The Point of Attack: Where and Why Does Oil Cause Armed Conflict in Africa?*

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Abstract

According to resource-curse theory, oil revenues constitute a lucrative prize, motivating rebel groups to fight for control of resource-rich territory. Yet, we demonstrate, rebels rarely attack sites with the most oil, such as oil fields and terminals. To explain this finding, we develop a new model with elements of crisis-bargaining and Blotto games and use geo-spatial data on the location of oil infrastructure and armed conflict events to assess its implications. First, we show that rebels focus their attacks on pipelines and that more critical infrastructure has no discernible effect on conflict. Second, to prevent the government from thwarting their attacks, we find that rebels strategically randomize where they strike. Third, we find that increased oil prices have countervailing effects: as the black-market price increases, so too do the returns to oil theft; but as the export price increases, violence abates because, we argue, governments are more eager to "bargain away" conflict. Overall, groups sabotage pipelines because they expect these sites to be vulnerable and because such disruption can compel governments to address their demands.

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1. Introduction

The resource curse literature documents a cross-national relationship between oil extraction and armed civil conflict (e.g., Lei and Michaels (2014); see Ross (2015) for a review). Scholars have further found that armed conflict and separatist civil wars are concentrated in countries' oil-producing provinces (Asal et al. 2016; Paine 2019). Oil rents constitute a lucrative "prize," which insurgent groups fight to win (Fearon 2005; Garfinkel and Skaperdas 2007).[1]

We show, however, that rebels rarely attack oil wells or terminals. The sites with the most oil below and above ground, i.e., the biggest prizes, are not the points of attack. Using panel data on the location of oil infrastructure (oil fields, wells, pipelines, and terminals) and armed conflicts across Africa, we show that only pipelines increase the likelihood of armed conflict. We employ a triple-difference empirical strategy to demonstrate that a pipeline coming online raises the probability of armed conflict above and beyond the negligible changes induced by building more critical oil infrastructure. Pipelines more than double the base rate of conflict — an effect that is many times larger than the minimal (sometimes negative) effects of oil fields, wells, or terminals.

To explain this finding and to further study why and where rebels attack oil infrastructure, we develop a game-theoretic model. The model integrates two common theoretical frameworks in armed conflict: a Blotto game in which belligerents must choose where to station their forces across multiple possible "battlefields," (Roberson 2006; Kovenock and Roberson 2012) and a crisis (ultimatum) bargaining game with incomplete information (Fearon 1995).Our analysis shows that these features generate four observable implications for which we find empirical support.

First, both the government and rebels want to behave unpredictably. If the government knew where rebels were going to strike, they could station their defenses at those locations and fend off attacks. On the other side, if rebels knew where the government was going to locate its defenses, they would evade those forces and attack unguarded targets. Intentional unpredictability implies that we should observe little correlation over time in the location of attacks because, if rebels attacked the same sites year after year, the government would know where to station its forces. We show empirically that violence along pipelines is not autocorrelated. Knowing where rebels previously attacked the pipeline is not a good predictor of their future targets. By contrast, we show that protests and riots have a much higher degree of autocorrelation — the sites of protests tend to be the sites of past protests.

Second, for both sides to be unpredictable, they can never defend or attack a site with certainty. In equilibrium, they both play mixed strategies, only locating at a site with some intermediate probability. It must also be the case that these probabilities leave the government (rebels) indifferent between defending (attacking) any two targets.[2] All else equal, rebels want to attack the most valuable targets — in our application, more critical oil infrastructure, such as terminals or wells — but in equilibrium the government

1. Other research argues that oil-rich leaders underinvest in state capacity and, thus, are more vulnerable to insurgency (e.g., Fearon and Laitin 2003), but see Glynn (2009) for contradictory evidence.

2. If this indifference condition is not met, then at least one actor would have a strict preference for locating at a particular site, rendering their behavior predictable and, thus, easily exploited by the other side, which cannot be an equilibrium under reasonable conditions that we specify below.

defends those larger prizes with higher probability. This leaves the rebels indifferent between attacking a critical piece of infrastructure or a more sporadically defended section of pipeline. For its part, all else equal the government wants to defend its critical infrastructure, but in equilibrium the rebels attack pipelines with greater probability, leaving the government indifferent between defending critical and peripheral infrastructure. Overall, this dynamic explains our initial finding, which is that rebels target the less valuable, but also less consistently defended pipelines. Anticipating that defenses will be stationed around more critical oil infrastructure, rebels wield a "weapon of the weak" (a la Scott 1985) and sabotage pipelines instead.[3]

Third, why would a government play this cat-and-mouse game and not strike a deal with would-be attackers to prevent sabotage? We argue that the government would like to bargain away conflict but has incomplete information about whether a group — one of the many making demands of the state — constitutes a real threat (Walter 2009). By attacking pipelines, the rebels can send a costly signal of their capacity and compel the government to offer concessions.[4] This dynamic creates two incentives for rebels to attack. The groups can directly benefit from looting oil (which we call their *prize incentive*) and indirectly from extorting the government (their *signaling incentive*). This matches qualitative evidence from Nigeria, where rebel groups sabotage pipelines to both pilfer oil and bring government to the bargaining table. The Nigerian government and oil companies have provided payouts to rebels who commit to peace, at one point paying lucrative security contracts to the same groups that had been sabotaging the pipelines (see Rexer and Hvinden 2020).[5]

Fourth, our theoretical analysis illustrates how changes in the price of oil modulate these incentives and therefore affect the likelihood of attacks. When the rebels' value of oil increases all else equal, their prize incentives increase, leading to more violence. When the government's value of oil increases all else equal, the government is more eager to avoid sabotage and willing to offer larger concessions. This amplifies rebels' signaling incentive, but larger payouts also help to "bargain away" conflict. As such, we show theoretically that increases in the rebel's value of oil should be more conflict enhancing than increases in the government's value. Furthermore, we find evidence of this relationship in the data. To proxy for the rebel's value of oil, we use local prices for gasoline, as stolen oil is often illegally refined and sold on the black market, and we use export (i.e., world) gasoline prices to measure the government's value. We demonstrate that increases in the local fuel price generally lead to more attacks on pipelines, whereas increases in the global price generally lead to less attacks.

This research helps advance the literature on armed conflict in three ways. First, we show that the points of attack are often not the largest prizes but rather less valuable targets. The prize logic is not incorrect — rebels fight to capture resource revenues — but it omits the government's strategic response. Rebels anticipate that high-value targets will be well defended and can only credibly threaten violence if they can

3. Oil-rich governments can afford military hardware that gives them the upper-hand in conventional warfare (Cotet and Tsui 2013; Wright, Frantz, and Geddes 2015; Paine 2016). Scott (1985) argues that theft and sabotage are tactics used by weaker groups who cannot survive a direct confrontation with the state.

4. Past research on civil war (Fearon 1995; Walter 2009) and terrorism (Kydd and Walter 2006) argues that belligerents use violence to signal their capacity or resolve. Thomas (2014) finds that rebels perpetrating terror attacks during civil wars are more likely to participate in negotiations and are offered more concessions.

5. This dynamic is present in cases beyond Nigeria. In Appendix Section A, we provide short vignettes from Colombia, Egypt, Mexico, and Turkey, where there has been more detailed reporting on infrastructure attacks.

locate "battlefields" where they can hope to prevail (e.g., soft targets, unassailable terrain). This insight helps explain why off-shore oil platforms do not provoke conflict (Lujala 2010; Ross 2012; Andersen, Nordvik, and Tesei 2022).[6] It also also helps to reconcile competing claims about the effects of oil on armed conflict. Some argue that resource revenues represent a tempting prize (Laitin 2007), but others claim that those revenues can be invested in military capacity that deters insurgents (Cotet and Tsui 2013; Wright, Frantz, and Geddes 2015). We show both can be true. Oil provides a material incentive to fight, but rebels battle on the periphery to avoid confronting well-equipped security forces. Like Paine (2016), our framework generates this dynamic by modeling how governments defend and rebels attack anticipating each other's strategies.

Second, we argue that pipeline sabotage is not just looting by "greedy" rebels (Collier and Hoeffler 2004). These attacks send costly signals to government and, in doing so, can induce bargaining to address the group's demands or grievances. The point of attacks can, thus, be both "greed" and "grievance." In fact, our model shows that aggrieved groups can only credibly threaten the government where there is a direct material incentive to engage in attacks.[7] If even the strongest rebel groups derive no net benefits from attacking, then the government anticipates that violent campaigns will flame out and offers no concessions.[8] Greed enables rebel groups and the communities they draw from to compellingly demand redress for their grievances.[9]

Third, we make several methodological contributions. We draw on detailed and previously unexploited data from an oil-industry research firm, Wood Mackenzie. The data provide the timing and location of oil field discoveries, as well as information on wells, pipelines, and export terminals across Africa up to 2014. To generate credible estimates of the causal effect of new infrastructure, we implement a two-way fixed effects design and use newly developed techniques to contend with concerns that arise when treatment timing is staggered (e.g., Callaway and Sant'Anna 2020; Goodman-Bacon 2021; De Chaisemartin and d'Haultfoeuille 2020). We use the data to test predictions of our theory that could not be assessed using more common data on oil production, which provide country-year measures (as in Ross and Mahdavi 2015) or only locate sub-surface deposits and not other components of the supply chain (as in Lujala 2010). In addition, our data enable us to provide one of the few real-world validations of the Blotto logic (see also Sonin and Wright (2019) on how rebels time attacks). Most prior empirical studies of Blotto-style interactions rely instead on lab experiments (Dechenaux, Kovenock, and Sheremeta 2015; Kimbrough, Laughren, and Sheremeta 2020; Holt and Palfrey 2022). A key step is developing a tractable Blotto model in which

6. More generally, our work implies that lootability, i.e., how easily resources can be appropriated, is not a commodity-specific feature as is commonly assumed in empirical work (Blair, Christensen, and Rudkin 2021). The same commodity may be more easily looted at different stages or sites of production.

7. Hoeffler (2011) offers another argument for why "greed" and "grievance" are complementary explanations: grievance redress through rebellion is a club good, and rebel leaders need to offer selective material incentives to recruits (see also Cederman and Vogt 2017).

8. While we focus on material incentives, benefits could also arise from advancing one's ideology or the "pleasure of agency" (Wood 2003).

9. This conclusion aligns with an argument made by Harsanyi (1962) about the sources of social power, which they argue is not just the capacity to change behavior (as in Dahl 1957), but depends on the costs of attempting to exert influence. Even if rebel groups can disrupt government, they wield little power when the benefits of attacking are meager and the costs, thus, prohibitive.

equilibrium strategies and expected utilities are derived in closed-form, allowing us to study comparative statics even when the value of winning varies across actors or infrastructure types.[10]

2. Motivating Case: Pipeline Sabotage, Theft, and Concessions in Nigeria

Nigeria is the largest oil producer in Africa, and oil exports make up two thirds of government revenues (Initiative 2021). During a particularly violent period in 2008, sabotage of the country's oil infrastructure deprived the state of at least USD 24 billion, a loss on the order of all government expenditure in the previous year (Adibe, Nwagwu, and Albert 2018).[11] We use this well-documented case to illustrate the strategic considerations affecting the sabotage and defense of oil infrastructure. The formal model we develop in the next section helps to rationalize the outcomes — both the insurgents' behavior and the government's response — that we observe in Nigeria and other oil-producing states in the Global South.

Nigeria's onshore oil infrastructure is dominated by long stretches of pipelines and a much smaller number of active oil fields, producing wellheads, and active onshore oil terminals. According to data from the Nigerian National Oil Spill Detection and Response Agency, most sabotage (94%) takes place along the pipelines. Few attacks take place near oil terminals (0.3%) or wells (6%).[12] Oriola, Haggerty, and Knight (2013: 84) observe that insurgents give "serious consideration. . . to the level of security at potential targets" when planning attacks on oil infrastructure. The length and location of pipelines make them easy targets: "with endless miles of undefended oil pipelines crisscrossing the Niger Delta, militants are able to commit acts of sabotage and oil theft at will" (Asuni 2009: 26).[13] Security forces focus on more compact and valuable oil infrastructure. The Joint Task Force, a military unit charged with protecting Nigeria's oil and gas facilities, guards terminals and oil platforms, supplementing the private security employed by oil companies. For example, the chief military commander for the region reported, "[c]ritical oil platforms have troops deployed on them round the clock to ensure their protection" (Oyadongha 2014). He described the difficulty of protecting the pipelines because these attacks take place "mostly in remote areas of the creeks carried out at night between 2300hrs to 0300hrs by criminal gangs who take advantage of the JTF's limited accessibility."

Militant groups, to varying degrees, have two motivations when launching these attacks. First, they sell stolen crude oil and illegally refined fuel on the black market, earning a local price well below the oil's market value (Oriola, Haggerty, and Knight 2013: 80). Not all the militant groups are involved in oil theft

10. This is most similar to Powell (2007), but here we are able to characterize the equilibrium in closed-form and conduct comparative statics. Like Hart (2008), we focus on a discrete Blotto model. Like Sonin and Wright (2019), the conflict technology is asymmetric where rebels attacks are only successful against undefended sections.

11. See Obi and Rustad (2011) and Watts and Ibaba (2011) for more detailed accounts of oil-related conflict in Nigeria. In this short vignette, we highlight features of the case that correspond to important assumptions and predictions of our theoretical framework.

12. The single event near a terminal was not an attack on the terminal, but rather leakage from a sunken oil theft vessel on the Brass River in August 2012.

13. Oil theft is often destructive. In rupturing the pipelines to siphon oil or gas, vandals use drills or torches that can immediately set off explosions or leak highly combustible fuel that is easily sparked.

operations, but most groups are involved in some way by tapping into pipelines, financing and managing small-scale refineries, or selling fuel (Katsouris and Sayne 2013).

Second, they use attacks to respond to unaddressed poverty and environmental degradation in Nigeria's oil producing regions (Eke 2015; Onuoha 2008; Ukiwo 2007). Ukeje (2001: 346) writes:

> [E]xpressing community grievances and even very legitimate social demands often produced limited response from oil company executives or government officials, or occasionally evoked outright indignation and hostility. Having failed to win any concessions or developmental projects through peaceful means, militant youth groups then seized flow stations, rigs, and other oil installations, and held local and expatriate oil company staff hostage.

Groups sabotage oil infrastructure to force the state to respond to their social, economic, and environmental demands (Onuoha 2008; Watts and Ibaba 2011; Oriola, Haggerty, and Knight 2013). For example, the large Nembe pipeline carried 130,000 barrels per day when it was attacked in July 2008. The Movement for the Emancipation of the Niger Delta (MEND) claimed credit (Wosu 2008). MEND's spokesperson tied its attacks to grievances in the Niger Delta:

> [MEND] will continue to nibble everyday at the oil infrastructure in Nigeria until the oil exports reaches zero. At such a time, we expect the government to take seriously our demands of effecting true federalism, including fiscal federalism as practiced in all genuine federal republics around the world (Amaize and Oyadongha 2008).

The demand for "fiscal federalism" is a call for more oil revenues to be allocated to Nigeria's oil-producing regions.

While sabotage is costly for both sides, there is a pervasive sense that the government will not seriously bargain until attacked: "the militias know that this government only listens to violence" (USAID 2006: 37). Eke (2015: 757) calls this the "rule of muscle," an environment in which violence is seen as the only way to garner a response. From the state's perspective, mounting an attack appears to differentiate those groups which they feel must be granted a concession to curb sabotage.

Once convinced of the threat, the Nigerian government has been willing to buy off its attackers. Following a spate of attacks from 2007 to 2008, the government signed an amnesty agreement in 2009 with militant leaders that called for financial payments and disarmament. In practice, few working weapons were turned in (Hazen and Horner 2007), and most of the money went to the several top leaders who led oil infrastructure attacks in their regions of influence (Obi 2014). Top commanders accepted the amnesty at ceremonial meetings in Abuja and in the Niger Delta and, according to U.S. Embassy cables at the time, received large payments in return for doing so (Lagos 2009). Monthly salary payments of USD 400 also began for rank-and-file militants as well as job training programs, though implementation was mixed. Oil production immediately began to rebound: the Minister of Petroleum Resources, Rilwan Lukman, tied the amnesty agreement to an increase in oil production from 1.2 million barrels per day to 1.7 million per day shortly after the agreement (Staff 2009).

The government began paying many of the same militant commanders pipeline protection contracts in 2012. Described by Eke (2015: 756) as an attempt to "buy peace in the Niger Delta," the government offered contracts to militants totaling over 6 billion Naira (roughly USD 40 million). At least in the medium-term, these payoffs appear to have reduced violence. Rexer and Hvinden (2020: 5) find that "areas controlled by rebels who received surveillance contracts see a nearly 75% reduction in oil theft." Even critics of the contracts note that attacks declined and production increased (Adibe, Nwagwu, and Albert 2018).

Oil companies have adopted strategies similar to the state. Amunwa (2012: 8) reports, "Oil companies have regularly made 'stay-at-home' payments to armed groups. . . Shell frequently uses payments and contracts to pacify armed groups and to regain access to oil facilities closed or damaged by the conflict." The report describes an episode in which Shell made repeated visits to a community where armed groups were competing for turf. During each visit, the company "allegedly paid whichever faction [currently] controlled access to the area." Payments were in proportion to the groups' threat to oil infrastructure: "If you negotiate with an AK-47 they will pay you a price for that, with a pistol, a bazooka, a gunboat [...] they will pay you based on your coercive power" (Zalik 2011).

Several features of this case inform assumptions or accord with implications from the formal model we develop below. Militants attack oil pipelines, which are less valuable but also more weakly defended than export terminals or wellheads. These groups have multiple motivations. Pilfered oil and illegally refined fuel can be sold on black markets (the prize incentive), and sabotage brings the government to the bargaining table (the signaling incentive). Consistent with costly signaling, the state and oil companies respond to violence, buying off those groups with the demonstrated capacity to sabotage oil infrastructure. The state will pay for peace but only after it is convinced that rebels will disrupt oil production.

Pipeline sabotage and payouts to saboteurs are not unique to Nigeria. Giroux, Burgherr, and Melkunaite (2013) identify 27 countries with more than ten attacks on oil and gas infrastructure from 1980–2013; six countries saw more than one hundred such attacks. Oil theft is common and substantial across these states. It has been documented in Angola, Iran, Iraq, Libya, Mexico, Nigeria, Pakistan, Russia, and Syria; smuggling has been observed in many more, including Ghana and Morocco (Katsouris and Sayne 2013; Nellemann et al. 2018). By some estimates, global oil theft amounts to roughly USD 20 billion and accounts for a fifth of revenues accruing to armed groups and organized crime (Nellemann et al. 2018). In Appendix Section A, we provide brief accounts from other cases (Colombia, Egypt, Mexico, and Turkey) where, as in Nigeria, groups have focused attacks pipelines to steal fuel or garner concessions.[14]

3. Theoretical Framework

We integrate two common strategic interactions between a government (G) and a group of rebels (R): a Blotto game with attack and defense across multiple potential sites of conflict and crisis bargaining amid incomplete information. We first introduce the Blotto-style model then use its equilibrium expected payoffs as the disagreement payoffs in a bargaining model with incomplete information and costly signaling.

14. In Egypt's Sinai Peninsula, Bedouin groups repeatedly attacked the Arab Gas Pipeline in 2011 and 2012 to "secure a livelihood" from the government. The government paid protection money to these groups to safeguard that same pipeline, similar to the pipeline security contracts in Nigeria.

3.1 One-shot Blotto Game: Sabotage of Oil Infrastructure

The oil infrastructure is comprised of $N \geq 2$ sections, categorized into two types. There are $N^c \geq 1$ critical pieces that represent high-value, costly repaired targets such as oil wells or terminals. There are $N^p \geq 1$ pieces of oil pipeline, which are low-value, cheaply repaired targets. We order the pieces of infrastructure such that $n = 1, ..., N^c$ indexes the critical pieces and $n = N^c + 1, \ldots, N$ indexes the pipelines, where $N^c + N^p = N$.

