and those that were never acquired. Although quantitatively small, there is a selection problem taking place at the firm level. Targeted firms are more geographically focused than the others, with projects in 0.98 states instead of 1.7 states for the other groups.[16] As a result, the targeted group drills in fewer basins than the non-targeted group. The total number of projects is statistically similar between the two groups, and on average, equals 100.

Panel B of table 3 depicts the raw differences at the project level, which are much more pronounced than at the firm level. Several stylized facts appeared. First, our targeted group is less productive. On average, they take 12 days longer to drill a well and obtain less production for each fracturation. Second, they drill in more rural areas. The wells they have are in places with fewer housing units and persons. Third, they drill more oil and less gas. Finally, although imprecise and non-statistically significant, they pollute less: they flare less, and, on average, use 0.1 fewer toxic chemicals than companies that were never acquired by PE firms.

Panel B of table 3 shows the differences in characteristics once the location-year fixed effects.[17] The observable differences between the two groups are severely reduced and become non-statistically significant for most. Importantly, the adjusted differences have a lower standard deviation (except for the completion time, which increases slightly). The differences between the well production per fracturation, population and housing where the well is located, its size (horizontal length and vertical depth), and gas production diminish considerably and become non-statistically significant, despite a lower standard deviation of the difference. The difference in the

[16]The total is not equal to 1 because we do not observe the states for 2% of the projects.

[17]The location-year fixed effect interacts with a year fixed effect with a location dummy defined as the first two digits of the latitude and longitude of the well, which is equivalent to a square of 6 by 6 miles.

number of toxic chemicals goes to -0.109 without fixed effects to -0.086, and the standard deviation is nearly divided by two, which implies that the difference becomes significant at the 10% level. The remaining differences in observables that are statistically significant after adding the fixed effects are the completion time and the amount of oil produced. Overall, this supports the view that wells located in the same area are a plausible counterfactual for the wells of PE-backed firms.

Panel A of table 4 reports the raw differences between firms that signed DrillCo deal and those that did not before such a transaction occured. Firms that sign a DrillCo are, on average, bigger; they have 387 projects, whereas the control firm has only 89 projects. As a result of having more projects, firms that will sign a DrillCo are drilling in more places and states. However, these differences are not statistically different, except for the number of coarser locations, which is significant at the 90% threshold.

Panel B of table 4 reports the raw differences for a DrillCo transaction using project-level information. There are differences between the firms that sign DrillCo deals and those that did not. For most, the raw differences are economically important but imprecise and exhibit a large standard deviation. These differences are thus non-significant, except for the production of gas, which is significant at the 10% level. The average firm signing a DrillCo transaction uses slightly more toxic components, is less productive and efficient as captured by the completion time and the production per fracturation, and uses more technologically advanced projects as measured by their vertical depth and horizontal length.

Panel B of table 4 shows the differences in characteristics between firms before they signed a DrillCo and those that did not, once the location controls are added, which also supports the identifying assumption. Most of the differences in absolute terms are strongly diminished between the two groups after the location is controlled for. For instance, the difference in production per fracturation rises from -16 to -2.44 after such location controls are added. The difference in the production of oil for the first six months goes from -4,759 to 2,627. Overall, this supports the view that wells located in the same area are also a plausible counterfactual for the wells of firms that signed a DrillCo.

2.2.3 Similarities between federal and Native American regions and others

I exploit the legal events taking place after 2015 regarding the ability to regulate fracking in Native American and Federal territories in the identification strategy. Therefore, it is important to investigate whether the projects that are drilled in Native American reservations and federal lands were similar to the others before the fracking rule was announced in March 2015. One concern would be that contract enforcement[18] or local labor costs would create fundamental differences between the two groups and would command different usages of toxic pollutants, making causal inferences difficult to obtain.

Panel A of table 5 shows the raw differences according to whether a well was drilled in Native American reservations and federal lands before March 2015. Pollution is higher among Native American reservations and federal lands, as captured by both the number of toxic chemicals and the level of flaring. This group is also less productive, as captured by completion time and production per fracturation, and produces less oil and gas per well. Projects have a lower horizontal length outside of federal lands and Native American reservations. Although statistically non-significant, projects on Native American reservations and federal lands are also located in places that have lower population density.

Once the location fixed effects are added, most of the differences in characteristics are reduced by an important magnitude and become non-statistically significant at the 5% threshold. This is consistent with the idea that location is an important driver in the heterogeneity of projects. Specifically, the differences in the production of oil goes from 2,015 to 43,47 BO, which is a division by 46, and the production of gas is greatly reduced, divided by 17. Both differences are non-statistically significant. The differences in the size and length of wells are also economically and statistically non-significant. The only remaining statistically significant differences are for variables on productivity and population density, if we set a confidence interval of 90%. However, the economic magnitudes are non-significant: for instance, projects take one day more to be completed on Native American reservations and federal lands or contain seven fewer persons

[18] Brown, Cookson, and Heimer (2017, 2019) exploit the 1953 enactment of PL280 to create plausibly exogenous variations in the enforcement of contracts within Native American reservations, where litigations were enforced following the shock on state courts instead of tribal courts for some reservations. The authors show that it affects credit markets, income, financial literacy, and trust. The shocks that are exploited in this study are different and exploit the regulatory power of the BLM to intervene in Native American reservations and federal lands on environmental matters. It is a shock on the *ex ante* ability to regulate fracking rather than a shock on the enforcement of contracts.

per county. Overall, these adjusted differences suggest that projects in their vicinity have similar characteristics that are not affected by their regulation by the BLM before March 2015.

2.3 Validation of the dataset

In this section, I present several tests that validate the consistency of this new dataset. Specifically, I show in dynamic event-windows that the measures of pollution increase just before a chapter 11 bankruptcy filings, but then drop. Moreover, the measures of pollution correlate with proxies for corporate short-termism. While these correlations do not have a causal interpretation, they are consistent with previously established findings.

Firms closer to filing for bankruptcy are more likely to pollute. They are riskier and therefore face a higher cost of capital, which reduces their investment in abatement projects. Moreover, firms close to bankruptcy are more likely to pollute due to a risk-shifting effect: they reap the full benefit of polluting, but part of the expected cost as these are discharged through bankruptcy. The fact that firms that are more financially constrained or close to bankruptcy are more likely to pollute has received extensive empirical support (Kim and Xu (2017), De Haas and Popov (2019), Levine et al. (2019), Cohn and Deryugina (2018)). Figure A.8 reports the yearly average of the number of toxic chemicals (panel A) and the fraction of wells flared (panel B) among firms that file for chapter 11 bankruptcies in an event study around the year of filing, which validates the results found in other settings. Specifically, pollution levels increase steadily before filing, peak the year of filing, and then decrease once the probability of default lessens.

Bertrand and Mullainathan (2001) and Davis and Hausman (2020) suggest that shareholders in publicly listed companies in the oil and gas industries do not closely monitor their corporate executives, who are thus able to extract a rent by being paid for outcomes untied to their efforts. These frictions create incentives to boost short-term performance, potentially at the expense of long-term performance as in Stein (1989) and Grenadier and Malenko (2011). Recent papers (Shive and Forster (2020), Kim and Xu (2017)) show that agency frictions create an incentive for firms to pollute.

I find this relationship between proxies for corporate short-termism and pollution. First, I begin by investigating whether publicly listing is associated with more toxic pollution. I compare pollution levels both before and after the IPO, exploiting six IPOs that take place during my sample period. Panel A of Table A.9 shows that the production of toxic chemicals increases significantly following the IPO. The magnitude of the effect of the IPO on pollution is an increase of 0.14, which is close in absolute terms to the reduction (-0.19) caused by PE ownership. One limitation of this specification is its reliance on a small number of firms.

Second, I show that firms missing the mean forecast of their annual earnings per share (henceforth, EPS) are more likely to increase pollution. Firms that have a realized EPS that is below the one expected by financial analysts are more likely to pollute. Figure A.7 reports the estimates of a regression of toxic pollution on the nine deciles of the sample EPS forecasting errors, after adding the geographical-year and firm fixed effect and controlling for the realized EPS. Being among the first two deciles of the errors on EPS, which means having the 20% lowest differences between the expected and realized EPS, leads to an increase in pollution of 0.1. In contrast, the other deciles are not associated with an economically and statistically significant effect on pollution, except for the highest decile (q9). Columns (4) and (5) of table A.9 confirm the effects of EPS on toxic pollution. After controlling for the realized EPS, if analysts expect a higher EPS than realized, then firms are more likely to pollute. The relationship does not hold for firms that are above the expectation of analysts. These tests are consistent with the view that firms that experience high expectations of their one-year earnings are more likely to pollute to meet these expectations.

3 The net effect of PE ownership on pollution

This section studies the net impact of PE ownership on the production of toxic pollution. The identification strategy is described in subsection 3.1. The baseline results are presented in subsection 3.2, and subsection 3.3 provides a sensitivity analysis of the baseline results.

3.1 Identification strategy

3.1.1 Empirical design and identifying assumption

The key identifying assumption of this paper is that heterogeneities in the marginal costs and benefits of polluting at the project level are driven by geographical variables. In the oil and gas industry, the main source of value creation comes from constructing an acreage, which is a portfolio of lease contracts that provide the right to drill oil and gas within a specific time range and location. The type of rock and its properties –such as its porosity and permeability, and the distance from existing infrastructure (such as pipelines), which increases the cost of flaring– are similar for two wells that are located in close proximity. Similarly, specific chemical suppliers in the region affect the prices and types of components sold to oil and gas operators. By comparing how oil and gas companies emit pollution when facing the same marginal costs and benefits both before and after a PE deal —in a difference-in-differences setting—, we can uncover whether firms tend to grow cleaner following a PE acquisition.

The first way to translate the identifying assumption into an econometric specification is to estimate the following equation on the full sample:

$$Y_{ijt} = \text{Firm}_i + \text{Year}_t \times \text{Location}_j + \sum_{\tau=-6}^{10} \gamma_\tau.(\tau \text{ semester(s) after the PE deal}) + \text{Controls}_{ijt} + \varepsilon_{ijt} \tag{1}$$

where Y_{ijt} is a measure of pollution (toxic chemicals or flaring); Firm_i is an operator fixed effect, which captures any heterogeneity at the firm level that is constant through time and affects the decision to use toxic chemicals; and Location_j is a geographical fixed effect and is equal to one for projects that are located in places with the same first two digits of latitude and longitude. Figure A.4 illustrates such groupings by plotting the wells with same color if they have the same first two digits of latitude and longitude and are situated in one half of the Marcellus formation. Year_t is a year fixed effect. Controls_{ijt} includes the first six months of oil and gas productions, which is a good measure of well production. I also include vertical depth and horizontal length as additional controls to capture potential time-varying heterogeneity in the type of technology used.

The second way to translate the identifying assumption in an econometric specification is to perform a matching approach at the project level. Contrary to previous studies that have matched firms before a buyout to another firm (following Boucly, Sraer, and Thesmar (2011)), I perform the matching at the project level both before and after the deal. Specifically, for each project of the treated group, I match a project from the control group that is made in the same basin during the same year and has the closest size (both horizontal length and vertical depth) and level of production (both six months of oil and gas production) using the Mahalanobis distance metric. Then, using this matched sample, I estimate the following equation:

$$Y_{ijt} = \text{Firm}_i + \text{Year}_t \times \text{basin}_j + \gamma.(\text{ Post PE deal})_{it} + \text{Controls}_{ijt} + \varepsilon_{ijt} \tag{2}$$

where (Post PE deal)$_{it}$ is a variable that takes one if the firm i at time t is under PE ownership. Controls$_{ijt}$ includes the size of the project (horizontal length and vertical depth) and its production (both six months of both oil and gas production). As I have a matching sample made with the nearest neighbor matching approach, this implies that the sample size is smaller. I cannot include all the fixed effects of equation (1) in this sample without dropping a significant number of observations. As a result, I include only a firm fixed effect and a basin$_j$ fixed effect interacted with a Year$_t$ fixed effect.

3.2 Results

3.2.1 Raw relationship

I start the analysis by the simplest way of statistically summarizing a database: plotting the data points and the fitted line, both before and after the year of a PE deal. Figure 4 shows the binscatter in red square dots. As we can see, the probability of using a toxic chemical during the production process increases before the year of the deal: it rises from around 0.00-0.05 one year before the deal to a peak of 0.2 the year of the deal. After the year of the deal, the mean number of toxic chemicals per project doubles to 0.4. It then starts to decrease slowly to reach the level of 0.2. The binscatter suggests that a linear specification can be used as a good parametric functional form for the econometric tests. The raw relationship suggests that PE ownership is associated with an increase in toxic pollution that decreases slowly before the sale of the firm.

The increase in pollution associated with PE ownership is not causal, as it is strongly exposed to a composition effect. The type of projects used by PE-backed firms changes following the acquisition. Figure 4 illustrates in blue dots the binscatter of the control projects from the matching sample,[19] a direct way to correct for this composition effect. We observe a common visual trend before the year of the deal. Two to three years after the deal, the production of toxic chemicals still increases for our control group, while it decreases for the group of PE-backed firms, highlighting a negative impact of PE ownership on pollution.

[19] Recall that we construct the matched sample by matching each project of our treated group with a project from the control group in the same basin during the same year with the closest size (both horizontal length and vertical depth) and production level (six months of oil and gas production) using the mahalanobis distance metric.

As the binscatter ignores time-unvarying shocks and geographical-specific trends as well as standard errors, the next part of the paper examines their relationship by exploiting the full panel dimension of the dataset and adding fixed effects.

3.2.2 Difference-in-differences

Toxic chemicals. Figure 5 reports the estimated $(\gamma_\tau)_{\tau=-6,\ldots,4,10}$ of equation (1) and confirms the negative relationship between PE ownership and pollution. While all the post-deal estimates are statistically significant at the 5% level (except for the sixth semester after the deal, which is significant at the 10% level), none of them are statistically significant before the deal. Further, there is no visual and significant pre-trend after the PE deal. We can observe a small but non-significant drop in the number of toxic chemicals used after the year of the deal. The negative impact of PE ownership grows stronger over time. After the first three years, the number of toxic chemicals is reduced by 0.4. As can be seen in table 2, the sample standard error of the number of toxic chemicals used during the production process is .55. Therefore, the reduction in pollution is economically meaningful, corresponding to a drop of more than half of the standard error. None of the coefficients of the controls are significant, and the point estimates are economically non-significant (below the 10^{-6} level), which is an indication that the observed heterogeneity between projects that is potentially correlated with proxies of productivity and technology has already been controlled with the fixed effects.

Table 6 contains the net post effects. Both columns (1) and (2) of panel A show that PE ownership leads to a mean average effect of -0.198, which is economically and statistically significant. The sample mean of toxic chemicals used is 0.282. A reduction of -0.198 implies that the drop is equivalent to 70% of the baseline usage of toxic chemicals. Column (3) of panel A contains the net effect using the matching approach of equation (2). Although the sample and fixed effects are different, the magnitudes are close, and the effect of PE ownership using this specification equals -0.209.

Flaring. I estimate the baseline equation (1) with a different measure of pollution, flaring. Figure 6 depicts the dynamic effect around the deal estimated on the sample, where we can unambiguously identify the identity of the owner of the well, when the wells are not too close to one another. Similar to the results of using toxic chemicals, we can observe a drop in pollution coming due to reduced flaring. Most of the decrease in flaring appears after year three, where PE ownership plausibly causes a drop by 10% in the probability of flaring. This is quantitatively significant, as the standard deviation in the practice of flaring is equal to 0.16. Columns (1), (2), and (3) of panel B from table 6 report the full post-deal effect of PE ownership on flaring. The overall net effect of PE ownership is negative, equals to -0.044, and stable to the inclusion of controls as well as statistically significant. Moreover, when estimated on the matched sample, we find magnitudes that are close to the results using the full sample.

The dynamic difference-in-differences specification shows no pre-trend before the deal is signed. Figure 5 reports the pre-trend before the deal happens, where the dependent variable is the number of toxic chemicals. The line is flat, slightly below 0, and the coefficients are not statistically significant. Similarly, Figure 6 depicts the pre-trend coefficients for another measure of pollution, the practice of flaring. In this graph, the coefficients are close to 0, the line is slightly above 0, and none of the coefficients are statistically significant.

3.3 Sensitivity analysis

I replicate the baseline specification of dropping projects that are in locations that account for a large fraction of the total firm projects. PE firms' purchase decisions are based on variables that are mostly driven by the main basin(s) where firms operate. The extreme case would be a situation where a PE firm purchases a target company after only considering its core assets. If the PE firm reduces pollution on all the projects of the target company, then dropping these core assets and focusing the analysis on the other wells would alleviate the endogeneity problem. By dropping these basins from the analysis, we are more likely to focus our attention on places that are not driving the decision of the PE to purchase the company.

To perform such a test, let us define $C=\frac{\text{Number of projects in basin j for firm i}}{\text{Total number of projects for firm i}}$. Table A.2 of panel A reports the baseline regressions where I drop firms that have a C value higher than a specific threshold. Specifically, in column (1), I drop all the projects where C=1, eliminating firms that are drilling in only one basin. The effect on this sample is equal to -0.183, close to the -0.198 found in the baseline specification. Columns (2), (3), and (4) estimate the relationship where C falls below 0.77 (75th percentile), 0.21 (median), and 0.11 (25th percentile). Although the baseline equation is estimated for different samples, the effects are within the same magnitude range and equal -0.174, -0.268, and -0.162 for columns (2), (3), and (4), respectively. Overall, this exercise suggests that the baseline results are robust and persist when we drop the assets within the firm that are more likely to lead to its purchase by a PE firm.

