Digging Deeper:
Mining Companies and Armed Bands in the DRC*

Preliminary draft
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Abstract

We investigate the relationship between armed groups and large-scale mining firms in the Democratic Republic of Congo using geo-referenced data over 2000-2015. We start by showing that the pattern of links between armed bands and concession owners significantly departs from the random benchmark, even after accounting for geographic proximity. After observing a given owner-band pair in a concession, we are significantly more likely to find the same pair in a different concession, possibly far away. We next explore the nature of the interaction by focusing on the timing and on the type of violence exerted by armed groups, and by exploring how it varies with local population density. Our results are consistent with the interpretation that mining companies and armed bands engage in repeated interactions, where the latter help clear the territory from competing armed bands and destabilize the surrounding environment in a way that potentially allows to access cheaper labor.

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1 Introduction

The African continent has been plagued by civil wars and violent conflict since the end of World War II. These conflicts often see the proliferation of armed groups that establish monopolies of violence, extract informal taxes and offer protection. Importantly, the extent of violence exerted by these groups has been shown to respond to economic incentives created by mineral resource extraction (Berman et al., 2017; Sánchez De La Sierra, 2020). This paper aims at exploring the connection between armed groups and mineral resources bringing a second actor into the picture: mining firms that make large scale investments in the extractive sector. In particular, we focus on the Democratic Republic of Congo (DRC), where more than 70 armed groups were active in 2015 and where the abundant presence of natural resources, together with the low cost of unskilled labor, has led to a spread in the activities of large-scale mining firms. These firms are located primarily in areas with a high density of armed groups, hence understanding the interaction between these two actors is crucial to understand the dynamics of political instability and conflict.

The main hypothesis we wish to investigate is that mining companies may engage in a patter of mutually advantageous repeated interactions with specific armed groups, where the latter provide services to the former, including clearing the territory from competing armed bands and destabilizing the surrounding environment in a way that potentially allows to access cheaper labor.[1] We develop this argument in two steps. First, we establish that the pattern of bilateral interactions between mining firms and rebel groups significantly differs from the one that would be predicted under random pairing, even when we account for geographic proximity possibly driven by mineral resource abundance. Second, we investigate the nature of the interaction by focusing on the timing and on the type of violence exerted by armed groups, and by exploring how it varies depending on local population density.

We use high resolution geo-localized data on mining concessions from the DRC Ministry of Mines and on conflict events from the Armed Conflict Location and Event Data (ACLED) to map the position of concession owners and armed bands over time in the whole country. This allows us to know which armed groups were observed exerting violence in any given concession of any given mining firm each year between 2000-2015.

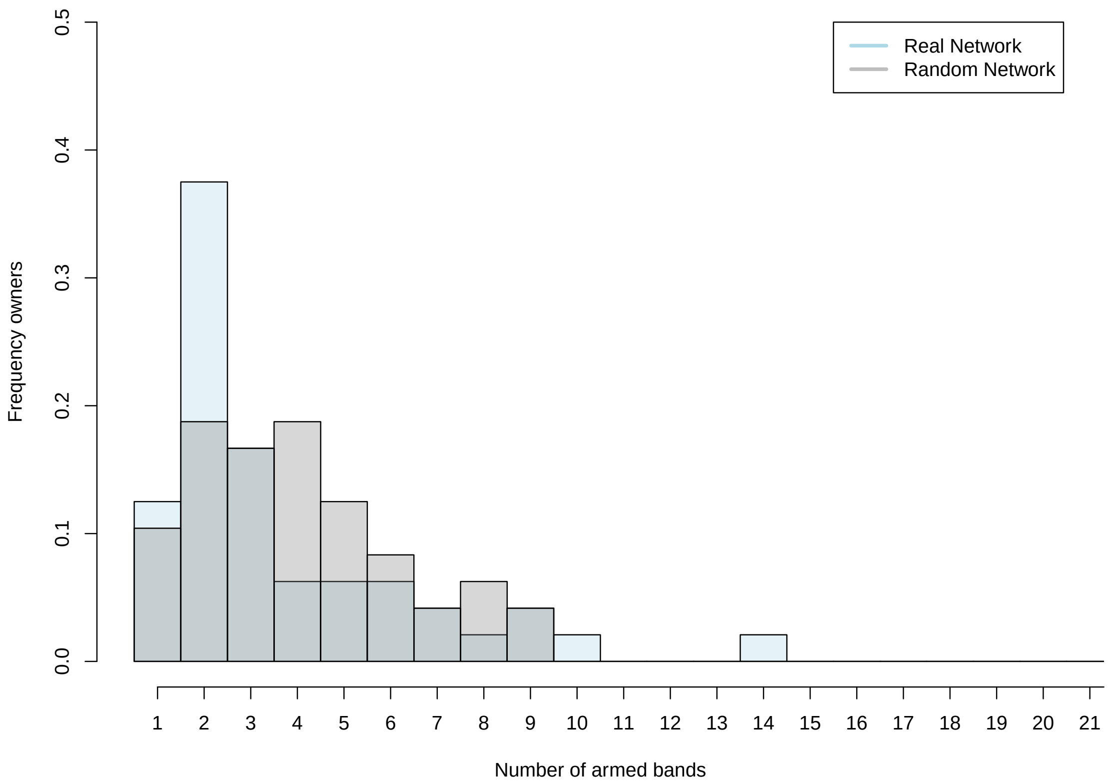
We say that an armed band and a mining firm have a "contact" in a concession if we observe a conflict event involving the band within the perimeter of that concession. In addition, we say that an armed band and a mining firm have a "link" if they had a contact *in the past*, in a *different* concession of the same owner.

We start by observing a simple fact, illustrated in Figure 1: owners have contacts with fewer bands relative to a random network. While random matching between firms and armed bands would produce a relatively spread out distribution of links, the empirical distribution we observe is significantly skewed to the left. In fact, 50% of the firms have contact with two or less armed bands. The pattern is even stronger if we restrict the set of potential dyads to firms and armed bands that are within 250 km of each other (Figure

[1] Throughout the paper, we use equivalently the terms "concession owner", "owner", "mining firm" and "firm" on one side, and "armed band" and "armed group" on the other.

A1). This suggests that firms repeatedly interact with the same armed group(s) in any given concession. Of course such a pattern may spuriously derive from the fact that both the firm and the armed group are interested in the same geographic area (mineral concession), hence our main analysis exploits bilateral *links* between the same owner and the same armed group that are observed *across different concessions*.

Figure 1: Contacts real and random network



Notes: The Figure presents the distribution of owners in the sample, with respect to the number of armed groups they have contacts with. An armed band b and a owner o have a contact at time t in the Interest Zone i if we observe a conflict event involving b in i at t. The sample is restricted to owners with at least one contact (intensive margin). For the extensive margin, please refer to Figure A7. In blue we show the true empirical distribution. In gray we plot the distribution from a random network constructed allocating contacts between owners and armed bands such that the resulting random network density ($\frac{\text{\# actual contacts}}{\text{\# potential contacts}}$) is the same as in the real one.

Our first set of results aims at showing that the interaction between firms and armed groups is strategic and not a spurious by-product of geography. Using the likelihood ratio index, we show that the probability of observing a pair that had a previous interaction elsewhere is significantly higher than under random matching. If we consider the number of different armed bands with which mining companies have contact, we find that owners in the real network tend to have contacts with significantly fewer armed groups than would be predicted in a random network. These results hold even when we take into account geographic proximity. Finally, we show that having a previous contact in a mining concession (*link*) is predictive of subsequent contact in *different* concessions operated by the same owner. Having a *link* increases the contact probability 247 times relative to the mean probability without *link*, and this effect is positive only for the years *after* the *link* is established. Moreover, the effect of having a *link* remains positive and significant even at distances above 1000 km (930 miles).

In the second part of the paper, we look at the nature of the repeated interaction between mining firms and armed groups. In particular, we focus on two potential, non-mutually exclusive mechanisms. The first is that armed bands provide security to mining owners. Consistent with this interpretation, we find that, after a *link* is made, there is a higher probability of observing the linked band, and a lower probability of observing other armed bands, close to the concession. Moreover, the higher is the number of rival groups initially located close to the concession (hence the value of having "protection"), the larger is the effect of having a *link*. In addition, when we focus on the time in which a firm *first* enters a mining area, approximated by the year in which a research concession is granted by the relevant ministry, we find that the probability of observing the *linked* band becomes positive and significant the year *before* the actual granting of the concession. This "anticipation effect" is driven by battle events and not by other types of violence, consistent with the idea that an armed group with which the company is already familiar is used to "clear the way" from other bands before the company opens the concession.

The second mechanism we explore is that armed bands may generate instability in a way that is potentially profitable for the mining firm, e.g., because it gives access to cheap unskilled labor. To shed light on this mechanism, we rely on highly disaggregated location data and test whether the previous interaction of a given firm with a given armed band (*link*) predicts the location of that band close to the centroid of the owner's concession or immediately outside it. Our hypothesis is that violence occurring in the exact same location where research or extraction activities take place would be dysfunctional for the firm, hence should be relatively less frequent if the band and the firm collaborate. On the other hand, if violence is used to intimidate the local population or disrupt their economic activity, so as to induce them to work in the mining site for low wages, the ideal target for such violence is outside the concession, but close enough to fall within the basin from which workforce can be recruited. Our interpretation is corroborated by the fact that the effect we estimate is stronger, the higher the population density in this surrounding area.

Our paper relates to different strands of literature. The first is the literature on conflict and firms performance. An significant number of studies have highlighted the negative consequences of conflicts on private firms (e.g., Abadie & Gardeazabal, 2003; Amodio and Di Maio (2018); Ksoll et al., 2016; Couttenier et al., 2021; Blumenstock et al., 2020; de Roux & Martinez, 2021; Klapper et al. (2013); Collier & Duponchel, 2013; Besley and Mueller (2018); and Korovkin & Makarin, 2021, among others). In contrast, other evidence indicates that firms may actually benefit from conflicts and, in general, political instability (e.g., Guidolin and La Ferrara (2007); Sonno and Zufacchi (2022)). Our paper contributes to this literature by presenting evidence on the pattern of relationships that mining firms and armed groups establish during periods of conflict and instability – relationships that may entail the scope for collaboration between the two. This is important to understand the incentives that these actors may have to prevent or perpetuate instability.

A second strand of literature studies rebel groups (e.g., Weinstein, 2006) and network structure in conflicts (e.g. Franke & Öztürk, 2015, Huremovic, 2014, Jackson & Nei, 2015, Hiller, 2017). In an influential paper, König et al. (2017) look at the network of military alliances in the Second Congo War, showing how each party's fighting effort responds to that of its allies and of its rivals. Differently from them, we focus on the network links between armed groups and mining firms (as opposed to links among armed groups). Particularly related to the context we study is the work of Sánchez De La Sierra (2020, in progress). Exploiting a unique dataset, Sánchez De La Sierra (2020) shows that an increase in the demand for coltan led armed bands in Eastern DRC to tax mining output and provide protection in the mines where it was extracted. Sánchez De La Sierra (in progress) discusses, among other things, the organization of the capital intensive mining sector in the DRC and its lack of transparency. We build on this work and attempt to provide evidence of the links between armed groups and mining firms for the entire DRC and over 15 years by uncovering systematic patterns in the data.

In this respect, our paper is related to the forensic economics literature, and in particular to work that identifies and quantifies hidden behavior by discovering anomalous patterns in the data (e.g., Fisman, 2001; Jacob & Levitt, 2003; Hsieh & Moretti, 2006; DellaVigna & La Ferrara, 2010; A. Dube, Kaplan, & Naidu, 2011; Zitzewitz, 2012; Colonnelli, Neto, & Teso, 2022). Particularly relevant fr us is the work of Trebbi and Weese (2019), who detect unobserved coalitions among insurgent groups in Afghanistan and Pakistan. To the best of our knowledge, ours is the first attempt to apply a statistical forensic economics approach to uncover the pattern of relationships between armed groups and private firms.

Finally, our paper also contributes to the large literature on conflict and natural resources (e.g., Collier & Hoeffler, 1998, 2004; Fearon, 2005; Humphreys, 2005; Van der Ploeg, 2011; O. Dube & Vargas, 2013; Aragón & Rud, 2013; Bazzi & Blattman, 2014, Lei & Michaels, 2014; Maystadt et al., 2014; Caselli et al., 2015; Morelli & Rohner, 2015; Berman et al., 2017). We contribute by shedding light on a potential mechanism behind the robust positive correlation between mineral resources and conflict, namely the link of mining companies with armed groups and the associated instability.

The rest of the paper is organized as follows. Section 2 provides some background on conflict and mining in the DRC. Section 3 presents the data and some descriptive evidence on the relationship between conflict events and the opening of mining concessions. Section 4 presents the main results of the paper.Section 5 contains sensitivity analysis and a placebo exercise. Section 6 concludes.

2 Background

The turbulent history of the Democratic Republic of Congo began with the Belgian Colonization. Leopold II of Belgium directly controlled the nation as private property from 1869 to 1908. During this period, the "Congo Free State" was known worldwide for the brutalities perpetrated by Belgians at the expense of locals for the production of rubber. Congo passed under the administration of the Belgian government at the beginning of 1908 and finally gained independence in 1960. Violence has characterized this country until recent days. In particular, the country faced two major wars, the First (1996-1997) and the Second (1998-2003) Congo Wars.

Although a peace agreement was signed in 2003, fighting never stopped, especially in the Eastern part of the country. The ceasefire implied a retreat of international forces from the battlefield, but it did not lead to the dissolution of the numerous rival armed groups and gangs formed over the years of war. The fragility of the new central government permitted non-state actors to hold sway over different spheres of social life - including politics, the economy, and conflict regulation. This phenomenon was facilitated by a long history of inter and intra-communal tensions, often related to contended territory, weak local authorities, and citizenship expressed in (ethnic) identity-based terms, especially in the eastern part of the country. Revenues from informal taxation and smuggling of minerals allowed these armed bands to survive and proliferate. In recent years, with the help of UN peacekeeping forces, the Congolese government tried to get back control of these areas through military operations (e.g., Kimia I and Kimia II), often without success. Armed groups continue to operate, and they control up to 95% of the territory in some administrative divisions.[2]. Moreover, new groups continue to form, motivated by the lack of economic opportunities and the relative abundance of natural resources. However, the taxation base of these groups has been gradually eroded by the arrival of large mineral multinational companies, replacing artisanal miners in various parts of the country.