The government and rebels simultaneously decide what infrastructure sections to defend and attack, respectively. The government has enough resources to defend S^G sections, where $1 \leq S^G < N$.[15] So its choice is a vector of locations $l^G = (l_1^G, \ldots, l_N^G) \in \{x \in \{0,1\}^N | \sum_n x_n = S^G\} \equiv \mathscr{L}^G$ such that $l_n^G = 1$ means the government defends section n and $l_n^G = 0$ means the government leaves section n undefended. The rebels have enough resources to attack S^R sections where $1 \leq S^R < N$; their choice is a vector of locations $l^R = (l_1^R, \ldots, l_N^R) \in \{x \in \{0,1\}^N | \sum_n x_n = S^R\} \equiv \mathscr{L}^R$, where $l_n^R = 1$ means the rebels attack section n and $l_n^R = 0$ means the rebels do not attack section n.[16]

Given a profile of defense and attack locations $l = (l^G, l^R)$, the rebels successfully sabotage section n if and only if they attack n and n is undefended (as in Sonin and Wright 2019). This contest success function reflects a common asymmetry in military capacity between government and rebel forces.[17] We assume rebels are surely defeated when facing the government head on. Specifically, payoffs from section n given locations are

$$\pi_n^G(l_n^G, l_n^R) = \begin{cases} -\theta v^G \cdot l_n^R \cdot (1 - l_n^G) & \text{if } n \leq N^c \\ -v^G \cdot l_n^R \cdot (1 - l_n^G) & \text{if } n > N^c \end{cases}$$

for the government and

$$\pi_n^R(l_n^G, l_n^R) = \begin{cases} \theta v^R \cdot l_n^R \cdot (1 - l_n^G) & \text{if } n \leq N^c \\ v^R \cdot l_n^R \cdot (1 - l_n^G) & \text{if } n > N^c \end{cases}$$

for the rebels. Total payoffs for actor i are $\Pi^i(l) = \sum_n \pi_n^i(l_n^G, l_n^R)$. In the expression above, $v^G > 0$ represents the government's loss after a successful attack on a pipeline. It captures the value of stolen oil and costs of repairs .Likewise, $v^R > 0$ represents the rebels' gains after a successful attack on a pipeline. These gains include the value of pilfered oil, which is often sold on black markets or refined (as gasoline or kerosene) and then soled on black markets. These gains also include any expressive benefits derived from successful sabotage.

The parameter $\theta > 1$ captures the asymmetric value between pipelines and critical pieces. When θ is large, critical infrastructure holds substantially more oil and is more costly to repair than pipeline sections. When θ is closer to 1, that asymmetry is muted. Because $\theta > 1$, absent government defenses, rebels prefer

15. In many oil-producing states, the government collaborates with extractive companies to secure oil infrastructure. We treat these parties as a unified actor, and S^G represents their total defensive resources.

16. We reserve subscripts to index infrastructure sections, $n = 1, \ldots, N$, and superscripts label actors or infrastructure types.

17. Each actor can locate at most one unit of force at each section. This is without loss of generality, as our contest success function eliminates incentives for the government or rebels to locate more than one unit of force at any section.

to attack critical rather than pipeline sections. Likewise, the government would prioritize defending critical rather than pipeline sections if were to be attacked with equal probability.

A strategy for actor i is a probability distribution $\sigma^i \in \Delta(\mathscr{L}^i)$, where $\sigma^i(l^i)$ is the probability that i chooses location vector $l^i \in \mathscr{L}^i$ and $\Delta(\mathscr{L}^i)$ is the $\#\mathscr{L}^i$ probability simplex. Let $U^i(\sigma)$ denote i's expected payoffs given σ where

$$U^i(\sigma) = \sum_{l^G \in \mathscr{L}^G} \sum_{l^R \in \mathscr{L}^R} \sigma^G(l^G)\sigma^R(l^R)\Pi^i(l^G, l^R).$$

We characterize Nash equilibria of the game.

To do this, let $s_n^i(\sigma^i)$ denote the probability that i locates at section n given strategy σ^i which means

$$s_n^i(\sigma^i) = \sum_{l^i \in \mathscr{L}^i} \sigma^i(l^i) l_n^i.$$

At times, we may suppress notation and write s_n^i instead of $s_n^i(\sigma^i)$ when it is clear that s_n^i depends on σ^i. In words, s^i is a marginal distribution of strategy σ^i and, thus, a simpler summary of the strategy. We say an equilibrium is fully mixed if the government and the rebels locate at each section n with probability between zero and one.

Definition I. *Profile σ is fully mixed if the rebels and government locate at each infrastructure section with probability strictly between zero and one, that is, $s_n^i \in (0,1)$ for all i and n.*

The next result characterizes the marginal distributions and expected utilities in every fully mixed equilibrium. Its proof, and those of the proceeding results, are in Appendix Section B.

Proposition I. *In a fully mixed equilibrium σ, the probability that the government defends and the probability that the rebels attack section n are*

$$s_n^G = \begin{cases} \dfrac{S^G + (\theta - 1)N^p}{N^c + \theta N^p} & \text{if } n \leq N^c \\ \dfrac{N^c + \theta(S^G - N^c)}{N^c + \theta N^p} & \text{if } n > N^c \end{cases} \qquad \text{and} \qquad s_n^R = \begin{cases} \dfrac{S^R}{N^c + \theta N^p} & \text{if } n \leq N^c \\ \dfrac{\theta S^R}{N^c + \theta N^p} & \text{if } n > N^c \end{cases},$$

respectively. Furthermore, expected utilities are

$$W^G = -\frac{\theta(N - S^G)S^R v^G}{N^c + \theta N^p} \qquad \text{and} \qquad W^R = \frac{\theta(N - S^G)S^R v^R}{N^c + \theta N^p}.$$

Using the characterization of fully mixed equilibria in Proposition I, Implication I summarizes our predictions about attacks on different types of infrastructure.

Implication I. *The following hold in every fully mixed equilibrium σ:*

1. *Every pipeline section is more likely to be attacked than every critical section. That is, for all $n \leq N^c$ and $n' > N^c$, $0 < s_n^R < s_{n'}^R$.*

2. *Let* $P^p = \dfrac{\theta S^R}{N^c + \theta N^p}$ *denote the probability of an attack on a pipeline section. It is strictly increasing in* θ*, and* $\lim_{\theta \to \infty} P^p = \dfrac{S^R}{N^p}$.
3. *Let* $P^c = \dfrac{S^R}{N^c + \theta N^p}$ *denote the probability of an attack on a critical section. It is strictly decreasing in* θ *and* $\lim_{\theta \to \infty} P^c = 0$.
4. *The rebels attack all pipeline sections with equal probability.*

Implication I says that most valuable targets are the least likely point of attack in equilibrium.[18] Furthermore, when the value of these targets is highly asymmetric (i.e., θ is large), we do not expect to see attacks on the more critical infrastructure.

To see the logic behind this, note that each actor is indifferent between locating at any two sections in a fully mixed equilibrium. When θ increases, critical infrastructure becomes a more attractive prize for the rebels and a greater vulnerability for the government, all else equal. To maintain the rebel's indifference condition, the government increases the likelihood that it defends the critical infrastructure and reduces the likelihood that it defends pipeline sections. To maintain the government's indifference condition, the rebels become less likely to attack the critical infrastructure and more likely to attack the pipeline sections.

Finally, rebels do not focus on a single segment of infrastructure. If they did, then the government would relocate its defenses to ward off attacks. Likewise, the government does not surely defend any one section of the infrastructure. If it did, the rebels would anticipate this and attack elsewhere. The final result demonstrates that, under reasonable conditions, a fully mixed equilibrium exists and all equilibria are fully mixed.

Proposition II. *A fully mixed equilibrium exists if and only if* $S^G > \dfrac{\theta - 1}{\theta} N^c$ *and* $S^R < \dfrac{N^c + \theta N^p}{\theta}$. *Moreover, if a fully mixed equilibrium exists, then all equilibria are fully mixed.*

Proposition II states two conditions that are jointly sufficient and individually necessary for fully mixed equilibria to be relevant. The first condition requires the government strong enough that it can defend at least $\dfrac{\theta - 1}{\theta} N^c$ sections. This holds for all $\theta > 1$ if $S^G \geq N^c$, i.e., the government can defend the critical infrastructure. The condition likely holds because, absent it, oil companies would be reluctant to build any critical oil infrastructure in a country. The second condition requires that the rebels are not too strong and can only attack less than $N^p + \dfrac{N^c}{\theta}$ sections. This holds for all θ if $S^R \leq N^p$, which means that the rebels cannot attack every section of the pipeline simultaneously. Appendix B.3 illustrates the types of equilibria that can arise when one of these inequalities does not hold.

3.2 Bargaining

We now consider an ultimatum-bargaining model in which the payoffs from the Blotto game represent each actor's reservation value.[19] More specifically, the government offers some payment to the rebels $x \geq 0$. The

18. A version of Implication I still holds when we focuson *successful* rebel attacks, i.e., $(1 - s_n^G)s_n^R$ instead of rebel attacks, s_n^R.
19. As such, we are implicitly assuming that the sufficient conditions in Proposition II hold.

rebels observe the offer and then decide to accept or reject. If the offer is accepted, then payoffs are $-x$ and x for the government and rebels, respectively. If the offer is rejected, then payoffs are W^G and $W^R - c$ for the government and rebels, respectively.

The value c is the rebel's cost of attacking the oil infrastructure and is private information to the rebels. This cost is drawn from the uniform distribution over $[0, C]$ at the beginning of the interaction, and $C > 0$ is an exogenous parameter. The cost c can be thought of as the inverse of the rebel's strength, where strong groups can more easily mobilize their troops to attack. In addition, notice the rebel's value of attacking the oil infrastructure is $W^R - c$, so c can also be interpreted as an internal, temporary shock to the cost of selling oil on the black market.

We view rebel strength as two dimensional, (S^R, c). The first dimension S^R represents the number of sections the rebels can attack. The second dimension c is the cost of mobilizing its forces or, alternatively, the expected cost of refining and processing stolen oil. This setup assumes that c is a dimension of the rebel's strength that is not easily known to the government, whereas S^R, which likely correlates with the rebel group's size, can be more directly observed.

The next assumption says the government has more to lose from the oil-sabotage game than the rebels have to gain.

Assumption I. *The government wants to avoid conflict: $v_G > v_R$.*

Assumption I implies $0 < W^R < -W^G$, i.e., the government would grant some transfers to the rebels if it knew it faced the strongest rebel type ($c = 0$). We maintain this assumption in the subsequent analysis for two reasons. First, after successful attacks against the oil infrastructure, the government incurs costs that are unrelated to the stolen oil such as the cost of repairs or those associated with depressed production elsewhere in oil supply chain. Second, the rebels are most likely selling stolen (either crude or refined) oil on the black market, and leaving the formal economy typically diminishes the value of a good. The next result characterizes the subgame perfect Nash equilibrium of the bargaining game. We omit the proof which follows the standard logic for these models.

Proposition III. *In the bargaining game, the rebels accept an offer if and essentially only if $x > W^R - c$. The government offers*

$$\chi = \begin{cases} 0 & \textit{if } C \geq W^R - W^G \\ \frac{1}{2}\left(W^R - W^G - C\right) & \textit{if } C \in (-W^R - W^G, W^R - W^G) \\ W^R & \textit{if } C \leq -W^R - W^G \end{cases}$$

The standard risk-reward tradeoff emerges. When $W^R \leq c$, attacking the oil infrastructure is not profitable for the rebels, so they would accept offer $x = 0$. As C increases, so too does the probability that attacks are not profitable for the rebels even if stiffed by the government with a low offer. The government thus reduces its offer as C grows larger.

Implication II (Uncertainty and the government's optimal offer)**.** *If $C \geq W^R - W^G$, then the government's optimal offer is zero. If $C < W^R - W^G$, then the government offers some transfers to the rebels.*

3.3 Signaling before Bargaining

Finally, we consider a model in which rebels can attack before bargaining to signal their strength. Specifically, the interaction proceeds over three phases:

1. The rebels observe their private information c and decide whether to attack $a_1 = 1$ or not $a_1 = 0$.
2. The government observes a_1 and makes an offer $x \geq 0$.
3. The rebels either reject the offer and attack $a_2 = 1$ or accept the offer and do not attack $a_2 = 0$.

Payoffs from this game are as follows:

$$u^R(a,x,c) = (a_1 + a_2)[W^R - c] + (1 - a_2)x$$
$$u^G(a,x,c) = (a_1 + a_2)W^G - (1 - a_2)x.$$

Every time the rebels attack, they pay some cost and then both actors accrue the payoffs derived from the Blotto game. If the rebels accept the government's offer of x, then no second attack occurs, and the government pays x to the rebels. We maintain the assumption that c is drawn from the uniform distribution over $[0,C]$ at the beginning of the game with PDF f and CDF F.

By using the Blotto model to microfound the benefits of attacking in both phases, we are implicitly assuming that rebels cannot be completely defeated when attacking. Substantively, this reflects our focus on small-scale conflicts, in which rebels do not risk the group's existence by attempting to sabotage oil infrastructure. More technically, note that in a fully mixed equilibrium $\lim_{N^p \to \infty} s_n^R s_n^G = 0$ regardless whether section n is critical or a pipeline. In words, when the oil pipeline is quite long, the probability that the rebels and government confront each other is close to zero. In such situations, we would expect the rebels to survive after attacks.[20]

The next result characterizes perfect Bayesian equilibria in pure strategies.

Proposition IV. *Assume $C > 2W^R$. The following hold in every pure-strategy equilibrium of the signaling game.*

1. *In phase 1, the rebels attack if and essentially only if $c < W^R + \chi_1 \equiv c^*$. The rebels accept offer x in phase 3 if and essentially only if $x > W^R - c$.*
2. *If there is no initial attack ($a_1 = 0$), the government offers $\chi_0 = 0$. After an initial attack ($a_1 = 1$), the government offers $\chi_1 = \min\left\{-\frac{1}{3}W^G,\, W^R\right\}$.*

20. Accommodating the possibility that rebels are defeated after attacking a defended section of the pipeline would not change the substantive qualities of the equilibrium characterization in Proposition IV, but it would decrease the signaling incentives in the model.

3. Beliefs are updated via Bayes rules with probability density function:

$$\mu(c|a_1) = \begin{cases} \dfrac{1}{C-c^*} & \textit{if } a_1 = 0 \textit{ and } c \in (c^*, C] \\ \dfrac{1}{c^*} & \textit{if } a_1 = 1 \textit{ and } c \in [0, c^*) \\ 0 & \textit{if } a_1 = 0, c \notin [c^*, C] \textit{ or } a_1 = 1, c \notin [0, c^*] \end{cases} .$$

Appendix Section B.4 contains the proof. An important step is showing that, if the government uses a pure strategy, then the rebel's expected payoff difference between attacking and not in phase 1 satisfies a single-crossing property with respect to c. This implies that the rebels use a cutpoint strategy in phase 1 where they attack if phase 1 ($a_1 = 1$) if and only if c is smaller than some cutpoint c^*. The remainder of the analysis follows a standard logic.

The cutpoint c^* incorporates two incentives for rebels to attack in phase 1. The value W^R is the prize incentive, i.e., the expected benefits from oil theft. The value χ_1 is the signaling incentive, i.e., the expected value from government concessions. Strong rebels with costs $c \leq W^R$ attack because they are able to immediately profit from stealing oil. By contrast, moderately weak rebels with costs $c \in (W^R, c^*)$ attack the pipeline even though their attacks are not immediately profitable, i.e., $W^R < c$. Nonetheless, they do so expecting future concessions from the government.[21]

Based on Proposition IV, we define two measures of violence: (1) the probability of at least one attack in equilibrium $P_1 = F(W^R + \chi_1)$, and (2) the probability of an attack due to bargaining failure $P_2 = F(W^R - \chi_1)$.

Implication III (Effects of prices on attacks)**.** *P_1 and P_2 weakly increase in the rebel's value of a successful attack (v^R). While P_1 weakly increases in the government's cost of successful attack (v^G), P_2 weakly decreases in v^G. That is:*

1. $\dfrac{\partial P_1}{\partial v^R} > \dfrac{\partial P_1}{\partial v^G} \geq 0.$

2. $\dfrac{\partial P_2}{\partial v^R} \geq 0 \geq \dfrac{\partial P_2}{\partial v^G}.$

If the rebels value oil more, this exacerbates violence by increasing both the prize and signaling incentives. Marginally weaker groups choose to launch an initial attack, and stronger groups are less likely to accept the government's offer. This effect is always larger than that of a corresponding increase to the government's value of oil. When v^G increases, the government makes weakly larger offers, so there are potentially two countervailing effects: weaker groups are more likely to initially attack in search of a larger payout (i.e., enhanced signaling incentive), but the government makes larger offers, thereby creating a lower likelihood of bargaining failure.[22] Depending on how the phases of the game map to real-world data (e.g.,

21. The model implicitly assumes that the government can attribute attacks to a specific groupm because, e.g., insurgent or ethnic groups have defined areas of control. This matches our case study of Nigeria where the government and oil companies invested resources to understand the geography of group control. In addition, territorial dominant groups, especially those who have the possibility of attacking, have incentives and resources to monopolize insurgent violence in their neighborhood.

22. The weak inequalities in Implication III hold strictly when $-W^G < 3W^R$.

whether we observe an interaction only after phase 1), increases in v^G could actually decrease violence. Returning to Implication I, asymmetries in the value of oil infrastructure imply that these price-induced increases in violence concentrate along pipelines and not at the critical infrastructure.

One potential criticism of our analysis might be that the rebels do not grow stronger after an attack. That is, rebels might use the profits from stolen oil to boost their capacity. One way to accommodate this would be to parameterize the expected payoff from the Blotto game as a function of S^R, i.e., $W^R[S^R]$. We could then rewrite the rebels' payoffs as

$$u^R(a,x,c) = a_1(W^R[S^R]-c) + a_2(W^R[S^R+\gamma a_1]-c) + (1-a_2)x.$$

In the above modification, rebels receive $W^R[S^R]-c$ from attacking in the first phase. After attacking in the final phase, they receive $W^R[S^R+\gamma a_1]-c$, where rebel capacity in the final phase is $S^R+\gamma a_1$. The parameter γ captures the rebel's enhanced capacity after attacking in the first phase, which is commonly known. In the baseline model $\gamma = 0$.[23] Yet, the relevant features of the equilibrium would not change when $\gamma > 0$. The key difference would be that c^* increases, that is, weaker rebels attack in phase 1 because they anticipate their capacity will grow. With higher capacity after attacking, the government would make more generous offers, thereby compensating the weaker groups who attacked in the first phase. Thus, there would exist a dynamic growth incentive when initially attacking in addition to the prize and signaling incentives already identified.

3.4 Observable Implications

Because the Nigerian case was used as a model-building exercise, we assess the model's implications in a larger sample of African countries. We want to explain variation in two theoretical quantities: the probability of an attack on a pipeline segment (P_tP^p) and critical pieces of infrastructure (P_tP^c) in a given period $t \in \{1,2\}$. We views these quantities as representing the added attack risk from having infrastructure of type c or p in phase t.

H1: *An operational pipeline increases the likelihood of attacks, and this effect exceeds the increase induced by other oil infrastructure.*

Our first hypothesis follows from Implication I. In fully mixed equilibria (which are the only equilibria under plausible assumptions), pipelines are more likely to be attacked than more critical sections regardless of the values of N^c, N^p or θ. Furthermore, as the asymmetry between the value of the pipeline and more critical infrastructure increases, P^p increases to $S^R/N^c > 0$ and P^c decreases to zero. We expect this asymmetry to be large, so we also expect a pipeline to increase the likelihood of attacks, and higher-value infrastructure to have a smaller, perhaps negligible, effect on violence.

H2: *Past attacks do not predict which sections of pipeline are subsequently sabotaged.*

Our second hypothesis reflects our expectation that rebels are deliberately unpredictable in choosing where to attack. Because rebels attack all pieces of the pipeline with probability P^p, past rebel attacks should not predict future attacks.

23. We need to assume $S^R + \gamma < N^p + \dfrac{N^c}{\theta}$ to ensure that fully mixed equilibria exist with rebel size $S^R + \gamma$.

Our final hypothesis describes the effects of oil prices on the likelihood of attacks along pipelines.

H3: *An increase in the black-market price of fuel induces a larger increase in attacks than an increase in the export price of fuel.*

In Implication III, increasing the value of oil to rebels (v^R) has a larger positive effect on violence than increasing the value of oil to the government (v^G). Our third hypothesis, thus, predicts that increases in the black-market price of fuel (our proxy for v^R) will have a larger effect on violence than equivalent increases in the export price (our measure of v^G). We discuss these proxies in greater detail below.

4. Data

4.1 Oil and Gas Infrastructure

We use proprietary geo-spatial data on oil and gas infrastructure from Wood Mackenzie, a private research firm. The data include information on where and when new infrastructure comes online, including oil and gas fields, wells, pipelines, and terminals. Figure A.1 maps these features up to 2014, the final year for which we have data.