Next, I focus the analysis on projects that account for a small fraction of the total number of projects in the basin. If a firm owns a large fraction of projects within a location, this results in a higher ability to negotiate the cost of inputs used as well as other costs that could change the project-level marginal costs and benefits of using toxic chemicals. To handle this concern, I first define the following ratio: $M = \frac{\text{Number of projects in basin j for firm i}}{\text{Total number of projects in basin j}}$. M is equal to 1 when the firm owns all the wells in the basin. Table A.2 of Panel B reports the baseline regressions, where I drop firms that have an M higher than a specific threshold. No firm has all the projects in one location. Columns (1), (2), and (3) drop if M is higher than 0.085 (75th percentile), 0.046 (median), and 0.01 (25th percentile), respectively. The coefficients for columns (1), (2), and (3) are equal to -0.198, -0.219, and -0.297 respectively. These coefficients imply an effect similar to the baseline magnitude, if not more important. Overall, the tests suggest that the effect is not driven by differential local bargaining powers correlated with PE ownership.

3.4 DrillCo contracts

I adopt a specification similar to equation (1) to investigate the impact of PE firms on pollution when they sign a DrillCo agreement with a firm. Figure 8 reports the estimated $(\gamma_\tau)_{\tau=-6,\ldots,4,10}$ of equation (1) when the deal variable is for DrillCo transactions and the dependent variable is the number of toxic chemicals. There is no pre-trend before the DrillCo contract is signed, and it is difficult to observe a subsequent effect.

I confirm the absence of a statistically significant effect following a DrillCo transaction by using different specifications and measures of pollution. Equations (4) to (6) of panel A from table 6 contains the net post effects for DrillCo contracts on the number of toxic chemicals. The point estimate is small in magnitude, around -0.03, close to 0, and statistically non-significant at conventional thresholds. Equations (4) to (6) of panel B from table 6 report the estimate when the dependent variable is flaring following DrillCo contracts. Similarly, the point estimate is close to 0 and statistically non-significant.

Overall, this test provides evidence that reducing pollution is not caused by a lack of financing for positive NPV projects. The reason for this is that the signature of a DrillCo contract is a positive wealth shock for a firm. Financing a set of projects through a DrillCo agreement preserves the cash reserves and the debt capacity of the firm. A firm with more financing capacity can invest in other positive NPV projects, including abatement technology that has a high payback period. If a financial constraint is hindering managers from investing in such a project, then we should also observe a drop in pollution when the constraint becomes less binding following a DrillCo contract, which is not the case. This non-result implies that corporate executives face specific incentives not to invest in pollution abatement projects and that such incentives are reversed when PE firms control the management team. Understanding these incentives is the focus of the next section.

4 The Role of Environmental Liability Risks

The timeline of events suggests that projects drilled on federal land and Native American reservations were subject to a lower amount of environmental regulation risks from June 2016 to January 2018, as evidenced by the court decision against the fracking rule in 2016, the Trump inauguration, and the subsequent shelving of the fracking rule, all of which created important hurdles regarding the ability of the BLM to regulate fracking. I exploit these factors in the identification strategy through two different empirical specifications.

The first specification is a difference-in-differences estimated within the sample of PE-backed firms. Specifically, I estimate by OLS the following equation:

$$Y_{ijt} = \text{Firm}_i \times \text{Year}_t + \text{Location}_j \times \text{Year}_t + \sum_{\tau=2013}^{2019} (\text{year=}\tau) \times (\text{BLM})_i \times \theta_\tau + X_{it} + \varepsilon_{ijt} \quad (3)$$

The second specification is a triple difference-in-differences over the full sample, where I estimate the differences for each year between PE-backed firms and non PE-backed firms, both before and after the regulatory shocks, for projects in regulated and non-regulated areas. Specifically, I estimate by OLS the following equation:

$$Y_{ijt} = \text{Firm}_i \times \text{Year}_t + \text{Location}_j \times \text{Year}_t + \sum_{\tau=2013}^{2019} (\text{year=}\tau) \times (\text{BLM})_i \times (\gamma_\tau + \beta_\tau.\text{PE}_{it}) + X_{it} + \varepsilon_{ijt} \quad (4)$$

For both equations, $(\text{BLM})_i$ is a variable that takes one if the well is located on federal lands or Native American reservations. The fixed-effect specification is similar to the one used before in equation (1). PE_{it} is a dummy that takes the value one if the firm i is PE-backed and 0 otherwise. The coefficients allow the differences to vary over time to capture potentially dynamic effects. The inclusion of firm fixed effects interacted with a year fixed effect is a notable empirical advantage of the oil and gas empirical setting. In particular, it allows us to absorb any time-varying firm-level unobserved variables that drive the decision to use toxic chemicals. These unobserved factors typically lead to the decision of PE firms to purchase a company.

The triple difference-in-differences specification allows us to compare projects drilled in the same year by the same firm in the same rock formation, where they differ because the only difference is that one is located on a federal land or a Native American reservation, and the other is not. This effect is decomposed between the impact of the regulation by non PE-backed firms, captured by γ_τ, and the one driven by PE-backed firms, measured by β_τ.

4.1 Results

Figure 7 plots the estimated coefficients $(\theta_\tau)_{\tau=2013,\ldots,2019}$ of equation (3), that is, the dynamic difference between regulated and non-regulated areas among PE-backed firms. We can observe a jump after 2016 in the usage of toxic chemicals for projects located in areas supervised by BLM and for PE-backed firms. After the preliminary injunction was granted, PE-backed firms started to use more toxic chemicals in their wells than the other firms, but this difference disappears after 2018. After 2018, the effect is economically and statistically small, consistent with the fact that the state of California's decision to sue the BLM created an increase in the probability of having a fracking rule. The effect peaks in 2017, the year when Trump took office and the rule was rescinded.

Table 7 reports the estimates of the triple difference-in-differences setting of equation (4). The variable Post Injunction takes a value equal to one between 09/30/2015 (the day of the preliminary injunction) and 01/24/2018 (the day when the state of California sued the BLM over the rescission), and 0 otherwise. Columns (1) and (2) estimate the full interactions with separate firm fixed effects and location-year fixed effects. Controls are added in column (2), and column (1) contains the results without any project-level controls. Columns (3) and (4) of panel A report the coefficients when firm-year fixed effects are added. Across all specifications, the coefficients of interest — namely the triple interaction coefficients between PE ownership, BLM, and post injunction— are positive and statistically significant, ranging from 0.3 to 0.38.

5 Economic Discussion

5.1 Suggested channel

The results are consistent with a channel driven by better monitoring of corporate executives and firms' profit objective. There are at least two ways through which increasing pollution enhances expected profits when environmental risks are lower. First, if regulation is more likely in the future, there is a benefit to over-comply now if the cost function of abatement exhibits dynamic increasing returns to scale, such as learning-by-doing effects. There is extensive evidence of such learning effects in the oil and gas industry, which makes this channel likely. For instance, Kellogg (2011) shows that oil and gas firms learn when working with the same contractors, which increases joint productivity, and Covert (2015) shows that passive learning is a strong force in the fracking sector.

Second, the shock could be interpreted as a reduction in the environmental enforcement of federal statutes. While oil and gas firms are exempt from the Comprehensive Environmental Response, Compensation, and Liability Act, this exemption no longer holds if they use toxic chemicals during the extraction process. A profit-maximizing agent increases environmental risks when this enforcement risk is lower.

The fact that suppressing flaring has a high payback period, as shown in appendix A.1, is indirect evidence in favor of the monitoring channel. Suppressing flaring costs several millions of dollars at time 0, but the benefit of it is diffuse over time. As modeled in Stein (1989) and Grenadier and Malenko (2011), the separation of ownership and control creates a moral hazard problem. As a result, the managers have an incentive to boost short-term profits. One way to maximize short-term profits is by flaring the wells, which saves several million dollars when a well is drilled[20] at the cost of future economically viable gas production.

5.2 Discussion of other possible channels

PE-backed firms reduce pollution less following lower regulation risks, which allows us to rule out a channel driven entirely by non-pecuniary motives, unless there are agency frictions between

[20]As mentioned earlier in the paper, most of the cost of reducing flaring is paid at the beginning of the project. First, on-site facilities and equipment, such as dehydrators and compressors, need to be installed close to the well. According to the Interstate Natural Gas Association of America (INGAA), they were on average $210,000 per well in the Bakken. Then, the well needs to be connected to a pipeline, and the price is a function of how far the well is to a pipeline and the diameter of the connecting facility. According to the INGAA, the prices in 2017 ranged from $29,000 to $167,000 per mile for a diameter range between 2 and 22 inches.

limited and general partners. Limited partners could prefer socially responsible investments and ask the general partners to invest accordingly. Standard models of moral hazard dictate that optimal effort should be exerted in states of the world where the signal is more informative about the agent's efforts. Litigation from federal agencies is a strong signal that the general partners polluted and did not adopt high environmental standards. As a result, the general partners will exert more effort —in our setting, pollute less— when the precision of the signal is higher; that is, when polluting can lead to litigation and fines from federal agencies, which is precisely what happened when the fracking rule was discussed and about to be implemented. However, this interpretation is unlikely, as we are using information that was also available to the limited partners and could have been used to monitor the general partner.

One way to explain the existence of non-pecuniary preferences among corporations and investors is to suppose the existence of frictions that prevent governments from implementing a regulatory framework consistent with social preferences (Bénabou and Tirole (2010)). For instance, if voting or representative democracy are limited in creating a legal environment that maximizes citizen welfare, then the for-profit world can adopt the role of realizing social preferences by taking non-profit actions. According to these theories, the BLM litigation can be thought of as a case where the government lacked the tools to implement social preferences. Therefore, if the results were driven by non-pecuniary motivations, as explained by this channel, then we should observe a decrease in pollution instead of an increase when regulatory risks become less important.

This result is not consistent with the idea that the reduction is driven by a technological upgrade. For this to be the case, we would have to assume a technological innovation that is worth using on Native American reservations and federal land between 2016 and 2018 but not in the wells in their vicinity. Moreover, the inclusion of controls that strongly correlate with a technological upgrade in this industry, namely the total production extracted and the size of the wells, does not affect the parameter of interests. This finding also implies that technological innovation should not alter these variables significantly. Overall, these results do not support the view that the effects are driven by a technological change inside the firm following PE acquisition.

Further, the results are not consistent with an effect of PE ownership on pollution fully driven by a reduction in financial constraints. Financially constrained firms have a higher marginal gain of polluting, as investing in abatement activities is costly. As a result, we should observe more pollution from non-PE-backed firms following a change in regulatory risk relative to PE-backed firms. This is the inverse of the effect that we observe.

Similarly, the lack of significant reductions following a PE DrillCo contract provides evidence that reducing pollution is not caused by a lack of financing for a positive NPV project. Indeed, the signature of a DrillCo contract is a positive wealth shock for a firm and financing a set of projects through a DrillCo preserves the cash reserves and the debt capacity of the firm. A firm with more financing capacity can invest in other positive NPV projects. For example, a positive NPV project could be an investment in abatement technology with a high payback period. If a financial constraint is hindering the manager from investing in such a project, then we should also observe a drop in pollution when the constraint becomes less binding following a DrillCo contract, which is not the case. This non-result implies that corporate executives face specific incentives not to invest in pollution abatement projects and that such incentives are affected when PE firms control the management team, which is again consistent with the monitoring channel. However, this evidence is only indirect, as different selection patterns could also explain the non-results for DrillCo contracts.

6 Identification Threats

In this section, I address two plausible identification threats: (1) a composition effect not captured by the fixed effects, and (2) an effect driven by strategic reporting, where PE firms report a toxic component as a confidential item instead of not using it. Finally, I replicate the results using another definition of toxicity.

6.1 Endogenous sorting on population and housing density

One potential concern is that PE firms could drill in places with higher populations or more housing units, implying that PE firms increase human exposure to pollution despite reducing production. The fixed-effect specification partially mitigates this concern by having a level of geographical comparison that is coarse, namely a square of 6 by 6 miles. However, there could still be population variation among these locations. This section shows that wells drilled by PE-backed firms are not located in census tracts with higher populations or more housing units and that controlling for these factors has no impact on the final results.

The first test is to adopt a specification similar to both the baseline results and the natural experiment, where the dependent variable is the total population of the census tract or the number of housing units where the well is located. Panel A of table A.7 contains the results for the baseline effects. The magnitudes are economically small: PE-backed firms drill in areas that have —at most— less than two housing units or one person, and the effect is not statistically significant at the 5% threshold. Panel B of table A.7 shows the results of the natural experiment. Similarly, the magnitudes are not economically and statistically significant. Specifically, after the BLM shock, PE-backed firms drill in areas that have at most less than four housing units or nine persons. Overall, the specifications suggest that the results are not driven by a composition effect where PE-backed firms compensate for reducing pollution by drilling in areas with a higher population or greater housing density.

The second exercise is to replicate the baseline tests and the natural experiment, adding the housing and dependent variables as controls. Table A.5 contains the results for the baseline specifications and table A.6 for the natural experiment. The controls are added in a linear way. Then, the controls and their squared value with their full interactions are added to capture potential non-linearity effects. Finally, I create a sample decile for the number of housing units or the total population of the census tract where the well is located and add it to the specifications as a fixed effect. Overall, the results remain similar when such controls are added.

6.2 Role of strategic reporting or greenwashing

The next verification tests whether the observed drop in toxic pollution is driven by firms reporting toxic components as confidential. This could be a concern as firms can report a component as a trade secret instead of providing its specific CAS number. PE-backed firms could simply be better at manipulating state disclosure.

The first test is to replace the dependent variable as the number of confidential items that is reported, in both the baseline results and the natural experiment specification. Table A.4 contains the results. Panel A shows that both PE ownership and financing through DrillCo contracts are associated with an improvement in reporting quality, as they lead to an important drop in the number of confidential items reported, which is both economically and statistically significant. Specifically, PE ownership and financing lead to a drop of four confidential items reported. Panel B shows that the BLM shock has no significant impact on the number of confidential items reported. The magnitudes are not statistically significant and minimal, below one item.

The second test adds the number of confidential items reported as a control. If the effect is driven by a substitution effect, then the drop in the number of toxic chemicals should be absorbed by the control. Table A.3 reports the results of this exercise. The controls are first added linearly or as a fixed effect for each number of confidential items. The baseline magnitudes are similar for both the natural experiment and the baseline effect.

Overall, these two tests suggest that the effects are not driven by a strategic reporting motive, where PE-backed firms report their toxic chemicals as confidential items.

6.3 Other measures of toxic chemicals and geographical distance

In appendix A.8, I replicate the results with another definition of toxic chemicals, using the EPA's Integrated Risk Information System (IRIS) instead of Congressional reports. While the IRIS classification is noisier, contains components that have not been proven toxic by scientific papers, and aggregates different levels of toxicity, the results are qualitatively the same. Panel A shows that PE ownership leads to a drop in pollution. The magnitudes are lower, as the effect is equal to -0.089 instead of 0.19. The effect is statistically significant. Similar to the baseline results, we find a small and statistically non-significant effect of DrillCo deals on pollution. Panel B confirms the results of the natural experiment, that PE-backed firms pollute more following an increase in regulatory risks. Consistent with the idea that this measure is noisier, the magnitudes are lower and equal to 0.17 but are statistically significant.
I estimate different variants of the baseline results to ensure that the main results are not entirely driven by how the econometrician groups the wells. Specifically, I estimate the dynamic event-study windows with a new set of fixed effects. I include a geographical-time fixed effect, that regroups within the same year, wells in the same basin, the same state, and the same latitude and longitude unit. Figure A.5 maps the different regions used to construct the same latitude and longitude unit. The results can be seen in Figure A.6 and are similar to the baseline estimation.

7 Conclusion

This paper has two main empirical results. First, on average, PE ownership leads to a reduction in pollution that is quantitatively significant, equivalent to a 70% reduction in the usage of toxic chemicals and a 50% reduction in flaring. The reduction is shown using dynamic differences-in-differences event study plots around 110 PE acquisitions in a specification that includes firm fixed effects (FE), hyper-local area FE interacted with year FE, and a large set of well-level characteristics. While I lack a complete randomization of PE acquisition, I provide several pieces of evidence that support a causal interpretation. The purchase decision by PE firms is more likely driven by firms' core assets, rather than peripheral projects. The effect still holds when I focus on projects from areas that do not belong to the core activities of the target firm. The reduction is not driven by strategic reporting from firms, different exposure to local population or housing and holds for different measures of chemical toxicity and geographical distance.

I hypothesize that PE ownership confers strong incentives to maximize shareholders value,[21] which leads to less pollution, when environmental regulation is likely to increase in the future. More environmental liability risks diminish the marginal benefit of over-complying. This benefit could take the form of more enforcement actions or passive learning effects on how to produce with a cleaner technology. While this interpretation is consistent with the context of the fracking industry, I exploit a natural experiment in a second step to better identify this channel.