Towards the end of the Second Congo War, the Kinshasa government started its project of transition from artisanal mining to large multinationals concessions enacting the new Congolese Mining Code (Law no. 007/2002) that replaced outdated mining legislation.[3] Providing favourable conditions to extracting companies at the expense of small local enterprises, this regulation increased foreign direct investments directed at constructing mining infrastructure and extracting minerals, especially in the south-eastern part of the country. To date, the DRC government has extended industrial mining permits to cover virtually all parcels of land where mineral deposits have been found, leaving almost no space for artisanal mining zones. The resulting competition between industrial and artisanal miners has become a source of tension in the country.[4]. The official objective of this transition was to increase revenues from the mining activ-

[2] Source: https://www.radiookapi.net/actualite/2013/02/28/shabunda-la-milice-raia-mutomboki-occupe-95-du-territoire-selon-son-administrateur

[3] For a detailed explanation of the new mining code, please refer to the dedicated section of the appendix (6)

[4] On the one hand, artisanal miners illegally occupied companies' concessions because of their lack of opportunities. On the other hand, multinational companies, often helped by the Congolese army, expelled them from their territories. To deal with the massive amount of violence resulting from this competition, Kinshasa enacted a new mining law in 2018. This compels

ities for the central government: taxes, royalties, and payments are collected by tax agencies on behalf of the government. In practice, the national treasury receives only a negligible amount of tax revenues and spends only a part of these to finance the economic development of the country.[5] Although unable to reach its primary objective, the transformation of Congo's industrial mining sector has been a success for production/extraction. For example, Congo as a whole produced just over 16.000 tonnes of copper in 2003, and since 2014 it has produced one million tonnes of copper per year, more than any other country in Africa (Global-Witness, 2017).

To sum up, armed groups and mining companies are two important actors in the DRC, with the latter eroding the "tax base" of the former (partly consisting of informal taxes on artisanal miners). In this scenario, there is extensive anecdotal evidence suggesting an emerging cooperation between the two. Among others, Global-Witness (2016, p. 7) documents a contract between an armed group and a mining company in the territory of Shabunda where "*In order to secure access to the river's gold, Kun Hou Mining illegally paid thousands of dollars to armed individuals calling themselves Raia Mutomboki*". The UN Security Council (S/2020/1283,p. 15) has also presented some evidence about a collaboration between the FARDC (DRC militia), and industrial mining companies in North Kivu: "*[...] FARDC members provided off-budget security to unidentified semi-industrial gold mining companies in Irumu and Djugu territories.*" Similar evidence comes from a report by International-Alert (2010, p.25) "*During 2006, GMB took possession of the mine after signing a contract with the Administrator of Walikale territory to ensure the safety of its staff and, above all, after reaching an understanding with the non-integrated* 85^{th} *brigade which had de-facto control over the mining zone. [...] The* 85^{th} *brigade, for its part, guaranteed the functioning of the system and a mininmum of security, in exchange for a share of the production as it left the mine.* "

The above anecdotal evidence has one important implication: by funding armed groups, multinational mining companies contribute to the continued local instability around mining areas.

3 Data and descriptives

In this section, we present the main data sources used in the rest of the analysis, covering the entire DRC over the period 2000-2015. We then report some summary statistics and preliminary correlational evidence on the relationship between open mining concessions and the incidence of violence.

3.1 Mining concessions

Our primary source of data is a comprehensive list of mining concessions in the DRC compiled by the Ministry of Mines Mining Registry (CAMI) and made available for download by Global Forest Watch

industrial mining companies to spend part of their revenues on community projects and allows them to subcontract work to artisanal mining companies. So far, this new legislation has been unsuccessful in fulfilling its goal (Crisis-Group (2020)).

[5] Between 2013 and 2015, payments by mining companies to the state totaled $ 3.63 billion, but the national treasury received only $2.3 billion. A total of $1.32 billion payments disappeared into state-owned companies, the three national tax agencies, and smaller state bodies, among others (Global-Witness, 2017).

(GFW).[6] The data contains a screenshot of the entire landscape of concessions in 2015, including information about the owner, minerals extracted, the status of the concession (active, new demand, renewal in progress, etc.), type of permit (research, exploit, artisanal), date in which the concession was granted and expiration date. Most importantly, we have the shape, location, and area of each concession.

We clean these raw data keeping in our sample only concessions that: (i) have non-missing information about the owner; (ii) have non-missing information about year-expiration dates; (iii) are not "research projects". As for this last restriction, we observe 20 research projects in the raw data. These are mainly state-led projects for the search of minerals in the country, hence cannot be assimilated to private mining companies: they tend to own a much larger number of concessions, strongly spatially clustered. Hence, concessions from research projects are not included in our analysis. In the cleaned version of the data, we observe 3966 concessions of 679 different owners. Figure A2 shows the spatial distribution of these concessions across the country. Table A1 presents some descriptive statistics of the CAMI data.

The average number of concession per owner is 20.89. It is useful to discuss how spatially concentrated these concessions are. Although it is common to observe concessions of the same owner sharing a border (a feature we will take into consideration in section 5), there is a significant degree of geographic dispersion. To test for spatial clustering of concessions of the same owner more formally, we divide the country into 0.5×0.5 degrees cells (approximately 55km $\times$ 55km at the equator) and we conduct two exercises. First, we compute Morans' I for each owner in terms of the number of concessions.[7] In Figure A3 we plot the distribution of these statistics computed for each owner. As one can see in the figure, this statistic takes extremely low values, excluding significant spatial correlation. However, using Morans' I is may not be fully satisfactory, as it focuses more on the intensive margin (number of concessions within a cell) than on the extensive one (number of close cells with concessions of the same owner). For this reason, we turn to an alternative strategy.

The second strategy compares the spatial distribution of concessions of the same owner with a random distribution. If there is a significant difference between the two, one can claim that concessions are spatially concentrated. To compare these distributions, we create a random geographical distribution of concessions of a given owner. In particular, we randomize the presence of a concession in each cell using as the probability the proportion of cells in which the owner has at least one concession. By doing so, we have in expectation the same number of cells in the randomized distribution as in the real one. After creating the random geographical distribution for each owner, we compare the two using the M test (Bonetti & Pagano, 2005). This test executes a Monte Carlo-type permutation to test the null hypothesis that two groups have the same spatial distribution. We reject the null at the 5% (1%) confidence level only for 17% (0%) of the owners. Finally, we use the full distribution of p-values to run a t-test with null

[6]Source: download; Accessed: Saturday the 19th of October 2019 14:23

[7]Morans' I is an index of global spatial correlation. It takes a higher value if cells with a high number of concessions are surrounded by other cells with a high number of concessions of the same owner. As a rule of thumb, if this index is higher than 0.5, there is a positive spatial correlation.

H_0 : pvalue $< p$ and we reject the null for $p = 0.01, 0.05, 0.10$ at any conventional significance level.

Turning to the permit type associated with the concessions, the overwhelming majority of permits are *research* ones (approximately 78%). This figure is probably driven by favourable taxation biased towards research concessions. Each permit can have, in general, four different statuses: (i) active; (ii) demand, meaning that the permit has been requested but not yet given; (iii) renewal, when a demand for renewing has been done but not yet approved; and (iv) radiation, if the concession is in the cancellation phase. Approximately 64% of concessions were active in 2015. The oldest concession we observe in the data was granted in 1994, while the newest, reassuringly, in 2015. The average length of research concessions, calculated as the difference between the expiring and the granting year, is 4.3 years. This is in line with the Mining Law legislation, which binds the granting time to be between four and five years for research permits.[8] Concessions for *exploitation* are granted for a much longer time, on average 12.57 years (by law, the maximum length of these concessions is 30 years, renewable for another 15). Typically, more than one mineral is extracted in the same concession: on average, approximately three different minerals are extracted in each concession.[9]

The main unit of analysis in the first part of the paper will not be the concession, but what we call an "Interest Zone". Recall from Figure A2 that the majority of concessions has a square shape. To define the Interest Zone, we draw a circular area around the concession. If a concession is a perfect square (with side length d), then the Interest Zone is the circle whose circumference touches all four vertices of the square. This circle has a radius $\sqrt{2}\frac{d}{2}$ (half of the square's diagonal) and center in the centroid of the concession, as depicted in Figure 2. The reason for choosing the Interest Zone as main unit of analysis is to work with standardized/convex sets defining the core of the region where mineral extraction takes place and the surrounding areas, rather than concessions that may have odd/concave shapes.

3.2 Armed groups

For the purpose of our analysis, ideally one would want geo-localized data on armed groups in the whole DRC for several periods. Unfortunately, these data do not exist.[10] A second-best solution is to use data from the Armed Conflict Location and Event Dataset, in short ACLED (Raleigh & Dowd, 2015).[11] ACLED

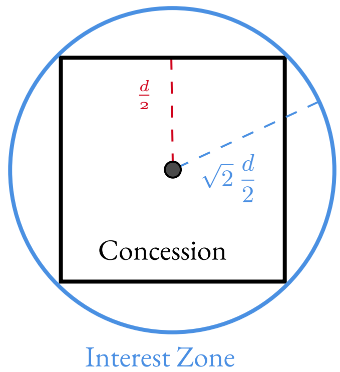
[8] For a detailed treatment of the regulation, please refer to Section 6.

[9] Gold is mined in approximately half of the concessions, while at least one 3T mineral (tungsten, tantalum, and tin) is extracted in more than 27% of the concessions.

[10] Similar data exist only for a subset of the armed bands, recent periods, and only for a portion of the DRC. For example, IPIS has visited several artisanal small mines over the period 2009-2015. For each of them they recorded whether an armed band was present and its name. We will use this information to validate the use of ACLED to track armed groups in section 5.1 of the Appendix.

[11] A different source of conflict data is the GDELT project. However, GDELT does not record the actor of the conflict event, hence we cannot use it to track armed groups.

Figure 2: Interest Zone



contains information on geo-located conflict events with and without fatalities for all African countries. It records all political violence, whether part of a civil conflict or not, and with no threshold for battle-related deaths. ACLED uses several sources, including press accounts from the region, local news, humanitarian agencies, and research publications. These data have been widely used in recent conflict literature (among others, Berman et al., 2017; Harari & La Ferrara, 2018; Manacorda & Tesei, 2020).

The data comprise the latitude, longitude, and the date of each conflict event, as well as its intensity (e.g., the number of fatalities). Importantly, for each conflict event it records the actors involved, which allows us to track the position of armed bands through the events in which they were involved. Note that we cannot observe the position of armed bands when not involved in a conflict event. To gauge the implications of this restriction, in Section 5.1 we validate our use of ACLED comparing the geo-localization of armed groups we produce to that obtained using information collected by the International Peace Information Service (IPIS) for a subset of armed bands, concessions and years.[12] IPIS visited several artisanal small mines in 2009-2015 recording the bands that were present, irrespective of whether they were engaged in conflict. We find that our error is quite small.

As standard in the literature, we only consider events that are geo-localized with the finest precision level and we drop duplicated events, that is, events for which all of the ACLED variables (date, location, description, etc.) are repeated for several observations. In these cases, we retain only one observation per event. Each event is characterized by two different actors, e.g., Militia A vs. Militia B. Being impossible to determine who was the attacker, we duplicate all events in the dataset assigning one actor each. Then, we retain all events involving an armed band. We define an *armed band* to be an actor that is involved in a conflict event and differs from armies (foreign or local), protesters/rioters, civilians, police forces and government forces. We restrict the sample to armed bands that are observed at least twice in the period 2000-2015 because, as will become clear from our analysis, we are interested in the possibility of repeated

[12] IPIS is an independent research institute that collects information with the goal of promoting peace, sustainable development and the fulfillment of human rights. (https://ipisresearch.be/)

interactions between firms and armed bands. The resulting data comprise 1353 conflict events in the period 2000-2015, involving 135 different armed groups. A comprehensive list of these is in Appendix Table A2.

3.3 Other data

Population. For population data, we use data from LandScan. This dataset has information about the population living in 30-arc second cells (approximately 1×1 km near the equator). The number of individuals is provided per cell. In particular, LandScan aims to "develop a population distribution surface in totality, not just the locations of where people sleep". For this reason, it integrates diurnal movements and travel habits in one measure called *ambient-population*.

Rainfall. Rainfall data come from the Global Precipitation Climatology Project (Adler et al., 2016). They provide estimated monthly rainfall data on a 2.5-degree global grid from 1979 to the present. As usual in the literature, we aggregate this data at our unit of analysis and then take the average rainfall each year.

Night lights. Annual composite images of stable night lights are available from the National Oceanographic and Atmospheric Agency (NOAA). These contain the information from daily observations taken by US Air Force Weather Agency satellites between 8.30 and 10.00 pm, discarding all images affected by cloud cover, sunlight, moon glare, aurora borealis, and ephemeral lights associated with fires and lightning strikes. Each pixel represents an area of approximately 1×1 km. The intensity of light emissions is coded on a six-bit scale, from 0 to 63 (black to white).

3.4 Descriptive statistics

Combining all these data sources, we construct a dataset structured following a network approach, since we want to investigate the relationship between concessions owners and armed bands. Each observation in the dataset is a triplet concession-band-year. Since we have 3966 concessions, 135 bands, and 16 years, the total number of observations in our sample is 3966×135×16=8566560. For each triplet we construct a series of dummy variables indicating whether we observe that specific armed band in the Interest Zone of the concession in that specific year. We then further differentiate these variables according to the type of conflict event observed (Violence against civilians, Battle, Riots, Protest).

For each concession-band dyad, we are interested in measuring the geographic distance, as this is a likely determinant of the probability that they interact. We do so by computing the distance between the coordinates of the place where the band was *first* observed when it enters the sample, and the centroid of the concession.[13] We denote this variable as *Initial distance* and this will be the main measure of distance

[13] Using the first location where the band is observed and not, say, the location in the previous year has two advantages. One is that it mitigates endogeneity concerns that would emerge of bands move over time in response to conflict activities that are occurring across concessions. The second is that this (time invariant) variable has considerably fewer missing values than one that

we use throughout the paper. Once we drop concessions that never experience the presence of an armed band over the period and observations with missing values in the controls (e.g., nightlights), we are left with a working sample of 3,968,470 observations. Summary statistics for this sample are reported in in Table 1).[14]

A few things are worth mentioning. First, the events we are looking at are quite rare: the average probability of observing a specific armed band in a given Interest zone in a given year is 0.00013658.[15] Second, mineral concessions are quite large, with an average area of 141 km^2 (equivalent to approximately 55 square miles). Third, population density in these geographic units is low. Fourth, the average night luminosity is also quite low (0.43 on a range from 0 to 62), consistent with the fact that they are mostly rural areas.

3.5 Correlational evidence: concessions and conflict

In this section, we provide preliminary evidence about the correlation between the presence of mining concessions and conflict events. We start with the standard *grid-level* analysis used in the literature. We divide the country into 0.5×0.5 degrees cells (approximately 55km $\times$ 55km, or 34 $\times$ 34 miles, at the equator) and we explore whether in cells with open concessions we observe a higher probability of conflict events. To do so, we estimate the following linear probability model:

$$C_{it} = \alpha + \beta O_{it} + \mu_i + \mu_t + \epsilon_{it}$$

where C_{it} is a dummy variable indicating whether a conflict event happened in cell i at time t and O_{it}, indicates whether there was at least one open concession at time t in the same cell.