Fields are tracts of land above known reservoirs of oil or gas. Wells (or wellheads) are found within these larger fields and are the specific points at which oil or gas is brought to the surface. We include both exploration wells used to assess the scale and viability of extraction from a field as well as production wells used for extraction. Gathering pipelines bring crude oil or natural gas from wells to processing facilities; larger transmission pipelines move crude and refined products over longer distances (e.g., between countries).[24] Terminals are industrial storage facilities, sometimes attached to refineries, where fuel is collected prior to being loaded on tankers or other delivery vessels. (Our data do not differentiate refineries from other oil and gas terminals.) Fields, wells, and terminals share several attributes relative to pipelines: they are compact features known to store large quantities of oil or gas below or above ground. Control of a wellhead or terminal implies control over the fuel at that site; hijacking a section of pipeline typically provides a smaller flow that can be remotely interrupted once the sabotage is detected. In the analysis below, we group together fields, wells, and terminals, as these pieces of infrastructure store relatively more value than pipelines and, thus, constitute more critical infrastructure for oil extraction and export (i.e., $\theta > 1$). These types of high-value infrastructure are also less common, and grouping these features improves the precision of our estimates. In our data, the scale of pipelines dwarfs other features. There are 90,000 km of pipelines on the African continent where we focus our analyses, less than 1,000 producing fields, and under 200 terminals as of 2014.

Our data are distinct from previous sources. Most analyses of oil and conflict rely on country-year data on oil exports (Collier and Hoeffler 1998; De Soysa 2002; Fearon and Laitin 2003), production (Humphreys 2005), reserves (Humphreys 2005; Cotet and Tsui 2013), discoveries (Lei and Michaels 2014), or rents (De Soysa and Neumayer 2007). These data can be used to estimate the total effect of oil on conflict at the country-level. However, our work and other recent research predicts that oil will have varied effects

24. We include only active pipelines and exclude those that are planned, under construction, or decommissioned.

depending on where extraction and refining take place. Lujala (2010) enabled initial tests of these claims by extracting (point) locations of oil fields and their discovery and production dates from the US Geological Survey's World Petroleum Assessment (see also Denly et al., n.d. who construct a field-year dataset with annual production values). Several studies use these data to relate separatist armed conflicts to oil reserves (e.g., Morelli and Rohner 2015; Asal et al. 2016). Our data improve upon this source in a few ways. We have the boundaries of oil and gas fields, whereas the earlier data used circular, 30-kilometer buffers as an approximation (which is many times larger than the average field). We have dates for individual fields, whereas the earlier data often used the earliest date across several combined fields. Finally, we have data on other types of infrastructure; oil fields are only the start of a long value chain.[25]

4.2 Gasoline Prices

Most analyses of oil price changes and conflict do not separately measure the value of oil to government and rebels (Blair, Christensen, and Rudkin 2021; Dube and Vargas 2013). And these prices can be correlated: for example, the "bush price" of stolen oil in Nigeria is often calculated as a percentage of the market price (Oriola, Haggerty, and Knight 2013: 80). Prior results do not, thus, allow us to infer whether increases in the world price exacerbate violence along existing pipelines by increasing v^G, v^R, or both.

To make empirical progress, we exploit variation in fuel subsidies. Many oil-producing states subsidize fuel, which creates a wedge between the global price and a lower price that consumers pay at the pump. Stolen oil is often illegally refined and resold locally as gasoline and kerosene, and subsidies depress the black-market value of fuel. Consumers will not pay more for stolen gas than the legal, potentially heavily subsidized supply. A 2011 headline about Togo's decision to curtail its fuel subsidies makes this relationship plain: "Higher Fuel Taxes Driving Togolese Motorists to Black Market" (VoA News 2011). And greater demand for black-market fuel should increase the prize incentive for rebels. A 2022 report from the International Crisis Group argues that lower subsidies exacerbated pipeline sabotage in Mexico, arguing that "the removal of fuel subsidies [. . .] increased the returns on theft, attracting more criminals to the business and ratcheting up conflict among them" (International Crisis Group 2022: 3).

We leverage fossil fuel subsidies to analyze whether changes to local and global prices differentially affect armed conflict along pipelines. Ross, Hazlett, and Mahdavi (2017) measure the wedge between local gasoline prices and the world price at the monthly level from 1997–2014. To construct an annual price, we simply average their monthly data. Between 2003 and 2014 in our sample of countries, the local price of fuel ranged from 31 to 364 percent of the world price (169 percent on average). We use the local fuel price as a proxy for the value of stolen oil for rebel groups (v_R). The global price then measures the value of gasoline to the government (v_G).

4.3 Armed Conflict

The Armed Conflict Location and Event Data Project (ACLED) provides event-level data on armed and social conflict from all African countries starting in 1997 (Raleigh et al. 2010). ACLED uses three types

25. The location of wellheads is particularly informative. Fields may never be exploited due to cost (Owen, Inderwildi, and King 2010) or political risk (see Massey and May 2005 on Chad).

of sources: "(1) more information from local, regional, national and continental media is reviewed daily; (2) consistent NGO reports are used to supplement media reporting in hard to access cases; (3) Africa-focused news reports and analyses are integrated to supplement daily media reporting" (Raleigh, Linke, and Dowd 2017). We only retain events that can be precisely geo-coded (e.g., placed in a specific town). To avoid concern about duplicated events, we code separate indicator variables that take a one if the following occurs: any ACLED event, a battle, a battle involving a rebel group, or a battle involving a rebel group or ethnic militia.[26] Given our interest in armed conflict involving rebels and militants, we focus on the last three outcomes. Unless noted, we omit social conflicts, such as protests, which make up a large share of all ACLED events.

Attacks on oil pipelines are often small clashes that do not involve battle deaths (consistent with our theory). For this reason, we opt for ACLED over the Uppsala Conflict Data Program's Geo-referenced Event Data (UCDP-GED). UCDP-GED only includes incidents that result in at least one direct death. We validate this choice using the Energy Infrastructure Attack Database (EIAD), which expands the Global Terrorism Database to include non-state violence directed at energy infrastructure between 1980–2011 (Giroux, Burgherr, and Melkunaite 2013). While ACLED and EIAD include different types of events and rely on different sources and geo-coding methods, we find that ACLED has much better overlap with EIAD than UCDP-GED. In grid cell-years in which the EIAD records an attack or attempted attack on an oil or gas pipeline or terminal, the probability that ACLED also codes an attack is five times higher than UCDP-GED. UCDP-GED does not record a conflict in any observation in which the EIAD records an attack on an oil or gas terminal.[27]

We do not use the EIAD in our analysis, as many results would be mechanical: attacks on oil and gas infrastructure can only increase in locations where such infrastructure is built. However, we note that in Africa between 1997 and 2011 (the overlap with our panel) the EIAD records over seven times more incidents related to pipelines than oil terminals — descriptive evidence that aligns with our first observable implication. Giroux, Burgherr, and Melkunaite (2013: 124) also observe this pattern in the global EIAD sample and write, "attacks predominantly take place on 'linear' energy infrastructures (e.g., pipelines and transmission lines) that are difficult to protect and often pass through remote areas."

4.4 Units of analysis

Appendix Section C illustrate how we construct our grid cell-by-year panel. For a given year, we map both infrastructure and conflict, and Figure A.3 uses 2001 and 2015 as examples. We then overlay equally sized grid cells and determine whether a particular type of infrastructure or conflict falls within each grid cell in that year. (Our actual panel uses 5 km $\times$ 5 km grid cells.) This results in tabular, grid cell-by-year data, as

26. ACLED defines a battle as a "violent interaction between two politically organized groups at a particular time and location" (Raleigh, Linke, and Dowd 2017: 8). Rebel groups are "political organizations whose goal is to counter an established national governing regime by violent acts" (16). Ethnic (or identity) militias are "groups organized around a collective, common feature including community, ethnicity, region, religion or, in exceptional cases, livelihood" (18). Events involving ethnic militias are often called "communal violence."

27. In the EIAD, we classify oil and gas command and control centers, pumping stations, refineries and processing plants, and storage facilities as terminals.

in the tables in the bottom of Figure A.3. Expanding this procedure to cover the whole region and all years, we generate our balanced panel of 1,474,363 grid cells over 18 years.

Many papers use a gridded dataset provided by PRIO, which uses grid cells that are 55 km $\times$ 55 km. We opt for a smaller grid for two reasons. First, we can more confidently attribute violence to oil infrastructure if the incidents occur close to those features.[28] Second, we are interested in whether rebels appear to change the sites of their attacks. A PRIO grid cell is 3,025 sq. km. If violence occurs at two sites separated by over 50 kilometers (hours of travel time in remote settings), we do not want to code those attacks as occurring in the same location. It is important to note that partitioning the grid more finely reduces the baseline probability of violence: the likelihood of conflict in any given year in a specific 25 sq. km area is, unsurprisingly, quite low. As with the PRIO grid, we spatially merge in other covariates and include time-varying measures of population and luminosity. The latter is a common proxy for economic development.[29]

5. Empirical Strategy and Results

We use different empirical strategies to assess our hypotheses (H1–H3). In the sections that follow, we introduce these strategies and discuss the associated results.

5.1 Armed Conflict Concentrates Along Pipelines (H1)

Our first hypothesis is that the presence of pipelines increases the probability of armed conflict, and that this effect exceeds any increase induced by other more critical oil infrastructure. Starting with descriptive statistics, Table 1 shows the percentage of observations experiencing different types of armed conflict (e.g., any ACLED event, any battle) when different types of infrastructure are present or absent. We differentiate two types of control observations: those from cells that never contain a particular type of infrastructure ("never treated' '), and those from cells that will eventually contain such infrastructure ("not yet treated' '). Looking at the first row of Table 1, a battle occurs in only 0.03 percent of observations from cells that never contain an oil or gas pipeline. This is higher (0.06) for control observations in cells that will eventually contain a pipeline, but still considerably lower than the likelihood in cell-years with an oil and gas pipeline (0.16). Across all of our conflict variables, the probability of violence is two or more times as large in cell-years with pipelines than those without. The same pattern does not hold for other types of infrastructure: the probability of violence is lower in cell-years with active wellhead, as is the probability of a battle in cell-years with an oil or gas terminal.[30]

28. We do not, however, want to opt for too high of a resolution: given some imprecision in the geo-coding of features and conflict, we risk dissociating oil-related conflicts from associated infrastructure if partition the map too finely.

29. We use population data from the LandScan (Bright and Coleman 2001) and Gridded Population of the World (version 4) datasets (Center for International Earth Science Information Network 2018). These data provide measures for each raster cell in 1990, 2000, 2005, 2010, and 2015; we linearly interpolate to construct an annual measure. We use annual luminosity data from NOAA's DMSP-OLS for 1996–2012 and then aggregate monthly data from VIIRS-DNB for 2013–2014.

30. The higher probability of any ACLED event in cell-years with an oil or gas terminal is due to higher rates of protests and riots. Terminals tend to be located in more densely populated areas: the average population count in cell-years with terminals is nearly 21,000 people, five times the average density of observations with pipelines. The median population count in cell-years with a pipeline is just 104.

Table 1: Oil and Gas Infrastructure and Armed Conflict

	ACLED Event	Battle	Rebel Battle	Eth. Militia Battle	Cell-Years
Pipelines					
Never treated	0.08	0.03	0.02	0.01	26,310,150
Not yet treated	0.23	0.06	0.02	0.01	35,327
Treated	0.45	0.16	0.06	0.03	193,057
Fields					
Never treated	0.08	0.03	0.02	0.01	26,429,688
Not yet treated	0.10	0.02	0.01	0.02	9,315
Treated	0.15	0.06	0.01	0.01	99,531
Wells					
Never treated	0.08	0.03	0.02	0.01	26,513,154
Not yet treated	0.08	0.03	0.01	0.01	23,542
Treated	0.00	0.00	0.00	0.00	1,838
Terminals					
Never treated	0.08	0.03	0.02	0.01	26,537,904
Not yet treated	0.61	0.61	0.61	0.00	164
Treated	2.79	0.43	0.21	0.00	466

Table 1: "Never treated" refers to cells that never receive oil infrastructure of each type; "not yet treated" refers to cell-years that later receive it but have not yet; and "treated" refers to cell-years in which the oil infrastructure exists. We calculate the proportion of cell-years experiencing different types of conflict events and multiply by 100.

We analyze whether the operation of oil and gas infrastructure increases the likelihood of armed conflict. To account for confounds that could affect both the siting of infrastructure and occurrence of violence (e.g., terrain, government turnover), we estimate the following two-way fixed effects (TWFE) model:

$$y_{ict} = \alpha_i + \delta_{ct} + \beta_1 \mathbb{1}(\text{Pipeline})_{it} + \beta_2 \mathbb{1}(\text{Field, Well, or Terminal})_{it} + \psi X_{it} + \varepsilon_{ict} \tag{1}$$

where i indexes grid cells, c countries, and t years. These models include a fixed effect for every grid cell (α_i) and for every country-year (δ_{ct}), as well as indicators for whether a pipeline or other type of infrastructure is present. In robustness checks, we include time-varying covariates for population and luminosity in X_{it} (see Appendix Table A.2). We cluster our standard errors on grid cell; to address concerns about spatial dependence, we also show robustness to clustering on larger spatial units in Appendix Table A.1.

Our first observable implication states that pipelines generate a larger increase in the probability of violence than other types of infrastructure (i.e., β_1 exceeds β_2). This is what we find across all models in Table 2: we can reject the null hypothesis that the coefficients are equal. Pipelines generate a significant increase in the likelihood of violence, whereas other types of infrastructure generate null or negative effects. In Appendix Figure A.4, we show that the results in model 2 are robust to dropping observations from any country in the sample. These effects are also large relative to the levels of violence observed prior to pipelines coming online. Looking at model 2, the effect of a pipeline is more than double the base rate of

0.06. Our point estimates and inferences are similar if we use larger 10x10-km grid cells as our units of analysis (see Appendix Table A.3).

Table 2: Effect of New Infrastructure on Armed Conflict

	ACLED Event	Battle	Rebel Battle	Rebel or Eth. Militia Battle
Pipeline ($\widehat{\beta_1}$)	0.256***	0.171***	0.036**	0.086***
	(0.052)	(0.039)	(0.016)	(0.026)
Field, Well or Terminal ($\widehat{\beta_2}$)	0.034	0.025	-0.019*	-0.027*
	(0.052)	(0.037)	(0.011)	(0.015)
Equivalence Test ($H_0 : \beta_1 = \beta_2$)	0.00	0.01	0.01	0.00
Cells	1,474,363	1,474,363	1,474,363	1,474,363
Country-Years	869	869	869	869
N	26,538,534	26,538,534	26,538,534	26,538,534

Table 2 presents the main results assessing the effect of construction of a new pipeline ($\hat{\beta}_1$), a new field, well or terminal ($\hat{\beta}_2$), as well as the p-value from an equivalence test of the difference between the two coefficients ($H_0 : \hat{\beta}_1 = \hat{\beta}_2$). The table reports on regressions for four outcomes: all ACLED events that are not protests or riots; battles; battles involving rebels; and battles involving rebels or ethnic militias. Models are estimated using OLS with cell and country-by-year fixed effects, with standard errors clustered on cell. We report the number of cells and country-years in the analysis as well as the total sample size. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

In settings like ours where treatment timing varies, recent work shows that TWFE models assume negligible treatment effect heterogeneity. In Appendix Section D.8 we employ the diagnostics and alternative estimation strategies developed by De Chaisemartin and d'Haultfoeuille (2020), Goodman-Bacon (2021), and Callaway and Sant'Anna (2020) to assess the effect of new pipelines on armed conflict. In particular, Goodman-Bacon's (2018) decomposition illustrates why the pathologies of TWFE models are unlikely to manifest in our setting. Given the large number of never-treated cells in our data, over 99 percent of the weight in our TWFE model is placed on the comparison of treated vs. never-treated cells (see Appendix Table A.6). Our results do not depend on comparisons of early-treated (or always-treated) vs. later-treated cells, which can be problematic if treatment effects change over time.

TWFE models also invoke the well-known parallel trends assumption, which we bolster in four ways. First, we control for two potential time-varying confounds, population and economic development, in Appendix Table A.2. Our point estimates and inferences are unchanged. Second, we conduct placebo tests by dropping all post-treatment data and recoding treatment as the five years prior to infrastructure coming online. In Appendix Table A.4, we cannot reject the null hypothesis of no effect for these placebo treatments across all models.[31] Third, our event-study plots in Appendix Figure A.5 reveal that, before treatment, we do not observe divergent changes in violence in treatment and control cells (see also the dynamic effect estimates in Appendix Figure A.6). Fourth, it is possible to focus on the "triple difference," that is, whether the effect of new pipelines exceeds the effects of other types of infrastructure. If governments or companies locate infrastructure in areas with rising violence or if new infrastructure induces similar time-varying

31. The negative point estimates suggest that infrastructure is sited in cells with decreasing violence, an unsurprising form of selection bias that would attenuate the positive effects of pipelines.

changes, such bias would shift both coefficients without necessarily affecting their difference. Furthermore, the triple-difference also alleviates concerns about reporting bias. Attacks on critical infrastructure are more unusual and occur in more populous areas than attacks on pipelines. As such, they are more likely to be covered by media and included in the ACLED data. This relative over-reporting of attacks on critical infrastructure would attenuate our triple-difference (by increasing $\widehat{\beta_2}$).

Finally, one alternative explanation for the patterns we observe in Table 2 arises from road construction as a potential confounder. That is, access roads are sometimes built alongside infrastructure, making it easier for rebels to attack certain areas. This effect should be stronger for pipelines that traverse more remote areas than for infrastructure that might be built in already accessible areas. To rule out this alternative explanation, we use digitized road maps of Africa complied by the Michelin Tire Company to code whether roads were present in a cell in 1990. In Appendix Table A.5, we estimate a TWFE model (similar to Equation 1) that includes our measures of new infrastructure and their interaction with an indicator for road presence in 1990.[32] We find that the conflict-enhancing effects of pipelines on conflict are primarily driven by the construction of pipelines in cells that already contained roads in 1990; they are not driven by the construction of pipelines in cells containing no roads where simultaneous road construction might be confounding.

5.2 Attackers Vary their Points of Attack (H2)

Our second hypothesis is that past attacks should not predict what segments of pipeline are subsequently sabotaged. If rebels concentrate on certain segments, then government could redeploy its defensive resources and more often thwart attacks. Militants, thus, maximize their payoffs by randomizing their points of attack. To assess this, we look at whether attacks repeatedly target the same locations along pipelines. At the very least, we expect there to be little positive autocorrelation in attack locations. We restrict attention to grid cells with oil or gas pipelines throughout the study period and then look at whether past conflict (over the prior two or three years) predicts where battles occur, estimating:

$$y_{ict} = \alpha_i + \delta_{ct} + \sum_{k=1}^{K} \lambda_k \, y_{i,t-k} + \varepsilon_{ict} \tag{2}$$

We present two quantities to summarize our findings. First, we sum the coefficients on the lags (a la Bazzi and Blattman 2014).[33] Second, we use the Yule-Walker equations to estimate the autocorrelation ρ_k at lag k, which is the correlation between y_t and y_{t-k} (Box et al. 2015). In both cases, we use the delta method to compute the standard errors. Appendix Tables A.7 and A.8 separately report the coefficients on the lags.[34]

32. We also include a measure of luminosity (and its interactions with our infrastructure variables) to control for development, which might also be correlated with road access and conflict.

33. Andrews and Chen (1994) illustrate the relationship between the cumulative impulse response function and the sum of autoregressive coefficients, arguing that the latter provides a good scalar measure of persistence.

34. In column 1 of Appendix Tables A.7 and A.8 the first lag of battles is positive and statistically significant $\widehat{\lambda_1} = 0.1$. That coefficient attenuates to zero and loses significance when we restrict attention to battles involving rebels and ethnic militias (columns 2–3). The significant coefficient appears to be driven by battles involving political militias, which are "not seeking the removal of a national power, but typically supported by, armed by, or allied with a political elite" (Raleigh, Linke, and Dowd 2017: 17). These militias — which are a different category than ethnic militias — are often allied with government and do not need to evade its defenses as in our Blotto model. When we remove battles involving political militias, the coefficient on the first lag attenuates and loses significance.

The null hypothesis — which is consistent with our theoretical prediction — is that past armed conflict incidence does not predict what cells with pipelines will see subsequent attacks.[35] We expect the sum of the autoregressive coefficients to be small and the autocorrelations to be negligible.