Specifically, I show that PE firms relatively double the amount of toxic components in Native American and federal territories when the Bureau of Land Management faced important legal hurdles to regulating fracking, caused by court decisions and the Trump administration's hostility toward environmental regulation. This highly localized relative increase in pollution does not reverse the average reduction observed during the whole period and for all shale basins. It also confirms the initial interpretation of the baseline results and allows us to plausibly reject an explanation fully driven by a non-pecuniary, financial constraint or technological upgrade channels.

This average reduction in pollution is conditional on production happening with a given technology and geological basins. This study is silent on any possible general equilibrium effects of PE

[21] A PE sponsor provides a form of ownership that better aligns the incentives of owners with the corporate managers (Jensen (1989), Gompers, Kaplan, and Mukharlyamov (2016), Morris and Phalippou (2020)). The use of greater debt disciplines managers, and PE firms increase managerial incentives to maximize profit through performance-based pay or better management practices (Bloom, Sadun, and Van Reenen (2015)). General partners, on behalf of limited partners, control the board of their portfolio companies and actively monitor them. Moreover, general partners do not generally have any personal connections with local communities that could interfere with pollution decisions.

financing on the total amount of pollution that this sector generates. Measuring such impact at the industry level is not in the scope of this study, as it would require knowing (1) how the financing provided by PE firms can be substituted by other sources of funds, (2) how the lack of PE financing delays production, and (3) how exogenous technological progress in the oil and gas industry affects pollution. Moreover, this study is silent regarding cross-industry effects. Acemoglu et al. (2019) highlight that shale gas activities can also have general equilibrium across industries. If shale activities reduce the usage of coal, which is more CO2 intensive, they also increase pollution by increasing total output and reducing the incentive to innovate in clean energy.

There are at least two questions for further work. First, it would be interesting to investigate whether private equity is an investment class that has superior contractual features for implementing the non-pecuniary preferences of their limited partners. This question is unclear and relevant given the recent surge of impact investing and the existence of impact investing in private markets (Barber, Morse, and Yasuda (2021)). The ability of PE firms to closely monitor their portfolio companies for environmental matters, as shown in this paper, is one way they could provide an advantage to investors interested in implementing more environmentally friendly policies. However, it becomes more difficult for limited partners to monitor PE's firms actions because of their private nature. Second, recent work highlights the importance of environmental liability risks in firms' ability to secure their debt (Bellon (2021) and Choy et al. (2021)) and document an important growth in ESG loans (Kim et al. (2021)) and green bonds (Flammer (2021)). How banks' sensitivity to environmental factors —either for risk or non-pecuniary motivations— affects the operational outcomes of PE leveraged buyouts through their ability to improve the pledgeable income of PE's portfolio companies is unknown.

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Tables / Figures

Figure 1: Importance of pollution among PE deals

Figure 1.A

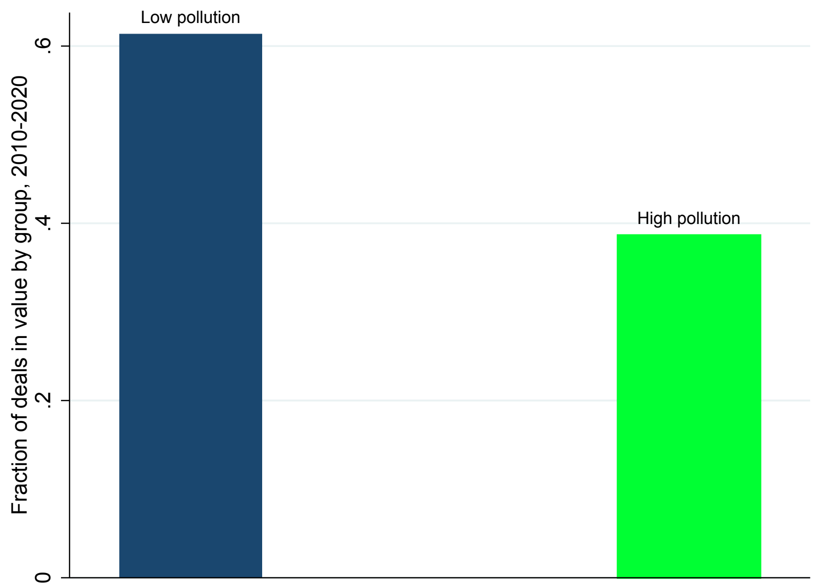
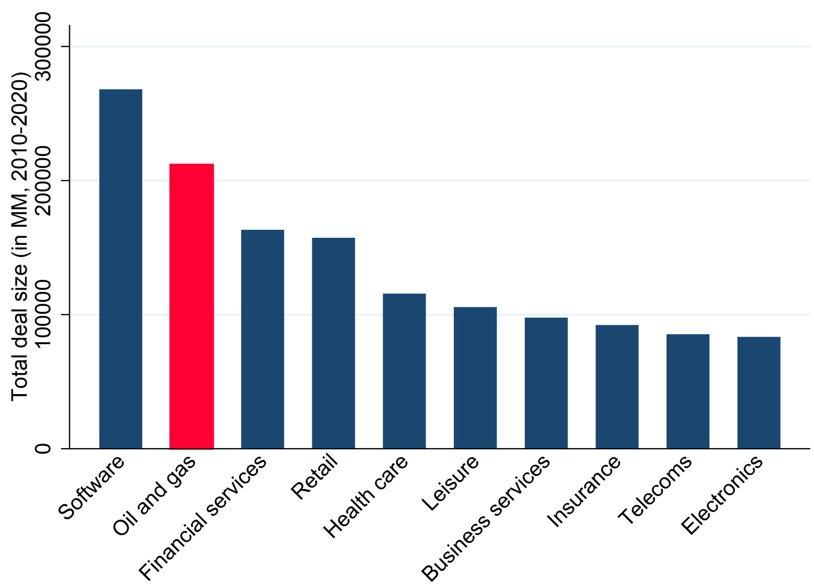


Figure 1.B



Note: Figure 1.A reports the fraction of PE investment in dollar value where a control right is transferred in industries that emit a significant amount of pollution. This includes natural resources, energy, transportation, infrastructure and manufacturing industries. Figure 1.B reports the cumulative amount of the deal size in million of dollars between 2010 and 2020 for the ten industries that have the highest amount of deals in dollar values. For both graphs, the investment types are: Add-on, Buyout, Growth Capital and PIPE. I use deal-level data from Preqin to compute the figures.

Figure 2: Distribution Of Projects

Figure 2.A: all projects

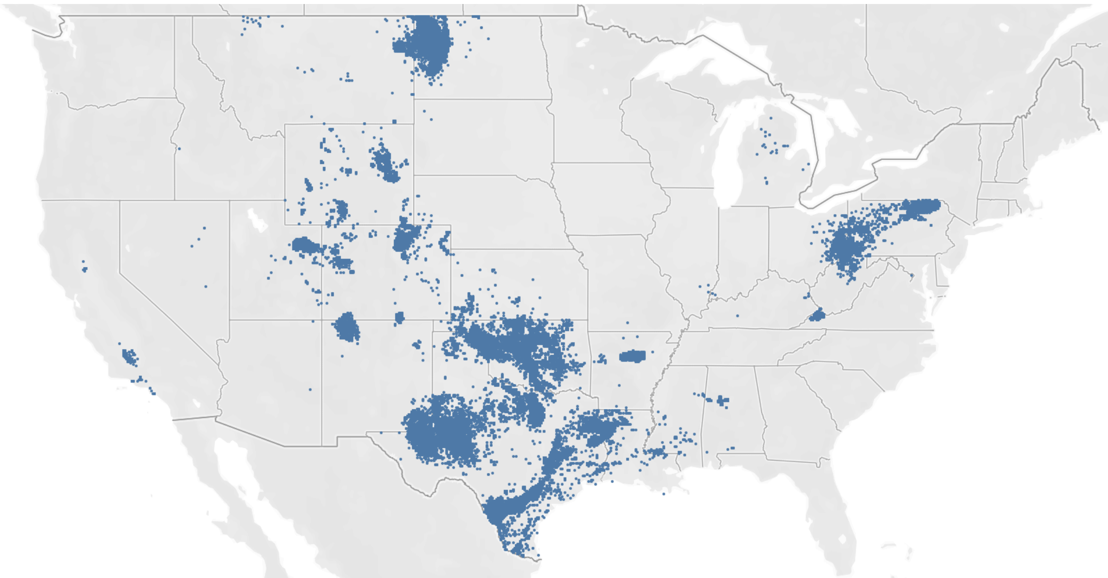
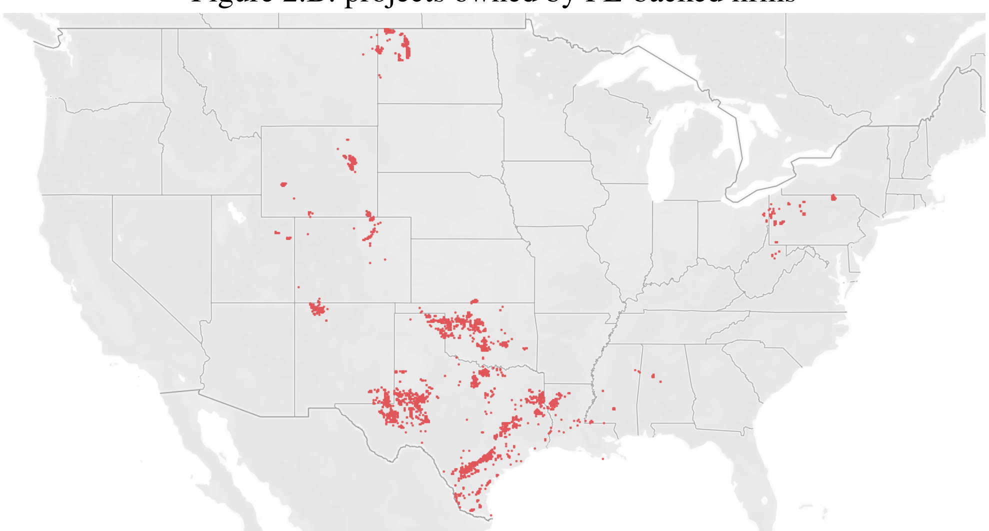
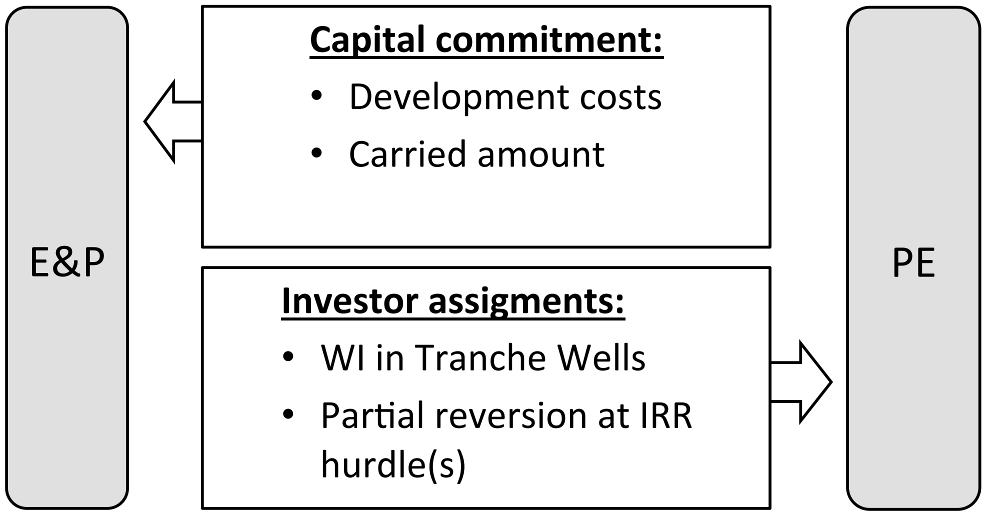


Figure 2.B: projects owned by PE-backed firms



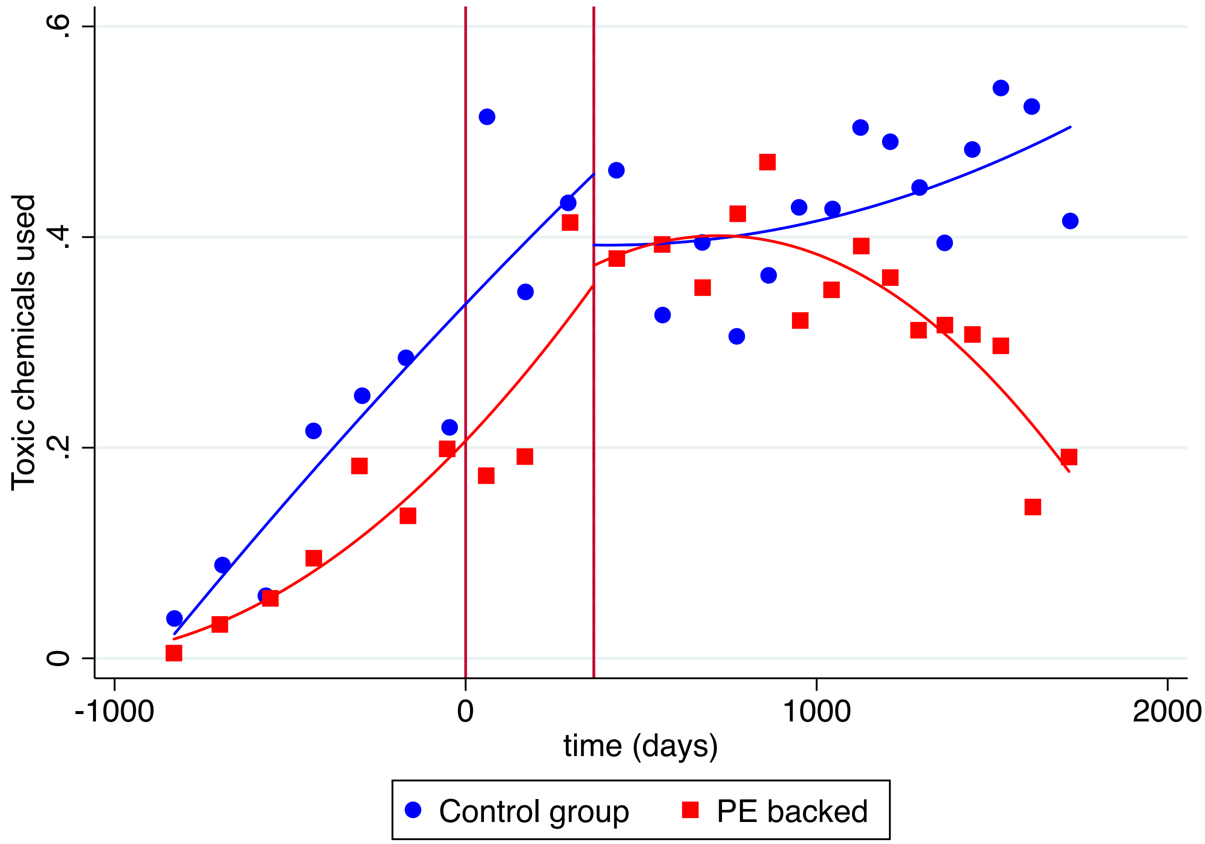
Note: These two figure show the location of the projects that I use in the statistical analysis. Sub-figure (a) shows all the projects, whereas sub-figure (b) only plots the projects that are owned by a PE-backed firm at some point in the sample.