Results are summarized in Table 2, panel A. In line with the existing literature, we find that having an open concession in the cell is associated with a higher probability of observing a conflict event of any type (column 1), as well as with each event type (Violence against civilians, Battle, Protest/Riots). This level of analysis is, however, not sufficiently granular to directly study the interaction between mining owners and armed groups. Indeed, within each cell we observe an average of 33 concessions of 11 different owners. Hence, we repeat the analysis at the level of each concession, or, to be precise, of the Interest Zone around it. To do so we use the same regression model as above, but now i indicates an Interest Zone (as defined in Figure 2 of section 3.1). It is worth mentioning the different interpretation that O_{it} has in this case. While before it indicated whether there was at least one open concession in the cell, now it takes value one if the concession upon which the Interest zone is constructed is open at time t.

The coefficients of this Interest Zone-level analysis are reported in panel B of Table 2, and are qualita-

would vary year to year, given that for many years we do not observe a given band engaged in conflict.

[14] Descriptive statistics for the full dataset are reported in Table A3.

[15] Estimating fixed effects models can be challenging with rare events data. Indeed, Maximum Likelihood methods may overstate predicted probabilities as events become more rare. Using Monte Carlo simulations, Timoneda (2021) shows that, in this scenario, Linear Probability Models (LPM) should be preferred since they are very accurate at both rare events and highly common events.

Table 1: Descriptive statistics

	Mean	SD	Min	Max	Obs
ACLED[a]					
Event	0.013658	1.168580	0	1	3,968,470
Violence against civilians	0.006955	0.833927	0	1	3,968,470
Battle	0.004410	0.664046	0	1	3,968,470
Contact and distances					
Link	0.003807	0.061585	0	1	3,968,470
Ever link	0.006611	0.081038	0	1	3,968,470
Previous distance km	970.886975	486.616968	0.930331	2,247.105718	598,437
Initial Distance	933.711170	477.946949	0.930331	2,229.073690	3,968,470
Previous distance | Link & contact	191.748379	133.090241	11.874948	932.525285	261
Concessions					
Mine's area km2	141.277988	143.951580	0.860551	405.322810	63,456
Year starting date	2,007.622794	2.760857	1,994	2,015	63,456
Year expiring date	2,013.589511	5.688452	1,998	2,043	63,456
Number of minerals extracted	3.525719	2.819113	0	19	63,456
Gold	0.560767	0.496298	0	1	63,456
3T Minerals	0.273323	0.445669	0	1	63,456
Exploit	0.190620	0.392793	0	1	63,456
Research	0.780635	0.413819	0.	1	63,456
Open concession	0.352985	0.477902	0	1	63,456
Controls					
Population	8,333.593843	31,492.842909	0	1,013,5416	63,456
Average rainfall	1,425.766519	287.073042	612.351609	2,968.495076	63,456
Average nightlights	0.432918	2.590944	-0.015745	62	47,592

[a] To ease the reporting of the descriptives, mean and standard deviation are multiplied by 100.

tively similar to the ones shown in Panel A.[16] Quantitatively, we see smaller coefficients in Panel B compared to Panel A, which is not surprising for two reasons. First, the cells in panel A are much bigger than Interest Zones, hence it is more likely that *at least* one conflict event will happen in a cell than in an Interest Zone. Second, concessions that are geographically close have opening dates that are temporally close (possibly due to mineral discoveries or bureaucratic procedures). As a result, the larger coefficients in panel A may also reflect the cumulative opening of different concessions, while in panel B it captures the effect of opening a single concession.

The above results are in line with the existing literature: there is a higher incidence of conflict events when mineral concessions open. In the remaining part of the paper we try to uncover the dynamics underlying this correlation, and we study the interaction between mining companies and armed groups.

[16]The only notable difference in terms of significance is when we use Battle as dependent variable. In this case, we do not see a higher probability of battles in the year in which the concession opens (we shall see below that battles among armed groups will happen the year *prior* to the opening of a concession.

Table 2: Mining concessions and conflict

Dep. Variable	(1) Conflict	(2) Violence	(3) Battle	(4) Protest-Riots
Panel A: Grid analysis				
Open Concession	0.0375***	0.0270***	0.0172***	0.00809***
	(0.00392)	(0.00314)	(0.00308)	(0.00197)
Obs.	20,262	20,262	20,262	20,262
R2	0.304	0.218	0.246	0.160
Cell FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Mean Dep. | Open Concession = 0	0.0101	0.0041	0.0072	0.0025
Panel B: Interest zone analysis				
Open Concession	0.00185**	0.00169**	-0.0000649	0.000585*
	(0.000894)	(0.000710)	(0.000709)	(0.000316)
Obs.	63,456	63,456	63,456	63,456
R2	0.313	0.222	0.265	0.124
Concession FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Mean Dep. | Open Concession = 0	0.0086	0.0040	0.0059	0.0009

Notes High Dimensional Fixed Effects Linear regression. Robust standard error. ***,**,* = indicate significance at the 1, 5, and 10% level, respectively. Dependent variable in column (1) is a dummy variable indicating the occurrence of a generic ACLED event in a cell (panel A)/Interest Zone (panel B) - year. From column (2) to (4) we focus on specific types of ACLED events. In particular, in column (2) we look at "Violence against civilians", in column (3) at "Battles" and, finally, in column (4) at both "Protest" and "Riots". In panel A, *Open Concession* is a dummy variable indicating whether in that cell, in that year, there is at least one open concession. In panel B, instead, *Open Concession* is a dummy variable indicating whether the concession around which is constructed the interest zone is open in that year or not. In panel A we include Cell and Year FE. In Panel B Interest zone and Year FE.

3.6 Defining connections and links

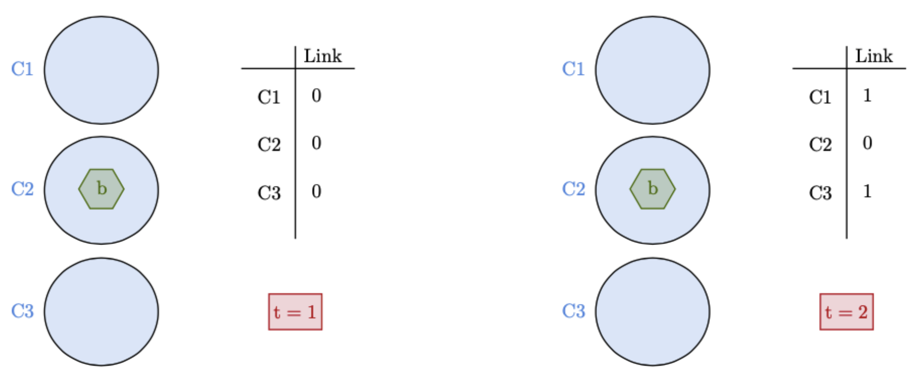
The goal of our empirical analysis is to study the pattern of contacts among concession owners and armed bands, and in particular to uncover whether such patterns are suggestive of a *repeated interaction* that may stem from a mutually advantageous collaboration. For this purpose, we define the following two terms.

Definition 1. An armed band b and concession owner o have a **contact** in Interest Zone i at time t if we observe a conflict event involving the band b in that Interest Zone at time t.

Definition 2. An armed band b and concession owner o have a **link** in Interest Zone i at time t if they had a contact at any time $t' < t$ in an Interest Zone $j \neq i$ operated by the same owner.

It is important to stress that our use of the term "link" in what follows will be literal in the sense of the above definition, hence it will only refer to interactions that happened *in the past* and in a *different* concession than the one being analyzed.[17] Figure 3 illustrates the definition of *link* with a simple example.

Figure 3: Links



The owner in Figure 3 has three Interest Zones: $C1, C2$, and $C3$. At time $t = 1$, we observe the armed band b in $C2$. Then, the dummy *link* will be equal to one from $t = 2$ onward, for all the Interest Zones of the same owner, apart from $C2$. Hence, the interest zone $C2$ in which the first contact between the armed band and the owner happened will have *link* equal to zero until there is another contact with the same band in another zone.

Over the period 2000-2015, we observe 679 different owners and 135 armed bands in our dataset. This leads to 91,665 possible combinations, of which 360 are actually observed in the data. In other words, there are 360 owner-band dyads characterized by at least one contact. Of these, 83 also have a *link*. Interestingly,

[17] We realize this is a somewhat atypical use of the word, but we adopt it as a way of avoiding lengthy sentences and repetitions.

all but one of these 83 dyads have contacts in more than one region, and 61 of them have contacts in more than two regions.

4 Results: mining companies and armed bands

4.1 Non-randomness of interactions

We start by establishing that the pattern of interactions between armed bands and concession owners significantly departs from what we would observe in a random network. A first way to do this is to compute the likelihood ratio index recently employed by Colonnelli et al. (2022), Eika et al. (2019), Chiappori et al. (2020). The idea is to compare the observed probability of observing a certain dyad with the probability one would obtain in the case of random interactions. In particular, for each owner $o \in O$ and band $b \in B$ we compute the following likelihood ratio:

$$LR = \frac{\mathbb{P}(O = o, B = b)}{\mathbb{P}(O = o)\ \mathbb{P}(B = b)} \tag{1}$$

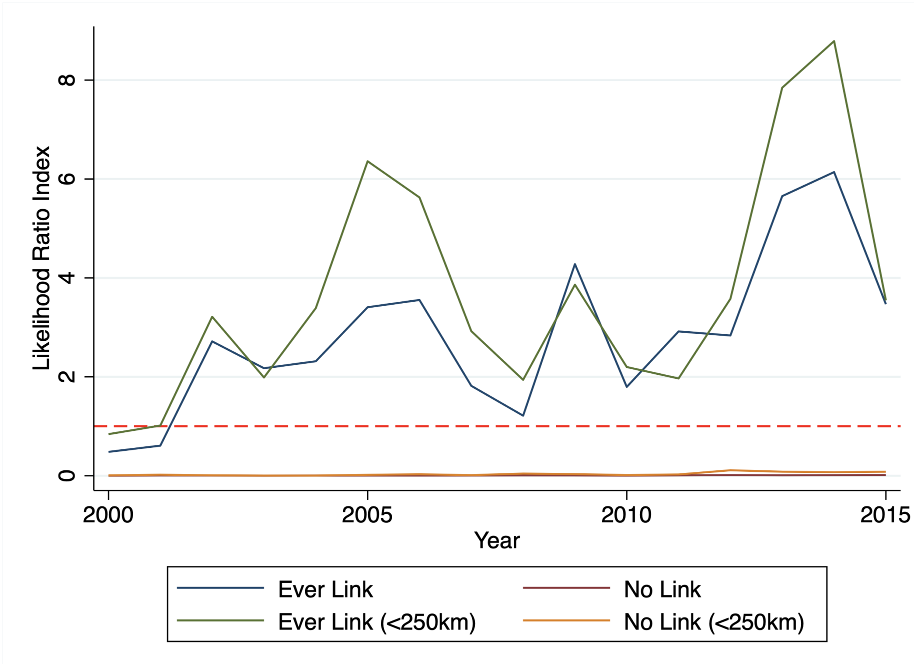
Under random interaction, $\mathbb{P}(O = o, B = b) = \mathbb{P}(O = o)\mathbb{P}(B = b)$ and the ratio is equal to 1. If the probability of observing the dyad is higher (lower) than in a random network, the ratio is greater (lower) than 1. The value of equation 1 calculated on the full sample is 0.009, and the evolution over time of this index is displayed in Figure A5.

However, the aggregate value of LR potentially masks an important heterogeneity. If it is true that the interactions between armed groups and mining forms respond to a logic of collaboration in a a repeated game, then we should observe the deviations from randomness to stem from those pairs that have already had contact in the past. To this purpose, we compute the ratio LR separately for dyads that ever experience a *link* and dyads that do not. The average value of LR for linked dyads is 2.83, while that for non-linked dyads is 0.006. If we further restrict the sample to include dyads with an initial distance shorter than 250 km (to account for geographical sorting), the values are 3.69 and 0.035, respectively. These values clearly suggest a deviation from randomness.

Figure 4 shows the temporal evolution of LR, reporting the values of equation 1 separately for linked and non-linked dyads, for the full sample and for "geographically close" sample.[18] One can immediately see that the LR index for linked dyads is consistently above 1 in almost all periods. Therefore, the probability of observing a pair that had a previous interaction elsewhere is significantly higher than under random matching. This is magnified when restricting the sample to geographically proximate (<250 km) armed bands. In this case the empirical probability of observing the dyad is *even more different* from the prob-

[18] Appendix Figure A6 reports the same estimates using distance in the previous period instead of initial distance. Results are very similar.

Figure 4: Likelihood Ratio test



Notes: The figure presents the likelihood ratio indexes for owner-band dyads with ever a link (blue), never a link (red), ever a link and closer than 250km (green), never a link and closer than 250km (yellow).

ability that would result from random interactions with the subset of bands that are located within the same perimeter. As we shall see below, this is already suggestive of the fact that the privileged relationship of an owner with a particular band makes it less likely that *different* armed groups engage in conflict events in the concession of that owner. Conversely, Figure 4 shows that the values of LR for non-linked dyads are very close to 0 throughout the period, both in the full sample and in the (geographically) restricted one. This means that we are *less likely* to observe non-linked owners and armed groups than in a completely random scenario.

Another way of detecting deviations from randomness is to look at the *number* of different armed bands with which mining companies have contact. Figure 5 shows the distribution of owners in the sample, with respect to the number of armed groups they have contacts with. We restrict the sample to owners with at least one contact (intensive margin). For the extensive margin, please refer to Figure A7 in the Appendix.

Panel (a) plots the true empirical distribution. 50% of the owners have contact with 1 or 2 armed groups over the period, 15% have contact with 3 groups, and beyond that the frequency decreases substantially. Panel (b) shows the distribution for *linked* owners. Almost 70% of the firms that have a previous contact with a group, end up having contact *only* with that group. This is a striking fact. Panel (c) shows the simulated distribution for a random network with a sample comparable to (a). To construct this random network, we randomly allocate contacts between owners and armed bands so that the resulting random network density ($\frac{\text{\# actual contacts}}{\text{\# potential contacts}}$) is the same as in the real one. This distribution is significantly more spread out than the one for the real network, and so is the distribution in Panel (d), where the random network is generated from the sample of linked owners.