Table 3: Predictive Power of Past Armed Conflict

	Battle	Rebel Battle	Rebel or Eth. Militia Battle	Protest or Riot
AR(2) Model:				
Sum of Coefficients: $\widehat{\lambda}_1 + \widehat{\lambda}_2$	0.067 (0.053)	-0.004 (0.059)	-0.018 (0.051)	0.312 (0.045)
Autocorrelations				
$\widehat{\rho}_1$	0.107 (0.030)	0.056 (0.041)	0.031 (0.032)	0.234 (0.036)
$\widehat{\rho}_2$	-0.033 (0.038)	-0.061 (0.034)	-0.05 (0.030)	0.15 (0.035)
$\widehat{\rho}_3$	-0.009 (0.007)	-0.007 (0.005)	-0.003 (0.003)	0.055 (0.019)
Cells	8,172	8,172	8,172	8,172
Country-Years	240	240	240	240
N	130,752	130,752	130,752	130,752
AR(3) Model:				
Sum of Coefficients: $\widehat{\lambda}_1 + \widehat{\lambda}_2 + \widehat{\lambda}_3$	0.075 (0.072)	-0.028 (0.066)	-0.054 (0.055)	0.318 (0.060)
Autocorrelations				
$\widehat{\rho}_1$	0.096 (0.031)	0.044 (0.039)	0.019 (0.031)	0.221 (0.037)
$\widehat{\rho}_2$	-0.038 (0.040)	-0.06 (0.041)	-0.051 (0.033)	0.135 (0.038)
$\widehat{\rho}_3$	0.012 (0.032)	-0.017 (0.041)	-0.022 (0.035)	0.08 (0.042)
Cells	8,859	8,172	8,172	8,172
Country-Years	225	225	225	225
N	122,580	122,580	122,580	122,580

Table 3 summarizes estimates from a two-period auto-regressive model (AR(2) in top panel) and a three-period model (AR(3) in bottom panel). The outcome of each regression is the contemporaneous indicator for whether an attack took place and the predictors are the lagged outcomes in the same cell. Results are presented for predicting battles; battles involving rebels; battles involving rebels or ethnic militias; and, for comparison, protests or riots. Models are estimated using OLS with cell and country-by-year fixed effects, with standard errors clustered on cell. We report two quantities: (1) the sum of the lags and (2) the autocorrelations derived using the Yule-Walker equations. We include standard errors computed using the delta method. We report the number of cells and country-years in the analysis as well as the total sample size.

Our results align with the predictions of our Blotto game. Past armed conflict (over the last two to three years) does not predict where battles occur along pipelines. Looking at the sum of the coefficients, we cannot reject the null hypothesis in the first three columns for either the AR(2) or AR(3) models. To help benchmark these results, we estimate the same models using the occurrence of a protest or riot as the outcome measure: the sum of the coefficients from the AR(2) and AR(3) models are 0.3 and highly significant. A similar pattern emerges when we look at the autocorrelations. The autocorrelations for battles, particularly those involving rebels or ethnic militia, are small in magnitude and quickly attenuate to zero. Again, this contrasts with social conflicts, for which the autocorrelation remains positive and of larger magnitude. Knowing the locations of recent protests or riots is informative about where subsequent social conflict will occur. The

35. We condition on country-year and cell fixed effects. In reality, some segments of pipeline may be infeasible to attack (e.g., deep underwater). The cell fixed effects help account for (un-modeled) variation that may reduce the baseline vulnerability of some segments.

same is not true of armed conflict along pipelines. This is consistent with attackers intentionally randomizing across potential pipeline segments to avoid direct confrontations with security forces.

5.3 Black-market and Export Prices Have Different Effects (H3)

Our third hypothesis predicts that increases in the rebel's value of oil should have stronger conflict-enhancing effects than increases in the government's value of oil. As described above, we use the local fuel price as a proxy for the rebels' value of stolen oil (v_R). The global price then measures the value of oil to the government (v_G). Interacting both prices with an indicator for whether a cell contains an oil pipeline permits us to assess our model's prediction that the effects of local prices exceed the violence-inducing effects of global prices. We restrict attention to grid cells with no change in oil infrastructure between 2003 and 2014, which is the study period for this analysis due to data constraints.[36] Specifically, we estimate:

$$y_{ict} = \alpha_i + \delta_{ct} + \gamma_1 \text{Log(Local Price)}_{ct} \cdot \mathbb{1}(\text{Pipeline})_i + \gamma_2 \text{Log(Global Price)}_t \cdot \mathbb{1}(\text{Pipeline})_i + \zeta Z_{it} + \varepsilon_{ict} \quad (3)$$

where the cell fixed effects (α_i) absorb the direct effect of having a pipeline throughout the study period, and the country-by-year fixed effects (δ_{ct}) absorb the direct effects of price fluctuations.

Table 4: Effect of Local and Global Fuel Prices on Armed Conflict around Existing Infrastructure

	Battle	Rebel Battle	Rebel or Eth. Militia Battle
Log(Local Price) x Pipeline (γ_1)	0.065	0.110*	0.106
	(0.113)	(0.061)	(0.066)
Log(Global Price) x Pipeline (γ_2)	0.008	-0.117**	-0.108*
	(0.083)	(0.057)	(0.060)
Equivalence Test ($H_0 : \gamma_1 = \gamma_2$)	0.76	0.05	0.07
Cells	1,464,041	1,464,041	1,464,041
Country-Years	536	536	536
N	17,216,229	17,216,229	17,216,229

Table 4 shows the effect of (log) changes in the local price of gasoline in places with pipelines ($\widehat{\gamma_1}$) and of (log) changes in the global price of gas in places with pipelines ($\widehat{\gamma_2}$), as well as a p-value for the equivalence test of difference between the two ($H_0 : \gamma_1 = \gamma_2$). Cell fixed effects are included and prices are interacted with indicators for the presence of each type of infrastructure throughout the time series, and therefore the estimates represent conditional effects of price changes on the probability of experiencing a conflict event among cells with pipelines. The table reports on regressions for three outcomes: battles; battles involving rebels; and battles involving rebels or ethnic militias. Models are estimated using OLS with cell and country-by-year fixed effects, with standard errors clustered on cell. We report the number of cells and country-years in the analysis as well as the total sample size. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Models 2 and 3 of Table 4 are consistent with our theoretical predictions. Increases to the local price of fuel have a larger effect on battles involving rebels and militants along pipelines than increases to the global price. We can reject the null hypothesis that these different prices have the same effect at conventional levels of statistical significance, and these p-values decline further if we perform the one-sided test implied

36. We are not estimating the total effect of oil prices on conflict: by limiting the sample to cells with no new infrastructure, we do not permit prices to affect conflict by motivating the construction of new infrastructure.

by our model. Holding the local price constant, we estimate that increases to the global price actually reduce the likelihood of violence. Relating this back to our theory, as the government's value of oil increases, it increases its offer to rebels, and this can reduce the probability of subsequent violence.

Appendix Table A.9 shows minimal increases in our standard errors when we cluster on larger geographies. Including the interaction terms of these prices with other types of oil infrastructure does not change any of our inferences (see Appendix Table A.10). Appendix Table A.10 also shows that our point estimates and inferences are unaffected by the inclusion of time-varying controls for population and luminosity.

6. Policy Implications

First, our analysis clarifies potential tradeoffs between promoting security and economic development. Suppose the goal is to reduce sabotage and promote security. One obvious approach is to physically secure pipelines. Yet, our model implies that leaving pipelines relatively undefended and stationing forces at more critical infrastructure is the optimal allocation of defensive resources. Instead, it may be more cost-effective to deter attacks by reducing the returns to sabotage or making it more costly for rebel groups to mobilize.

Deterring attacks can cut against economic development, however. In contexts where rebel groups and the communities they draw from need to flex to garner concessions from government, discouraging violence may not improve welfare (Wick and Bulte 2006). Policies that raise the cost of attacks eliminate a "weapon of the weak." This restricts the set of groups that can credibly threaten violence, thereby reducing both the frequency and scale of government payouts. Where government cannot otherwise commit to payouts for aggrieved groups (e.g., due to electoral incentives), violence provides an accountability mechanism, albeit one divorced from need and generating social and environmental externalities. As Levi (1988: 12) observes, "since bargaining resources are distributed unequally throughout the population, a single ruler will form different contracts with different groups of agents or constituents."

Suppose instead that the goal is to promote economic development. We could, for example, require oil producers to clean up the spills caused by pipeline sabotage. To avoid that expense, they would be keen to bargain with potential attackers and offer larger payouts. More generous payouts and environmental reclamation could both benefit communities in oil-producing regions. This policy could also encourage attacks, however. The promise of bigger payouts induces a larger share of groups to attack in hopes of securing a seat at the bargaining table. There is some evidence of this in Nigeria where the distribution of amnesty payments was followed by pipeline sabotage by new rebel groups. One group actually called itself "Third Wave Federal Amnesty," referring to its goal of being included in an future wave of government payouts (Eke 2015: 758). A policy that advances economic development by increasing payouts to aggrieved groups could undermine security by generating perverse signaling incentives that provoke violence. Promoting both peace and economic development requires a more accountable state, a setting in which groups and communities do not need to take up arms to see their needs addressed. A responsive state could then repress violence without also hampering development.

Finally, our analysis suggests a new avenue through which fossil-fuel subsidies can encourage peace. Past scholarship argues that, by reducing energy prices, fuel subsidies prevent urban riots and protests (Bates

1981; Kim and Urpelainen 2016). Fossil fuel subsidies also have spillover effects by depressing demand for illegally refined oil. This reduced demand decreases the rebels' expected benefits from oil theft, decreasing the likelihood of attacks. Our research suggests that subsidies also discourage armed conflict around pipelines crisscrossing more rural areas, a claim consistent with recent analyses of pipeline sabotage and oil theft in Mexico (International Crisis Group 2022).

7. Conclusion

We develop a model that integrates common approaches to modeling conflict including crisis bargaining with incomplete information and contests with multiple battlefields a la Blotto. We use the model to study the effects of oil infrastructure on conflict. Three plausible assumptions drive the model's predictions. First, some components of the grid are more critical, such that sabotaging these elements generates a larger payoff for rebels and imposes more pain on the government. Second, in a head-to-head battle the government will prevail over rebels due to its superior firepower. Finally, while many groups may demand concessions, government does not know the strength of each group.

We use geo-spatial data on the location of oil infrastructure and armed conflict events to assess several of the model's observable implications. First, we predict and show empirically that rebels focus their attacks on new pipelines and that the construction of more critical infrastructure (e.g., oil wells and terminals) has no discernible effect on armed conflict. Rebels anticipate that government will station its defenses around critical infrastructure (i.e., the largest prizes), so rebels choose instead to attack pipelines, which are softer targets. Second, to prevent the government from forecasting and preventing their attacks, rebels randomize where they strike. We find that past attacks (over the last two or three years) do not predict which sections of pipeline will be subsequently sabotage. This contrasts sharply with social conflict events (e.g., protests), which we show tend to recur in the same locations year after year. Third, the model uncovers two potentially offsetting effects of increased oil prices. As the black-market price increases, so too do the returns to oil theft; yet as the export price increases, the government is more eager to "bargain away" conflict. We find empirical support for these predictions, showing significantly different effects of increases in the local price of gasoline (which establishes a ceiling on the local black-market price) and the global price of gasoline (which reflects its export value).

These findings contribute to our understanding of where and why armed conflict occurs. While rebels want to capture prized targets, they also want to live to fight another day and will attack peripheral targets to elude the government's defenses. Our model better predicts where violence will occur by forcing rebels to consider both the size of the potential prize and also their ability to evade strategically positioned security forces. We also argue that, even with instances of oil theft, attacks on pipelines are not entirely attributable to greed. Rebel groups and the communities they draw from often have grievances related to economic, environmental, or political inequality. Sabotaging pipelines can send a costly signal of a group's capacity to credibly threaten the government, and doing so compels the government to grant concessions. Greed and grievance can be complementary explanations for conflict: if a group profits from pilfering oil (greed), then government needs to seriously engage with its demands (grievance) to deter violence.

Several limitations of our work might be addressed in future research. Theoretically, we assume that rebel groups' strength is uniformly distributed and focus on observable implications that do not turn on this auxiliary assumption. Future work might exploit case knowledge to assert a more realistic distribution. For example, if weaker groups are more likely than stronger groups, then policies encouraging larger government payoffs will increase the expected number of attacks, because the signaling incentive for weaker groups overwhelms the pacifying effect of payouts on stronger ones. Empirically, a number of data limitations might be overcome in future work. We have general descriptions of well-fortified oil terminals, but lack detailed data on the deployment of security forces at different sites. We rely on a proxy for black-market fuel prices. Measuring black-market prices more directly would factor in international demand for stolen oil. Finally, we study one important sector, but other supply chains may face similar threats. International Alert (2005: 132), for example, observes that projects which rely on "linear components" such as transmission lines or transportation bottlenecks are especially vulnerable to disruption.[37] Future research will reveal whether the patterns we uncover manifest in other sectors.

37. In our empirical setting, the government is interested in "bargaining away" conflict, because it internalizes some of the costs of conflict through lost oil revenues and repair costs. In an illicit sector, such as illegal drug production, government does not bear those same costs and, thus, may be less inclined to bargain.

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Supporting Information

The Point of Attack:
Where and Why Does Oil Cause Armed Conflict in Africa?

Following text to be published online.

Contents

A. Evidence from Other Cases

A.1 Colombia: Oil pipeline attacks and oil theft, 1986–2014

Crude oil is Colombia's most valuable export commodity. The country's oil infrastructure — including over 15,000 km of oil, gas, and product pipelines (Agency, n.d.) — has been the victim of thousands of attacks over decades by armed groups including the left-wing guerrilla groups the ELN and the FARC, most along pipelines. Both groups "have extracted so-called 'war taxes' from oil companies and local contractors, using kidnaps, extortion and bombings of oil pipelines as leverage," and are also paid by municipal governments a share of their oil revenues (Dunning and Wirpsa 2004). Indeed, competition between the two for these side payments from oil companies, contractors, and the government led the FARC in the late 1990s to "increase pipeline bombings in an attempt to wrest rents channeled to the ELN" (Dunning and Wirpsa 2004). Between when one pipeline, Caño Limón-Coveñas, was constructed in 1986 and 2014, there were 1,317 attacks causing the pipeline to be shut off for 3,701 days at a loss of USD 611 million including spilled oil and repair costs alone (Cuéllar 2016). Dube and Vargas (2013) document evidence of oil theft by several armed groups, most notably the right-wing paramilitaries, suggesting that just in the two year period between 2001 and 2003 USD 10 million of oil was stolen.

The features of the case match assumptions and implications of our formal model, as in the Nigeria case. The armed groups attack pipelines, the less valuable and more difficult to defend portions of the oil infrastructure, and not terminals or wells. The groups engage both in theft and sabotage attacks that force government to the bargaining table. And the state, as well as oil companies, respond to the groups who have demonstrated their ability to interrupt oil production, with the "war taxes."

A.2 Turkey: Pipeline attacks and oil theft in southeastern Turkey, 2009–16

The Kurdistan Workers' Party (PKK), founded in 1974 to fight for a secessionist state in southeastern Turkey, has relied on pipeline attacks since the early 1980s. The group's demands of the Turkey government include "the Kurdish identity be recognized, and that Kurds be able to freely exercise their civic rights through constitutional guarantees. They also seek some form of autonomy in the Kurdish areas (east and southeast of the country) where they are concentrated" (Savran 2020: 778).

Pipeline attacks preceded several major episodes of bargaining between the Turkish government and the PKK. In 2009, Prime Minister Tayyip Erdogan announced the "Kurdish Opening," the beginning of a peace process with the PKK. The proposed concessions included "greater cultural rights for Kurds, some form of local autonomy, and incentives to Kurdistan Workers' Party (PKK) fighters to lay down arms" (International Peace 2009). The move followed a series of pipeline bombings perpetrated by the PKK in May, August, and November 2008 (Weiss et al. 2012). The negotiations stalled but began again in 2013, preceded by a series of bombings in late 2012 claimed by the PKK (BBC 2012). The negotiations in 2013 led to a ceasefire, but resumed in 2015 when the talks broke down (Coskun 2015). None of these negotiations led to implementatino of the concessions, interrupted by outside events in the war against ISIS or violations of ceasefires.

After several pipeline attacks in 2015, the government announced heightened pipeline security, deploying patrols on horseback and thermal cameras. A think-tank expert warned: "Even the best security plan would not be able to stop attacks. We're talking about hundreds of kilometers of pipelines being patrolled 24/7 – that's not possible" (Coskun and Pamuk 2015).

Turkey, and especially the southeastern region that is the homeland of the PKK, has been a hotspot for oil and fuel smuggling, oil theft, and local refining (Bozcali 2011). The government accuses the PKK of involvement in oil theft. For example, in 2016, the government arrested 27 accused members of the PKK and seized nearly 200,000 liters of crude, saying that "suspects set up a small refinery to convert crude oil to fuel" and that "[r]evenues were used to finance the activities of the PKK" (Staff 2016).

The PKK case matches overlaps in important ways with our formal framework. The armed group engages both in sabotage attacks of oil infrastructure and in oil theft, it focuses nearly all of its attacks on difficult-to-defend pipelines and not on other infrastructure like terminals, and the government has responded to its demands by offering concessions in line with its demands (though they did not follow through on implementing these concessions). The group profits from the presence of the oil industry through theft, but also seeks to use its attacks to demand the government finally respond to longstanding grievances of the Kurdish ethnic group.

A.3 Egypt: Gas pipeline attacks in the northern Sinai Peninsula, 2011-12

Egypt is a major producer of both oil and natural gas. Its Sinai peninsula, between the Suez Canal and Israel, contains large oil and gas terminals on the Mediterranean Sea, oil fields, and several important gas pipelines. The 1,200-km Arab Gas Pipeline crosses the Sinai and connects Egypt's gas pipeline grid with its neighbors in Lebanon, Jordan, Syria, and, at the time, Israel. In 2011 and 2012, pipelines in the Sinai were attacked more than a dozen times (Stocker 2012), leading to shutdowns and economic losses in Egypt and the countries the gas was delivered to on the order of billions of dollars. Nomadic Bedouin groups who historically populated the Sinai desert were allegedly behind, or complicit, in the attacks. The groups, who share more historical ties with groups across the border in Gaza and Israel than with Egyptians, harbor a series of grievances regarding political autonomy and repression under the Mubarak regime. A Bedouin leader wanted by the Egyptian police wrote in letter to the Egypt Independent in 2010, during a campaign of violence that preceded the pipeline attacks: "We are forced to use illicit methods to secure a livelihood for the government has left us with no alternative" (El-Dalah 2010). In talks with the government over the pipeline attacks, Bedouin leaders demanded an amnesty for Bedouins accused in the violence, payments to tribes whose land the pipelines traverse, hiring Bedouins to protect pipelines, and other political demands that shift local decision making power from the central government to the Bedouins. Not all of these demands were met, but the Egyptian government did offer protection money payments to Bedouin groups to safeguard the pipelines (Pelham 2012).[38]

The outlines of this case also link to our formal framework. It is the long, difficult-to-defend gas pipelines in the desert that are attacked, and not the terminals in the cities. Though the Bedouins do not

38. See also Barkat (2012).

appear to engage in oil theft, there was some contemporaneous uncertainty about exactly who undertook the attacks and the government may have worried about the risk of theft by the violent extremist groups present in the Sinai at the time. The state, as in the model, responds with protection payments to the demands of the Bedoins, who demonstrated their strength in interrupting gas production.

A.4 Mexico: Oil pipeline attacks and theft of crude oil and petroleum products, 2007

Mexico has over 50,000 km of oil and gas pipelines crisscrossing the country. At several points in recent decades, armed groups have attacked them in order to achieve political aims. Oil theft has also become increasingly common. In 2007, for example, a leftist armed group, Ejército Popular Revolucionario (EPR), launched a series of attacks using plastic explosives and potassium nitrate on natural gas pipelines that run from the Gulf of Mexico to the interior (Tobar 2007). The attacks caused economic losses on the order of hundreds of millions of dollars (McKinley and Betancourt 2007). The group described the attacks as the start of a "campaign of harassment against the interests of the oligarchy and this illegitimate government has been launched" (Comandancia military de zona del Ejercito Popular Revolucionario 2007). EPR was, at the time, thought to have minimal military capacity, perhaps less than 100 fighters. The group demanded the release of two of their leaders that they said had been detained in Oaxaca by the federal government. EPR was founded in the mid-1990s with the goal of overthrowing the Mexican state, in response to rising inequality and state oppression (Comandancia general del Ejercito Popular Revolucionario 1996). Armed groups — but notably not the EPR — have engaged in oil theft for several decades in Mexico, labeled "huachicoleros" or oil thieves. Recent estimates suggest that USD 1 billion of petroleum products, mostly fuels, is stolen each year (Hunn 2017). In 2018, the state-owned PEMEX which at the time controlled most of the pipeline infrastructure in the country, it discovered 15,000 illegal oil taps in its pipelines (Peschard Mariscal, Salazar Rebolledo, and Olea Gómez 2021). Many armed groups are involved in oil theft in Mexico, particularly the powerful drug trafficking organizations.

Several features of the EPR case align with our formal framework, but there is some ambiguity. The group focuses attacks on pipelines, not other energy infrastructure, as our framework predicts. With little ability to challenge the state militarily, the group used this "weapons of the weak" strategy to force the state to the bargaining table. Though the EPR did not engage in oil and gas theft, other groups did; as a result, it is possible the government believed the EPR could have, increasing the credibility of the group's bargaining position. The state did not at least publicly respond to these attacks, perhaps because they did not continue, demonstrating the weakness of the group. They were clearly worried, however, and paying attention.