Figure 3: Structure Of A DrillCo Deal



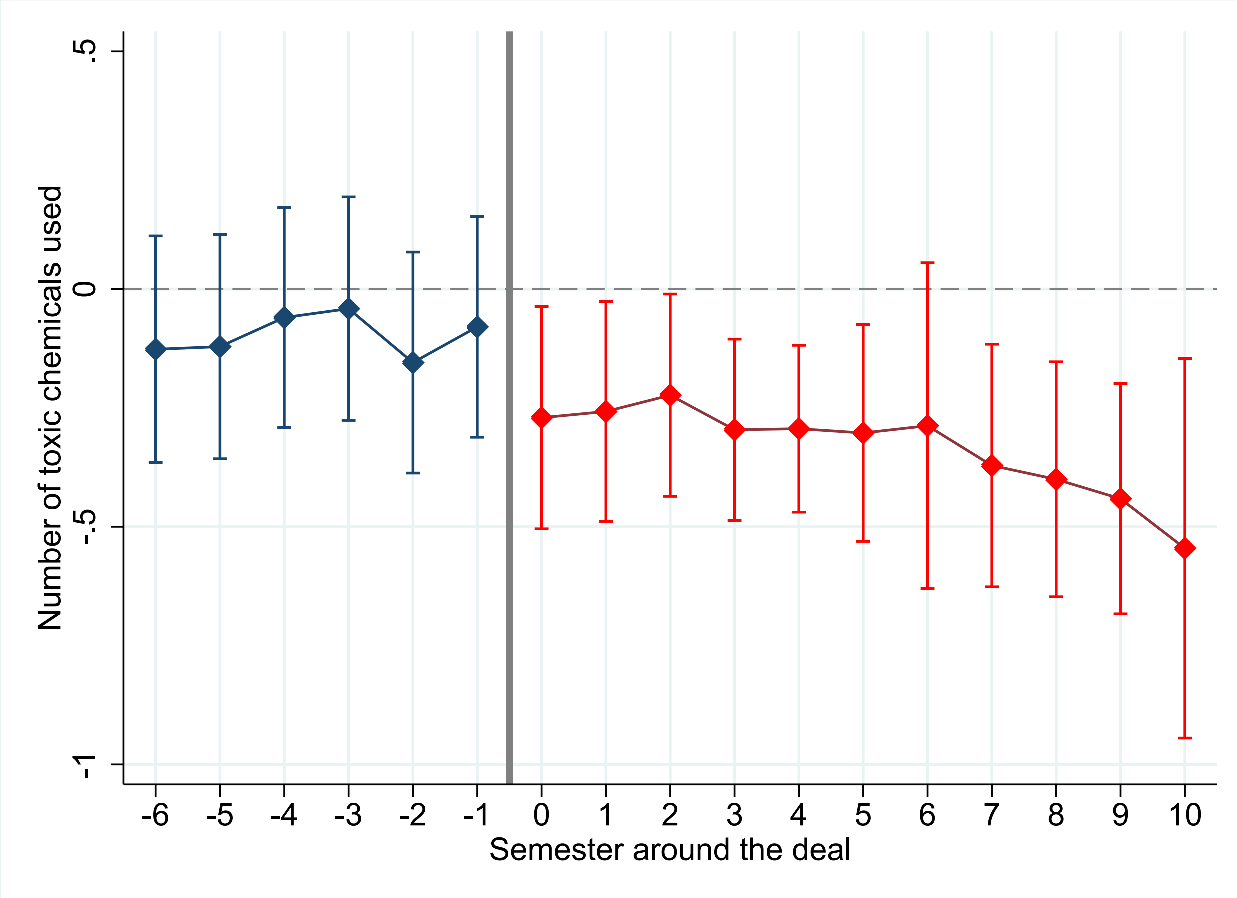
Note: This figure summarizes the structure of a DrillCo deal between a Private Equity (PE) firm and an exploration & production (E&P) company.

Figure 4: Raw Binscatter Of Pollution Around The PE Deal



Note: This figure reports the binscatter of the toxic chemicals used during the production process around the year of the PE deal. Each dot is the average of the number of toxic chemicals calculated on 5% of the sample that have the closest distance in days after or before the deal for both the treated and control group. Our treated group is the sample of projects made by firms that will be purchased by a PE, whereas our control group is the sample of projects made by firms that will not be purchased by a PE. The control group is constructed as follow: for each project among the treated group, we select with replacement the project in the control group that has been completed in the same basin and year, and has the closest size (horizontal length and vertical depth) and production (both oil and gas) using the mahalanobis metric. We restrict the analysis on the sample of firms that exist both before and after the deal for the treated group, although the graph remains similar if we include unbalanced firms. Notice here that we are performing the matching both before and after the deal, at the project level. The pattern observed is supporting the view that PE firms reduced pollution, and the effect is the strongest three years after the deal. This analysis should be interpreted in a non-causal way, as no fixed effect and controls are included.

Figure 5: Impact Of PE Buyout On The Number Of Toxic Chemicals

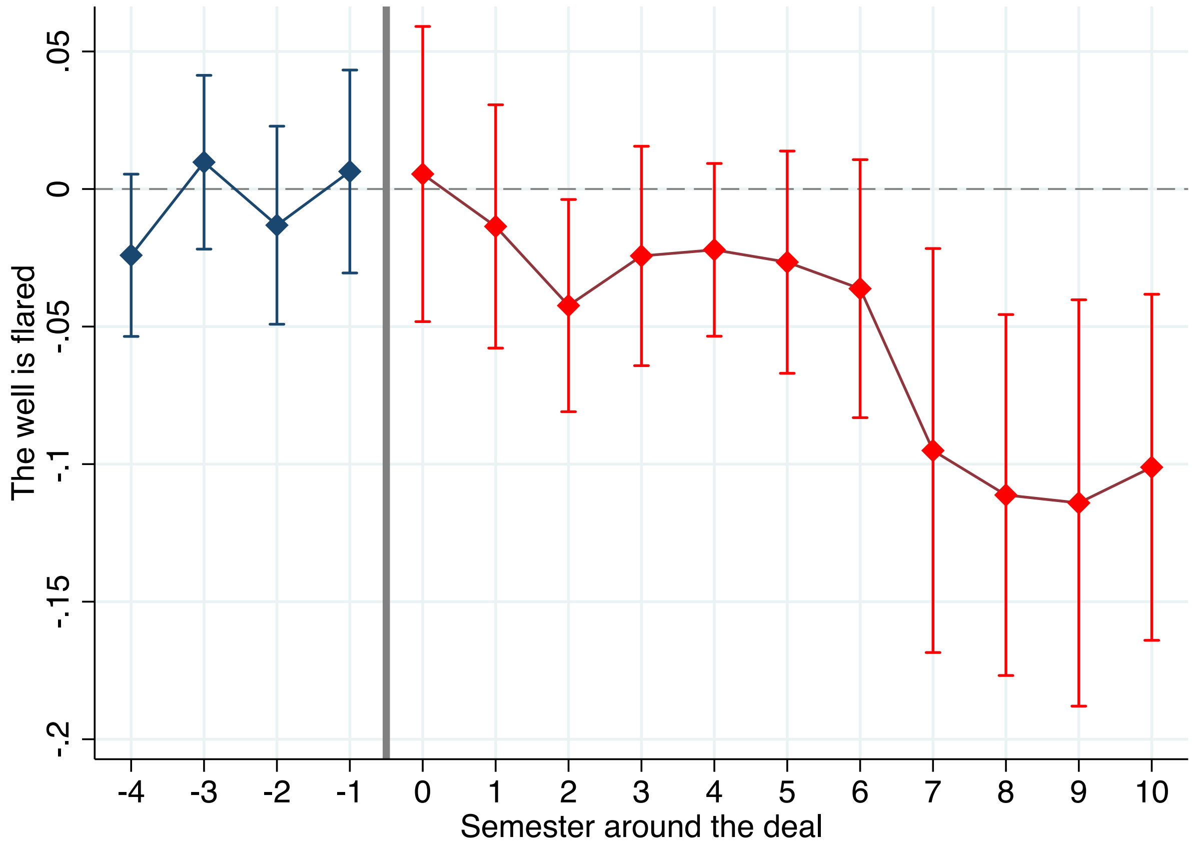


Note: This figure reports the dynamic difference-in-differences estimates around the PE buyout as well as its confidence interval estimated in the full sample. More specifically, the $(\gamma_\tau)_{\tau=-6,\ldots,9,10}$ of the following estimated equation are reported:

$$Y_{ijt} = \text{Firm}_i + \text{Location}_j \times \text{Year}_t + \sum_{\tau=-6}^{10} \gamma_\tau.(\tau \text{ semester(s) after the PE deal}) + controls_{it} + \varepsilon_{ijt}$$

Where Y_{ijt} is the total number of toxic chemicals used for a well and as defined in Table 1. Firm_i is an operator fixed effect, that captures any heterogeneity at the firm level that is constant through time and affects the decision to use toxic chemical. Location_j is a geographical fixed effect, that regroups all wells that have the same first 2-digit longitude and latitude. To illustrate this grouping, Figure A.4 plots the wells with a same color if they have the same first two digits of latitude and longitude and if they are situated in one half of the Marcellus formation. This location fixed effect is interacted with a year Fixed effect (Year_t). $controls_{it}$ includes the production of oil and gas of the well, its vertical depth and horizontal length. Standard errors are clustered at the firm level and confidence intervals at the 5% level are reported.

Figure 6: Impact Of PE Buyout On Flaring

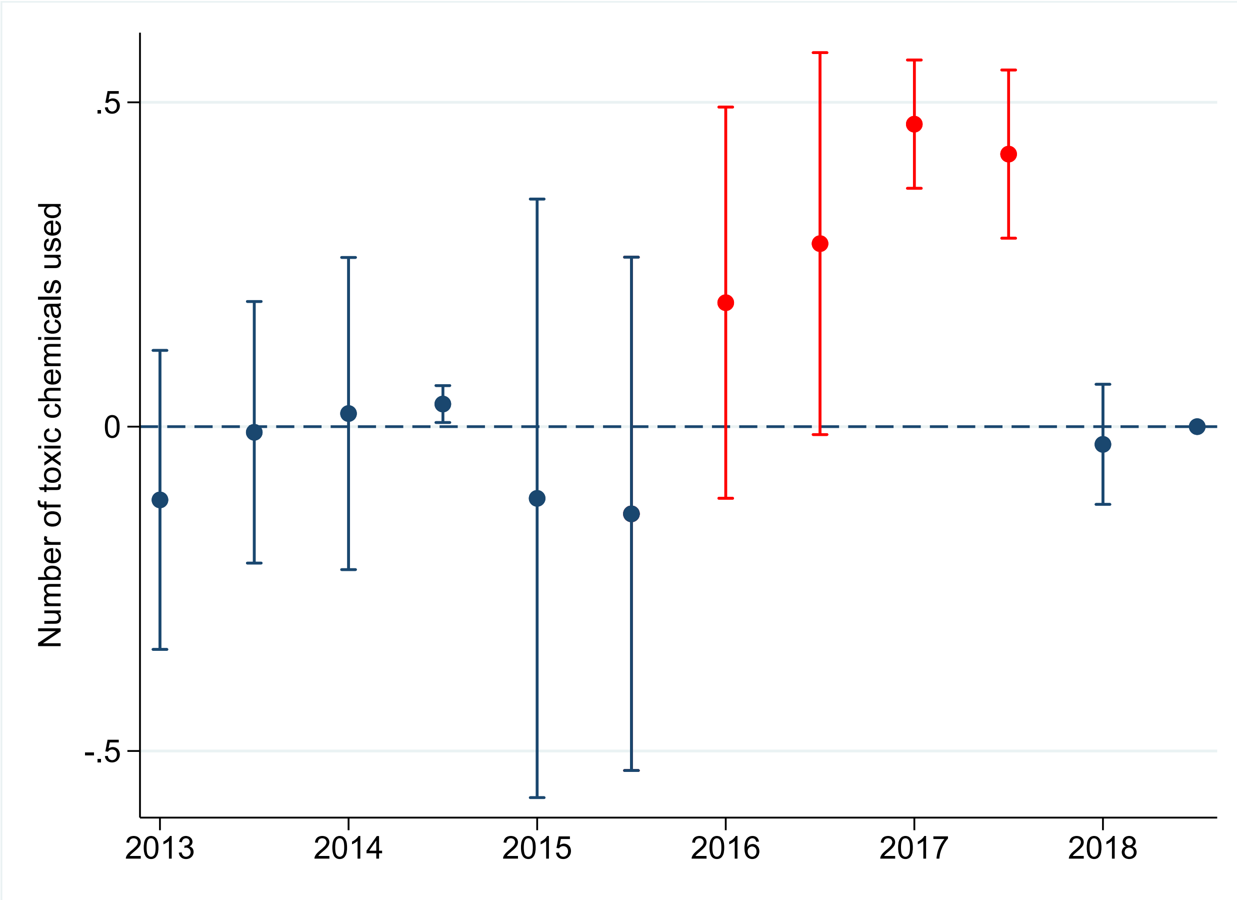


Note: The dependent variable takes one if the firm is flaring gas for the well i, 0 otherwise. I construct the depend variable using satellite data, available starting from 2012. I validate this data source by showing that the measure correctly captures the geographical (see figure A.2) and temporal (see figure A.3) distribution of well activities. I restrict the sample to wells that are not too close one from the other, although as we show in the online appendix, the results remain the same without this restriction. The dynamic difference-in-differences estimates around the PE buyout as well as its confidence interval are estimated using the full sample. The $(\gamma_\tau)_{\tau=-4,\ldots,9,10}$ of the following estimated equation are reported:

$$Y_{ijt} = \text{Firm}_i + \text{Location}_j \times \text{Year}_t + \sum_{\tau=-4}^{10} \gamma_\tau.(\tau \text{ semester(s) after the PE deal}) + controls_{it} + \varepsilon_{ijt}$$

where Y_{ijt} is whether the company is flaring the well i. Firm_i is an operator fixed effect, that captures any heterogeneity at the firm level that is constant through time and affects the decision to flare. Location_j is a geographical fixed effect, that regroups all wells that have the same first 2-digit longitude and latitude. To illustrate this grouping, Figure A.4 plots the wells with a same color if they have the same first two digits of latitude and longitude and if they are situated in one half of the Marcellus formation. $controls_{it}$ include the vertical depth and horizontal length of the well, but does not include the production variables, as they are mechanically correlated with the dependent variable. Standard errors are clustered at the firm level and confidence intervals at the 5% level are reported.

Figure 7: Impact Of Decreased Litigation Risks

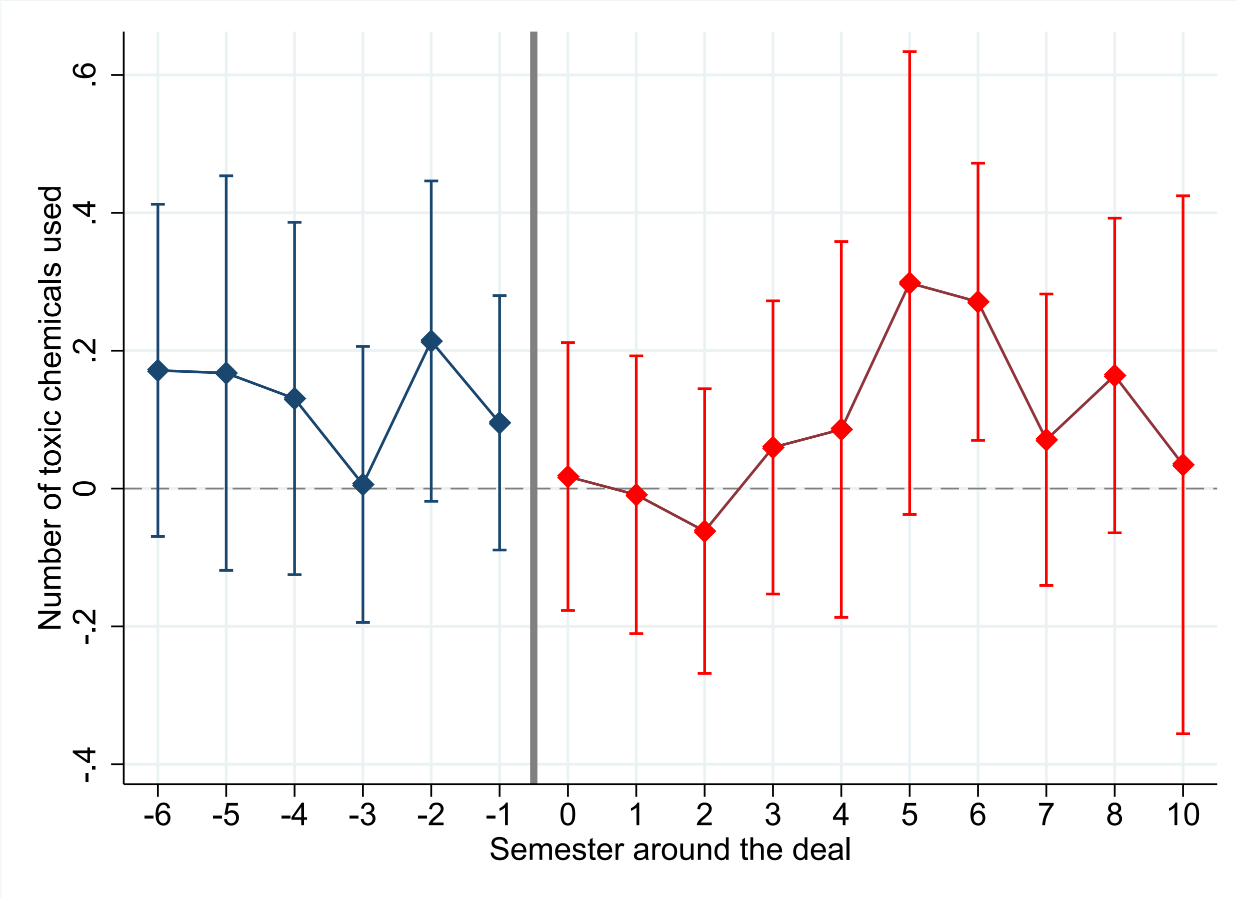


Note: This figure shows the dynamic difference-in-differences estimates on how PE-backed firms reacted to changes in BLM authority to regulate fracking in Federal lands and Native American reservations. It plots the difference in the usage of toxic pollutants for each semester between projects in regulated and non-regulated areas within PE-backed firms. More specifically, the $(\theta_\tau)_{\tau=2013,\ldots,2019}$ of the following estimated equation are reported:

$$Y_{ijt} = \text{Firm}_i \times \text{Year}_t + \text{Location}_j \times \text{Year}_t + \sum_{\tau=2013}^{2019} (\text{year}{=}\tau) \times (\text{BLM})_i \times \theta_\tau + X_{it} + \varepsilon_{ijt} \qquad (5)$$

Y_{ijt} is the total number of toxic chemicals used and as defined in Table 1. BLM_i is a dummy that takes one if the well is located in a Federal land or a Native American reservation, 0 otherwise. Firm_i is an operator fixed effect, that captures any heterogeneity at the firm level that is constant through time and affects the decision to use toxic chemical. Location_j is a geographical fixed effect, that regroups all wells that have the same first 2-digit longitude and latitude. To illustrate this grouping, Figure A.4 plots the wells with a same color if they have the same first two digits of latitude and longitude and if they are situated in one half of the Marcellus formation. This location and firm fixed effect are both interacted with a year Fixed effect (Year_t). Standard errors are clustered at the firm level and confidence intervals at the 10% level are reported. 2016 to 2017 include the time when the preliminary injunction was granted, the rule stroke down by the district of Wyoming and when the rule was voided by BLM (July 25, 2017) following the Trump administration. Finally, the period between 2018 and 2019 correspond to the time during which the State of California Jan. 24, 2018 sued BLM for his decision to rescind the rule.