One may argue that the higher concentration for the real link compared to the random one is an artifact of spatial concentration of certain owners and certain armed groups. To account for this possibility, in panels (e) and (f) we construct two alternative distributions. In Panel (e) we plot the distribution of contacts in a hypothetical random network restricting the sample of potential contacts to groups located closer than 250km to the owner in the first period in which they appear in the data. This restriction does not alter our findings: the empirical distribution in (a) remains significantly more skewed to the left compared to (e). In Panel (f) we use an alternative random network constructed by weighing the probability of contact inversely with respect to the initial distance between the owner's concession and the band.[19]

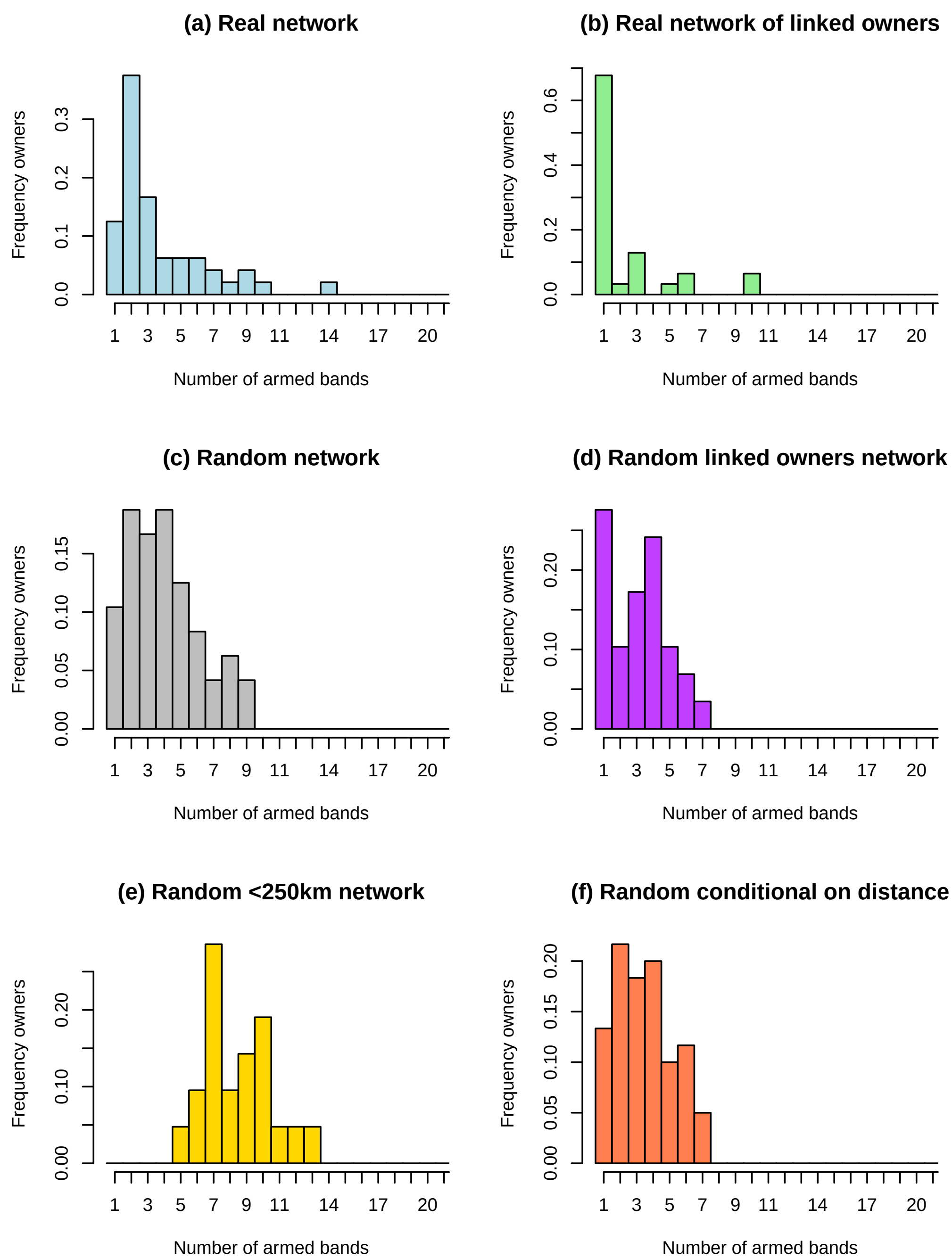
Again, the true distribution (a) is far more left-skewed than That in (f). These results clearly show that, owners in the real network have contact with significantly fewer armed groups than would be predicted in a random network, even when we take into account geographic proximity.

[19] Specifically, for the random network in Panel (f) the probability of a contact is:

$$1\text{-}\frac{log(\text{initial distance})}{log(\text{maximum initial distance})}$$

This implies that the probability of contact is higher, the closer the owner and the band.

Figure 5: Distribution contacts



Notes: The Figure presents the distribution of owners in the sample, with respect to the number of armed groups they have contacts with. An armed band b and a owner o have a contact at time t in the Interest Zone i if we observe a conflict event involving b in i at t. The sample is restricted to owners with at least one contact (intensive margin). For the extensive margin, please refer to Figure A7. In blue there is the true distribution. In green the distribution restricting the sample to owners with at least one link with an armed group. We say that an armed band b and an owner o have a link in the Interest Zone i at time t if they had a contact in the past, in another Interest Zone of the same owner.In gray we plot the distribution from a random network constructed allocating contacts between owners and armed bands such that the resulting random network density ($\frac{\text{\# actual contacts}}{\text{\# potential contacts}}$) is the same of the real one. In purple and yellow we plot the same distribution restricting the sample to groups closer than 250 and 500 km respectively in the first period. In red we plot the distribution from a random network constructed tacking into account the geographic dimension of the interaction where the probability of having a contact is $1 - \frac{log(\text{initial distance})}{log(\text{maximum initial distance})}$.

4.2 Repeated interactions

Motivated by the above evidence, we proceed to explore the dynamic pattern of contacts between mining firms and armed groups. We start by testing the following conjecture. If concession owners and armed bands have a relationship based on repeated interaction, then having a *link* should be predictive of subsequent contact even in a different location. To investigate this, we estimate the linear probability model:

$$\text{Contact}_{iobt} = \alpha + \beta \text{ Link}_{iobt} + X'_{iobt}\gamma + \mu_i + \mu_b + \mu_t + \epsilon_{iobt} \tag{2}$$

where the dependent variable takes value one if we observe a conflict event involving band b, in interest zone i owned by firm o at time t, and zero otherwise. The main explanatory variable of interest is Link_{iobt}, a dummy indicating whether owner o and band b have a *link* at time t in Interest Zone i. Recall that having a *link* means that there was a conflict event involving the same band and the same owner in a *different* interest zone in the past. Controls X_{iobt} include total population in the area, nightlights, rainfall, and the logarithm of the distance between the centroid of the concession and the location where the armed band was observed for the first time; μ_i represents Interest Zone fixed effects, μ_b armed band fixed effects, and μ_t year fixed effects. We adjust standard errors for clustering at the Interest Zone level.[20]

Table 3 reports the estimates from this model, including different sets of controls. Columns (1) and (2) show that having a *link* is positively associated with the probability of observing the armed band in a different concession operated by the same owner. The magnitude of the coefficient is very large: having a *link* increases the contact probability 247 times relative to the sample mean with no *link*. Although not all concessions owned by the same firm are close to each other, distance of the armed band from the concession may be an omitted variable, creating bias in the estimates of columns (1) and (2). To deal with this issue, in columns (3) to (6) we control for the *Initial distance* (in logs) between the band and the owner. As described in section 3.4, *Initial distance* is the distance between the centroid of the Interest Zone of owner o considered at t and the location of the armed band when it was *first* observed anywhere in Congo.[21] In column (4), in addition to initial distance, we also control for other important determinants of conflicts, including the population in the Interest Zone, the average rainfall, and the average night luminosity.

To account for a potentially highly nonlinear role of distance, in column (5) we restrict the sample to those armed bands that were *within 250 km* (155 miles) of the Interest Zone centroid the first time they were observed. The average probability of observing an unlinked armed band increases drastically, as expected (from 0.00007 in columns 1-4 to 0.00042 in column 5). However, linked bands still have a significantly higher probability of being observed in the owner's Interest Zone. In column (6), we restrict the sample to Interest Zones that experience at least one contact with any armed band during the sample period. The probability of observing the linked band, after the *link* takes place, is still significantly

[20] Table A6 shows robustness to other standard error adjustments.

[21] In Table A5 we replicate Table 3 using two alternative measures of distance: (i) distance in the *previous* period, and (ii) distance from the *last* location where the armed band has been observed. Results are very similar.

Table 3: Links and probability of observing the armed band

Dep. Variable:	*Contact* = 𝟙 { armed band observed in Interest Zone of concession at *t* }						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Link	1.740***	1.735***	1.722***	1.722***	1.630***	5.521***	
	(0.237)	(0.240)	(0.239)	(0.239)	(0.404)	(0.839)	
Initial Distance (log)			-0.0186***	-0.0186***	-0.229***	-0.195***	-0.0268***
			(0.00420)	(0.00420)	(0.0450)	(0.0357)	(0.00458)
Placebo link							0.0849
							(0.0567)
Obs.	3968470	3968470	3968470	3968470	260005	260064	3968470
R2	0.00841	0.0144	0.0144	0.0144	0.0314	0.0407	0.259
Concession FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Armed Band FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Population, Rain, Nightlights	No	No	No	Yes	Yes	Yes	Yes
Sample	Full	Full	Full	Full	<250km	Ever Band	Full
Mean Dep. | Link = 0	0.0070	0.0070	0.0070	0.0070	0.0425	0.1087	0.0070

Notes: High Dimensional Fixed Effects Linear regression. Standard errors clustered at the interest zone level in parentheses. ***,**,* = indicate significance at the 1, 5, and 10% level, respectively. The dependent variable is a dummy indicating a generic ACLED event in the interest zone involving the armed band.To ease the reporting of the estimates, coefficients and mean dependent variable are multiplied by 100. Model (5) restricts the sample to armed bands closer than 250km from the interest zone considered in the previous period. Model (6) restricts the sample to Interest Zones with at least one contact over the entire sample (an armed band b and a owner o have a contact at time t in the Interest Zone i if we observe a conflict event involving b in i at t). Proximity begin is a measure of how close were the concession and the band the first time we observe the latter. Link is a dummy variable indicating whether, at time t, in Interest Zone i, the owner of the concession and the armed band have a link. We say that an armed band b and an owner o have a link in the Interest Zone i at time t if they had a contact in the past, in another Interest Zone of the same owner. Model (7) uses a placebo version of Link that is equal to 1 before the actual link takes place. Table A5 replicate this table using two alternative measures of distance: (1) distance in the previous period, (2) distance from the last location in which the armed band has been observed.

higher, about 50 times relative to the benchmark mean. Finally, in column (7) we conduct a falsification test creating a "placebo link". This variable is equal to 1 for linked bands, but *before* the *link* takes place. Reassuringly, the coefficient on the placebo link is more than one order of magnitude smaller and not statistically significant.

In Appendix Table A6 we replicate column (3) of table 3 with different fixed effects and standard error adjustments. Our results are robust whether we cluster standard errors at the (i) owner level, (ii) region level, (iii) armed band level, or use (iv) heteroskedasticity robust standard errors. Moreover, the estimates are virtually the same whether we use (v) Interest × Band and Year FE, (vi) Interest, Band, and Region × Year FE, (vii) Interest and Year FE, (viii) Region and Year FE.

To corroborate the causal interpretation of the coefficient on the variable *Link*, we conduct an event study and estimate the probability of observing an armed group immediately before and immediately after the *link* takes place. Let $t = 0$ the time in which the *link* is first formed. Our regression model is:

$$\text{Contact}_{iobt} = \alpha + \sum_{t=-5}^{t=-2} \beta_t \text{Link}_{iobt} + \sum_{t=0}^{t=10} \beta_t \text{Link}_{iobt} + X'_{iobt}\gamma + \mu_i + \mu_b + \mu_t + \epsilon_{iobt} \quad (3)$$

where variables are defined as in equation 2 and we omit $t = -1$ from the controls because we use the year prior to establishing the *link* as reference category.

Figure 6 reports the estimated β's and the associated 95% confidence intervals. Panel A considers the full sample of armed bands, and Panel B restricts the sample to bands within 250 km of the concession (to account for geographic proximity). The value 0 on the horizontal axis refers to the year when the contact between a concession owner o and an armed group b *first* occurs, in a concession different from i. Values to the left (right) of 0 represent years before (after) that moment. The vertical axis measures the effect of the *link* on the probability of observing band b in concession i operated by o. Figure 6 clearly shows that the effect of being *linked* on the probability of contact is positive only for the years *after* the *link* is established (and not before). This is true both in the full and in the restricted sample.[22] These results increase our confidence in interpreting the coefficient of *Link* in Table 3 in a causal way.

To further investigate how the effect of having a *link* changes with the distance between the concession and the armed band, we estimate the model in column (2) of Table 3 interacting the variable *link* with dummies corresponding to different distance bins. Figure 7 displays the point estimates and the associated 95% confidence intervals. We find that having a *link* is *always* associated with a higher probability of observing the armed band, and the point estimates do not decline as sharply as one may expect, event at large distances. This suggests that spurious correlation driven by owner-band pairs that independently locate in the same geographical area is unlikely to drive the effect of having previous contacts on the probability of current contact.[23]

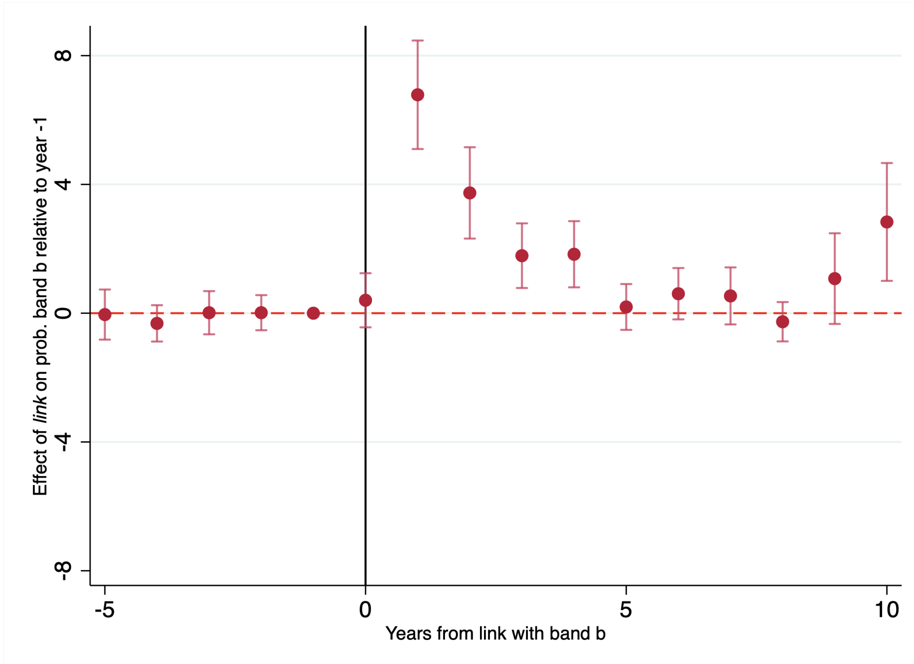
The estimates in Table 3 and Figures 6 and 7 have two implications. First, having a *link* contributes to the probability of observing a conflict event involving the armed band, no matter the distance between the concession and the armed band. Second, armed bands are quite mobile once they have a *link* with a certain owner. We next try to understand why this repeated interaction across locations is observed and, in particular, whether it may simultaneously benefit concession owners and armed bands.

[22] The fact that the magnitude of the coefficients is larger in Panel A compared to Panel B is intuitive, if one thinks that the reference category in panel A are bands that may be located very far away from the concession, while in Panel B they are bands that are geographically proximate, hence have a higher intrinsic probability of contact.