B. Proofs

B.1 Proof of Proposition I

To characterize fully mixed equilibria, we need three preliminary results. The first result establishes two properties about the marginal distributions s^i.

Lemma 1. *For every actor $i = G, R$, the following hold:*

1. $\sum_n s_n^i(\sigma^i) = S^i$ *for every* $\sigma^i \in \Delta(\mathscr{L}^i)$.
2. *for every* $x \in [0,1]^N$ *such that* $\sum_n x_n = S^i$, *there exists* $\sigma^i \in \Delta(\mathscr{L}^i)$ *such that* $s_n^i(\sigma^i) = x_n$ *for all* $n = 1, \ldots, N$.

Proof. The first result follows from the definition of s_n^i and the assumption that for all $l^i \in \mathscr{L}^i$, we must have $\sum_n l_n^i = S^i$. To prove the second result, fix $x \in [0,1]^N$ such that $\sum_n x_n = S^i$. Define the function $f^i : \Delta(\mathscr{L}^i) \to \Delta(\mathscr{L}^i)$ as

$$f_{l^i}^i(\sigma^i) = \frac{\sigma^i(l^i) + \frac{1}{\kappa^i} \sum_n l_n^i \cdot \max\{0, x_n - s_n^i(\sigma^i)\}}{1 + \sum_n \max\{0, x_n - s_n^i(\sigma^i)\}}.$$

where $f^i(\sigma^i) = \times_{l^i \in \mathscr{L}^i} f_{l^i}^i(\sigma^i)$ and $\kappa^i = \binom{N-1}{S^i-1} > 0$ is a normalizing constant. Notice f^i is continuous. Furthermore, for all σ^i, $f_{l^i}^i(\sigma^i) \geq 0$ as $f_{l^i}^i$ is the ratio of two non-negative numbers (with a positive denominator). Likewise, we can sum up over l^i:

$$\begin{aligned}
\sum_{l^i \in \mathscr{L}^i} f_{l^i}^i(\sigma^i) &= \frac{\sum_{l^i \in \mathscr{L}^i} \left[\sigma^i(l^i) + \frac{1}{\kappa^i} \sum_n l_n^i \cdot \max\{0, x_n - s_n^i(\sigma^i)\}\right]}{1 + \sum_n \max\{0, x_n - s_n^i(\sigma^i)\}} \\
&= \frac{1 + \frac{1}{\kappa^i} \sum_{l^i \in \mathscr{L}^i} \sum_n l_n^i \cdot \max\{0, x_n - s_n^i(\sigma^i)\}}{1 + \sum_n \max\{0, x_n - s_n^i(\sigma^i)}} \\
&= \frac{1 + \frac{1}{\kappa^i} \sum_n \sum_{l^i \in \mathscr{L}^i} l_n^i \cdot \max\{0, x_n - s_n^i(\sigma^i)\}}{1 + \sum_n \max\{0, x_n - s_n^i(\sigma^i)}} \\
&= \frac{1 + \frac{1}{\kappa^i} \sum_n \max\{0, x_n - s_n^i(\sigma^i)\} \sum_{l^i \in \mathscr{L}^i} l_n^i}{1 + \sum_n \max\{0, x_n - s_n^i(\sigma^i)}} \\
&= \frac{1 + \frac{1}{\kappa^i} \sum_n \max\{0, x_n - s_n^i(\sigma^i)\} \binom{N-1}{S^i-1}}{1 + \sum_n \max\{0, x_n - s_n^i(\sigma^i)}} \\
&= \frac{1 + \sum_n \max\{0, x_n - s_n^i(\sigma^i)\}}{1 + \sum_n \max\{0, x_n - s_n^i(\sigma^i)}} = 1.
\end{aligned}$$

In the algebra above, we invoke $\sum_{l^i \in \mathscr{L}^i} l_n^i = \binom{N-1}{S^i-1}$. To see why, note that, for a fixed n, there are $\binom{N-1}{S^i-1}$ vectors $l^i \in \mathscr{L}^i$ such that $l_n^i = 1$. Because $f_{l^i}^i(\sigma^i) \geq 0$ and $\sum_{l^i \in \mathscr{L}^i} f_{l^i}^i(\sigma^i) = 1$, the range of f^i is indeed $\Delta(\mathscr{L}^i)$, which is convex, compact, and nonempty. So f^i has a fixed point by Brouwer's Theorem. At a fixed point, we much have $x_n - s_n^i(\sigma^i) = 0$ for all n. □

Define i's expected value added from locating at section n given σ^{-i} as $V_n^i(\sigma^{-i})$:

$$V_n^R(\sigma^G) = \begin{cases} \theta v^R(1 - s_n^G(\sigma^G)) & \text{if } n \leq N^c \\ v^R(1 - s_n^G(\sigma^G)) & \text{if } n > N^c \end{cases}$$

and

$$V_n^G(\sigma^R) = \begin{cases} \theta v^G s_n^R(\sigma^R) & \text{if } n \leq N^c \\ v^G s_n^R(\sigma^R) & \text{if } n > N^c \end{cases}.$$

At times we may suppress notation and write V_n^i instead of $V_n^i(\sigma^{-i})$ when it is clear that V_n^i depends on σ^{-i}. Notice that $V_n^G(\sigma^R) = 0$ if and only if $s_n^R(\sigma^R) = 0$ and $V_n^R(\sigma^G) = 0$ if and only if $s_n^G(\sigma^G) = 1$. In addition, $V_n^i(\sigma^{-i}) \geq 0$ and $V_n^i(\sigma^{-i}) \leq v^i(\theta \mathbb{1}[n \leq N^c] + \mathbb{1}[n > N^c])$ for all i.

The next result follows from manipulating the definitions of U^i, s_n^i and V_n^i. Namely, due to the linearity of expectation and the independence of the mixed strategies, i's expected total payoffs are the sum of expected section-specific payoffs.

Lemma 2. *Given strategy profile σ, we can write i's expected utility from choosing locations l^i as*

$$U^R(l^R;\sigma^G) = \sum_n l_n^R \cdot V_n^R(\sigma^G) \quad \text{and} \quad U^G(l^G;\sigma^R) = -\sum_n (1 - l_n^G) V_n^G(\sigma^R)$$

Furthermore, $U^R(\sigma) = \sum_n s_n^R(\sigma^R) V_n^R(\sigma^G)$ and $U^G(\sigma) = -\sum_n (1 - s_n^G(\sigma^G)) V_n^G(\sigma^R)$.

The next result establishes two properties that must hold in every equilibrium.

Lemma 3. *If σ is an equilibrium, then for all sections n and n' the following hold:*

1. $s_n^i, s_{n'}^i \in (0,1)$ *implies* $V_n^i = V_{n'}^i$.
2. $V_n^i < V_{n'}^i$ *and* $s_n^i > 0$ *imply* $s_{n'}^i = 1$.

Proof. We prove Lemma 3.1 and the proof for 3.2 follows along similar lines. Suppose not. Then there exists an equilibrium $\sigma = (\sigma^G, \sigma^R)$ and sections n^* and n' such that $s_{n^*}^i, s_{n'}^i \in (0,1)$ and $V_{n^*}^i \neq V_{n'}^i$. Without loss of generality, assume $V_{n^*}^i < V_{n'}^i$. Define $x \in [0,1]^N$ such that

$$x_n = \begin{cases} s_n^i & \text{if } n \notin \{n^*, n'\} \\ s_{n'}^i + \varepsilon & \text{if } n = n' \\ s_{n^*}^i - \varepsilon & \text{if } n = n^* \end{cases}$$

where $0 < \varepsilon < \min\{1 - s_{n'}^i, s_{n^*}^i\}$. Notice $x_n = s_n^i$ for all $n \notin \{n^*, n'\}$, and $x_{n^*} + x_{n'} = s_{n^*}^i + s_{n'}^i$. So $\sum_n x_n = S^i$. By Lemma 1, there exists $\tilde{\sigma}^i \in \Delta(\mathscr{L}^i)$ such that $s_n^i(\tilde{\sigma}^i) = x_n$ for all sections n.

Furthermore, i can profitably deviate to strategy $\tilde{\sigma}^i$. To see why, suppose $i = R$. By Lemma 2, we can write the net gain from deviating as as

$$\begin{aligned}
U^R(\tilde{\sigma}^R, \sigma^G) - U^R(\sigma) &= \sum_n [s_n^R(\tilde{\sigma}^R)V_n^R - s_n^R(\sigma^R)V_n^R] \\
&= x_{n^*}V_{n^*}^R + x_{n'}V_{n'}^R - s_{n^*}^R V_{n^*}^R - s_{n'}^R V_{n'}^R \\
&= (x_{n^*} - s_{n^*}^R)V_{n^*}^R + (x_{n'} - s_{n'}^R)V_{n'}^R \\
&= -\varepsilon V_{n^*}^R + \varepsilon V_{n'}^R \\
&= \varepsilon(V_{n'}^R - V_{n^*}^R) > 0
\end{aligned}$$

where the last inequality follows because $V_{n^*}^i < V_{n'}^i$. A similar argument shows that we can also construct a profitable deviation when $i = G$. □

We are now ready to prove the proposition.

Proof of Proposition I. In a fully mixed equilibrium, Lemma 3.1 implies $V_n^R = V_{n'}^R$ for all sections n, and n'. When $n, n' \leq N^c$, this implies $s_n^G = s_{n'}^G \equiv \gamma^c \in (0,1)$. When $n, n' > N^c$, this implies $s_n^G = s_{n'}^G \equiv \gamma^p \in (0,1)$. So the government is defending pieces of critical infrastructure with probability γ^c and defending pieces of the pipeline with probability γ^p. When $n \leq N^c < n'$, we must have

$$V_n^R = \theta v^R(1-\gamma^c) = v^R(1-\gamma^p) = V_{n'}^R. \tag{4}$$

Here, Equation (4) is the rebel's indifference condition between attacking critical infrastructure n and attacking pipeline section n'. From Lemma 1.1, we have a feasibility constraint for the government:

$$\sum_n s_n^G = N^c\gamma^c + N^p\gamma^p = S^G. \tag{5}$$

Solving Equations (4) and (5) gives $\gamma^c = \frac{S^G + N^p(\theta-1)}{N^c+\theta N^p}$ and $\gamma^p = \frac{N^c+\theta(S^G-N^c)}{N^c+\theta N^p}$.

Equations (4) and (5) have counterparts that are used to derive the rebels' probability of attacking. Namely, let $\rho^c \in (0,1)$ denote the probability that rebels attack pieces of critical infrastructure and let $\rho^p \in (0,1)$ denote the probability that rebels attack pieces of the pipeline. For $n \leq N^c < n'$, the government's indifference condition is

$$V_n^G = \theta v^G \rho^c = v^R \rho^p = V_{n'}^G. \tag{6}$$

The rebels' feasibility constraint is

$$\sum_n s_n^R = N^c\rho^c + N^p\rho^p = S^R. \tag{7}$$

Solving Equations (6) and (7) gives $\rho^c = \frac{S^R}{N^c+\theta N^p}$ and $\rho^p = \frac{\theta S^R}{N^c+\theta N^p}$.

Using Lemma 2, we can compute the government's equilibrium expected utility as follows:

$$\begin{aligned}
W^G &= -N^c(1-\gamma^c)\overbrace{\rho^c\theta v^G}^{V_n^G:n\le N^c} - N^p(1-\gamma^p)\overbrace{\rho^p v^G}^{V_n^G:n>N^c} \\
&= -\frac{\theta(N-S^G)S^R v^G}{N^c+\theta N^p}.
\end{aligned}$$

In the first equality, $\gamma^c = s_n^G$ for $n \le N^c$ and $\gamma^p = s_n^G$ for $n > N^c$. Likewise, we can compute the rebel's equilibrium expected utility as:

$$\begin{aligned}
W^R &= N^c\rho^c\overbrace{(1-\gamma^c)\theta v^R}^{V_n^R:n\le N^c} + N^p\rho^p\overbrace{(1-\gamma^p)v^G}^{V_n^R:n>N^c} \\
&= \frac{\theta(N-S^G)S^R v^R}{N^c+\theta N^p}.
\end{aligned}$$

□

B.2 Proof of Proposition II

B.2.1 Existence

Let s_n^i denote the probability that actor i locates at section n in a fully mixed equilibrium, as stated in Proposition I. To see that a fully mixed equilibrium exists if and only if $S^G > \frac{\theta-1}{\theta}$ and $S^R < N^p + \frac{N^c}{\theta}$, we establish these two intermediate claims:

(a) $s_n^G \in (0,1)$ for all n if and only if $S^G > \frac{\theta-1}{\theta}N^c$

(b) $s_n^R \in (0,1)$ for all n if and only if $S^R < N^p + \frac{N^c}{\theta}$

To see (a), first consider section $n \le N^c$. So $s_n^G = \frac{S^G+(\theta-1)N^p}{N^c+\theta N^p}$. The denominator and numerator are positive so $s_n^G > 0$. For $s_n^G < 1$, we need

$$S^G + (\theta-1)N^p < N^c + \theta N^p \iff S^G < N^c + N^p,$$

which holds by assumption $S^G < N$. Consider section $n > N^c$ where $s_n^G = \frac{N^c+\theta(S^G-N^c)}{N^c+\theta N^p}$. The numerator is positive if and only if

$$N^c + \theta(S^G - N^c) > 0 \iff S^G > \frac{\theta-1}{\theta}N^c.$$

To see that $s_n^G < 1$, note that

$$\begin{aligned}
s_n^G < 1 &\iff N^c + \theta(S^G - N^c) < N^c + \theta N^p \\
&\theta S^G < \theta(N^p + N^c),
\end{aligned}$$

which holds because $\theta > 1$ and $S^G < N$.

To see (b), note that $S^R < N^c + N^p$ and $\theta > 1$ imply that (i) $s_n^R > 0$ for all n and (ii) $s_n^R < 1$ for $n \le N^c$. For $n > N^c$, rearranging the expression in Proposition I gives $s_n^R < 1 \iff S^R < N^p + \frac{N^c}{\theta}$.

Thus, the marginal distributions in Proposition I satisfy $s_n^i \in (0,1)$ for all n and i if and only if $S^G > \frac{\theta-1}{\theta}N^c$ and $S^R < N^p + \frac{N^c}{\theta}$. By construction, $\sum_n s_n^i = S^i$ for all i. Thus, when $s_n^i \in (0,1)$ for all n and i, Lemma 1 implies that there exist a strategy profile σ that produces these marginal distribuitons. Under σ, $V_n^i = V_{n'}^i$ for all n, n' and all i by the construction of the marginal distribution. As such, $U^i(l^i; \sigma^{-i}) = U^i(\sigma)$ for all i and all $l^i \in \mathscr{L}^i$. So there is no profitable deviation.

B.2.2 Uniqueness

The goal is to prove that, if $S^G > \frac{\theta-1}{\theta}N^c$ and $S^R < N^p + \frac{N^c}{\theta}$, then all equilibria are fully mixed. Note that if the rebels are playing a fully mixed strategy in equilibrium σ—i.e., $s_n^R \in (0,1)$ for all n—then s^G will take the form stated in Proposition I to satisfy the rebels' indifference condition in Equation 4 subject to the government's budget constraint in Equation 5. Then $S^G > \frac{\theta-1}{\theta}N^c$ implies $s_n^G \in (0,1)$ for all n, which means the government would be fully mixing. Thus, it suffices to show that $S^G > \frac{\theta-1}{\theta}N^c$ and $S^R < \frac{N^c+\theta N^p}{\theta}$ are jointly sufficient for the rebels to be fully mixing in every equilibrium.

Lemma 4. *In every equilibrium σ, $s_n^R = 0$ implies $s_n^G = 0$.*

Proof. To see this, suppose not. Then there exist an equilibrium σ and a section n^* such that $s_{n^*}^R = 0 < s_{n^*}^G$. By Lemma 1, $V_{n^*}^G = 0$. Now consider some n such that $s_n^R > 0$. By definition, $V_n^G > 0$. By Lemma 3.2, $V_n^G > V_{n^*}^G$ and $s_{n^*}^G > 0$ imply $s_n^G = 1$. So R is only attacking sections that are defended with probability one. As such, $U^R(\sigma) = 0$. It is thus straightforward to find a profitable deviation for R. Because $\sum_{n'} s_{n'}^G = S^G$ and $S^G < N$, there exists section $n^\dagger$ such that $s_{n^\dagger}^G < 1$, which implies $V_{n^\dagger}^R > 0$. Consider some $l^R \in \mathscr{L}^R$ such that $l_{n^\dagger}^R = 1$. Then $U^R(l^R; \sigma^G) \geq V_{n^\dagger}^R > 0 = U^R(\sigma)$. $\square$

Claim 1. *Assume $S^G > \frac{\theta-1}{\theta}N^c$. In every equilibrium σ, $s_n^R > 0$*

Proof. Suppose not. Then there exists an equilibrium σ and a section n^* such that $s_{n^*}^R = 0$. Thus, $s_{n^*}^G = 0$ by Lemma 4. Consider two cases.

1. $n^* \leq N^c$ implies $V_{n^*}^R = \theta v^R$. Consider some n such that $s_n^R > 0$. It must be the case that $V_n^R = \theta v^R$. If not, then $V_n^R < \theta v^R = V_{n^*}^R$ and $s_n^R > 0$ imply $s_{n^*}^R = 1$ by Lemma 3, a contradiction. So R is only attacking sections n such that $n \in \{1, \ldots, N^c\} \setminus \{n^*\}$ and $s_n^G = 0$. This means G can only be defending sections that are not attacked, which contradicts Lemma 4.
2. $n^* > N^c$ implies $V_{n^*}^R = v^R$. For accounting purposes, define two sets:

$$A^p = \{n \mid n > N^c, s_n^R > 0\} \qquad \text{and} \qquad A^c = \{n' \mid n \leq N^c, s_n^R > 0\}.$$

First consider some $n \in A^p$. Then $V_n^R = v^R(1 - s_n^G)$. If $s_n^G > 0$, then $V_n^R < V_{n^*}^R$. Therefore, by Lemma 3.2, $s_n^R > 0$ implies $s_{n^*}^R = 1$, a contradiction. So we have $n \in A^p$ implies $s_n^G = 0$. Next consider some $n \in A^c$. Then $V_n^R = \theta v^R(1 - s_n^G)$. If $s_n^G > \frac{\theta-1}{\theta}$, then $V_n^R < V_{n^*}^R$. Therefore, by Lemma 3.2 $s_n^R > 0$ implies

$s^R_{n^*} = 1$, a contradiction. So we have $n \in A^c$ implies $s^G_n \le \frac{\theta-1}{\theta}$. Some accounting gives us

$$\begin{aligned}\sum_n s^G_n &= \sum_{n\in A^c} s^G_n + \sum_{n\in A^p} s^G_n + \sum_{n\notin A^p\cup A^c} s^G_n \\ &= \sum_{n\in A^c} s^G_n \\ &\le (\#A^c)\frac{\theta-1}{\theta} \\ &\le N^c\frac{\theta-1}{\theta} < S^G.\end{aligned}$$

So $\sum_n s^G_n < S^G$, which contradicts Lemma 1. □

Claim 2. *Assume $S^G > \frac{\theta-1}{\theta}N^c$. In every equilibrium σ, $n \le N^c$ and $s^R_n = 1$ imply $s^G_n = 1$.*

Proof. Suppose not. Then there exists equilibrium σ and $n^* \le N^c$ such that $s^R_{n^*} = 1$ and $s^G_{n^*} < 1$. Then $V^G_{n^*} = \theta v^G$. Define the two sets:

$$D = \{n \mid s^G_n > 0\} \qquad \text{and} \qquad A^c_1 = \{n \mid n \le N^c, s^R_n = 1\}.$$

First, $D \neq \emptyset$. Second, $D \subseteq A^c_1$. To see this, take some $n \in D$. If $V^G_n < \theta v^G = V^G_{n^*}$, Lemma 3.2 implies $s^G_{n^*} = 1$, a contradiction. So $n \in D$ implies $V^G_n = \theta v^G$. Thus, $D \subseteq A^c_1$, and as a consequence $D \subseteq \{1,\dots,N^c\}$. Third, $A^c_1 = \{1,\dots,N^c\}$. It is clear that $A^c_1 \subseteq \{1,\dots,N^c\}$ by construction. So take some $n \le N^c$ and suppose $n \notin A^c_1$ to draw a contradiction. Then $n \notin D$, which means $V^R_n = \theta v^R$. Recall $n' \in D$ implies $s^R_{n'} > 0$ by Lemma 4 and $V^R_{n'} = \theta v^R(1-s^G_{n'}) < \theta v^R = V^R_n$. So Lemma 3.2 implies $s^R_n = 1$. Thus, $A^c_1 = \{1,\dots,N^c\}$. Because $S^R < N^c + N^p$, there exists $n^\dagger > N^c$ such that $s^R_{n^\dagger} < 1$. By Claim 1, $s_{n^\dagger} > 0$. Furthermore, because $D \subseteq A^c_1$, $V^R_{n^\dagger} = v^R$. To rule out a profitable deviation (i.e., a contardition with Lemma 3.2), we require

$$V^R_{n^\dagger} = v^R \le \theta v^R(1-s^G_n) = V^R_n$$

for all $n \in D$. This implies $s^G_n \le \frac{\theta-1}{\theta}$ for all $n \in D$. But $D \subseteq \{1,\dots,N^c\}$, so $S^G = \sum_{n\in D} s^G_n \le \frac{\theta-1}{\theta}N^c$, a contradiction. □

Claim 3. *Assume $S^G > \frac{\theta-1}{\theta}N^c$. In every equilibrium σ, $n \le N^c$ implies $s^G_n > 0$*

Proof. Suppose not. So there exists an equilibrium σ and section $n^* \le N^c$ such that $s^G_{n^*} = 0$. This implies $V^R_{n^*} = \theta v^R$. By Claim 2, $s^R_{n^*} < 1$. We claim that R is only attacking undefended pieces of critical infrastructure, i.e., $s^R_n > 0$ implies $V^R_n = \theta v^R$. To see this, suppose not. Then $s^R_n > 0$ and $V^R_n < \theta v^R = V^R_{n^*}$ for some n. But then Lemma 3.2 implies $s^R_{n^*} = 1$, a contradiction. Because R is only attacking undefended pieces of critical infrastructure, this means G is defending sections that are not attacked, contradicting Lemma 4. □

Claim 4. *Assume $S^G > \frac{\theta-1}{\theta}N^c$ and $S^R < \frac{N^c+\theta N^p}{\theta}$. In every equilibrium σ, there exists $n > N^c$ such that $s^R_n < 1$.*

Proof. Suppose not. Then there exists equilibrium σ such that $s_n^R = 1$ for all $n > N^c$. Obviously, $S^R \geq N^p$, but we must also have must have $S^R > N^p$. If not, then $N^p = S^R$, which means sections $n \leq N^c$ have $s_n^R = 0$, contradicting Claim 1.