Figure 8: Role Of Financial Constraints: Impact Of PE DrillCo On Pollution



Note: This figure reports the dynamic difference-in-differences estimates around PE DrillCo deals as well as its confidence interval estimated in the full sample. DrillCo deals are PE funding without any transfer of control rights or changes in the firm's capital structure. The $(\gamma_\tau)_{\tau=-6,\ldots,9,10}$ of the following estimated equation are reported:

$$Y_{ijt} = \text{Firm}_i + \text{Location}_j \times \text{Year}_t + \sum_{\tau=-6}^{10} \gamma_\tau.(\tau \text{ semester(s) after the PE deal}) + controls_{it} + \varepsilon_{ijt}$$

Where Y_{ijt} is the total number of toxic chemicals used for a well and as defined in Table 1. Firm_i is an operator fixed effect, that captures any heterogeneity at the firm level that is constant through time and affects the decision to use toxic chemical. Location_j is a geographical fixed effect, that regroups all wells that have the same first 2-digit longitude and latitude. To illustrate this grouping, Figure A.4 plots the wells with a same color if they have the same first two digits of latitude and longitude and if they are situated in one half of the Marcellus formation. This location fixed effect is interacted with a year Fixed effect (Year_t). $controls_{it}$ includes the production of oil and gas of the well, its vertical depth and horizontal length. Standard errors are clustered at the firm level and confidence intervals at the 5% level are reported.

Table 1: Definition And Source Of Toxic Chemicals

Chemical name	CAS number	Toxicity
2-butoxyethanol	111-76-2	cause hemolysis (destruction of red blood cells), spleen, liver, and bone marrow.
Xylene	1330-20-7	human carcinogen, SDWA, CAA
Toluene	108-88-3	human carcinogen, SDWA, CAA
Ethylbenzene	100-41-4	human carcinogen, SDWA, CAA
Benzene	71-43-2	human carcinogen, SDWA, CAA
Bis(2-ethylhexyl) phthalate	117-81-7	human carcinogen, SDWA, CAA
2-Propenamide	79-06-1	human carcinogen, SDWA, CAA
Copper	7440-50-8	human carcinogen, SDWA, CAA
Lead	7439-92-1	human carcinogen, SDWA, CAA

Note: The Table reports the chemicals used as our main dependent variable. They have in common that they are both highly toxic and salient as they have been reported in environmental reports as well as reports from the United States House of Representatives Committee on Energy and Commerce (for instance, April 2011). Most of them are regulated at the federal level, but the hydraulic fracturing benefits from several exemptions: this industry is not subject to the Safe Drinking Water Act (SDWA) and to several permitting and pollution control requirements from the Clean Air Act (CAA). Human carcinogens are substances that promote the formation of cancers.

Table 2: Descriptive Statistics

Panel A: Descriptive statistics, full sample (project level)

	Mean	S.D.	Min	Max
Number of toxic chemicals	.282	.546	0	4
Flaring	.216	.411	0	1
Productivity	8.043	32.632	0	2208
Production per fracturation	48.092	75.930	0	2340.63
Density population	107.571	616.922	0	6211.5
Density housing	47.1048	258.970	0	2479.6
Vertical depth	8984.05	2463.7	628	36386.56
horizontal depth	6552.907	2503.967	0	19982.37
First 6 months gas	256476.3	376568.3	0	8030048
First 6 months oil	45543.9	45877.21	0	608979

Panel B: Descriptive statistics, full sample (Firm level)

	mean	S.D.	min	max
Projects	97.49	490.65	1	7765
Basin	1.70	1.82	1	23
Coarser location	10.68	36.83	1	603
Location	2.94	5.42	1	85
State	1.372	1.1740	1	18

Note: These tables report the baseline descriptive statistics. Panel A reports information for the full sample at the project level and Panel B when data at the firm level are used.

Table 3: Comparison: PE ownership

Panel A: Firm level

Variables	Group treated	Control group	Diff	S.D.
Projects	101.00	98.26	2.740	70.204
Basin	1.23	1.71	-0.397*	0.219
Coarser location	12.52	10.58	2.092	5.827
Location	2.94	2.91	0.031	1.014
State	0.98	1.38	-0.375*	0.203

Panel B: Project level

	Treated	Control	Diff.	S.D	Adj Diff	Adj S.D.
Nb toxic chemicals	0.18	0.29	-0.109	0.091	-0.086*	0.050
Flaring	0.14	0.15	-0.009	0.015	-0.007	0.017
Completion time	12.28	6.15	6.127***	2.179	6.649***	2.307
Prod. per Frac.	30.06	58.64	-28.577***	5.550	-1.145	1.500
Population	56.16	146.32	-90.158***	25.584	6.343	6.905
Housing	25.12	63.29	-38.174***	10.729	2.393	3.034
True Vertical Depth	9284.62	8472.03	812.586***	270.587	-92.787	80.136
Horizontal Length	5840.44	6606.14	-765.703***	192.083	-57.728	67.369
First 6 Gas	127451.91	231403.38	-103951.476***	24957.240	-2383.608	6038.700
First 6 Oil	44577.78	29711.73	14866.054**	6836.856	11747***	3986.702

Note: These tables report descriptive statistics. Panel A depicts the difference in characteristics when there is no PE ownership for both the control and treated group. Panel B reports the difference in characteristics at the firm level when there is no PE ownership for both the control and treated group. Adj diff and adj p are after the inclusion of the following FE, that are used in the regressions: (1) geographical groups based on the first two digits of the latitude and longitude interacted with a year FE. Standard errors are clustered at the basin-year level. S.D. stands for the standard deviation of the difference.

Table 4: Comparison: DrillCo Transactions

Panel A: Firm level

Variables	Group treated	Control group	Diff.	S.D.
Projects	387.89	89.03	298.914	197.390
Basin	2.18	1.67	0.504	0.615
Coarser location	27.75	10.17	17.576*	9.064
Location	5.29	2.85	2.438	1.706
State	1.57	1.36	0.214	0.413

Panel B: Project level

Variables	Group treated	Control group	Diff.	S.D.	Adj. Diff.	Adj. S.D.
Nb toxic chemicals	0.31	0.28	0.027	0.123	0.071	0.053
Flaring	0.1	0.15	-0.048	0.031	-0.022	0.034
Completion time	4.54	6.46	-1.92	1.513	0.582	0.401
Prod. per Frac.	43.08	59.22	-16.139	11.509	-2.441	2.244
Population	136.82	142.2	-5.375	91.913	-0.815	3.794
Housing	59.99	61.49	-1.507	38.614	-0.618	1.811
True Vertical Depth	8650.31	8487.59	162.719	427.494	20.226	60.098
Horizontal Length	6637.25	6543.04	94.209	554.741	173.417**	86.767
First 6 Gas	168061.98	233148.38	-65086.401*	35680.1	10744.812*	5901.011
First 6 Oil	25676.5	30436.48	-4759.975	8054.986	2627.599	2269.102

Note: These tables report descriptive statistics. Panel A depicts the difference in characteristics before a DrillCo is signed for both the control and treated group. Panel B reports the difference in characteristics at the firm level when there is no DrillCo signed for both the control and treated group. Adj diff and adj p are after the inclusion of the following FE, that are used in the regressions: (1) geographical groups based on the first two digits of the latitude and longitude interacted with a year FE. Standard errors are clustered at the basin-year level. S.D. stands for the standard deviation of the difference.

Table 5: Comparison: Native American reservations / Federal Lands And The Others

Variables	Group treated	Control group	Diff.	S.D.	Adj. Diff.	Adj. S.D.
Nb toxic chemicals	0.31	0.21	0.105**	0.05	0.017	0.029
Flaring	0.17	0.12	0.051*	0.029	0.013	0.009
Completion time	4.38	4.19	0.189	0.811	1.067*	0.547
Prod. per Frac.	44.2	57.04	-12.842*	7.637	-1.289*	0.762
Population	135.41	137.34	-1.929	48.067	-7.175*	4.189
Housing	54.83	60.28	-5.457	18.154	-3.389*	2.023
True Vertical Depth	8803.85	8384.6	419.254	364.981	51.574	41.177
Horizontal Length	6559.74	6010.92	548.824*	327.777	119.689	101.757
First 6 Gas	129676.43	189215.88	-59539.453**	24341.688	-3448.482	2236.68
First 6 Oil	20226.34	22241.5	-2015.155	3715.142	-43.474	765.643

Note: These tables report descriptive statistics. This table depicts the differences in characteristics between projects in federal lands and Native American reservations before the preliminary injunction of September 2015. Adj diff and adj p are after the inclusion of the following FE, that are used in the regressions: (1) geographical groups based on the first two digits of the latitude and longitude interacted with a year FE. Standard errors are clustered at the basin-year level. S.D. stands for the standard deviation of the difference.

Table 6: Impact Of PE On Pollution: Baseline Results

Panel A: Toxic chemicals

	Dependent variable: Number of toxic chemicals					
	PE deal with control rights			Drillco (no control rights)		
	(1)	(2)	(3) NNM	(4)	(5)	(6) NNM
Post deal	-0.198***	-0.198***	-0.209***	-0.038	-0.038	-0.022
	(0.054)	(0.054)	(0.036)	(0.046)	(0.046)	(0.048)
Controls		X	X		X	X
Firm FE	X	X	X	X	X	X
Location × Year FE	X	X		X	X	
Basin × Year FE			X			X
Adjusted R^2	0.56	0.56	0.35	0.55	0.55	0.45
Observations	135554	135554	21433	135738	135738	28581

Panel B: Flaring

	Dependent variable: Whether the well is flared					
	PE deal with control rights			Drillco (no control rights)		
	(1)	(2)	(3) NNM	(4)	(5)	(6) NNM
Post deal	-0.044**	-0.045**	-0.028**	0.039***	0.040***	0.038***
	(0.019)	(0.019)	(0.013)	(0.010)	(0.011)	(0.010)
Controls		X	X		X	X
Firm FE	X	X	X	X	X	X
Location × Year FE	X	X		X	X	
Basin × Year FE			X			X
Adjusted R^2	0.37	0.37	0.21	0.37	0.37	0.26
Observations	96787	96787	14252	96787	96787	21324

Note: Columns (1), (2) and (3) report the impact of PE ownership on pollution and columns (4), (5) and (6) study the impact of PE financing through DrillCo contracts on pollution. Column (1) and (4) estimate the relationship without controls, that are added in column (2) and (5). The coefficients remain stable when the controls are added. Column (3) and (6) contain the results when the relationship is estimated on the matched sample using a nearest neighbor matching (NNM) approach, both before and after the deal at the project level. The matched sample is constructed as follow: for each project that belongs to a firm that is acquired by a PE, we matched within the same geographical area (basin) and year, the project that has the closest size (horizontal length and vertical depth) and production (6 first months production of oil and gas). For Panel A, the dependent variable is the number of toxic chemicals used in the production process. Panel B reports the results where the dependent variable is a dummy that takes one if the project has flared gas. Standard errors are clustered at the firm level.

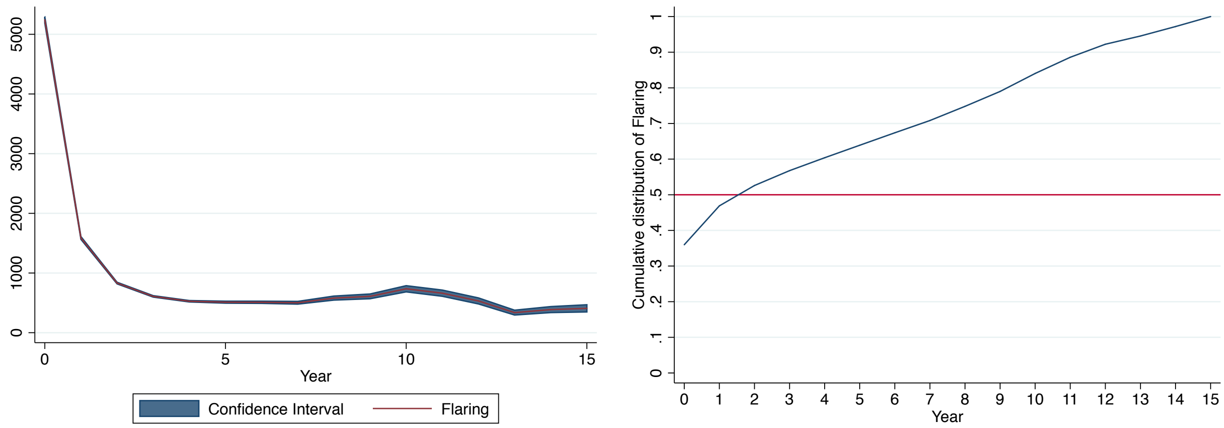
Table 7: BLM Natural Experiment

	Dependent variable: Number of toxic chemicals			
	(1)	(2)	(3)	(4)
Federal or Indian well × Post deal × Post Injunction	0.383***	0.382***	0.308***	0.309***
	(0.090)	(0.091)	(0.084)	(0.084)
Post deal × Post Injunction	-0.016	-0.016	-0.005	-0.005
	(0.054)	(0.054)	(0.058)	(0.058)
Federal or Indian well × Post deal	-0.053	-0.052	-0.032	-0.033
	(0.055)	(0.055)	(0.061)	(0.061)
Federal or Indian well × Post Injunction	-0.015	-0.015	-0.045	-0.045
	(0.052)	(0.052)	(0.046)	(0.046)
Post deal	-0.191***	-0.191***	(.)	(.)
	(0.056)	(0.056)	(.)	(.)
Federal or Indian well	0.033	0.033	0.044*	0.044*
	(0.026)	(0.026)	(0.024)	(0.024)
Post Injunction	0.014	0.015	0.013	0.013
	(0.024)	(0.023)	(0.024)	(0.024)
Controls		X		X
Firm × Year FE			X	X
Firm FE	X	X		
Location × Year FE	X	X	X	X
Adjusted R^2	0.56	0.56	0.62	0.62
Observations	135738	135738	135257	135257

Note: The table reports a triple difference-in-differences that estimate the differential impact of the BLM litigation on pollution for Native American reservations and federal lands for firms that are owned by a PE firm. The variable "Post Injunction" takes the value one if the project starts between 30/09/2015 (day of the preliminary injunction) and 24/01/2018 (day when the State of California sued BLM over the rescission). The coefficient of particular interest is: Federal or Indian well × Post deal × Post Injunction and is negative, which shows that PE-backed firm increases pollution following a reduction in litigation and compliance risks. Panel B reports the net effect. For both panels, columns (1) and (2) contain a firm fixed effect, whereas columns (3) and (4) contain a firm-year fixed effect. Controls are added in column (2) and (4) and the coefficients of interest remain stable.

ONLINE APPENDIX

Figure A.1: Cash Flows of Flaring



Note: This graph reports the production curves of the gas flared for wells that are potentially not connected to a pipeline in North Dakota. The data come from the North Dakota Industrial Commission that requires operators to report the quantity of gas flared. The left Figure reports for each year after the well is completed, the total number of gas flared, in MCF (thousand cubic feet). The right figure represents the cumulative distribution of the amount of gas flared during the first 15 years. As can be seen, more than 50% of all the flared gas is done within the first 2 years after the well is completed. Whether the well is connected to a pipeline is confidential information. I make the assumption that wells flaring a large amount of gas are more likely not to be connected to a pipeline. Therefore, I first compute the total amount of gas flared during the well first 15 years and then I keep the 25% with the highest amount of flaring. The distributions look similar if I use different ways of selecting the data, only the level of the curves changes.

Interpretation Reducing flaring is costly and most of the cost of reducing flaring is paid at the beginning of the project, while the benefits are only available in the medium long-run. Connecting the well to a pipeline and has two components. On-site facilities and equipment, such as dehydrators and compressors need to be installed close to the well. Their prices vary greatly according to the location and the year, so precise project-level estimates are hard to come by. According to the Interstate Natural Gas Association of America (INGAA) the costs were on average $210,000 per well in the Bakken. Then, the well needs to be connected to a pipeline and the price is a function of how far the well is to a pipeline and the diameter of the connecting facility. According to the INGAA, the prices in 2017 ranged from $29,000 to $167,000 per mile for a diameter range between 2 and 22 inches.

The cash flows follow a predictably declining curve. Production of gas flared is available for North Dakota, but information on whether the well is connected to a pipeline is not available. Focusing on projects that are most likely not to have been connected to a well, Figure 7 plots the production of gas for each year after the well starts producing. As can be seen and consistent with an ARPS model used by practitioners (Fetkovich (1980)), we have a convex declining curve of gas production. Half of all the gas flared during the first 15 years of the life of a well is done within the first year and a half.