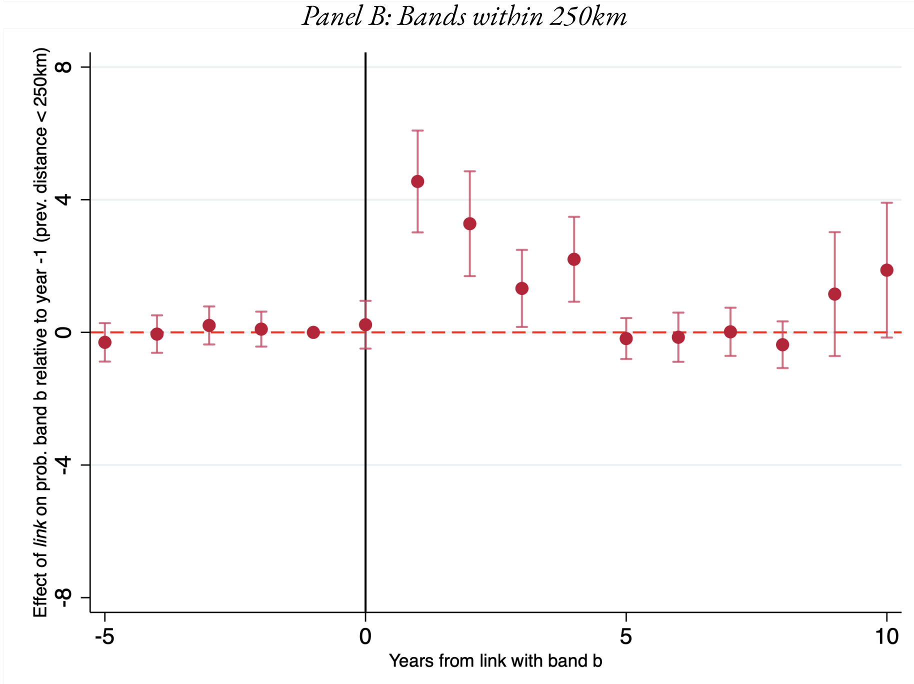
[23] Appendix Figure A4 decomposes the coefficient of *link* into the expected probability of observing a linked band and that of observing an unlinked band, and shows that the latter is virtually zero in almost all distance bins.

Figure 6: Event study: probability of observing *linked* band

Panel A: Full sample

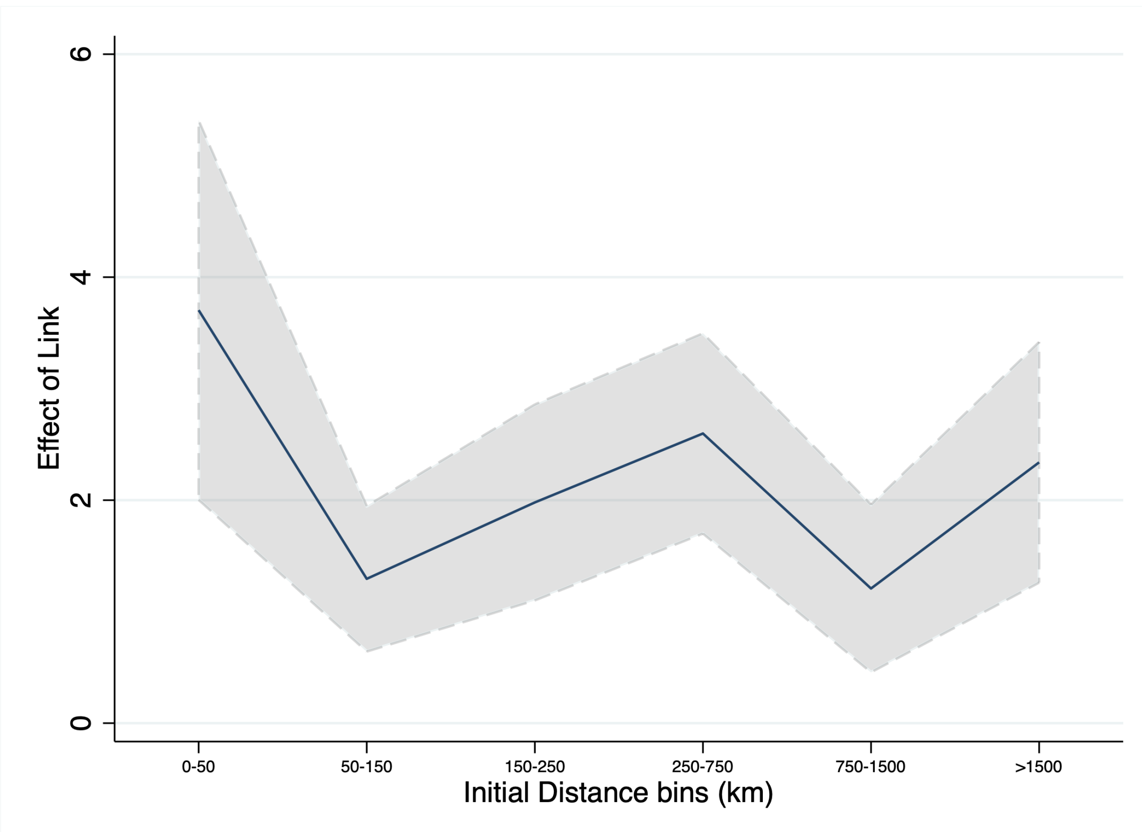


Panel B: Bands within 250km



Notes: Notes: The figure reports the estimated coefficients β_t from equation 3 with 95% confidence intervals. Panel A considers the full sample of armed bands, and Panel B restricts the sample to bands within 250 km of the concession. On the horizontal axis, $t = 0$ represents the year in which armed band b is first observed in a concession $j \neq i$ operated by owner o (*Link*). The point estimates on the vertical axis represent the differential probability of observing *linked* band b versus an unlinked band, relative to the year before the *link* is established. Standard errors clustered at the interest zone level. Coefficients are multiplied by 100. We control for Concession, Band, and Year FE, log distance between the centroid of the concession and the location the first time we observe the armed group in the sample, rainfall, nightlights and population in the Interest Zone.

Figure 7: Effect of *link* at different distances



Notes: The figure presents the 95% confidence intervals together with the point estimate of the coefficient of *link* in model (2) of Table 3, interacted with different bins of *Initial distance*. Coefficients are multiplied by 100. *Initial distance* is the distance between the centroid of the Interest Zone and the location where we observe the armed band for the first time.

4.3 The "protective" role of armed bands

The anecdotal evidence presented in section 2 suggests that armed groups may behave like private-security forces for mining companies. In the DRC landscape, characterized by a wide presence of rebel groups, as well as illegal artisanal miners, enjoying the protection of a strong armed group may be quite profitable for private companies. Different concessions of the same owner may face different pools of armed groups. This increase the uncertainty faced by the mining firm, and the potential benefits from having a repeated relationship with one of these groups. In this section we explore this idea through a variety of empirical tests.

We start by estimating the event study regression in (2), but looking at *links* with *different* bands from the one being considered. In other words, we estimate:

$$\text{Contact}_{i,o,t,b} = \alpha + \sum_{t=-5}^{t=-2} \beta_t \text{Link}_{i,o,t,-b} + \sum_{t=0}^{t=10} \beta_t \text{Link}_{i,o,t,-b} + X'_{iobt}\gamma + \mu_i + \mu_b + \mu_t + \epsilon_{i,o,t,b} \quad (4)$$

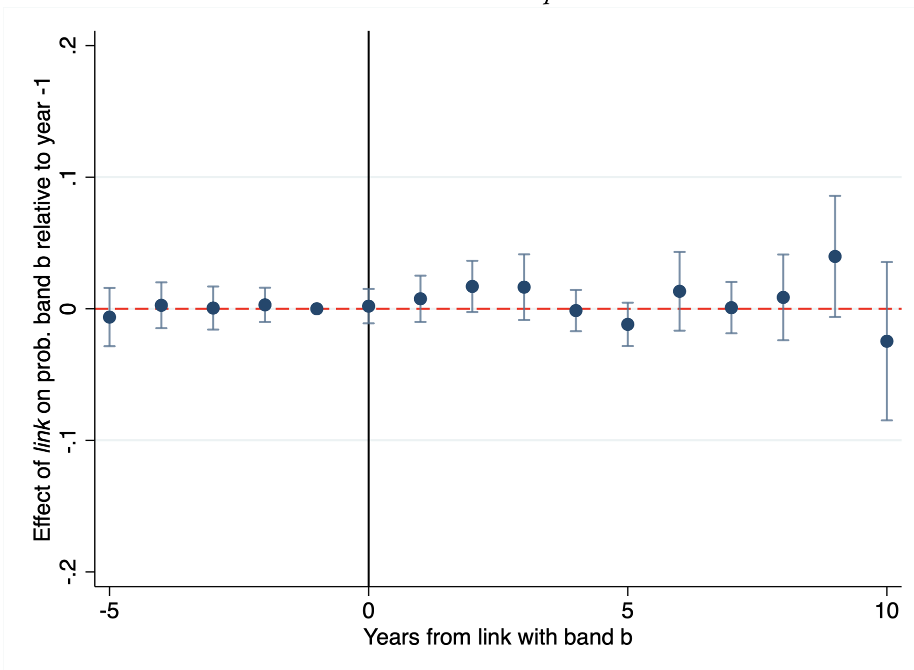
where the subscript $-b$ refers to armed bands other than the one being considered in the dependent variable. The results are displayed in Figure 8, in panel A using the full sample of bands, and in panel B restricting to bands within 250 km of the concession. We see no significant effect in the full sample, likely because this includes armed groups also very far away from the concession considered. However, when we move to bands closer to the concession, the coefficients become negative and significant for all $t > 0$. This means that, once an owner establishes a *link* with band b in a certain concession, there is a lower probability of observing bands *different from* b in *other* concessions operated by the same owner.

Jointly considered, Figure 6 and Figure 8 previously discussed suggest that, after a *link* is made, there is a higher probability of observing the linked band, and a lower probability of observing other armed bands close to the concession. This, in turn, leads to a very left-skewed distribution of owners' contacts with respect to a random network, as we saw in Figure 5.

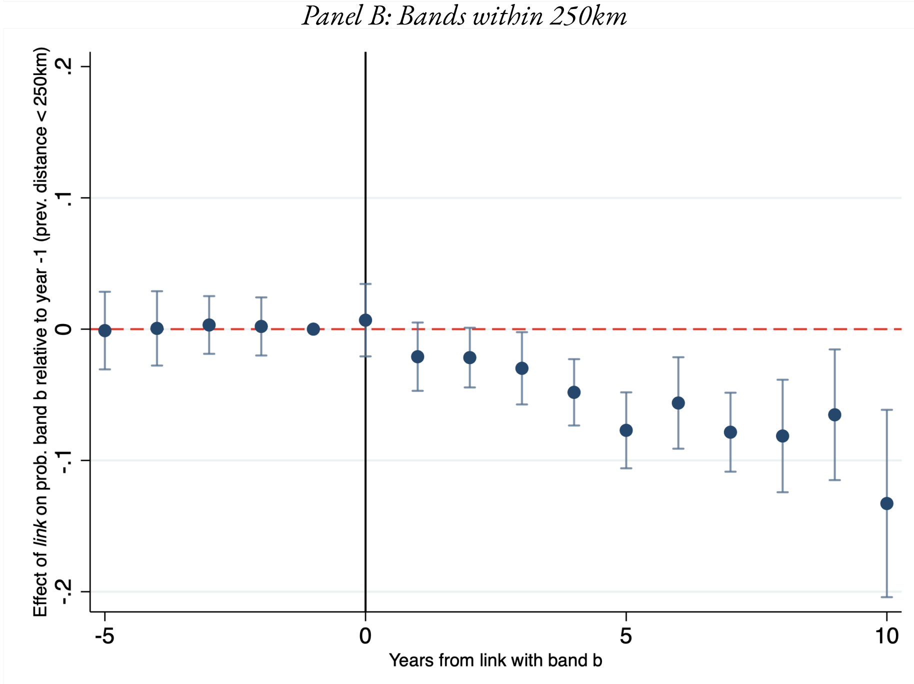
A second piece of evidence on the nature of the relationship between concession owners and linked bands can be gathered by looking at how the coefficient of the variable *Link* in regression 2 varies with the number of armed groups present in the area. From the owner's point of view, having a preferential relationship with an armed band that may serve a "protective" role should be more valuable, the higher the number of rival groups located close to the concession. In Figure 9 we plot the coefficient and 95% confidence intervals for the variable *Link* in model (3) of Table 3 for different bins of the number of bands closer than 250 km in the first period of contact with the concession owner. For completeness, the shaded histogram bars in the figure show the percentage of the sample falling within each bin. As one can see, the

Figure 8: Event study link - Other bands

Panel A: Full sample



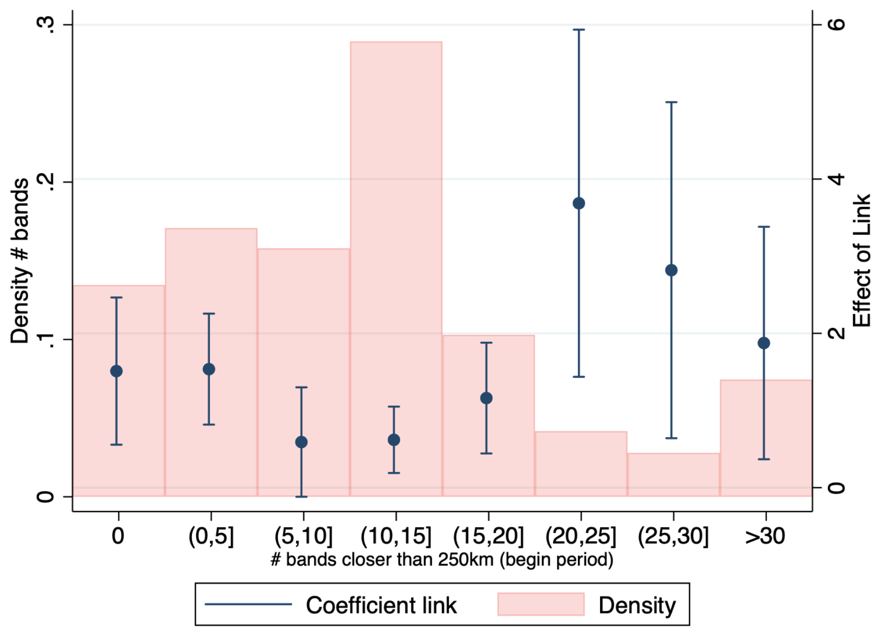
Panel B: Bands within 250km



Notes: Notes: The figure reports the estimated coefficients β_t from equation 4 with 95% confidence intervals. Panel A considers the full sample of armed bands, and Panel B restricts the sample to bands within 250 km of the concession. On the horizontal axis, $t = 0$ represents the year in which armed band b is first observed in a concession $j \neq i$ operated by owner o (*Link*). The point estimates on the vertical axis represent the differential probability of observing *linked* band b versus an unlinked band, relative to the year before the *link* is established. Standard errors clustered at the interest zone level. Coefficients are multiplied by 100. We control for Concession, Band, and Year FE, log distance between the centroid of the concession and the location the first time we observe the armed group in the sample, rainfall, nightlights and population in the Interest Zone.

magnitude of the coefficient on the variable *Link* increases when the number of rival bands exceeds 20, consistent with the above conjecture.