I claim that $n > N^c$ implies $s_n^G = 1$. To see this suppose not. Then there exists $n^* > N^c$ such that $s_{n^*}^G < 1$. Take some $n' \leq N^c$. By Claim 3, we have $s_{n'}^G > 0$. By Lemma 3.2, we need $V_{n'}^G \geq V_{n^*}^G$ or else $s_{n'}^G > 0$ would imply $s_{n^*}^G = 1$. That is, we must have

$$V_{n^*}^G = v^G \leq V_{n'}^G = \theta v^G s_{n'}^R,$$

for all $n' \leq N^c$, which holds if and only if $s_{n'}^R \geq \frac{1}{\theta}$. Accounting reveals that

$$S^R = \sum_{n''} s_{n''}^R = \sum_{n'' \leq N^c} s_{n''}^R + \sum_{n'' > N^c} s_{n''}^R \geq \frac{N^c}{\theta} + N^p,$$

a contradiction.

Now because $S^G < N^p + N^c$ and G is surely defending $n > N^c$, there exists an $n^\dagger \leq N^c$ such that $s_{n^\dagger}^G < 1$. Recall for $n > N^c$ we have $s_n^R = 1$ and $V_{n^\dagger}^R > 0 = V_n^R$. Thus Lemma 3.2 implies $s_{n^\dagger}^R = 1$, but then Claim 2 implies $s_{n^\dagger}^G = 1$, a contradiction. □

Claim 5. *Assume $S^G > \frac{\theta-1}{\theta} N^c$ and $S^R < \frac{N^c + \theta N^p}{\theta}$. In every equilibrium σ, there exists $n > N^c$ such that $s_n^R < 1$ and $s_n^G < 1$.*

Proof. Suppose not. Then, for all $n > N^c$ such that $s_n^R < 1$, we have $s_n^G = 1$. To draw a contradiction, we first establish that $n > N^c$ and $s_n^R = 1$ imply $s_n^G = 1$. To see this, note that $n > N^c$ and $s_n^R = 1$ imply $V_n^G = v^G$. By Claim 4, there exists $n^* > N^c$ such that $s_{n^*}^R < 1$. By the supposition, $s_{n^*}^G = 1$ and $V_{n^*}^G = v^G s_{n^*}^R < v^G = V_n^G$. Thus, Lemma 3.2 implies $s_n^G = 1$. So we have $n > N^c$ implies $s_n^G = 1$, i.e., $V_n^R = 0$.

Because $S^G = \sum_n s_n^G < N^c + N^p$, there exists $n^\dagger \leq N^c$ such that $s_{n^\dagger}^G < 1$. If $s_{n^\dagger}^R = 1$, then Claim 2 implies $s_{n^\dagger}^G = 1$, a contradiction. So $s_{n^\dagger}^R < 1$. Because $s_{n^\dagger}^G < 1$, $V_{n^\dagger}^R > 0 = V_n^R$ for every $n > N^c$. By Claim 1, $s_n^R > 0$ for all $n > N^c$. Thus, Lemma 3.2 implies $s_{n^\dagger}^R = 1$, a contradiction. □

Claim 6. *Assume $S^G > \frac{\theta-1}{\theta} N^c$ and $S^R < \frac{N^c + \theta N^p}{\theta}$. In every equilibrium σ, $s_n^G < 1$.*

Proof. Suppose the contrary. Suppose there exists n^* such that $s_{n^*}^G = 1$, which means $V_{n^*}^R = 0$. By Claim 5, there exists $n^\dagger > N^c$ such that $s_{n^\dagger}^R < 1$ and $s_{n^\dagger}^G < 1$, which means $V_{n^\dagger}^R > 0$ and $n^\dagger \neq n^*$. By Claim 1, we have $s_{n^*}^R > 0$. So $V_{n^*}^R < V_{n^\dagger}^R$ and Lemma 3.2 imply $s_{n^\dagger}^R = 1$, a contradiction. □

Claim 7. *Assume $S^G > \frac{\theta-1}{\theta} N^c$ and $S^R < \frac{N^c + \theta N^p}{\theta}$. In every equilibrium σ, $n \leq N^c$ implies $s_n^R \in (0,1)$.*

Proof. Consider some $n \leq N^c$. By Claim 1, we have $s_n^R > 0$. If $s_n^R = 1$, then Claim 2 implies $s_n^G = 1$, but this contradicts Claim 6. □

Claim 8. *Assume $S^G > \frac{\theta-1}{\theta} N^c$ and $S^R < \frac{N^c + \theta N^p}{\theta}$. In every equilibrium σ, $n > N^c$ implies $s_n^R \in (0,1)$.*

Proof. By Claim 1, we just need to show $s_n^R < 1$ for all $n > N^c$. Suppose not. That is, suppose there exists $n^* > N^c$ such that $s_{n^*}^R = 1$. So $V_{n^*}^G = v^G$. By Claim 6, $s_{n^*}^G < 1$. Thus, $s_n^G > 0$ implies $V_n^G \geq v^G$, or else there is a contradiction with Lemma 3.2. So G is defending sections n such that (i) $n \leq N^c$ and $s_n^R \geq \frac{1}{\theta}$ or (ii) $n > N^c$ and $s_n^R = 1$.

By Claim 5, there exists $n^\dagger > N^c$ such that $s_{n^\dagger}^R < 1$ and $s_{n^\dagger}^G < 1$. Of course, $n^* \neq n^\dagger$. In addition, (ii) implies $s_{n^\dagger}^G = 0$, which means $V_{n^\dagger}^R = v^R$.

Consider some $n > N^c$. By Claim 1, $s_n^R > 0$. If $V_n^R < v^R = V_{n^\dagger}^R$, then Lemma 3.2 implies $s_{n^\dagger}^R = 1$, a contradiction. So $V_n^R = v^R$ implying $s_n^G = 0$. So we have $n > N^c$ implies $s_n^G = 0$. Second, consider some $n \leq N^c$, and again we must have $s_n^R > 0$ by Claim 1. So $V_n^R = \theta v^R (1 - s_n^G)$. As before, Lemma 3.2 implies $V_n^R \leq V_{n^\dagger}^R$, which means $s_n^G \leq \frac{\theta - 1}{\theta}$. So we have $n \leq N^c$ implies $s_n^G \leq \frac{\theta-1}{\theta}$. Summing up gives us

$$\begin{aligned}\sum_n s_n^G &= \sum_{n \leq N^c} s_n^G + \sum_{n > N^c} s_n^G \\ &\leq N^c \frac{\theta - 1}{\theta} < S^G.\end{aligned}$$

So $\sum_n s_n^G < S^G$, which contradicts Lemma 1. □

B.3 Examples of equilibria that are not fully mixed

Example 1. *Suppose $N = 5$ with $N^c = 2$ and $N^p = 3$. Both actors can only locate at $S^i = 1$ location. Assume $v^R = v^G = 1$ and $\theta = 10$. Notice $S^R < N^p + \frac{N^c}{\theta}$ but $S^G \leq \frac{\theta-1}{\theta} N^c$, so the sufficient condition in Proposition II does not hold. Consider the following strategy profile σ:*

- *The government defends each piece of critical infrastructure with equal probability. That is, G plays $(1,0,0,0,0)$ with probability $\frac{1}{2}$ and $(0,1,0,0,0)$ with probability $\frac{1}{2}$.*
- *The rebels defend each piece of critical infrastructure with equal probability. That is, R plays $(1,0,0,0,0)$ with probability $\frac{1}{2}$ and $(0,1,0,0,0)$ with probability $\frac{1}{2}$.*

The above strategy profile is an equilibrium. For the rebels, $n \leq N^c$ implies $V_n^R = \frac{1}{2}\theta v^R = 5$, and $m > N^c$ implies $V_m^R = 1$. So R is only attacking sections with the highest value. For the government, there is clearly no profitable deviation, as the only relevant deviation is to defend a pipeline that is never attacked by the rebels.

Example 2. *Suppose $N = 5$ with $N^c = 2$ and $N^p = 3$. The government can defend $S^G = 3$ sections and the rebels can attack $S^R = 4$ sections. Assume $v^R = v^G = 1$ and $\theta = 10$. Notice that $S^G > \frac{\theta-1}{\theta} N^c$ but $S^R \geq N^p + \frac{N^c}{\theta}$, so the sufficient condition in Proposition II does not hold. Consider the following strategy profile σ:*

- *The government surely defends the two pieces of critical infrastructure and defends each section of pipeline with equal probability. That is, G plays $(1,1,1,0,0)$ with probability $\frac{1}{3}$, $(1,1,0,1,0)$ with probability $\frac{1}{3}$, and $(1,1,0,0,1)$ with probability $\frac{1}{3}$,*

- *The rebels surely attack the three sections of the pipeline, and mix between attacking the pieces of critical infrastructure with equal probability. That is, R plays* $(1,0,1,1,1)$ *with probability* $\frac{1}{2}$ *and plays* $(0,1,1,1,1)$ *with probability* $\frac{1}{2}$.

The above strategy profile is an equilibrium. To see that rebels do not have a profitable deviation, note that $n \leq N^c$ *implies* $V_n^R = 0$ *and* $m > N^c$ *implies* $V_m^R = v^R(1 - s_m^G) = \frac{2}{3}$. *So R is surely attacking all sections with positive value, and is attacking two sections with value zero with probability strictly between zero and one. Here,* $U^R(\sigma) = N^c 10 \frac{1}{2} 0 + N^p \frac{2}{3} = 2$.

To see that the government does not have a profitable deviation, note that $n \leq N^c$ *implies* $V_n^G = \frac{1}{2}\theta v^G = 5$ *and* $m > N^C$ *implies* $V_n^G = v^G = 1$. *So the government is surely defending the targets with highest value and is defending targets with the lowest value with probability strictly between zero and one.*

B.4 Proof of Proposition IV

In every equilibrium, the rebels choose to attack in the final phase if $x < W^R - c$, and they do not attack if $x > W^R - c$. Thus, when R expects the government to use strategy $\chi = (\chi_0, \chi_1)$, we can write R's expected payoffs from choosing $a_1 \in \{0,1\}$ in phase 1 as

$$EU^R(a_1|\chi, c) = a_1[W^R - c] + \max\{\chi_{a_1}, W^R - c\}.$$

Define the function $\Delta(c;\chi)$ as

$$\begin{aligned}\Delta(c;\chi) &= EU^R(1|\chi, c) - EU^R(0|\chi, c) \\ &= W^R - c + \max\{\chi_1, W^R - c\} - \max\{\chi_0, W^R - c\}.\end{aligned}$$

So $\Delta(c;\chi)$ is R's payoff difference between attacking and not in the first phase with cost c and expected offers $\chi = (\chi_0, \chi_1)$. When $\Delta(c;\chi) > 0$, R strictly prefers to attack in the first phase with cost c, and when $\Delta(c;\chi) < 0$, R strictly prefers to not attack. Finally, $\Delta(c;\chi) = 0$ implies R is indifferent.

The next result shows that Δ satisfies the single-crossing property with respect to c. As such, when the government uses a pure strategy, the rebel group will also use a pure strategy in phase 1, and this strategy will be a cutpoint strategy.

Lemma 5. *Fix the government offers* $\chi = (\chi_0, \chi_1)$ *such that* $\chi_0 \geq 0$ *and* $\chi_1 \geq 0$. *The function* $\Delta(c;\chi)$ *satisfies the single-crossing property with respect to c: if there exists* c^* *such that* $\Delta(c^*;\chi) = 0$, *then* $c < c^*$ *implies* $\Delta(c;\chi) > 0$ *and* $c > c^*$ *implies* $\Delta(c;\chi) < 0$.

Proof. Define the function $f(c;\chi) = \max\{\chi_1, W^R - c\} - \max\{\chi_0, W^R - c\}$. We prove the lemma by considering two cases: $\chi_1 > \chi_0$ and $\chi_1 \leq \chi_0$.

Case 1: $\chi_1 > \chi_0$. Then the function $f(c;\chi)$ is weakly increasing in c. Furthermore, for all c, $f(c;\chi) \in \{0, \chi_1 - W^R + c, \chi_1 - \chi_0\}$, $f(c;\chi) \geq 0$, and $f(c;\chi) \leq \chi_1 - \chi_0$.[39] To prove the result for this case, we need to establish two intermediary claims:

1. $\Delta(c^*;\chi) = 0$ implies $\chi_0 > W^R - c^*$.
2. $\Delta(c^*;\chi) = 0$ implies $f(c^*;\chi) = \chi_1 - \chi_0$.

To prove the first claim, suppose not. Then $\Delta(c^*;\chi) = 0$ and $\chi_0 \leq W^R - c^*$. Therefore, we can write

$$\begin{aligned}
\Delta(c^*;\chi) &= W^R - c^* + \max\{W^R - c^*, \chi_1\} - \max\{W^R - c^*, \chi_0\} \\
&= W^R - c^* + \max\{W^R - c^*, \chi_1\} - (W^R - c^*) \\
&= \max\{W^R - c^*, \chi_1\} \\
&> 0,
\end{aligned}$$

where the final strict inequality follows because $\chi_1 > \chi_0 \geq 0$. But $\Delta(c^*;\chi) > 0$ is a contradiction. To prove the second claim, note that $\Delta(c^*;\chi) = 0$ implies $\chi_0 > W^R - c^*$. So $\chi_1 > \chi_0 \geq W^R - c^*$, and $f(c;\chi) = \chi_1 - \chi_0$.

To see that Δ satisfies the single-crossing property, suppose $\Delta(c^*;\chi) = 0$. Then for any c, we can write:

$$\begin{aligned}
\Delta(c;\chi) &= \Delta(c;\chi) + \Delta(c^*;\chi) \\
&= c^* - c + f(c;\chi) - f(c^*;\chi) \\
&= c^* - c + f(c;\chi) - \chi_1 + \chi_0. \qquad (8)
\end{aligned}$$

Above, the last equality follows from preliminary result 2 which says that $f(c^*;\chi) = \chi_1 - \chi_0$.

Now, consider some $c < c^*$. We need to show $\Delta(c;\chi) > 0$. Because $\chi_1 > \chi_0$, $W^R - \chi_1 < W^R - \chi_0$. So there are three possibilities:

(a) Suppose $c \leq W^R - \chi_1$. Then $W^R - c \geq \chi_1 > \chi_0$. As such $f(c;\chi) = 0$. So we can write Equation 8 as

$$\begin{aligned}
c^* - c - \chi_1 + \chi_0 &> c^* - c - \chi_1 + W^R - c^* \\
&= W^R - c - \chi_1 \\
&\geq 0.
\end{aligned}$$

Above, the strict inequality follows from preliminary result 1 which says $\chi_0 > W^R - c^*$. The weak inequality follows from $c \leq W^R - \chi_1$.

(b) Suppose $W^R - \chi_1 < c < W^R - \chi_0$. As such $f(c;\chi) = \chi_1 - W^R + c$. So we can write Equation 8 as

$$c^* - c + \chi_1 - W^R + c - \chi_1 + \chi_0 = c^* - W^R + \chi_0 > 0,$$

where the strict inequality follows from preliminary result 1 which says $\chi_0 > W^R - c^*$.

39. To see that $f(c;\chi)$ is bounded above by $\chi_1 - \chi_0$, suppose not. So $f(c;\chi) > \chi_1 - \chi_0 > 0$. Then $f(c;\chi) = \chi_1 - W^R + c$. Because $f(c;\chi) = \chi_1 - W^R + c > \chi_1 - \chi_0$, $\chi_0 > W^R - c$. This means $\max\{\chi_0, W^R - c\} = \chi_0$ and $\max\{\chi_1, W^R - c\} = \chi_1$ as $\chi_1 > \chi_0$ in this case. So $f(c;\chi) = \chi_1 - \chi_0$, a contradiction.

(c) Suppose $c \geq W^R - \chi_0$. So $f(c;\chi) = \chi_1 - \chi_0$, and we can write Equation 8 as

$$c^* - c + (\chi_1 - \chi_0) - \chi_1 + \chi_0 = c^* - c > 0,$$

where $c^* > c$ by assumption.

Second, consider some $c > c^*$. We need to show $\Delta(c;\chi) < 0$. Note that $f(c;\chi) = \chi_1 - \chi_0$ because $f(c^*) = \chi_1 - \chi_0$, f is weakly increasing in c and f is bounded above by $\chi_1 - \chi_0$. Thus, equation 8 reduces to $c^* - c < 0$, as required.

Case 2: $\chi_0 \geq \chi_1$. So $f(c;\chi)$ is weakly decreasing in c. Thus for $c < c^*$ we have

$$\begin{aligned} 0 = \Delta(c^*;\chi) &= W^R - c^* + f(c^*;\chi) \\ &< W^R - c + f(c^*;\chi) \\ &\leq W^R - c + f(c;\chi) = \Delta(c;\chi), \end{aligned}$$

where the last inequality follows because $c < c^*$ and f is weakly decreasing in c. So $c < c^*$ implies $\Delta(c) > 0$. For $c > c^*$ we have

$$\begin{aligned} 0 = \Delta(c^*;\chi) &= W^R - c^* + f(c^*;\chi) \\ &> W^R - c + f(c^*;\chi) \\ &\geq W^R - c + f(c;\chi) = \Delta(c;\chi), \end{aligned}$$

where the last inequality follows because $c > c^*$ and f is weakly decreasing in c. So $c > c^*$ implies $\Delta(c;\chi) < 0$. □

As a consequence of Lemma 5, we know that if G uses a pure strategy $\chi = (\chi_0, \chi_1)$, then R's best response is essentially (outside the case that R is of type c such that $\Delta(c;\chi) = 0$, which occurs with probability zero) a pure strategy in phase 1. This pure strategy takes the form of a cutpoint where R attacks if c is below the cutpoint and R does not attack if c is above the cutpoint. This cutpoint c^* will be implicitly defined by $\Delta(c^*;\chi) = 0$. The next result says that, under assumption $C > 2W^R$, this cuptoint falls in the interval $(0, C)$.