Quote And Citations From The Main PE Sponsors In The Oil And Gas Industry

“Well-managed sustainability strategies not only reduce pressure on our resources, they also yield operational cost savings, healthier and more productive work environments, and more valuable assets." "Saving water helps to preserve our environment as it is limited resource on earth and it will help to ensure a sustainable adequate water supply in future". **TPG Capital**.

“Protecting the environment of the communities in which we operate is critically important." **GSO Capital Partners**.

“We firmly believe that ESG issues can affect the risk-adjusted performance of our investment portfolios to varying degrees across asset classes over time". **GCP Capital Partners**.

“Contributed to national environmental standards formulation process through collaboration with the US Department of Energy to improve shale gas production best practices, disclosure and technology". **First Reserve Corporation**.

“We encourage and embrace the efficient use of natural resources and continuously look for and expect the best environmental solutions for our portfolio companies’ operations. We believe that economic considerations in isolation do not provide sufficient guidance for environmentally conscious decision-making that balances the interests of individuals, communities and future generations. We seek to fully comply and/or exceed compliance with applicable environmental regulatory requirements." **EnCap Investments**.

“We recognize the importance of climate change, biodiversity, and human rights, and believe negative impacts on project-affected ecosystems, communities, and the climate should be avoided". **Denham Capital Management**.

“Seek to grow and improve the companies in which they invest for long-term sustainability and to benefit multiple stakeholders, including on environmental, social and governance issues". **Carlyle Group.**

“Protecting the environment of the communities in which we operate is critically important". **Blackstone Group**.

Fracking Rule: Additional Background

The Bureau of Land Management (BLM) is responsible for the environmental regulation of federal land and Native American reservations. It oversees one eighth of the land in the continental United States. It is a federal agency within the U.S. Department of the Interior. Its core mission is "to sustain the health, diversity, and productivity of the public lands for the use and enjoyment of present and future generations." Within its mission, the BLM supervises the leasing of oil and gas reserves and provides technical advice for drilling operations on Native American reservations.

In 2012, the BLM started drafting a regulation aimed at reducing the negative externalities caused by hydraulic fracturing. The rule was finalized and made available on March 26, 2015 after collecting feedback, remarks, and comments. The regulation was supposed to be effective on June 24, 2015. It comprised several points: (1) improve the disclosure of operational activities, (2) increase the quality and integrity of the wellbore, and (3) increase the standard of water protection. This rule did not forbid the usage of highly toxic chemicals, but increased their indirect costs. Specifically, operators were required to "isolate all usable water and other mineral-bearing formations and protect them from contamination." The rule expanded the definition of usable water to include "waters containing up to 10,000 parts per million (ppm) of total dissolved solids," which doubled the previous threshold.

On March 20, 2015, various petitioners filed a motion for preliminary injunction to challenge the fracking rule[a]. The preliminary injunction was granted by the Federal Court of the 10th Circuit. The Federal Court found that "BLM did not have the authority to regulate fracking" (Williams (2015)), ending uncertainty over whether the BLM had legislative power over fracking activities. Specifically, each of the acts used by the BLM to justify its right to enact the Fracking rule, such as the Federal Land Policy and Management Act ("FLPMA"), the Mineral Leasing Act ("MLA") , was rejected by the court, under the reason that "none of them gave BLM authority to regulate fracking" (Williams (2015))[b].

On June 21, 2016, the rule is abrogated by the District of Wyoming and three days after the BLM appealed. On January 20, 2017, Trump is inaugurated and proceed to a change in the political orientation of the BLM, which now no longer supports the fracking rule. An interior Department Assistant Secretary stated that an "initial review has revealed that the 2015 Rule does not reflect . . . the current Administration's policies and priorities concerning the regulation of hydraulic fracturing on Federal and Indian lands". Shortly after, the Trump administration issued an executive order asking for the BLM to rescind the rule[c]. This causes the Tenth Circuit to dismiss the lawsuit as moot on September 21, 2017. The rescind is made official on December 29, 2017.

[a]The petitioners included the Independent Petroleum Association of America ("IPAA"), the Western Energy Alliance ("Alliance"), the states of Utah, North Dakota, Wyoming, Colorado and the Ute Indian Tribe.

[b]The remaining reasons to grant the preliminary injunction were the following. First, the regulation was not supported by "substantial evidence and lacked rational justification". Second, the consultation meetings with indigenous American tribes were not made in a way consistent with procedures and policies that this regulatory authority should respect. The next two reasons stated that the petitioners would have incurred "irreparable harm" if the regulation was allowed while the litigations were pending and these costs outweighs any potential harm to BLM.

[c]Executive Order No. 13,783, Presidential Executive Order on Promoting Energy Independence and Economic Growth, 82 Fed. Reg. 16,093 (Mar. 28, 2017).

Fracking rule: additional background (2/2)

Following this rescind, the State of California and a group of environmental activists sue the BLM on January 24, 2018 for voiding the fracking rule. Three main reasons were put forward to justify such an action. Firstly, this decision of the BLM was accused to be capricious. The Administrative Procedure Act (henceforth, APA) requires that any agency that decides to change its policy should explain why the new policy is better. The rescind was motivated by the fact that it was supposed to promote energy development on federal and tribal lands by removing regulatory burden. However, this explanation was not supported by the evidence put forward by the BLM itself that finds that the price of oil and gas is the main factor affecting the production of fracking activities. Thus the explanation "runs counter to the evidence before the agency". Secondly, the APA requires that agencies should always act in a way that is allowed by their statute. The rescind of the fracking rule was seen as contradicting its statute. Indeed, the core missions of the BLM are to prevent "unnecessary or undue degradation" of public lands and to enable the development of energy while ensuring environmental protections. Thirdly, the decision to rescind the rule violates the National Environmental Policy Act as the BLM didn't carry out an environmental impact analysis of the repeal.

Figure A.2: Geographical Distribution Of Flaring Practices

This figure plots the geographical distribution of the practice of flaring as detected by the satellite measure. It matches the spatial distribution of oil and gas basins.

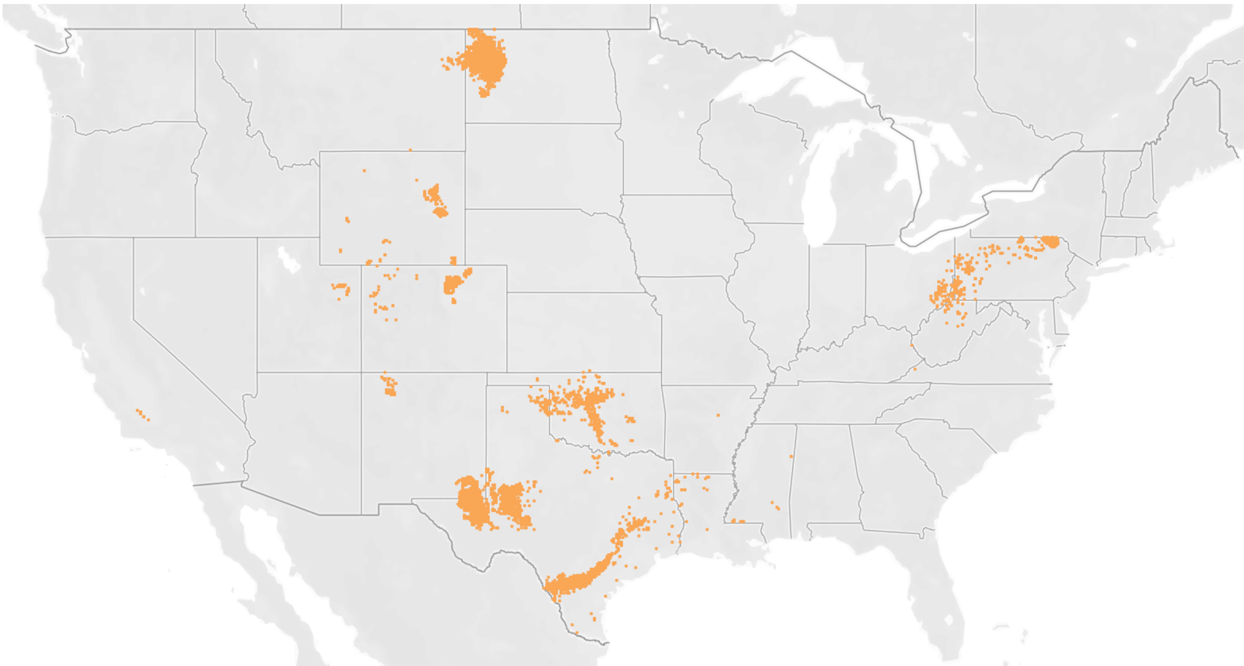


Figure A.3: Probability Of Observing Flaring Before And After The Well Completion

This figure plots the probability of observing the practice of flaring as detected by the satellite measure before and after the well completion. The pattern is consistent with the idea that the satellite measure is able to detect correctly the practice of flaring.

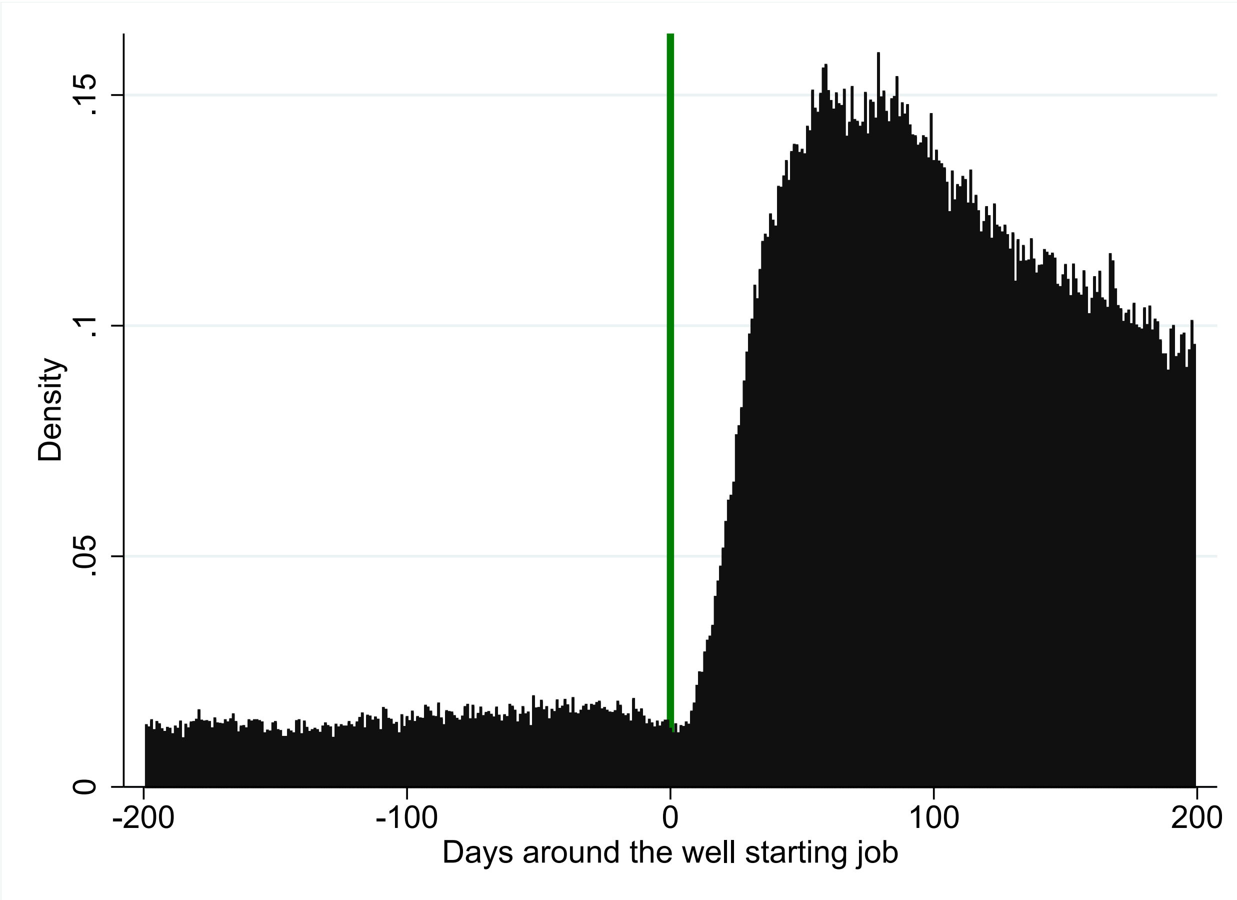


Figure A.4: High-frequency Geographical Fixed Effect: Geographical Example Using The Marcellus Formation

This map illustrates the coarser geographical fixed effect after zooming on the Marcellus formation.

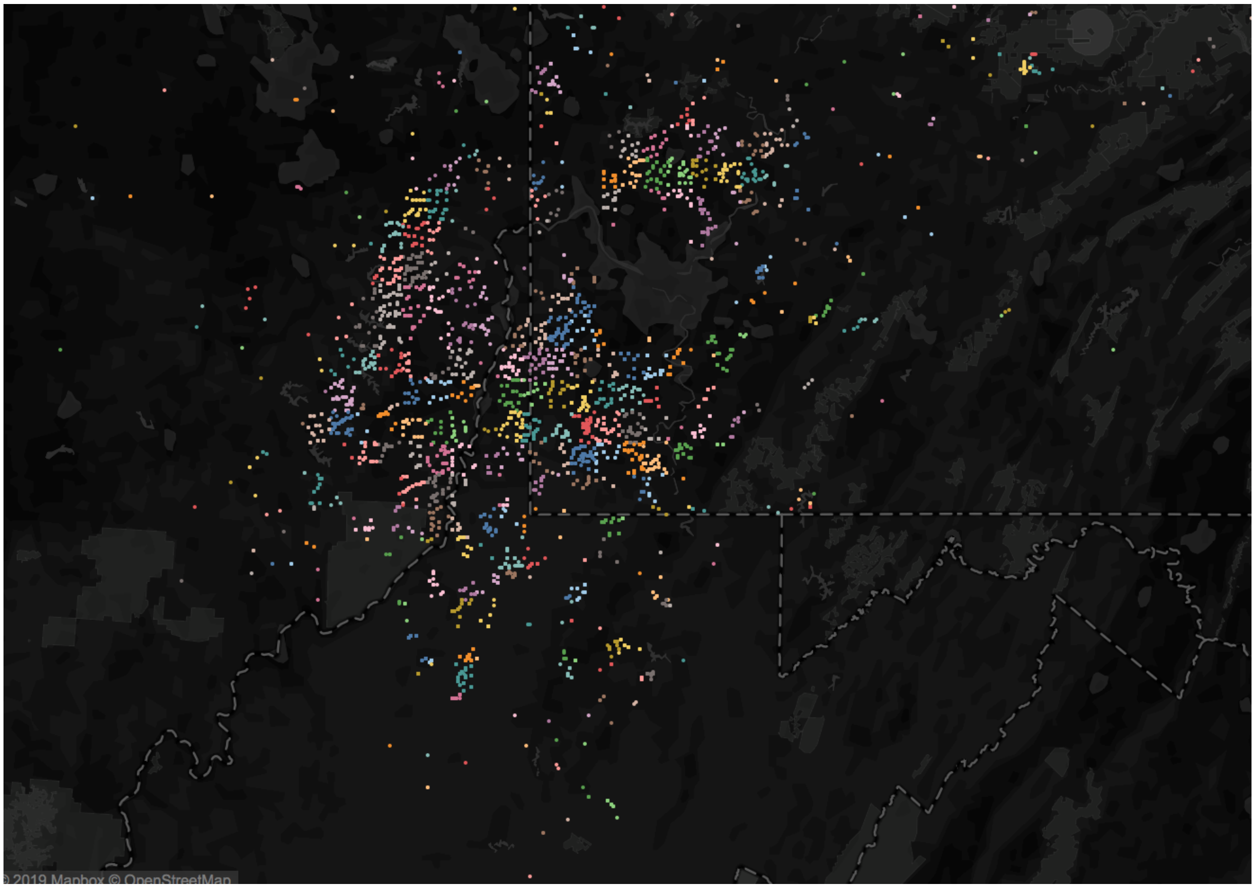


Figure A.5: Geographical Fixed Effect: Illustration Of The Longitude And Latitude Unit Square

This Table plots the 60 miles by 60 miles geographical fixed effect.