Figure 9: Link's effect over number of close bands



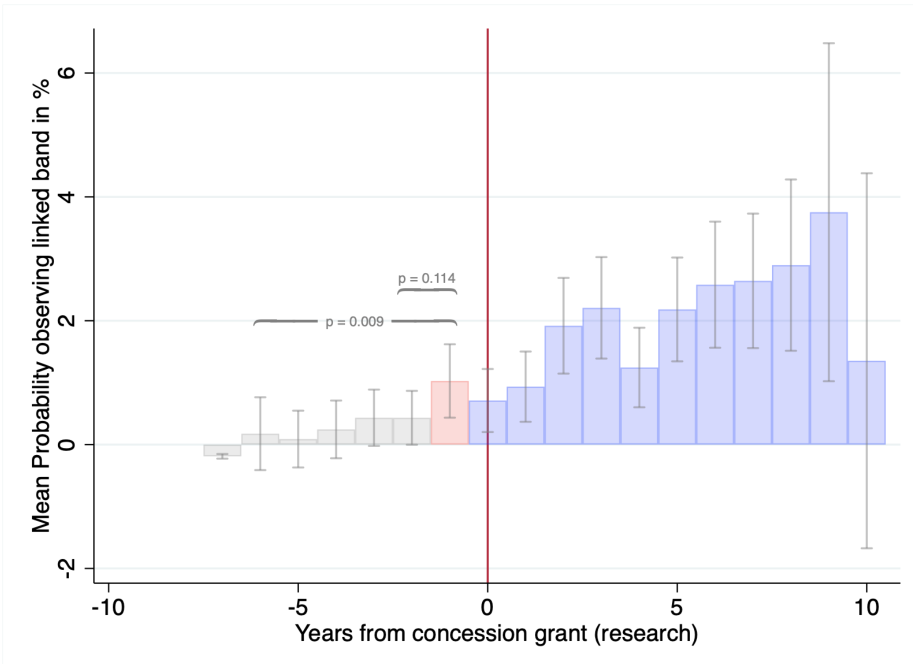
Notes: The figure presents the 95% confidence interval together with the point estimate of Link's coefficient (in blue) in model (3) of Table 3 restricted at different bins of the number of bands close to the Interest Zone the first time we observe them in the sample. Coefficients are multiplied by 100. We say that an armed band is close to the Interest Zone if the distance between the centroid of the latter and the location the first time we observe the armed group in the sample is lower than 250km. In red we plot the percentage of the sample in each bin.

One may interpret the above results as driven by the fact that the band itself may be trying to extract mineral resources in a given concession, and the decrease in the number of different bands may be indicative of the fact that the band is successful in defending their extraction area from others. However, this interpretation does not explain why such an effect would apply to *linked* bands relative to other bands. If a local band is effective in displacing other bands, having had a contact with that specific owner *somewhere else in the country* should not necessarily imply a higher fighting success. Anyway, in what follows we propose two additional pieces of evidence that more clearly point to the potential for a mutually advantageous interaction between concession owners and armed groups.

Our third empirical fact establishes how the probability of observing the linked armed group changes with the bureaucratic timing of the concession. In this case we focus only on *research* concessions, as these represent the first point of entry of a company in a given mining area. In Figure 10 we plot the probability of observing the linked band over the years with respect to the granting of the research concession

($t = 0$).[24] As we can see, up to one year before the granting of the concession this probability is very low, and not statistically different from zero. The probability becomes positive and significant in the year *before* the actual granting of the concession. This coefficient is statistically different from all previous periods pooled together (it is not statistically different from the period -2).[25]

Figure 10: Probability linked band



Notes: This Figure presents the mean probability, together with 95% confidence intervals, of observing the linked armed group b (in percentage) within the Interest Zone i of the owner o, for different years relative to the opening of the concession. Sample restricted to research concessions only. We say that an armed band b and an owner o have a link in the Interest Zone i at time t if they had a contact in the past, in another Interest Zone of the same owner. An armed band b and a owner o have a contact at time t in the Interest Zone i if we observe a conflict event involving b in i at t. We control for Concession, Band, and Year FE, log distance between the centroid of the concession and the location the first time we observe the armed group in the sample, rainfall, nightlights and population in the Interest Zone. Figure 11 replicates this focusing only on battle events in Panel A, and only on violence against civilians ones in Panel B.

This *anticipation* effect is consistent with the anecdotal evidence presented in section 2: mining companies may be using their relationships with armed groups to "clear the way" from other bands, before the company opens the concession. To interpret the same effect as resulting from an uncoordinated initiative of the armed band one should assume that (i) the armed band has an interest in attacking the concession of an owner with whom they had a previous link before that concession actually opens, and (ii) they are

[24] As usual, we control for Concession, Band, and Year FE, distance between the centroid of the concession and the location the first time we observe the armed group in the sample, rainfall, nightlights and population in the Interest Zone. Note that the X axis here differs from the previous event study figures. While before we were comparing before/after the establishment of a link, here we are comparing before/after the granting of a research concession.

[25] Similar results are obtained if we look a the effect of having a link (Figure A8).

able to predict when exactly the research concession for that area will be granted to that owner. While not impossible, this does not seem a highly plausible scenario.

The last piece of evidence to corroborate the "security" interpretation exploit variation in the type of conflict event observed the year before the opening of the concession. If anticipation is driven by the necessity of the owner to deal with the other groups located close to the future concession, then we should observe the *linked* armed band to be more likely to engage in battles with other groups, rather than in other types of violence. In Figure 11 we replicate Figure 10 restricting the sample to battles (panel A) and violence against civilians (panel B).

Figure 10 clearly shows that the anticipation result is completely driven by battle events. The probability of observing the linked armed group engage in battles in an area increases significantly the year before the research concession is granted for that area. The effect is statistically different from all previous periods, and not different from subsequent periods. Interestingly, there is no anticipation when we turn to violence events (panel B).[26] This pattern is consistent with our conjecture.

4.4 The "destabilizing" role of armed groups

While the above results are consistent with the idea that repeated interactions with selected armed groups may be used by concession owners to protect mining sites from competing armed groups, this may not be the only mechanism at play. If this were the case, we should observe a lower incidence of conflict events after a link is formed, due to the security provided by the armed group. However, this is not the case.[27] In this section we explore the idea that *linked* armed groups may purposefully increase instability in the surroundings of the concession, in a way that is beneficial to the firm. Chaotic periods, instability, and conflict may be beneficial for extractive firms (Guidolin & La Ferrara, 2007, Sonno & Zufacchi, 2022). Uncertainty may limit the regulatory attention of central government, facilitate massive extraction of natural resources, and decrease labor costs in a way that will become clear.

To study this mechanism, for each concession we decompose the associated Interest Zone in two areas. The reason for this is to differentiate between the area the owner would like to protect, in order to make the extraction of minerals as efficient as possible, and another area that is sufficiently close to the concession but potentially not directly used for extraction. This is the area where some degree of violence and looting may indirectly benefit the mining firm, for example by destroying the means of livelihood of the local population and inducing them to supply cheap labor to the mines. Violence in these surrounding areas also limits the extent to which external actors and monitors may get close to the mines.

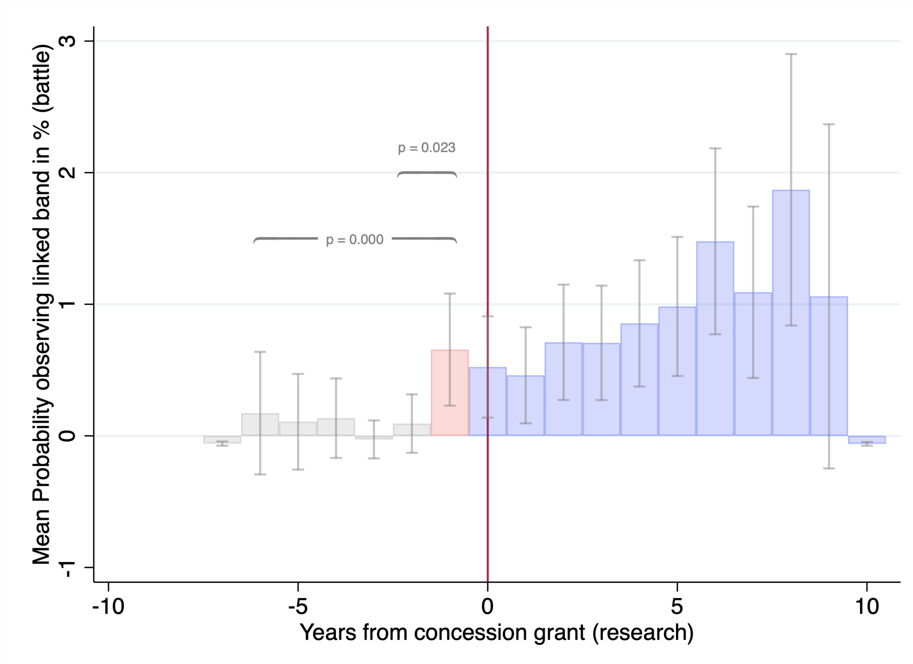
Figure 12 illustrates the way in which we construct these areas. Recalling that most concessions have a

[26] Results are similar when we look at the effect of a *Link* on the probability of observing the armed group engage in battle events (Figure A9).

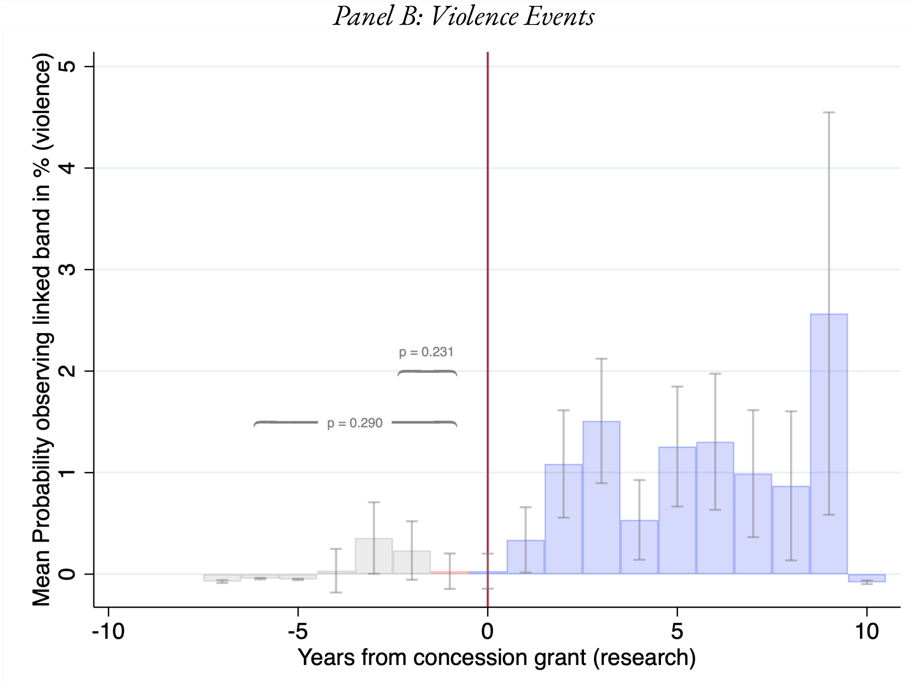
[27] The average probability of observing any armed group is 6.17% for linked concessions, after the link, 0.48% for non linked ones, and 1.21% for linked ones before the links takes place.

Figure 11: Probability linked band - battle and violence events

Panel A: Battle Events



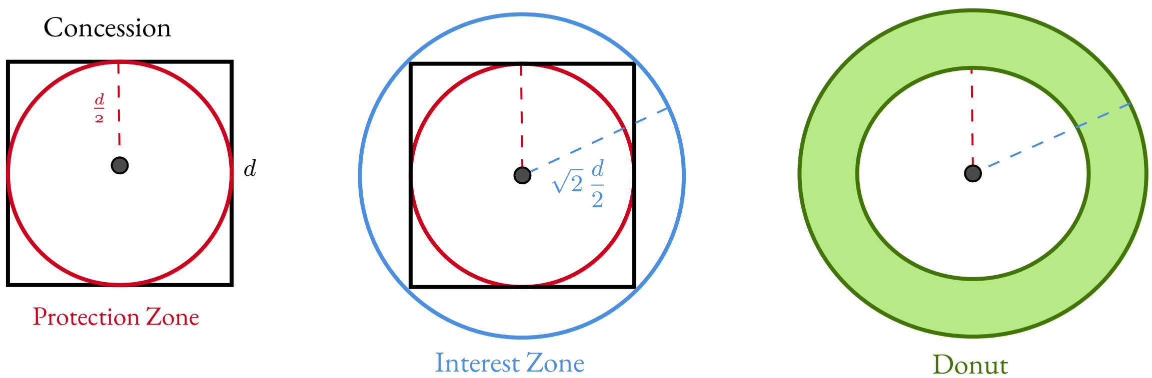
Panel B: Violence Events



Notes: This Figure presents the mean probability, together with 95% confidence intervals, of observing the linked armed group b (in percentage), involved in battle events (panel A), or violent events (panel B), within the Interest Zone i of the owner o, for different years relative to the opening of the concession. Sample restricted to research concessions only. We say that an armed band b and an owner o have a link in the Interest Zone i at time t if they had a contact in the past, in another Interest Zone of the same owner. An armed band b and a owner o have a contact at time t in the Interest Zone i if we observe a conflict event involving b in i at t. We control for Concession, Band, and Year FE, distance between the centroid of the concession and the location the first time we observe the armed group in the sample, rainfall, nightlights and population in the Interest Zone.

square shape, we inscribe a circle in the square and denote it as *Protection zone* (in red in the figure). This is the area that the owner would like to protect from conflict, in order to ensure a smooth operation of productive activities. This area is centred in the centroid of the concession and has a diameter equal to the average side length of the concession. The blue circle around the concession is what in section 3 we defined as *Interest zone*, and is the geographical unit used in the analysis so far. Tacking the difference between the two, we obtain what we denote as the *Donut zone* (the green shaded area in the figure). Section 5 discusses the sensitivity of our results to different definitions of Protection and Donut zones. Appendix Figure A10 maps the distribution of Donut zones, color coded based on their population in 2009.

Figure 12: Protection, Interest and Donut zones



If violence is used strategically by armed groups to create instability without disrupting productive activities, we should observe a higher probability of observing the armed group engage in conflict in the Donut zone than in the Protection zone. We therefore estimate the effect of having a *link* on the probability of observing the armed group in these two different areas. Our results are reported in Figure A11 and Table 4.