Lemma 6. *There does not exist an equilibrium in which rebels use a cutpoint strategy $c^* \leq 0$ in phase 1. If $C > 2W^R$, then there does not exist an equilibrium in which rebels use a cutpoint strategy $c^* \geq C$ in phase 1.*

Proof. If R with cost c does not attack in first phase, then its payoff is $EU^R(0|\chi, c) = \max\{\chi_0, W^R - c\}$. We know that R surely accepts offer χ_0 if $\chi_0 > W^R - c$. Furthermore, the government can ensure acceptance with probability 1 by offering $x = W^R$ as $\Pr(c > 0) = 1$ (because c is uniformly distributed over the interval $[0, C]$). So sequential rationality requires $\chi_0 \leq W^R$, which then implies $EU^R(0|\chi, c) \leq W^R$. If R with cost c

does attack, then its payoff is

$$\begin{aligned} EU^R(1|\chi,c) &= W^R - c + \max\{\chi_1, W^R - c\} \\ &\geq 2[W^R - c]. \end{aligned}$$

Thus, $c \in [0, \frac{W^R}{2})$ implies $EU^R(1|\chi,c) > EU^R(0|\chi,c)$. In addition, by the same argument as above, $\chi_1 \leq W^R$, so $EU^R(1|\chi,c) \leq W^R - c + W^R$. In addition, $\chi_0 \geq 0$, implying $EU^R(0|\chi,c) \geq 0$. Thus, $c \in (2W^R, C]$ implies $EU^R(0|\chi,c) > EU^R(1|\chi,c)$. □

Lemma 7. *There does not exist an equilibrium in which the rebels use cutpoint strategy $c^* \in (0, W^R)$ in phase 1.*

Proof. To draw a contradiction, suppose not. By Lemma 5, c^* solves $\Delta(c^*;\chi) = 0$, where χ is the strategy of the government. This means

$$\Delta(c^*;\chi) = 0 \iff \max\{\chi_0, W^R - c^*\} = W^R - c^* + \max\{\chi_1, W^R - c^*\}$$

Because $c^* < W^R$ by assumption, $\max\{\chi_1, W^R - c^*\} > 0$. Thus, $\chi_0 > W^R - c^*$, or else the equation above would reduce to $W^R - c^* = W^R - c^* + \max\{\chi_1, W^R - c^*\}$, a contradiction. Notice that R's cutpoint strategy implies that, after observing no attack in phase 1 ($a_1 = 0$), the government's posterior can only put positive probability on types $[c^*, C]$, and $\Pr(c = c^*) = 0$ as c is distributed according to a continuous distribution with no mass points. Thus, after observing $a_1 = 0$, G believes it can guarantee acceptance by offering $x = W^R - c^*$, so sequential rationality implies that $\chi_0 \leq W^R - c^*$, a contradiction. □

Lemma 8. *In equilibrium, if the rebel's use cutpoint strategy $c^* \in [W^R, C)$ in phase 1, then the following hold:*

$$\begin{aligned} &\chi_0 = 0, \\ &\chi_1 = \min\left\{-\frac{W^G}{3}, W^R\right\}, \\ &c^* = W^R + \chi_1, \textit{ and} \end{aligned}$$

$$\mu(c|a_1) = \begin{cases} \frac{1}{C-c^*} & \textit{if } a_1 = 0 \textit{ and } c \in (c^*, C] \\ \frac{1}{c^*} & \textit{if } a_1 = 1 \textit{ and } c \in [0, c^*) \\ 0 & \textit{if } a_1 = 0, c \notin [c^*, C] \textit{ or } a_1 = 1, c \notin [0, c^*] \end{cases}.$$

Proof. First, μ follows from Bayes rule, the uniform distribution, and the rebel's cutpoint strategy in which they attack in phase 1 if $c < c^*$ and do not attack when $c > c^*$. Specifically,

$$\mu(c \mid a_1) = \begin{cases} \frac{f(c)}{1-F(c^*)} & \text{if } a_1 = 0 \text{ and } c \in (c^*, C] \\ \frac{f(c)}{F(c^*)} & \text{if } a_1 = 1 \text{ and } c \in [0, c^*) \\ 0 & \text{if } a_1 = 0,\ c \notin [c^*, C] \text{ or } a_1 = 1, c \notin [0, c^*] \end{cases},$$

and the functional form above follows from substitution where $f(c) = \frac{1}{C}$ and $F(c) = \frac{c}{C}$ for $c \in [0, C]$ are the pdfs and cdfs of the uniform distribution. Second, after observing no attack in phase 1 ($a_1 = 0$), G knows R's cost satisfies $c \in [W^R, C]$. Furthermore, R with cost $c > W^R$ accepts any offer $x \geq 0$. Because $\Pr(c = W^R) = 0$, offer $x = 0$ will be accepted by R with probability 1. Thus, in an equilibrium where the rebel's use cutpoint strategy $c^* \in [W^R, C)$ in phase 1, the government offers $\chi_0 = 0$ after seeing no attack . Third, by Lemma 5, R's cutpoint strategy c^* satisfies $\Delta(c^*; \chi) = 0$:

$$\begin{aligned} \Delta(c^*; \chi) = 0 &\iff W^R - c^* + \max\{\chi_1, W^R - c^*\} - \max\{\chi_0, W^R - c^*\} = 0 \\ &\iff W^R - c^* + \chi_1 - \chi_0 = 0 \\ &\iff W^R - c^* + \chi_1 = 0. \end{aligned}$$

Above, the second biconditional follows because $\chi_{a_1} \geq 0$ and because $c^* \geq W^R$ by assumption of the lemma. The third follows because $\chi_0 = 0$. Thus, $c^* = W^R + \chi_1$. Finally, after a phase-1 attack ($a_1 = 1$), G knows $c \in [0, c^*]$. G's optimal offer will be $x^* \in [0, W^R]$, where offer $x = W^R$ will be accepted with probability 1 and offer $x = 0$ will be accepted with probability $\int_{W^R}^{c^*} \mu(c|1)dc$. We can write G's expected utility from offer x as

$$\begin{aligned} U_G(x|c^*, a_1 = 1) &= \overbrace{-\int_{W^R - x}^{c^*} x\mu(c|1)dc}^{x \text{ accepted}} + \overbrace{\int_0^{W^R - x} W^G \mu(c|1)dc}^{x \text{ rejected}} \\ &= -\int_{W^R - x}^{c^*} x\frac{1}{c^*}dc + \int_0^{W^R - x} W^G \frac{1}{c^*}dc \\ &= \frac{1}{C}\left[(W^R - x)(W^G + x) - c^* x\right]. \end{aligned}$$

Notice $U_G(x|c^*, a_1 = 1)$ is a strictly concave function of x, with $D_x^2 U_G(x|c^*, a_1 = 1) = -\frac{2}{C}$. So the first-order condition is necessary and sufficient to characterize G's optimal offer when it is in $(0, W^R)$:

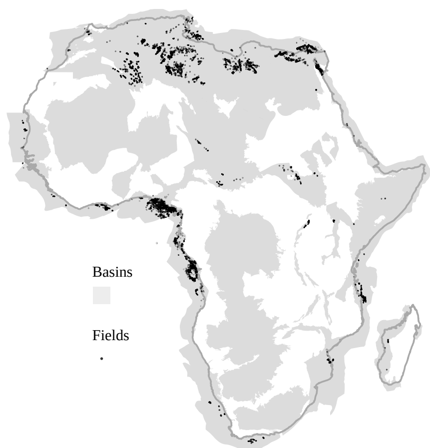
$$\begin{aligned} D_x U_G(\chi_1|c^*, a_1 = 1) = 0 &\iff (W^R - \chi_1)(W^G + \chi_1) - c^* \chi_1 = 0 \\ &\iff \chi_1 = \frac{1}{2}(W^R - W^G - c^*) \\ &\iff \chi_1 = \frac{1}{2}(W^R - W^G - W^R - \chi_1) \\ &\iff \chi_1 = -\frac{W^G}{3}. \end{aligned}$$

Notice that $-\frac{W^G}{3} > 0$ because $W^G < 0$. In addition, R accepts any offer $x > W^R - c$, so G can guarantee $x = W^R$ is accepted with probability 1 as $\Pr(c > 0) = 1$. So $\chi_1 \leq W^R$ in equilibrium. This gives us $\chi_1 = \min\left\{-\frac{W^G}{3}, W^R\right\}$. $\square$

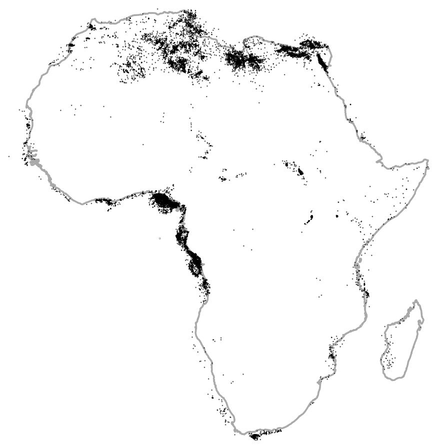
To complete the proof, note that R accepts in the final phase after offer x if and essentially only if $x > W^R - c$. Lemma 5 shows that the rebels employ a cutpoint strategy where they attack in phase if and only if c is below the cutpoint. Furthermore, Lemmas 6 and 7 demonstrate that any cutpoint falls in the interval $[W^R, C)$. Lemma 8 then characterizes all equilibria with such a cutpoint.

C. Construction of Gridded Panel Data

Figure A.1: Oil and Gas Infrastructure in Africa



(a) Basins and fields



(b) Wells (exploration and production)

(c) Pipelines

(d) Terminals

Figure A.1 displays the geography of (a) oil basins and oil and gas fields; (b) oil and gas wells, both used for exploration and production; (c) commissioned oil and gas pipelines; and (d) oil and gas terminals, such as export terminals.

Figure A.2: Example Area

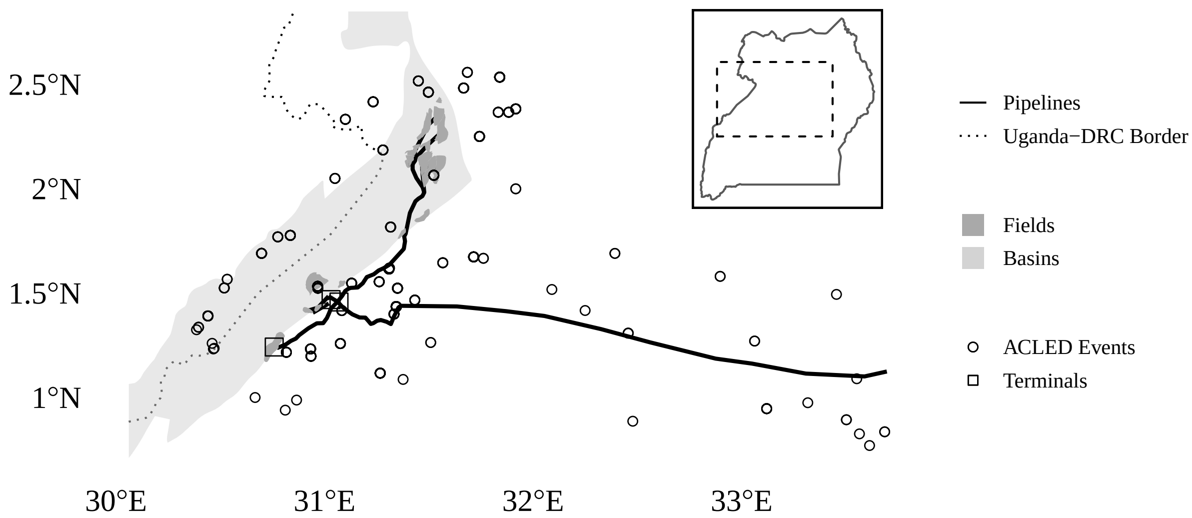
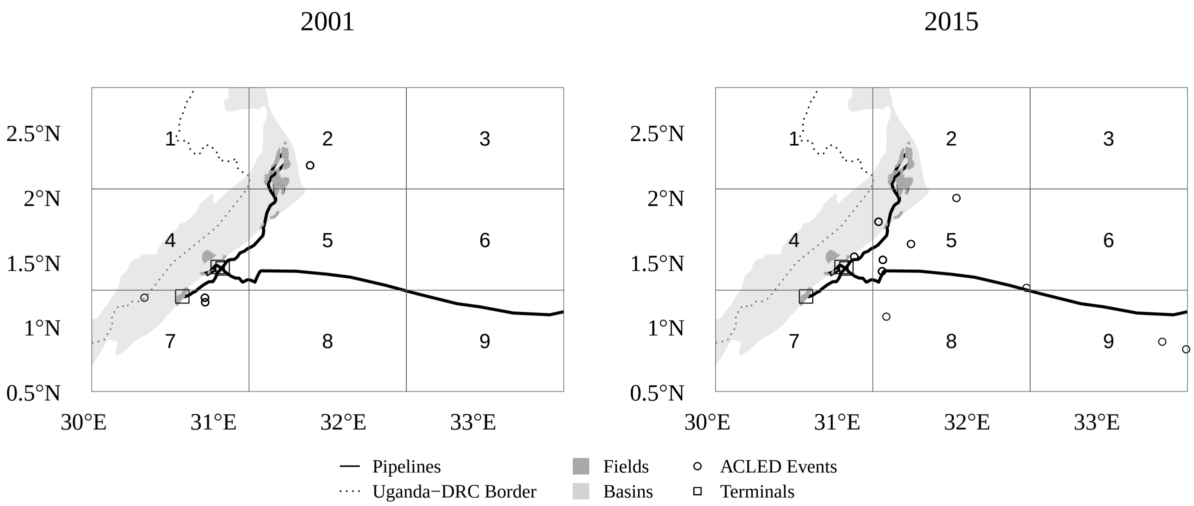


Figure A.2 is a map of an area in Uganda which will be used as an example of how we construct our cell-year panel, by associating geographic features from oil infrastructure and conflict to grid cells by year. The oil infrastructure used to construct the independent variables includes oil fields in dark gray, oil terminals in black squares, and pipelines in black. We also show the basin where oil is formed in light gray. Conflict events from ACLED are displayed in outlined circles.

Figure A.3: Construction of Cell-Year Panel



Year	Cell	Basin	Field	Terminal	Pipeline	ACLED
2001	1	1	0	0	0	0
2001	2	1	1	0	1	1
2001	3	0	0	0	0	0
2001	4	1	1	1	1	0
2001	5	1	1	0	1	0
2001	6	0	0	0	0	0
2001	7	1	1	1	1	1
2001	8	0	0	0	1	0
2001	9	0	0	0	1	0

Year	Cell	Basin	Field	Terminal	Pipeline	ACLED
2015	1	1	0	0	0	0
2015	2	1	1	0	1	0
2015	3	0	0	0	0	0
2015	4	1	1	1	1	1
2015	5	1	1	0	1	1
2015	6	0	0	0	0	0
2015	7	1	1	1	1	0
2015	8	0	0	0	1	1
2015	9	0	0	0	1	1

Figure A.3 illustrates the construction of the cell-year panel used in the main analyses in the paper. In the upper left, the example region displayed in Figure A.2 is divided into nine rectangles. Each rectangle is labelled with a numerical cell value and each cell can be attributed information that is contained within, e.g. whether a cell contains a (portion of) pipeline, terminal, and/or an ACLED conflict event. The time dimension of the panel is created by merging the oil infrastructure that exists in a given year to the grid as well as the conflict events that took place. In the upper left is the infrastructure that existed and the conflict events that took place in 2001. In the upper right is the same grid, but with the oil infastructure and conflict events that took place in 2015. Below each image is the data that results, in terms of the presence of oil infrastructure (Basin, Field, Terminal, Pipeline) and conflict events (ACLED) in each cell-year.

D. Effect of New Infrastructure

D.1 Leave-one-out Analysis

Figure A.4: Leave-one-out Analysis of the Effects of Pipeline Construction

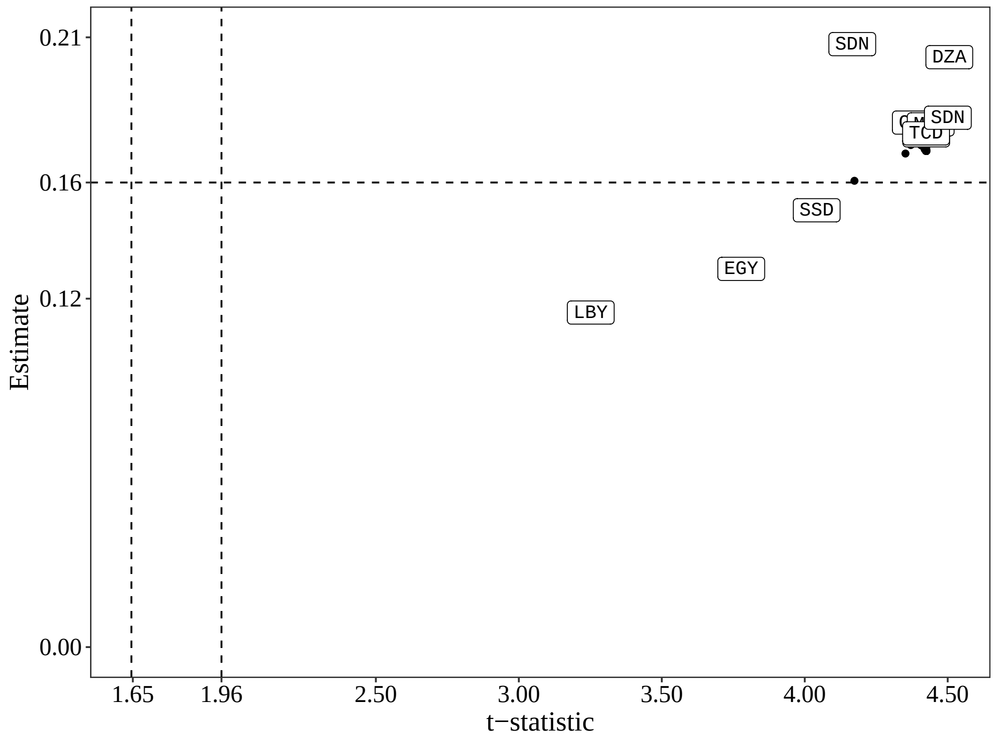


Figure A.4 presents the results of reestimating model 2 of Table 2 after dropping a given country's data from the panel entirely. On the x-axis is the t-statistic, with the critical values of 1.65 (90% confidence) and 1.96 (95% confidence) noted in dashed lines. On the y-axis is the estimate, with the full sample estimate of 0.16 denoted by a dashed line. All results remain statistically significant and large.

D.2 Alternative clustering

Table A.1: Effect of New Infrastructure on Armed Conflict with Alternative Clustered Standard Errors

	ACLED Event	Battle	Rebel Battle	Rebel or Eth. Militia Battle
Pipeline ($\widehat{\beta_1}$)	0.319	0.160	0.031	0.076
S.E. clustered by ...				
5-km grid cells	(0.059)	(0.036)	(0.014)	(0.024)
10-km	(0.066)	(0.036)	(0.014)	(0.024)
20-km	(0.070)	(0.039)	(0.016)	(0.025)
Field, Well or Terminal ($\widehat{\beta_2}$)	0.032	0.026	-0.018	-0.026
S.E. clustered by ...				
5-km grid cells	(0.052)	(0.037)	(0.011)	(0.015)
10-km	(0.056)	(0.037)	(0.011)	(0.015)
20-km	(0.056)	(0.037)	(0.011)	(0.015)
Equivalence Test ($H_0 : \beta_1 = \beta_2$) with S.E. clustered by ...				
5-km grid cells	p = 0.00	p = 0.01	p = 0.01	p = 0.00
10-km	0.00	0.01	0.01	0.00
20-km	0.00	0.01	0.01	0.00
5-km Cells	1,474,363	1,474,363	1,474,363	1,474,363
10-km Cells	370,003	370,003	370,003	370,003
20-km Cells	93,171	93,171	93,171	93,171
Country-Years	869	869	869	869
N	26,538,534	26,538,534	26,538,534	26,538,534

Table A.1 presents a reanalysis of Table 2 using two alternative levels of clustering, 10x10-km clusters (containing four 5x5-km grid units of analysis), and 20x20-km grid clusters (containing 16 5x5-km grid units). Models estimated using OLS.