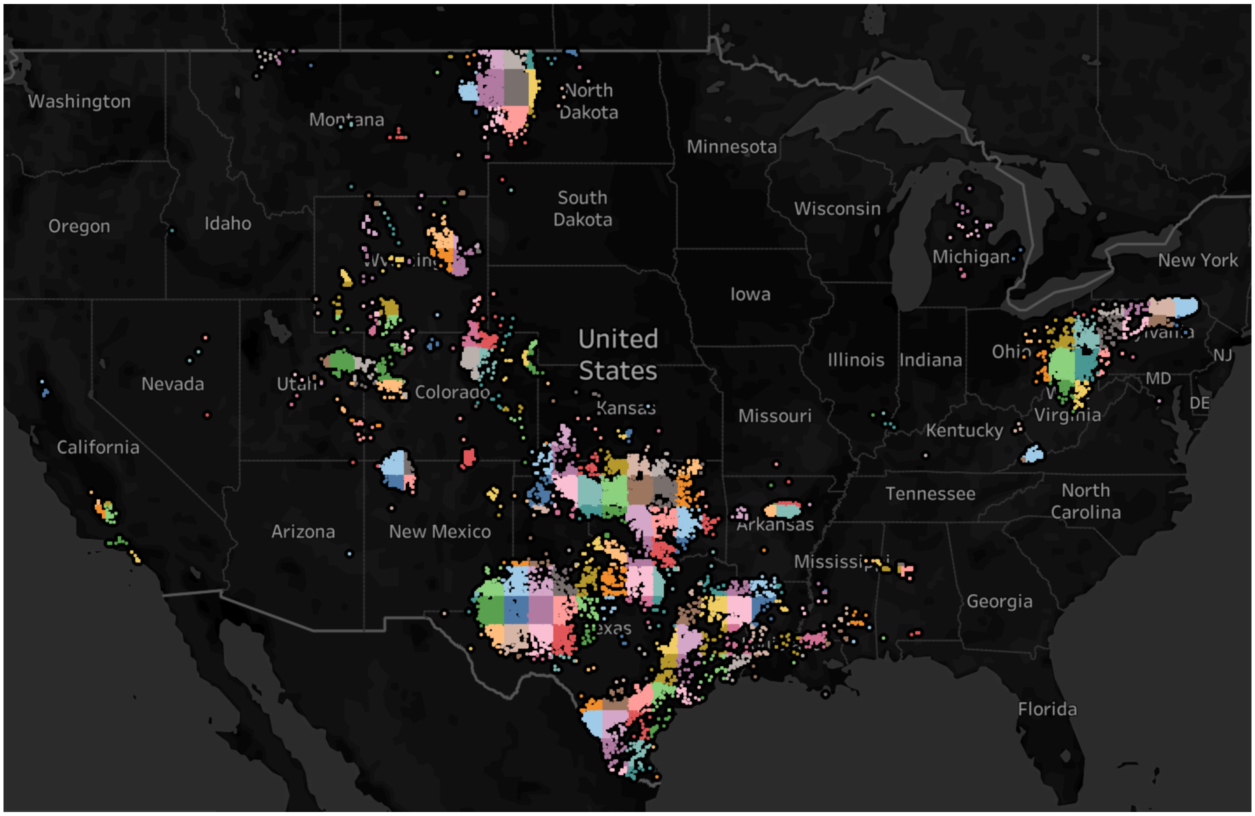
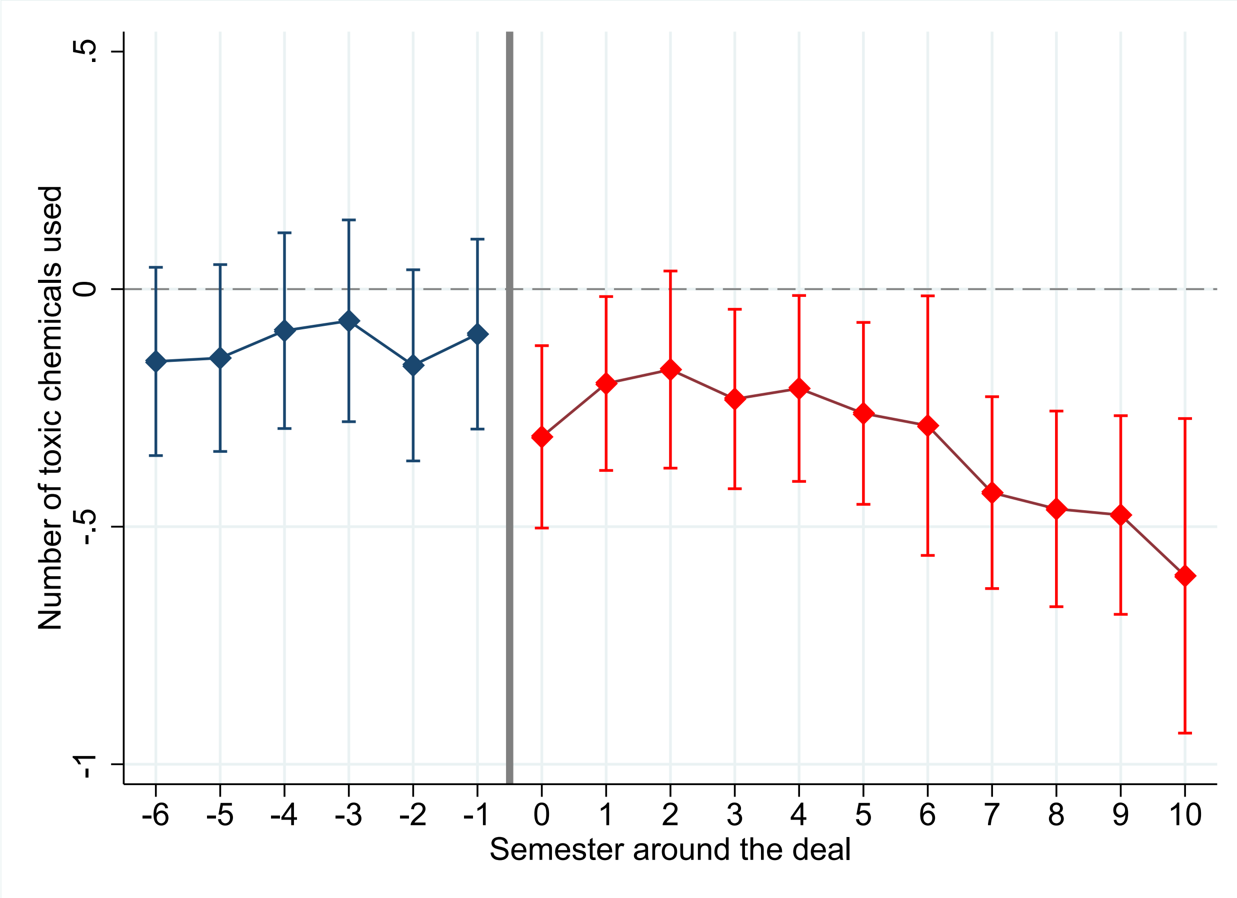


Figure A.6: Impact Of PE Buyout On The Number Of Toxic Chemicals: robustness test

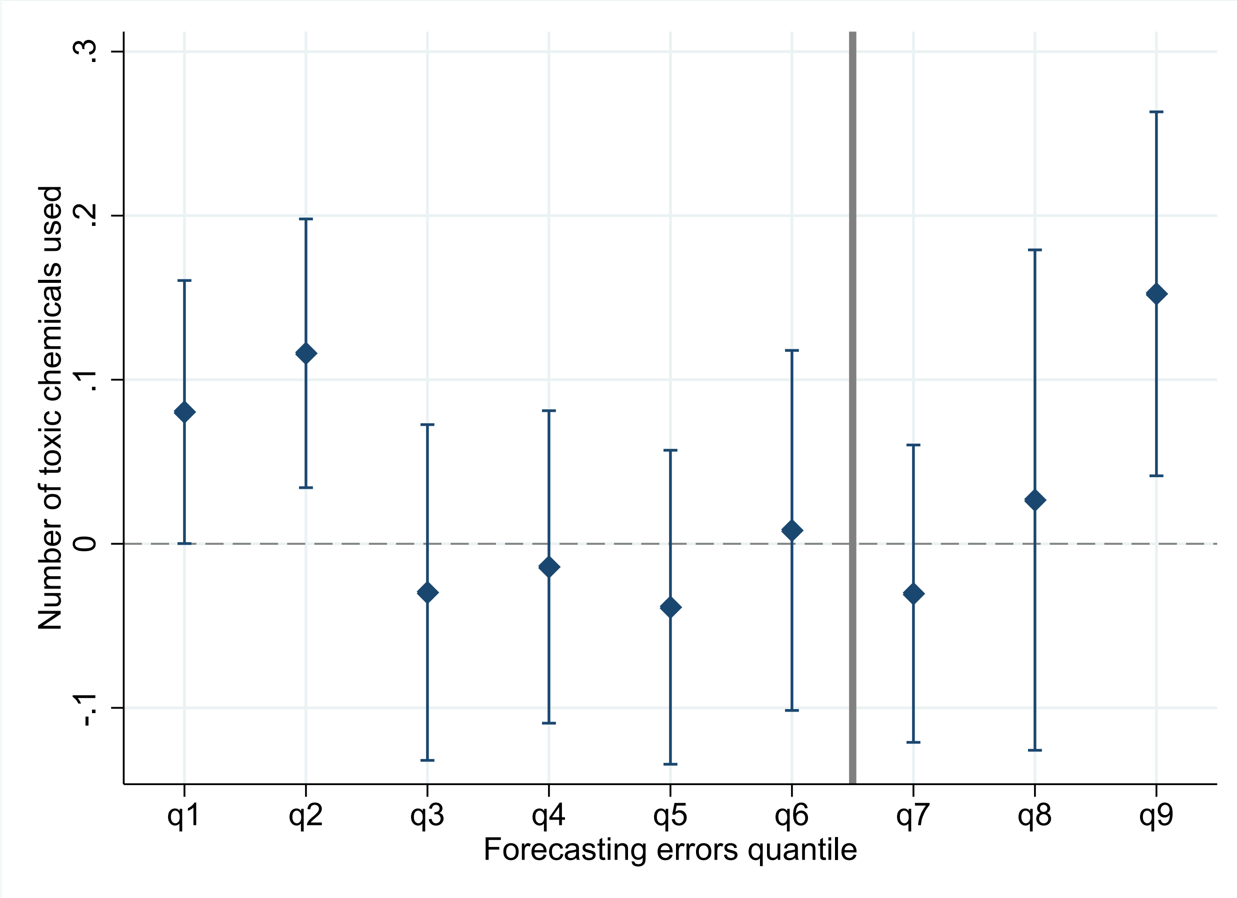


Note: This figure reports the dynamic difference-in-differences estimates around the PE buyout as well as its confidence interval estimated in the full sample. More specifically, the $(\gamma_\tau)_{\tau=-6,\ldots,9,10}$ of the following estimated equation are reported:

$$Y_{ikt} = ID_i + BY_{jt} + GEO\_coarse_k + \sum_{\tau=-6}^{10} \gamma_\tau.(\tau \text{ semester(s) after the PE deal}) + controls_{it} + \varepsilon_{ikjt}$$

where Y_{ijt} is the total number of toxic chemicals used for a well and as defined in Table 1. ID_i is an operator fixed effect, that captures any heterogeneity at the firm level that is constant through time and affects the decision to use toxic chemical. BY_{tj} is a geographical-time fixed effect, that regroups within the same year, wells that are in the same basin, the same state as well as the same latitude and longitude unit (equivalent to 60 by 60 miles square). Figure A.5 maps the different regions that are used to construct the 60 by 60 miles square. Finally, GEO_coarse_k is a fixed effect that regroups wells within the same first two digits of the latitude and longitude -equivalent to a 7 miles to 4 miles square-. To illustrate this grouping, Figure A.4 plots the wells with a same color if they have the same first two digits of latitude and longitude and if they are situated in one half of the Marcellus formation. $controls_{it}$ includes the production of oil and gas of the well, its vertical depth and horizontal length. Standard errors are clustered at the firm level and confidence intervals at the 5% level are reported.

Figure A.7: Role Of EPS Targets On Toxic Chemicals



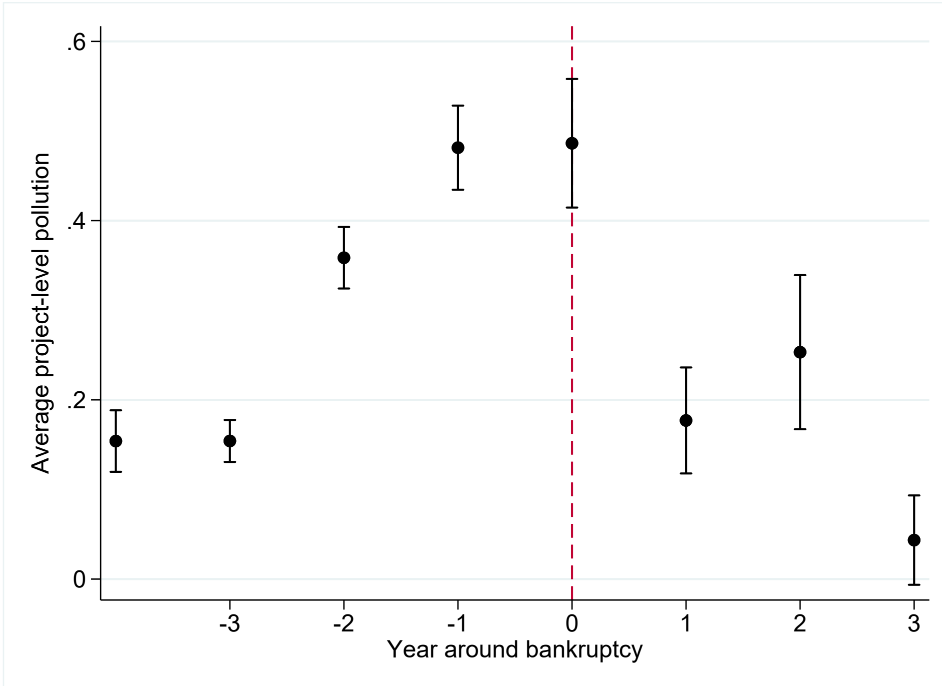
Note: This figure plots the estimates $(q_\tau)_{\tau=1,\ldots,9}$ of the following regression:

$$Y_{ijt} = \text{Firm}_i + \text{Location}_j \times \text{Year}_t + \sum_{\tau=1}^{9} q_\tau.(\tau \text{ decile of the forecast errors})_{it} + controls_{ijt} + \varepsilon_{ijt}$$

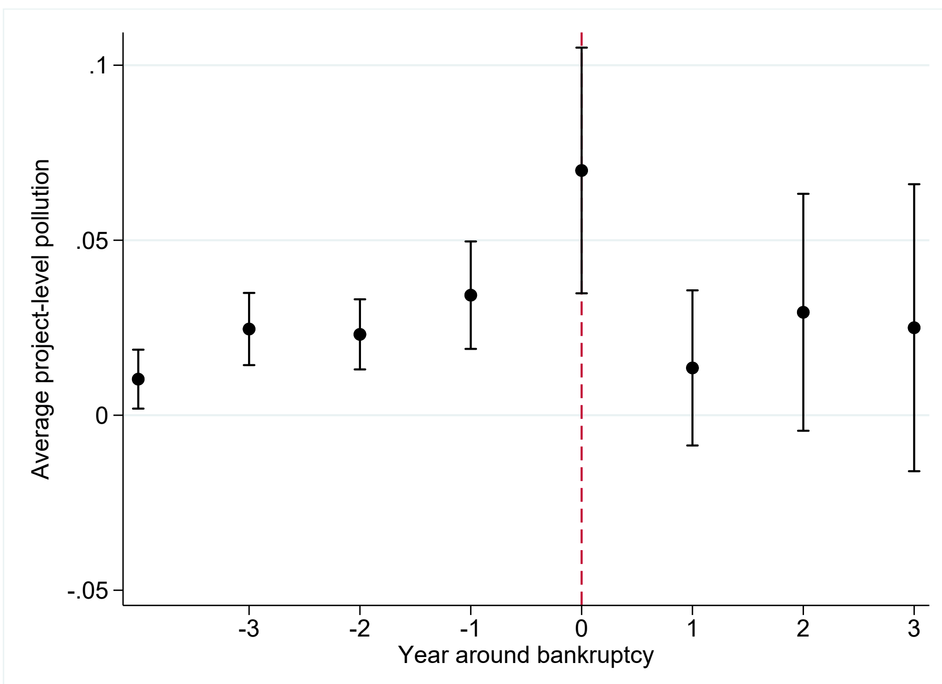
The variable $(\tau \text{ decile of the forecast errors})_{it}$ is constructed as follow. We first calculate the differences between the average one year forecast of earning per share (EPS) made by analysts and the realized one. This provides us a measure of how accurate the analysts forecast were. Then, we take the decile of the errors for each year-firm observations. $(\tau \text{ decile of the forecast errors})_{it}$ is a dummy that is equal to one if the project i made at time t belongs to a firm that has an error of EPS forecast that belongs to the quantile τ. The horizontal bar separates errors where analysts are wrong because they anticipate a higher EPS than the realized one (left side) from the cases where they anticipate a lower EPS than the realized one (right side). The rest of the variables are the same as before. Namely, Y_{ijt} is the total number of toxic chemicals used for a well and as defined in Table 1. Firm_i is an operator fixed effect, that captures any heterogeneity at the firm level that is constant through time and affects the decision to use toxic chemical. Location_j is a geographical fixed effect, that regroups all wells that have the same first 2-digit longitude and latitude. To illustrate this grouping, Figure A.4 plots the wells with a same color if they have the same first two digits of latitude and longitude and if they are situated in one half of the Marcellus formation. This location fixed effect is interacted with a year Fixed effect (Year_t). $controls_{it}$ includes the production of oil and gas of the well, its vertical depth and horizontal length as well as the realized EPS. Standard errors are clustered at the firm level and confidence intervals at the 5% level are reported.