Figure A11 shows that *linked* bands are more likely to be observed than non-linked ones in both Donut and Protection zones, but they are significantly more likely to be found in Donut zones (p-value 0.02).[28]

In Table 4 we reshape our data so that we observe each concession-band dyad, in each year, in both areas.[29] Columns (1) and (3) show that the average probability of observing an armed group in the Donut zone is marginally higher than in the Protection zone.[30] However, this average effect masks an important heterogeneity. Column (2) shows that *linked* groups have an overall higher probability of being observed near the concession of the owner with whom they have the *link*, and this probability is even higher in

[28]In Figure A12 we control for distance in the first period, Concession, Year and Band fixed effects. Results are unchanged.
[29]Appendix Table A7 shows the results splitting the sample.
[30]The magnitude of the coefficient is 14% of the mean and the effect is significant at the 10 percent level.

Table 4: Link donut vs protection

	(1)	(2)	(3)	(4)
Donut	0.00103*	0.000295	0.00103*	0.000304
	(0.000575)	(0.000412)	(0.000576)	(0.000412)
Link		0.793***		
		(0.0735)		
Link × Donut		0.192*		0.192*
		(0.106)		(0.106)
Obs.	7936940	7936940	7936940	7936940
R2	0.0243	0.0328	0.5460	0.5460
Concession FE	Yes	Yes	No	No
Armed Band FE	Yes	Yes	No	No
Year FE	Yes	Yes	No	No
Concession × Band × Year FE	No	No	Yes	Yes
Population, Rain, Nightlights, Initial Distance (log)	Yes	Yes	No	No
Mean Dep. | Link = 0	0.0036	0.0036	0.0036	0.0036

Notes: High Dimensional Fixed Effects Linear regression. Standard errors clustered at the interest zone level in models (1)-(2), and interest,year,band level in models (3)-(4) in parentheses. ***,**,* = indicate significance at the 1, 5, and 10% level, respectively. The dependent variable is a dummy indicating a generic ACLED event in the Interest zone involving the armed band. To ease the reporting of the estimates, coefficients and mean dependent variable are multiplied by 100. Link is a dummy variable indicating whether, at time t, in Interest Zone i, the owner of the concession and the armed band have a link. We say that an armed band b and an owner o have a link in the Interest Zone i at time t if they had a contact in the past, in another Interest Zone of the same owner. An armed band b and a owner o have a contact at time t in the Interest Zone i if we observe a conflict event involving b in i at t. Donut is a dummy variable indicating the Donut zone with respect to the Protection one.

the Donut area relative to the Protection one (alhough the coefficient is only significant at the 10 percent level). The magnitude of this increase is particularly relevant. The average probability of observing the linked group is 221 times higher than the sample mean in the Protection area, and approximately 273 times higher in the Donut one. Hence, there is a 23% increase in the effect of having a link in the Donut relative to the Protection zone. Results are virtually unchanged when we directly compare Donut and Protection area with a Concession × Band × Year fixed effect, as shown in column (4).

In the last part of this section we explore the idea that repeated interaction between concession owners and armed groups may be beneficial to the former if the instability directs cheap labour towards the concession. If this were the case, the effects of having a *link* on the probability of contact should be higher, the higher the population in the Donut area. In Table 5 we introduce an interaction term between the *Link* dummy and the population of the area at the beginning of the sample.[31] As one can see in columns (1)-(3) the effect of a *link* on the probability of observing the armed group is increasing in population size in all the areas. In column (1), a one standard deviation increase in population is associated with a 50% increase in the effect of *Link*. In columns (7) and (8), where the data is reshaped, we see that the interaction effect between *link* and initial population is significantly higher in the Donut zone than in the Protection

[31] We use initial population to mitigate endogeneity concerns that would arise if the local population moved in response to the presence of armed bands. In Appendix Table A8 we replicate Table 5 using population in the same period (Panel A), and its time lag (Panel B). Results are very similar.

one. The is consistent with the interpretation that the higher the potential benefits from instability for the owner, in terms of cheap labour, the higher is the probability that an armed group that had a previous contact with the same concession owner (*Link*) is observed exerting violence in the area around the concession.

Table 5: Link and Population

	Different zones			Donut vs Protection	
	(1)	(2)	(3)	(4)	(5)
	Interest	Donut	Protection	-	-
Link	1.167***	0.555***	0.541***	0.547***	
	(0.229)	(0.174)	(0.125)	(0.0682)	
Link × Population Begin	0.403**	0.346**	0.208***	0.212***	
	(0.175)	(0.173)	(0.0768)	(0.0413)	
Donut				0.000240	0.000234
				(0.000414)	(0.000414)
Link × Donut				0.00451	-0.117
				(0.104)	(0.111)
Population Begin × Donut				0.00254**	0.00130
				(0.00109)	(0.000993)
Link × Population Begin × Donut				0.136**	0.239***
				(0.0684)	(0.0678)
Obs.	3968470	3968470	3968470	7936940	7936940
R2	0.0167	0.0140	0.00933	0.00950	0.539
Concession FE	Yes	Yes	Yes	Yes	No
Armed Band FE	Yes	Yes	Yes	Yes	No
Year FE	Yes	Yes	Yes	Yes	No
Concession × Band × Year FE	No	No	No	No	Yes
Rain, Nightlights, Initial Distance (log)	Yes	Yes	Yes	Yes	Yes
Mean Dep. | Link = 0	0.0070	0.0038	0.0035	0.0036	0.0036

Notes: High Dimensional Fixed Effects Linear regression. Standard errors clustered at the interest zone level in models (1) to (6), and interest,year,band level in models (7)-(8) in parentheses. ***,**,* = indicate significance at the 1, 5, and 10% level, respectively. The dependent variable is a dummy indicating a generic ACLED event in the Interest zone (1),(4),(7),(8), Donut zone (2),(5), Protection zone (3),(6), involving the armed band. To ease the reporting of the estimates, coefficients and mean dependent variable are multiplied by 100. Link is a dummy variable indicating whether, at time t, in Interest Zone i, the owner of the concession and the armed band have a link. We say that an armed band b and an owner o have a link in the Interest Zone i at time t if they had a contact in the past, in another Interest Zone of the same owner. An armed band b and a owner o have a contact at time t in the Interest Zone i if we observe a conflict event involving b in i at t. Donut is a dummy variable indicating the Donut zone with respect to the Protection one. Table A8 replicates this using using population in the same period (Panel A), and its time lag (Panel B).

5 Sensitivity analysis

In this section, we discuss how our results compare to those obtained using IPIS data, instead of ACLED, to measure the presence of armed groups in mining concessions. We then perform some sensitivity analysis changing the geographical definition of our areas of interest. To conclude, we conduct a placebo exercise using links formed with other owners.

5.1 Validation of ACLED-based location of armed groups

In our analysis, we track armed groups by using the "actor" information contained in ACLED. This implies that we observe an armed band in a location only if it is involved in a conflict event in that location. A legitimate concern is that this may induce selection in our data. In particular, this would be problematic if involvement of armed bands in conflict events responded endogenously to the opening of a concession, the distance from the latter, and their potential relationships with mining companies. In this section we validate our method of identifying contact using ACLED with an alternative that does not require the armed group to be involved in conflict in order to be observed. This is possible thanks to the data collected by IPIS. As discussed in section 3.2, IPIS visited several artisanal small mines (ASMs) over the period 2009-2015 and, for each ASM, they recorded whether one or more armed bands were present and their name.[32] Hence, we can observe the location of armed groups in the IPIS data even when they are not involved in any conflict event.

We observe 26 distinct bands in the IPIS data. For these bands, we compare the location provided by IPIS and the location derived using ACLED. In particular, we calculate the distance between the two. Figure A18 plots the distribution of the 3-year moving average of this distance. As one can see, the distribution is quite left-skewed. 87% of the observations are within 50 km (31 miles). The average "distance error" is approximately 30km (red line), which is very low if compared with distance measures we use in the paper. The median distance (blue line) is even smaller, approximately 25km. As a result, it seems we are not committing a large error in approximating the location of armed bands using conflict events. This is likely due to the fact that most of the times, when armed bands are present in an area, they commit some form of violence (either against other armed actors or against civilians), hence we observe them in ACLED.

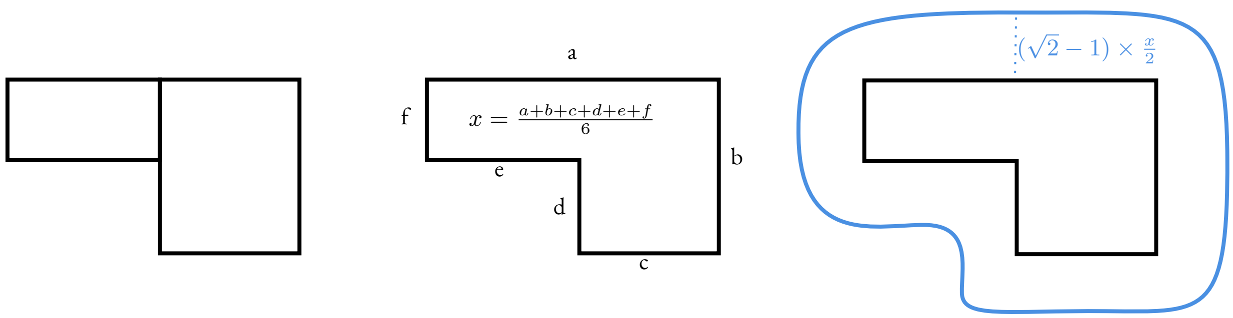
To further explore the reliability of our approach, we replicate our main results from Table 3 restricting our sample to the 26 bands present in both datasets (Panel A) and comparing the estimated effect of *links* when the location of the band is determined using IPIS data (Panel B). Results are shown in Table A9. We find that the two methods yield consistent results. This suggests that selection may not be a significant problem in our case.

[32] The map of the ASMs visited is shown in Figure A17.

5.2 Alternative definition of zones

As one can observe in Figure A2, concessions are typically adjacent. This will determine an overlap of Interest Zones and may lead to distortion in our estimates. Another feature that can be noticed in the same map is that some concessions don't have a perfect squared shape. For this reason, *Interest*, *Protection* and *Donut* zone defined as above may led to an imprecise definition of production zones. This subsection tackles both limitations with a new definition of the zones created for the analysis. In particular, we first merge all sideways concessions of the same owner, treating them as a single one. Then, we use the concession as a whole as a Protection zone. Consequently, the Donut zone is no longer a circular area, but rather follows the shape of the merged concession. Figure 13 shows an example of how these new zones are constructed. Their location and distribution over the DRC territory is mappedn in Figure A13.

Figure 13: New zones



Suppose for simplicity that the owner under consideration has only two adjacent concessions, the rectangles in the leftmost part of Figure 13. The first step of our new approach is to merge them into a single one: this larger concession will be the new *Protection* zone. Then, we compute the average length of the sides of the concession.[33] We use this measure to construct the *Donut* zone (the blue line in the figure), respecting the ratios we used for our benchmark definition of Donut zones in the main analysis. Recall that in the benchmark definition, the radius of the Interest zone was $\sqrt{2}\frac{d}{2}$. Hence, the Donut zone was the locus of points within a distance of $(\sqrt{2}-1)\frac{d}{2}$ from the border of the Protection circumference. Therefore, in the new definition, the Donut zone is the locus of pints with distance of $(\sqrt{2}-1) \times \frac{\text{average side}}{2}$ from the border of the "merged" Protection zone. The new Interest Zone is of course the sum of the new Donut and Protection zones.

Using these new definitions, we replicate the main results from the previous sections and show the new estimates in Table 6.[34] All results are consistent with what we found before, except for the coefficient on

[33] This is the sum of all the sides divided by the number of sides: in Figure 13, it is $(a+b+c+d+e+f)/6$.

[34] In particular, columns 1-3 in the new table correspond to columns 2, 5 and 6 in Table 3), where the distance threshold in

the interaction between *Link* and number of armed bands (column 6), which is not statistically different from zero. The magnitude of the effects is also comparable, when assessed in relative terms to the mean of the dependent variable. Finally, Appendix Figure A14 replicates the anticipation result of Figure A8, showing a very similar pattern.

Table 6: Sensitivity new zones

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Link	2.966***	3.472***	6.659***			3.132***	0.768***		2.551***	
	(0.453)	(1.060)	(1.144)			(0.529)	(0.145)		(0.403)	
Link other band				-0.0941***	-0.710***					
				(0.0268)	(0.203)					
Link × # Bands close						-0.00175				
						(0.00240)				
Initial Distance (log)	-0.00277	-0.00720	-0.0159							
	(0.00400)	(0.0437)	(0.0309)							
Donut							0.0145***	0.0145***		0.0145***
							(0.00106)	(0.00106)		(0.00106)
Link × Donut							1.324***	1.325***		1.155***
							(0.268)	(0.268)		(0.259)
Link × Population Begin									0.834	
									(0.526)	
Population Begin × Donut										0.0317***
										(0.00321)
Link × Population Begin × Donut										0.576***
										(0.196)
Obs.	2534103	62698	326601	2534103	62698	2534103	5068206	5068206	2534103	5068206
R2	0.0116	0.102	0.0266	0.00618	0.0984	0.0116	0.00747	0.535	0.0136	0.536
Concession FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Armed Band FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Concession × Band × Year FE	No	No	No	No	No	No	No	Yes	No	Yes
Population, Rain, Nightlights, Initial Distance (log)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Sample	Full	$<$ 500km	Ever Band	Full	$<$ 500km	Full	Full	Full	Full	Full
Mean Dep. | Link = 0	0.0202	0.0.1317	0.1579	0.0202	0.1317	0.0202	0.0105	0.0105	0.0202	0.0105

Notes: High Dimensional Fixed Effects Linear regression. Standard errors clustered at the interest zone level in models (1) to (7) and (9), and interest,year,band level in models (8) and (10) in parentheses. ***,**,* = indicate significance at the 1, 5, and 10% level, respectively. The dependent variable is a dummy indicating a generic ACLED event in the Interest zone involving the armed band. To ease the reporting of the estimates, coefficients and mean dependent variable are multiplied by 100. Link is a dummy variable indicating whether, at time t, in Interest Zone i, the owner of the concession and the armed band have a link. We say that an armed band b and an owner o have a link in the Interest Zone i at time t if they had a contact in the past, in another Interest Zone of the same owner. An armed band b and a owner o have a contact at time t in the Interest Zone i if we observe a conflict event involving b in i at t. Donut is a dummy variable indicating the Donut zone with respect to the Protection one. # Bands close is the number of armed groups closer than 500km to the concession's centroid the first time we observe them. Link other band is a dummy variable indicating whether the owner of the concession has a link with another armed group. In this table we replicate the higher probability of observing the linked armed group - (1) to (3) - (Table 3), the comparison of this effect between the two zones - (7) and (8) - (Table 4), and the interaction with the population dimension - (9) and (10) - (Table 5). We also replicate in a synthetic way the specialization result (Figures 6, ??, ?? and 8) by running the following regression:

$$\text{Band}_{i,o,t,b} = \alpha + \beta\text{Link}_{i,o,t,-b} + X'_{iobt}\gamma + \mu_i + \mu_b + \mu_t + \epsilon_{i,o,t,b}$$

Results are shown in column (4). In column (5) we restrict the sample to armed groups closer than 500km to the centroid of the concession the first period we observe them in the sample, in the same fashion we did in Figures ?? and 8. In column (6) we replicate the third empirical fact.

column 2 is increased to 500 km (310 miles), due to the larger size of the newly defined Interest Zones. Columns 4 and 5 in Table 6 reproduce in an alternative way the result displayed in Figure 8; and column 6 in Table 6 is a parsimonious version of Figure 9. Columns 7 and 8 in Table 6 correspond to columns 2 and 4 in Table 4; and columns 9 and 10 correspond to columns 1 and 5 in Table 5.