D.3 Including Additional Time-varying Controls

Table A.2: Effect of New Oil/Gas Infrastructure on Armed Conflict (with Controls)

	ACLED Event	Battle	Rebel Battle	Rebel or Eth. Militia Battle
Pipeline	0.257***	0.169***	0.037**	0.087***
	(0.052)	(0.039)	(0.016)	(0.026)
Field, Well or Terminal	0.022	0.022	-0.019*	-0.027*
	(0.053)	(0.037)	(0.011)	(0.015)
Equivalence Test	0.00	0.01	0.00	0.00
Controls	✓	✓	✓	✓
Cells	1,474,360	1,474,360	1,474,360	1,474,360
Country-Years	869	869	869	869
N	26,405,190	26,405,190	26,405,190	26,405,190

Table A.2 presents a reanalysis of Table 2 with added controls for (lagged) population and (lagged) night lights density, a measure of economic development. Models estimated using OLS with standard errors clustered at the grid cell level. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

D.4 Alternative units of analysis

Table A.3: Effect of New Oil/Gas Infrastructure on Armed Conflict (10x10-km Grid Cells)

	ACLED Event	Battle	Rebel Battle	Rebel or Eth. Militia Battle
Pipeline	0.796***	0.414***	0.049	0.222***
	(0.150)	(0.094)	(0.039)	(0.061)
Field, Well or Terminal	0.358**	0.173	-0.025	-0.045
	(0.171)	(0.117)	(0.027)	(0.058)
Equivalence Test	0.06	0.12	0.13	0.00
10-km Cells	370,003	370,003	370,003	370,003
Country-Years	869	869	869	869
N	6,660,054	6,660,054	6,660,054	6,660,054

Table A.3 presents a reanalysis of Table 2 with the units of analysis as 10x10-km grid cells rather than 5x5-km grid cells. Models estimated using OLS; standard errors clustered on 10x10-km grid cell. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

D.5 Placebo Tests

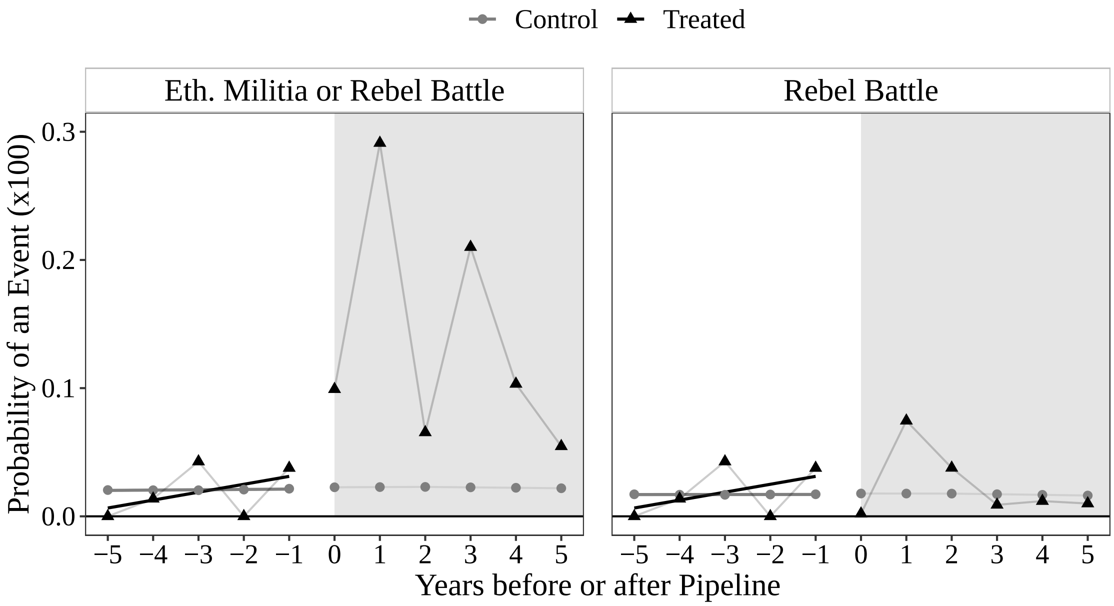
Table A.4: Placebo Test for New Infrastructure

	ACLED Event	Battle	Rebel Battle	Rebel or Eth. Militia Battle
Placebo Pipeline	-0.032	-0.007	-0.007	-0.026
	(0.053)	(0.051)	(0.025)	(0.027)
Placebo Field, Well or Terminal	-0.015	-0.013	-0.010	-0.011
	(0.025)	(0.013)	(0.013)	(0.013)
Equivalence Test	0.77	0.91	0.89	0.62
Cells	1,462,352	1,462,352	1,462,352	1,462,352
Country-Years	869	869	869	869
N	26,268,180	26,268,180	26,268,180	26,268,180

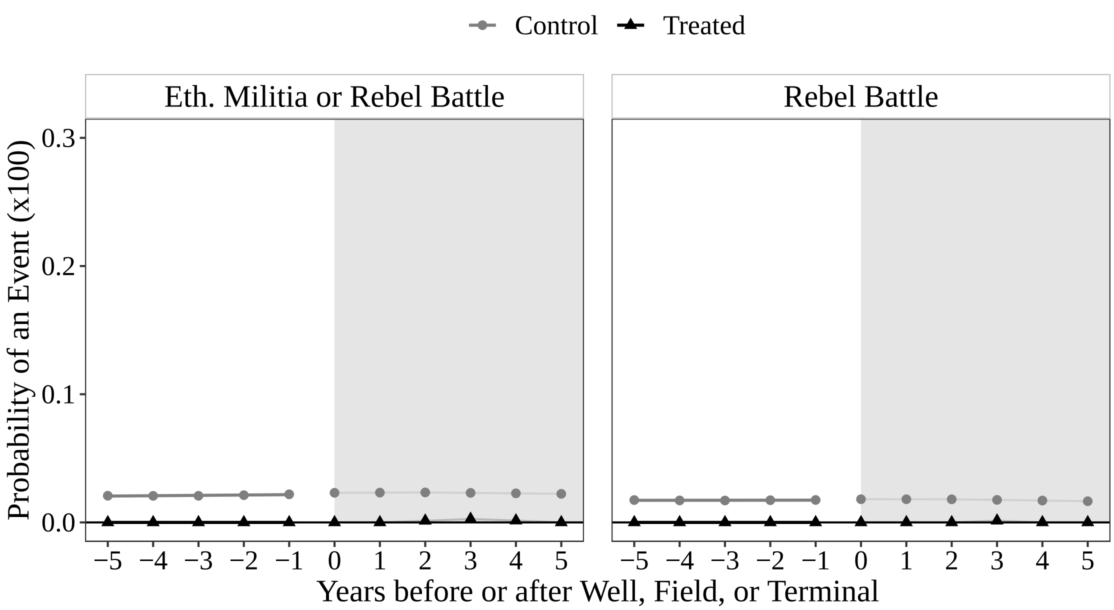
Table A.4 presents the results of a placebo (falsification) test in which we drop all post-treatment data and recode treatment as the five years prior to infrastructure construction. We cannot reject the null hypothesis of no effect for these placebo treatments.

D.6 Event Study Plots

Figure A.5: Event Study Plots



(a) Pipelines



(b) Field, Well, or Terminal

Figure A.5 presents an event study analysis based on Equation 1. The figure displays the probability of a conflict event (multiplied by 100 for readability) in each of the five years before, the year of, and each of the five years after a piece of oil infrastructure is constructed in a grid cell. Panel (a) presents the results for the construction of pipelines for battles involving ethnic militia or rebels (left) and just battles involving rebels (right). Panel (b) presents the results for the construction of fields, wells, or terminals for battles involving ethnic militia or rebels (left) and battles involving rebels (right).

D.7 Moderation analysis

Table A.5: Moderated Effect of Lagged Road Presence

	ACLED Event		Battle		Rebel Battle		Rebel or Eth. Militia Battle	
Pipeline	0.931***	0.777***	0.479***	0.389***	0.072	0.053	0.248***	0.207***
	(0.175)	(0.156)	(0.126)	(0.112)	(0.047)	(0.042)	(0.088)	(0.078)
Field, Well or Terminal (FWT)	-0.283***	-0.281***	0.164	0.163	-0.069	-0.075	-0.091	-0.091
	(0.109)	(0.106)	(0.213)	(0.210)	(0.070)	(0.069)	(0.071)	(0.069)
Pipeline x	-0.696***	-0.732***	-0.287**	-0.308***	-0.020	-0.025	-0.160**	-0.170**
No Road in 1990	(0.156)	(0.160)	(0.113)	(0.116)	(0.043)	(0.044)	(0.078)	(0.080)
FWT x	0.369***	0.370***	-0.160	-0.161	0.069	0.066	0.076	0.076
No Road in 1990	(0.123)	(0.121)	(0.209)	(0.211)	(0.069)	(0.069)	(0.070)	(0.070)
No Nightlights	✓		✓		✓		✓	
No Nightlights x Pipeline	✓		✓		✓		✓	
No Nightlights x FWT	✓		✓		✓		✓	
Cells	1,474,363	1,474,363	1,474,363	1,474,363	1,474,363	1,474,363	1,474,363	1,474,363
Country-Years	869	869	869	869	869	869	869	869
N	26,538,534	26,538,534	26,538,534	26,538,534	26,538,534	26,538,534	26,538,534	26,538,534

Table A.5 shows the effect of new pipeline construction moderated by whether roads were present in 1990 (all columns) and whether there the cell had any luminosity in the previous year (odd columns). The uninteracted variables for infrastructure in these models capture the effects of construction in cells that already had road access but no luminosity. Our measure of road access comes from digitized road maps of Africa compiled by the Michelin Tire Company. Models are estimated using OLS with cell and country-by-year fixed effects, with standard errors clustered on cell. We report the number of cells and country-years in the analysis as well as the total sample size. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

D.8 Diagnostics for Two-way Fixed Effects (TWFE) Estimates

A burgeoning literature in econometrics identifies potential issues with the use of TWFE estimators for staggered designs, in which the timing of treatment varies across treated units. This work provides helpful diagnostics and alternative approaches that we employ below to demonstrate the robustness of our finding that new pipeline construction increases the likelihood of armed conflict (see Table 2). Given the size of our panel, we rewrote large portions of the `TwoWayFEWeights` and `bacondecomp` packages (using data.table syntax) to handle our data.

D.8.1 De Chaisemartin and d'Haultfoeuille (2020)

De Chaisemartin and d'Haultfoeuille (2020) demonstrate that the TWFE estimator is a weighted sum of the average treatment effects for each treated cell. For staggered designs in which treated units are not all exposed simultaneously, some of these weights can be negative. When treatment effects are not constant, negative weights can generate a TWFE estimate with a different sign than all of the constituent ATTs. Under the common trends assumption, the authors provide a method for recovering the weights placed on each ATT.

We run their diagnostic for the models in Table 2. We find that the sum of the positive weights is 1.011, while the sum of the negative weights is just -0.011. This indicates that our TWFE estimate and the true ATT could only be opposite sign under substantial treatment effect heterogeneity. We also find that these weights are not strongly correlated with cells' population ($\rho = -0.01$) or luminosity ($\rho = -0.06$), two covariates that might generate treatment effect heterogeneity.

D.8.2 Goodman-Bacon (2021)

Goodman-Bacon (2021) shows that the TWFE estimator is a weighted average of all of the two-group (units with changing treatment status vs. all others), two-period (pre- and post-treatment) estimators in the data. They provide a method for decomposing the TWFE estimate for a particular sample, which allows us to discern which comparisons drive the overall result.

Table A.6: Goodman-Bacon (2021) TWFE Decomposition

Comparison	Total Weight	Average Estimate
Treated vs. Untreated	0.993	0.182
Later vs Always Treated	0.006	0.075
Later vs. Earlier Treated	0.001	0.084
Earlier vs. Later Treated	0.001	0.081

Table A.6 displays a decomposition based on Equation 1 of the implied weight assigned to two-by-two comparisons of treated units to untreated units, of those comparing later vs. always-treated units, of those comparing later vs. earlier-treated units, and those comparing units treated earlier vs. later. In addition, for each group, the average of the two-by-two estimates is presented. The regression predicts units with any ACLED battle as the outcome variable with an indicator for new pipeline construction (our treatment variable) and year fixed effects.

Table A.6 summarizes this decomposition for our sample.[40] Given the large number of untreated cells in our data, over 99 percent of the weight is placed on the comparison of treated vs. never treated cells. The averages of the treatment effect estimates are positive for all types of comparisons. This exercise alleviates concern that our results hinge on "forbidden comparisons" that use early-treated (or always-treated) cells as controls for later-treated cells. Such comparisons can be problematic if treatment effects change over time, as dynamic treatment effects imply a violation of the parallel trends assumption: counterfactually, cells switching their treatment status would not be expected to follow the same trend as already-treated cells. As the middle two rows of Table A.6 demonstrate, the TWFE estimator assigns little weight to these comparisons.

D.8.3 Callaway and Sant'Anna (2020)

Callaway and Sant'Anna (2020) provide a method for recovering disaggregated treatment effect estimates for each treated cell, which never use already-treated units as controls. These effects can then be aggregated in ways that avoid the use of negative weights or the down-weighting of early- or late-treated units — two issues that arise when using TWFE estimators to analyze staggered designs.

We use their method to generate two estimates of the overall ATT. First, we use weights proportional to the size of each treated cell: borrowing the authors' notation, $\widehat{\theta_W^O} = 0.141\ (0.034)$.[41] This "simple" aggregation overweights early-treated groups, which are observed over more post-treatment periods. Second, we average the effect across treated cells: $\widehat{\theta_{sel}^O} = 0.145\ (0.049)$. Both estimates are quite similar to the TWFE estimate of $\widehat{\beta}_{fe} = 0.171$.

We next employ their method to generate an event-study plot, which shows the average treatment effect for units exposed to treatment for different lengths of time. Figure A.6 shows the dynamic effects for four years before and five years after the construction of a new oil or gas pipeline, with bootstrapped 90% confidence intervals adjusted for multiple testing. Parallel trends appear to hold in the pre-treatment period. The average effect does not differ dramatically by length of exposure.

40. We estimate Equation 1 with any ACLED battle as the outcome variable, an indicator for new pipeline construction (our treatment variable), and year fixed effects. This model generates results nearly identical to Table 2; the simplification permits us to run diagnostics which require considerable computational resources given the size of our data.

41. As with Table A.6, we estimate Equation 1 with any ACLED battle as the outcome variable, an indicator for new pipeline construction (our treatment variable), and year fixed effects.

Figure A.6: Dynamic Effects of New Pipelines on the Probability of an ACLED Battle

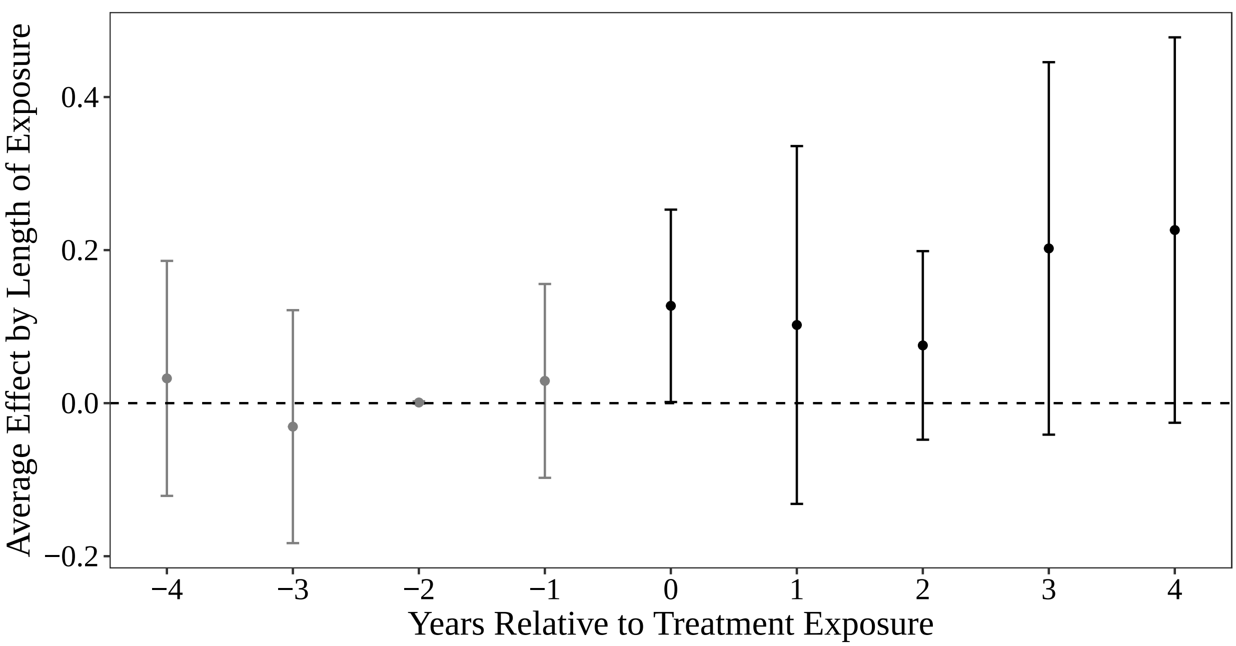


Figure A.6 displays a Callaway and Sant'Anna (2020) event-study plot, which shows the average treatment effect across different lengths of exposure to a new pipeline, with bootstrapped 90% confidence intervals adjusted for multiple testing.

E. Autoregressive Models of Conflict Near Pipelines

E.1 Full models

Table A.7: Predictive Power of Past Armed Conflict (AR(2) Model)

	Battle	Rebel Battle	Rebel or Eth. Militia Battle	Protest or Riot
t - 1	0.112	0.060	0.033	0.210
	(0.030)	(0.043)	(0.034)	(0.030)
t - 2	-0.045	-0.064	-0.051	0.101
	(0.036)	(0.032)	(0.029)	(0.029)
Sum of Coefficients	0.067	-0.004	-0.018	0.312
Std. Error	(0.053)	(0.059)	(0.051)	(0.045)
Cells	8,172	8,172	8,172	8,172
Country-Years	240	240	240	240
N	130,752	130,752	130,752	130,752

Auto-regressive models; standard errors clustered on grid cell.

Table A.8: Predictive Power of Past Armed Conflict (AR(3) Model)

	Battle	Rebel Battle	Rebel or Eth. Militia Battle	Protest or Riot
t - 1	0.101	0.046	0.019	0.197
	(0.031)	(0.041)	(0.032)	(0.031)
t - 2	-0.046	-0.063	-0.052	0.086
	(0.037)	(0.039)	(0.033)	(0.029)
t - 3	0.020	-0.011	-0.020	0.034
	(0.030)	(0.042)	(0.035)	(0.034)
Sum of Coefficients	0.075	-0.028	-0.054	0.318
Std. Error	(0.072)	(0.066)	(0.055)	(0.06)
Cells	8,172	8,172	8,172	8,172
Country-Years	225	225	225	225
N	122,580	122,580	122,580	122,580

Auto-regressive models; standard errors clustered on grid cell.

F. Effect of Prices on Conflict Near Existing Infrastructure

F.1 Alternative clustering

Table A.9: Effect of Local and Global Fuel Prices on Armed Conflict around Existing Infrastructure with Alternative Clustered Standard Errors

	Battle	Rebel Battle	Rebel or Eth. Militia Battle
Log(Local Price) x Pipeline (γ_1)	0.065	0.110	0.106
S.E. clustered by ...			
5-km grid cells	(0.113)	(0.061)	(0.066)
10-km	(0.114)	(0.062)	(0.066)
20-km	(0.117)	(0.068)	(0.072)
Log(Global Price) x Pipeline (γ_2)	0.008	-0.117	-0.108
S.E. clustered by ...			
5-km grid cells	(0.083)	(0.057)	(0.060)
10-km	(0.082)	(0.057)	(0.059)
20-km	(0.088)	(0.066)	(0.067)
Equivalence Test ($H_0 : \gamma_1 = \gamma_2$) with S.E. clustered by ...			
5-km grid cells	p = 0.76	p = 0.05	p = 0.07
10-km	0.76	0.05	0.07
20-km	0.77	0.08	0.11
5-km Cells	1,464,041	1,464,041	1,464,041
10-km Cells	368,183	368,183	368,183
20-km Cells	92,731	92,731	92,731
Country-Years	536	536	536
N	17,216,229	17,216,229	17,216,229

Table A.9 presents a reanalysis of Table 4 using two alternative levels of clustering, 10x10-km clusters (containing four 5x5-km grid units of analysis), and 20x20-km grid clusters (containing 16 5x5-km grid units). Models estimated using OLS.

F.2 Including Additional Time-varying Controls

Table A.10: Effect of Local and Global Fuel Prices on Armed Conflict around Existing Infrastructure (with Controls)

	Battle		Rebel Battle		Rebel or Eth. Militia Battle	
Log(Local Price) x Pipeline (γ_1)	0.057	0.055	0.112*	0.112*	0.105	0.103
	(0.113)	(0.115)	(0.061)	(0.062)	(0.066)	(0.067)
Log(Global Price) x Pipeline (γ_2)	-0.003	-0.001	-0.115**	-0.119**	-0.109*	-0.115*
	(0.083)	(0.084)	(0.057)	(0.058)	(0.060)	(0.060)
Equivalence Test ($H_0 : \gamma_1 = \gamma_2$)	0.75	0.77	0.05	0.05	0.07	0.07
Luminosity & Luminosity x Infrastructure interactions		✓		✓		✓
Controls	✓	✓	✓	✓	✓	✓
Cells	1,457,414	1,457,414	1,457,414	1,457,414	1,457,414	1,457,414
Country-Years	536	536	536	536	536	536
N	17,123,381	17,123,381	17,123,381	17,123,381	17,123,381	17,123,381

Table A.10 presents a reanalysis of Table 4 with added controls for population and nightlights (all columns), as well as interactions between local and global gas prices and the presence of critical oil infrastructure (even columns). Models estimated using OLS with standard errors clustered at the grid cell level. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

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