Figure A.8: Pollution for Firms Close to Bankrupty

Panel A



Panel B



Note: This figure reports the yearly average of the number of toxic chemicals (Panel A) and the fraction of wells flared (panel B) within firms that file for bankruptcy chapter 11 in an event study around the year of filing.

Table A.1: Reporting

2010	2011	2012	2013	2014	2015
Wyoming	Louisiana	Colorado	Alabama	Alaska	Kentucky
	Michigan	Idaho	Arkansas	California	North Carolina
	Montana	Indiana	Kansas	Illinois	
	Texas	New Mexico	Mississippi	Nevada	
		North Dakota	Nebraska	West Virginia	
		Ohio	Tennessee		
		Oklahoma	Utah		
		Pennsylvania			
		South Dakota			

Note: This Table shows the year when reporting to FracFocus became mandatory.

Table A.2: Results On Marginal Wells

Panel A: Marginal well within the firm

	Dependent variable: Number of toxic chemicals			
	(1)	(2)	(3)	(4)
Post deal	-0.183***	-0.174***	-0.268***	-0.162***
	(0.054)	(0.062)	(0.066)	(0.040)
Observations	134551	133301	130848	128572
Controls	X	X	X	X
Firm FE	X	X	X	X
Location × Year FE	X	X	X	X

Panel B: Marginal well within the basin

	Dependent variable: Number of toxic chemicals		
	(1)	(2)	(3)
Post deal	-0.198***	-0.219***	-0.297***
	(0.054)	(0.065)	(0.096)
Observations	134512	130566	128078
Controls	X	X	X
Firm FE	X	X	X
Location × Year FE	X	X	X

Note: This table replicates the baseline regressions after dropping projects that are in places that could create an endogeneity problem. Panel A drops project from PE-backed firms that are in their main region of activity. Specifically, I first calculate the variable C= $\frac{\text{Number of projects in basin j for firm i}}{\text{Total number of project of firm i}}$. If the ratio C is low, then it implies that this basin is a marginal location for the PE firm and is therefore less likely to be the main reason for which a PE bought the company in the first place. I take different threshold value for what "low" means. Equation (1) drops firms that drill in only one location (ratio=1). Equation (2) estimates the baseline relationship on locations that account for less than 0.77 of the total firm project (.77 is the 75th percentile of the ratio C). Equation (3) does the same but with a threshold equals to .21 (median of the ratio C) and equation 4 for .11 (25th percentile of ratio C).
Finally, Panel B replicates the exercise but with a different ratio M= $\frac{\text{Number of projects in basin j for firm i}}{\text{Total number of project in basin j}}$. The intuition of panel B is to drop projects in basins where the PE backed firm accounts for a large fraction of the local projects. The thresholds for M are 0.085, 0.046 as well as 0.01 and corresponds to the 75th, 50th and 25h percentile. Equation (1) drops projects located in basin(s) where M is above 0.085, equation (2) when M is above 0.046 and equation (3) drops all projects located in basin(s) where M is above 0.46.

Table A.3: Controlling for Confidential Reporting

Panel A: Baseline results and confidential reporting

	Dependent variable: Number of toxic chemicals							
	PE deal with control rights				Drillco (no control rights)			
	(1)	(2)	(3) NNM	(4) NNM	(5)	(6)	(7) NNM	(8) NNM
Post deal	-0.188***	-0.178***	-0.205***	-0.196***	-0.028	-0.041	-0.003	-0.034
	(0.054)	(0.055)	(0.036)	(0.038)	(0.045)	(0.048)	(0.042)	(0.043)
Controls	X	X	X	X	X	X	X	X
Firm FE	X	X	X	X	X	X	X	X
Basin × Year FE			X	X			X	X
Location × Year FE	X	X			X	X		
Confidential		X		X		X		X
Adjusted R^2	0.56	0.57	0.35	0.37	0.55	0.57	0.45	0.49
Observations	135554	135544	21433	21423	135738	135728	28581	28575

Panel B: Natural experiment

	Dependent variable: Number of toxic chemicals							
	Net effect				Full interactions			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Beta	0.354***	0.285***	0.314***	0.252***	0.386***	0.316***	0.329***	0.257***
	(0.065)	(0.067)	(0.059)	(0.059)	(0.089)	(0.087)	(0.085)	(0.082)
Observations	135738	135257	135728	135246	135738	135257	135728	135246
R^2	0.60	0.67	0.61	0.68	0.60	0.67	0.61	0.68
Controls	X	X	X	X	X	X	X	X
Firm × Year FE		X		X		X		X
Firm FE	X		X		X		X	
Location × Year FE	X	X	X	X	X	X	X	X

Note: Panel A contains the baseline specifications where the number of confidential items reported is taken into account. Columns (1), (3), (5) and (7) adds the total number of confidential items reported for a well as a linear control. Columns (2), (4), (6) and (8) include a dummy for each number of confidential items. Column (1), (2) (4) and (5) are estimated on the full sample, whereas column (3), (4) (7) and (8) use the matching sample. Columns (1) to (4) measure the impact of PE ownership, whereas columns (5) to (8) evaluate the effect of PE DrillCo. Panel B contains regressions that perform the same exercise on the natural experiment. Beta stands for the coefficient: Federal or Native American reservations well × Post deal × Post Injunction. The dependent variable is the number of toxic chemicals. Column (1) to (4) are estimated when only the interaction is specified. Column (5) to (8) presents the results where the full interactions is made, as in a triple difference-in-differences. Columns (1), (3), (6) and (7) contains a firm FE, that is interacted with a year-FE in column (2), (4), (6) and (8). Column (1), (2), (5), and (6) include as a control the number of confidential items reported, and column (3), (4), (7) and (8) include this number as a fixed effect.

Table A.4: Role Of Confidential Reporting

Panel A: Impact on confidential reporting (net effect)

	Dependent variable: Number of inputs reported as confidential					
	PE deal with control rights			Drillco (no control rights)		
	(1)	(2)	(3)	(4)	(5)	(6)
Post deal	-4.328***	-4.317***	-3.420***	-4.316***	-4.327***	-4.798***
	(0.635)	(0.630)	(0.695)	(0.788)	(0.778)	(0.854)
Controls		X	X		X	X
Firm FE	X	X	X	X	X	X
Basin × Year FE			X			X
Location × Year FE	X	X		X	X	
Adjusted R^2	0.61	0.61	0.57	0.61	0.61	0.46
Observations	135554	135554	21433	135554	135554	28581

Panel B: Impact on confidential reporting (Natural experiment)

	Dependent variable: Number of inputs reported as confidential			
	(1)	(2)	(3)	(4)
Federal or Indian well × Post deal × Post Injunction	0.994	0.992	0.205	0.213
	(0.817)	(0.814)	(0.996)	(1.000)
Controls		X		X
Firm × Year FE			X	X
Firm FE	X	X		
Location × Year FE	X	X	X	X
Observations	135738	135738	135257	135257
Adjusted R^2	0.61	0.61	0.66	0.66

Note: Columns (1), (2) and (3) of Panel A report the impact of PE ownership on the total number of confidential items reported and columns (4), (5) and (6) of Panel A study the impact of PE financing through DrillCo on the same outcome variable. Column (1) and (4) estimate the relationship without controls, that are added in column (2) and (5). The coefficients remain stable when the controls are added. Column (3) and (6) contain the results when the relationship is estimated on the matched sample using a nearest neighbor matching (NNM) approach, both before and after the deal at the project level. The matched sample is constructed as follow: for each project that belongs to a firm that is acquired by a PE, we matched within the same geographical area (basin) and year, the project that has the closest size (horizontal length and vertical depth) and production (6 first months production of oil and gas). Standard errors are clustered at the firm level. Panel B investigates the impact of BLM fracking rule preliminary injunction and subsequent rescind in a triple difference-in-differences on the number of confidential items reported. Specifically, the dependent variable is regressed on all the interactions between the post acquired dummy, a dummy for wells in federal lands or Native American reservations and a dummy for the period between. Only the triple coefficient is reported. Column (1) and (3) do not include time-varying controls, that are added in column (2) and (4). The controls are the same as the one used in Panel A. Column (1) and (2) report the results with a location and year FE as well as a firm FE. Column (3) and (3) add a year FE interacted with a firm FE.

Table A.5: Controlling For Population And Housing Density In The Baseline Results

Panel A: PE ownership and control

	Dependent variable: Number of toxic chemicals					
	(1)	(2)	(3)	(4) NNM	(5) NNM	(6) NNM
Post deal	-0.198***	-0.198***	-0.198***	-0.209***	-0.209***	-0.212***
	(0.054)	(0.054)	(0.053)	(0.036)	(0.035)	(0.035)
Observations	135554	135554	135554	21433	21433	21433
Controls	X	X	X	X	X	X
Firm FE	X	X	X	X	X	X
Location × Year FE	X	X	X	X	X	X
Housing FE			X			X
Population FE			X			X

Panel B: PE financing (DrillCo)

	Dependent variable: Number of toxic chemicals					
	(1)	(2)	(3)	(4) NNM	(5) NNM	(6) NNM
Post deal	-0.037	-0.037	-0.038	-0.022	-0.020	-0.020
	(0.046)	(0.046)	(0.046)	(0.048)	(0.049)	(0.047)
Observations	135554	135554	135554	28581	28581	28581
Controls		X	X		X	X
Firm FE	X	X	X	X	X	X
Location × Year FE	X	X	X	X	X	X
Housing FE			X			X
Population FE			X			X

Note: Panel A replicates the baseline results where housing and population of the census tract where the well is located are added as controls. Column (1) and (4) adds the control in a linear way. Column (2) and (5) add the controls by adding all interactions of the two variables and their squared values. Column (3) and (6) add a decile fixed effect of the controls. Regressions from columns (1) to (3) are estimated on the full sample and columns (4) to (6) on the matched sample. Panel B has the same structure, except that the post variable takes the value 1 after a DrillCo deal.

Table A.6: Controlling For Population And Housing Density In The Natural Experiment

Panel A: Natural experiment (net effect)

	Dependent variable: Number of toxic chemicals					
	(1)	(2)	(3)	(4)	(5)	(6)
beta	0.346***	0.275***	0.346***	0.275***	0.346***	0.274***
	(0.066)	(0.064)	(0.066)	(0.064)	(0.066)	(0.065)
Observations	135738	135257	135738	135257	135738	135257
Controls	X	X	X	X	X	X
Firm × Year FE		X		X		X
Firm FE	X		X		X	
Location × Year FE	X	X	X	X	X	X
Housing FE					X	X
Population FE					X	X

Panel B: Natural experiment (full interaction)

	Dependent variable: Number of toxic chemicals					
	(1)	(2)	(3)	(4)	(5)	(6)
beta	0.383***	0.309***	0.383***	0.309***	0.382***	0.308***
	(0.090)	(0.084)	(0.090)	(0.084)	(0.090)	(0.084)
Observations	135738	135257	135738	135257	135738	135257
Controls	X	X	X	X	X	X
Firm × Year FE		X		X		X
Firm FE	X		X		X	
Location × Year FE	X	X	X	X	X	X
Housing FE					X	X
Population FE					X	X

Note: Panel A and B contains the estimations of the natural experiment. Panel A reports the net effect when only the triple interaction term beta is included, and panel B reports the triple difference-in-differences estimates where all the intermediary interactions are included. Beta stands for the coefficient Federal lands or Native American reservations $\times$ Post deal $\times$ Post Injunction. Column (1) and (2) add the control housing and population density of the census tract where the well is located in a linear way. Column (3) and (4) add as a control the full interaction terms with their square value to capture any non-linearity effect. Finally, column (5) and (6) add the decile of housing and population density as a fixed effect. Column (2), (4), (6), (8) include a firm interacted with a year fixed effect and column (1), (3), (5) and (7) a firm fixed effect.

Table A.7: Sorting on population

Panel A: Baseline effect

	PE ownership				PE drillco			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post deal	-2.114	-2.088	-1.164*	-1.149*	-1.160	-1.313	0.018	-0.037
	(1.681)	(1.684)	(0.665)	(0.667)	(2.683)	(2.701)	(1.025)	(1.031)
Controls		X		X		X		X
Firm × Year FE								
Firm FE	X	X	X	X	X	X	X	X
Location × Year FE	X	X	X	X	X	X	X	X
Observations	135738	135738	135738	135738	135738	135738	135738	135738
Adjusted R^2	0.51	0.51	0.53	0.53	0.51	0.51	0.53	0.53

Panel B: Natural experiment

	Dependent variable: population				Dependent variable: housing			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Beta	6.274	5.405	8.804	8.414	2.635	2.100	3.776	3.612
	(8.208)	(6.767)	(7.889)	(7.084)	(3.522)	(2.821)	(3.399)	(2.956)
Controls	X	X	X	X	X	X	X	X
Firm × Year FE		X		X		X		X
Firm FE	X		X		X		X	
Location × Year FE	X	X	X	X	X	X	X	X
Observations	135738	135257	135738	135257	135738	135257	135738	135257
Adjusted R^2	0.51	0.52	0.51	0.52	0.53	0.54	0.53	0.54

Note: Note: Panel A investigates whether PE-backed firms locate their wells in less populated area. The dependent variable is the total population in the census tract for columns (1), (2), (5) and (6) or the total number of housing units for columns (3), (4), (7) and (8). Column (1), (3), (5) and (7) don't contain controls that are added in columns (2), (4), (6) and (8). Columns (1) to (4) estimate the relationship for PE contracts where there is a transfer of controls. Columns (5) to (8) estimate the relationship for DrillCo contracts.
Panel B investigates the effect of the BLM shock for PE-backed firms on the population and housing density where the well is located. Beta stands for . The dependent variable of columns (1) to (4) of Panel B is the total population of the census tract where the well is located. The dependent variable of columns (5) to (8) of Panel B is the number of housing units in the census tract where the well is located. Columns (1), (3), (5), (7) include a firm fixed effect that is interacted with a year fixed effect in columns (2), (4), (6) and (8). Columns (1), (2), (5) and (6) report the net effect. The triple difference-in-differences effect are contained in columns (3), (4), (7) and (8). Standard errors are clustered at the firm level.

Table A.8: Impact Of PE On Pollution: Other Definition Of Toxicity

Panel A: Net effect

	Dependent variable: Number of toxic chemicals (EPA definition)					
	PE deal with control rights			Drillco (no control rights)		
	(1)	(2)	(3) NNM	(4)	(5)	(6) NNM
Post deal	-0.089***	-0.089***	-0.080***	0.028	0.027	0.033
	(0.021)	(0.021)	(0.023)	(0.031)	(0.031)	(0.041)
Observations	135554	135554	21433	135738	135738	28581
Controls		X	X		X	X
Firm FE	X	X	X	X	X	X
Basin × Year FE			X			X
Location × Year FE	X	X		X	X	

Panel C: Natural experiment

	(1)	(2)	(3)	(4)
Beta	0.172***	0.172***	0.121***	0.121***
	(0.047)	(0.047)	(0.030)	(0.030)
Controls		X		X
Firm × Year FE			X	X
Firm FE	X	X		
Location × Year FE	X	X	X	X
Observations	135554	135554	135071	135071
Adjusted R^2	0.80	0.80	0.82	0.82

Note: The dependent variable is the number of toxic chemicals used in the production process, where the toxicity is defined in another way as in the baseline regression. Columns (1), (2) and (3) report the impact of PE ownership on pollution and columns (4), (5) and (6) study the impact of PE financing through DrillCo contracts on pollution. Column (1) and (4) estimate the relationship without controls, that are added in column (2) and (5). The coefficients remain stable when the controls are added. Column (3) and (6) contain the results when the relationship is estimated on the matched sample using a nearest neighbor matching (NNM) approach, both before and after the deal at the project level. The matched sample is constructed as follow: for each project that belongs to a firm that is acquired by a PE, we matched within the same geographical area (basin) and year, the project that has the closest size (horizontal length and vertical depth) and production (6 first months production of oil and gas).

Table A.9: Pollution For Public Listed Firm

	Effect of going public			Earnings forecasts	
	(1)	(2)	(3)	(4)	(5)
Post IPO	0.140*	0.141*	0.275*		
	(0.077)	(0.077)	(0.143)		
Before IPO			0.210		
			(0.211)		
Under estimate				0.062***	0.062***
				(0.022)	(0.022)
Over estimate				-0.011	-0.012
				(0.088)	(0.088)
(mean) actual				-0.013	-0.013
				(0.012)	(0.012)
Observations	135724	135724	135724	53411	53411
Controls		X	X		X
Firm FE	X	X	X	X	X
Location × Year FE	X	X	X	X	X

Note: Equations (1), (2) and (3) estimate the impact of going public on the usage of toxic chemicals. Relying on the Field-Ritter dataset, I identify 7 IPO between 2011 and 2019 that can be matched to the sample: (1) Athlon Energy (2) Bonanza Creek Energy (3) Diamondback Resources (4) Extraction oil & gas (5) Jagged Peak Energy (6) Kinder Morgan and (7) RSP Permian. Post IPO is a variable that takes the value one after the firm went public. Similarly, Before IPO is a variable that takes the value one three years before the IPO. Equations (4) and (5) investigate the magnitude of missing the one-year EPS forecasts by analysts on the usage of toxic chemicals. The controls are defined as in the previous specifications and include the realized EPS.