5.3 Placebo links

Our last exercise is a falsification test where we use two alternative definitions of "placebo links". The first, *Link with another owner*, is a dummy variable equal to 1 if band b had a contact, in a previous period, with a **different** concession owner. However, these owners may have very distant concessions, and this variable may pick up armed groups that are too far away. The second variable, *Link with another owner close*, takes value 1 if band b had a contact, in a previous period, with a different owner in a concession **closer than 50 km**. Hence, the latter definition captures armed groups that are close to the concession being considered, but had previous contacts with *other* owners.

We start by replicating Figure A11 for these two definitions of placebo links. The results are shown in Figure A15. We detect a higher probability of observing the armed band only when there is a *real* link between the band and the owner (rightmost part of the graph). With both definitions of placebo links, as well as without any link, the probability of observing the armed band is virtually zero. Moreover, the average probability of observing the armed group is higher in the Donut zone relative to the Protection zone only when we consider real links.[35]

As with the sensitivity exercise, we then proceed to replicate all main results of the previous sections using these two definitions of placebo links. The specifications follow the same structure as in Table 6. Results are shown in Appendix Table A10.

6 Conclusions

In this paper, we have explored the interactions between rebel groups and mining firms in the Democratic Republic of Congo over the period 2000-2015. We have combined data on position, ownership, and characteristics of mineral concessions with conflict data from ACLED, which allows us to track the position over time of armed groups. In particular, we have adopted a "forensic economics" approach to uncover a pattern of potentially mutually advantageous repeated interactions. The main pieces of evidence in this respect are the following:

- The number of different armed bands with which a firm has contact over the period is significantly lower than what would be predicted by random matching, also if we account for geographic proximity;
- Previous contact between a concession owner and an armed band predicts subsequent contact in *other* concessions of the same owner, even if located very far from the initial one;
- The presence of a previously linked armed band on a concession makes it more likely that we see different armed bands on that concession, after (but not before) the link is established;

[35] Appendix Figure A16 displays the same results controlling for distance, as well as Concession, Year, and Band fixed effects.

- We see an increase in violence involving a band with a previous link to an owner, during the year before the concession is granted. This is driven by battle events, possibly because the band is "preparing the territory" and clearing it from rival bands;
- The probability of observing violent events involving a band with a previous link to an owner is higher in the area immediately surrounding the "core" of the concession than where extraction actually takes place. This is consistent with a destabilizing effect of armed bands, that intimidate the local population in a way that may induce them to provide cheap labor to the mines. In fact, the effect we find is stronger, the higher the population density in this surrounding area.

It is important to underline that none of the above results "proves" the existence of a cooperative relationship between armed bands and mining firms. Our point is that it is unlikely, though not impossible, that the systematic pattern of associations that we uncover is generated by chance. Ours is a statistical approach, although ample anecdotal evidence by advocacy groups and human rights organizations (some of which we reference in section 2), points to mechanisms very consistent with the patterns we find.

The DRC is a country with immense mineral resources and holds the largest reserves in the world of minerals that are crucial for contemporary and future technological investments (e.g., coltan). Yet almost none of the wealth generated by mineral extraction goes to benefit the local population, which still lives in poverty for the most part. The reason is often blamed on low state capacity and "ethnic" fighting among rival armed groups. Our paper is an attempt to dig deeper into the political instability generated by these groups, and the interplay between their incentives and those of the large scale extractive industry. Further research is needed on this topic.

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Appendix

A Congolese Mining Code

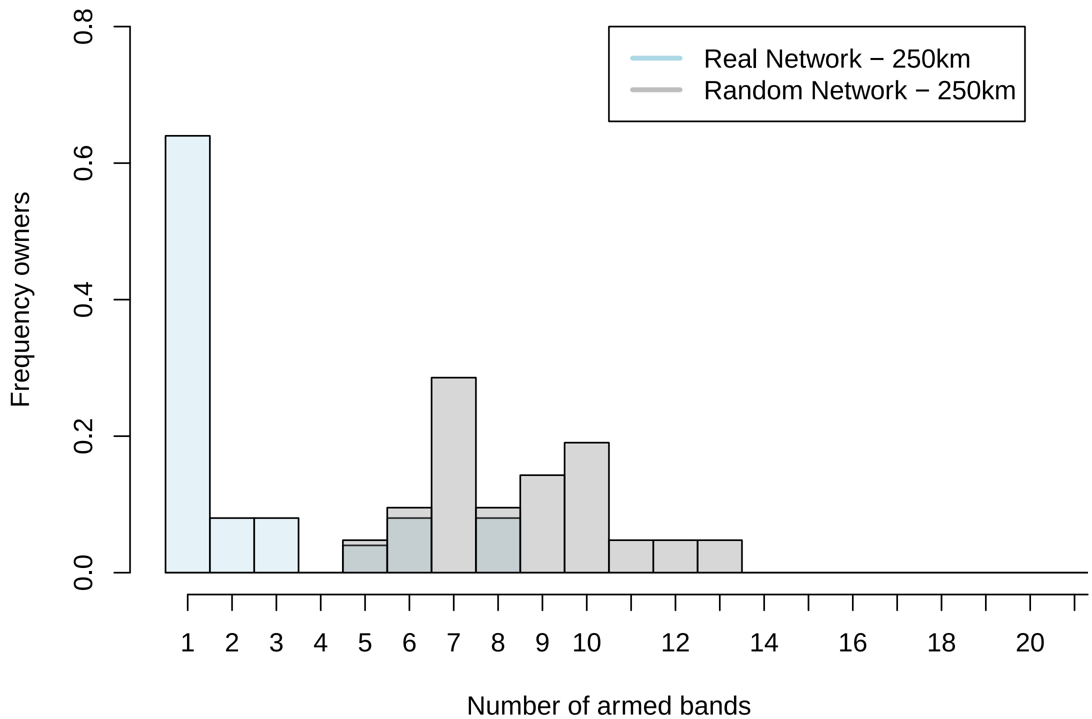
The legal framework active in the majority of our time span is the Congolese Mining Code (Law no. 007/2002), enacted in 2001 and enforced since January 2002. This new mining code deals with three general aspects of minerals extraction: (1) Dimension of miners and participation of Congolese's companies; (2) Typology of permits; (3) Taxes and Royalties. Let us touch upon these points briefly in order.

Article 104 of the code stipulates that small-scale miners (investment less than $2m and not exceed 10Y of operation) must operate through a Congolese company where local investors must own 25% or more of the share of capital. In all other cases, usually, multinational companies create joint ventures project for research and extraction of minerals with state-owned enterprises (*Gecamines*, in particular). Three different types of permits were created. First, "Research permit". These are concessions for the research of minerals. The maximum mining area granted for a research permit is 400 km2, while the maximum mining area held by one person and his/her affiliated companies is 20000 km2. It can be obtained in a maximum of 47 calendar days from the date of filing the request. It is granted for four years for precious stones and 5 for other minerals. The holder of a research permit must commence the exploration activity within five months from the date of issue of the permit. Second, "Exploitation permit". Instead, these permits allow for the extraction of minerals and can be obtained in a maximum of 252 calendar days. To obtain an exploitation permit, the party is required to transfer 5% carried interest to the government. There are three types of exploitation permits according to the dimension of the investments in the exploitation activity. The higher the investment, the longer the concession duration and the probability of getting a renewal. Last, "Artisanal mining permits". These are areas dedicated to artisanal miners. In line with the central government objectives, a very low amount of them have been released. A 2015 survey (here the report) found that, in the eastern part of the country, out of 2000 mines visited, only 15 were allocated to artisanal mining.

Mining companies have to pay a mixture of taxes and royalties. They are first of all subject to a professional tax of 30% of net profits. Then they have to pay a tax on the surface of the mining area (this tax is higher for exploitation permits) and an annual area fee per square km. Finally, mining companies are required to pay a mining royalty from the date of commencement of effective exploitation. Nevertheless, there are several preferential tax rates for mining companies (fully exempt from all custom duties and other taxes for exports concerning the mining project, all goods, and products imported for mining purposes before the effective commencement of exploitation work is subject to import duties at the preferential rate of 2%, they subjected to a preferential rate of 3% for the purchase of locally manufactured products for mining activities, a preferential Mining Code rate of 5% applies to services received by the mining companies that are directly related to their corporate purpose).

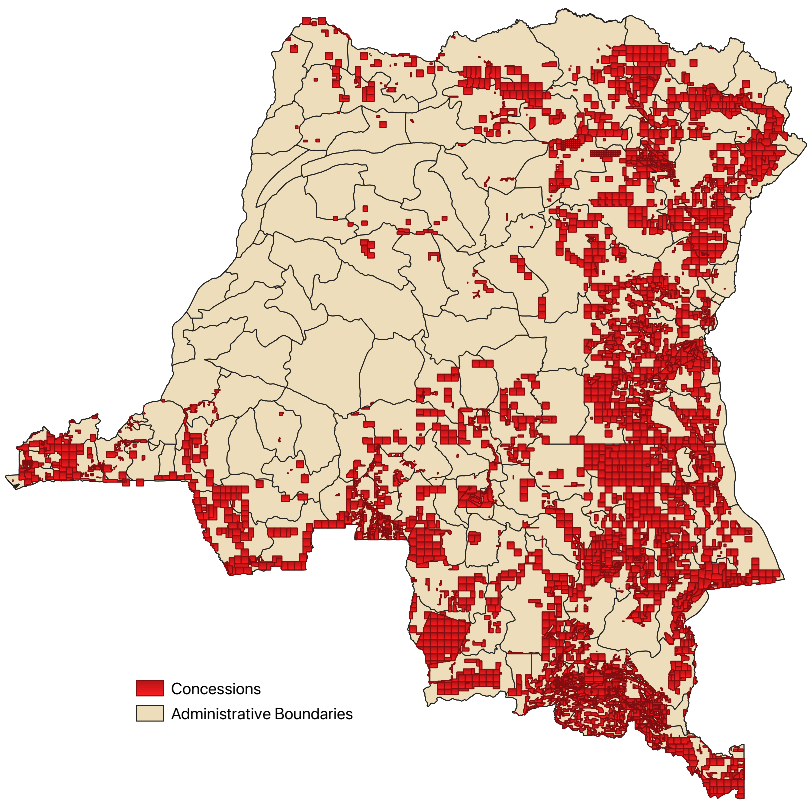
B Extra Graphs

Figure A1: Contacts real and random network - distance < 250km



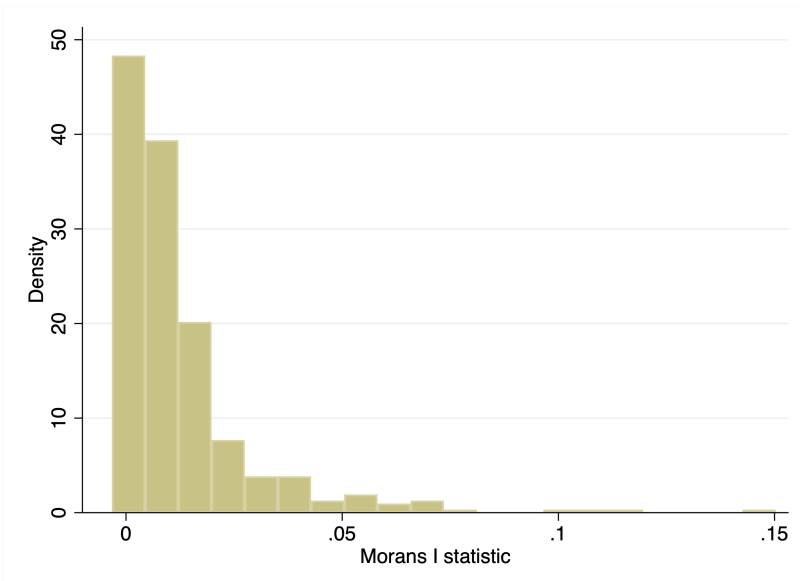
Notes: The Figure presents the distribution of owners in the sample, with respect to the number of armed groups they have contacts with. An armed band b and a owner o have a contact at time t in the Interest Zone i if we observe a conflict event involving b in i at t. The sample is restricted to owners with at least one contact (intensive margin) and armed bands closer than 250km to the concession the first time we observe them. For the extensive margin, please refer to Figure A7. In blue we show the true empirical distribution. In gray we plot the distribution from a random network constructed allocating contacts between owners and armed bands such that the resulting random network density ($\frac{\text{\# actual contacts}}{\text{\# potential contacts}}$) is the same as in the real one.

Figure A2: Map of Concessions



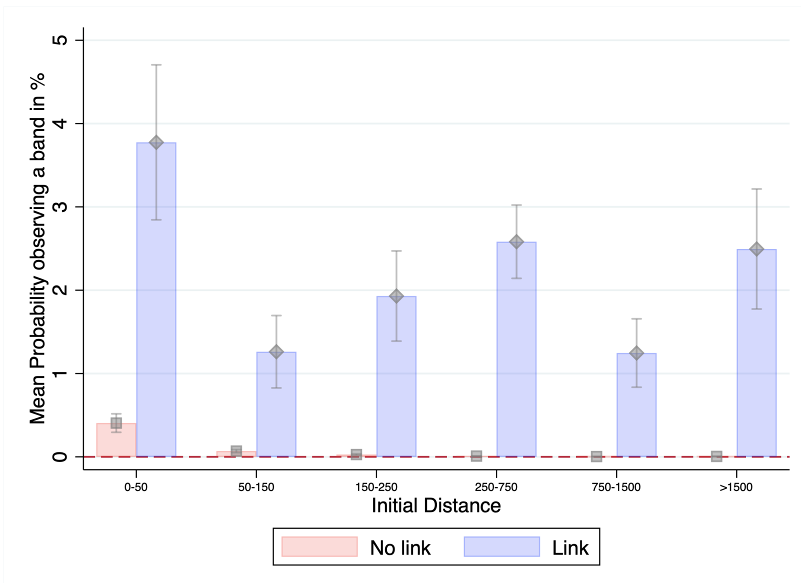
Notes: The figure presents mining concessions in the Democratic Republic of Congo (in red) together with administrative boundaries.

Figure A3: Distribution Morans I statistics



Notes: The figure presents the distribution of Morans I statistics computed for each owner.

Figure A4: Link and Distance thresholds - Decomposition

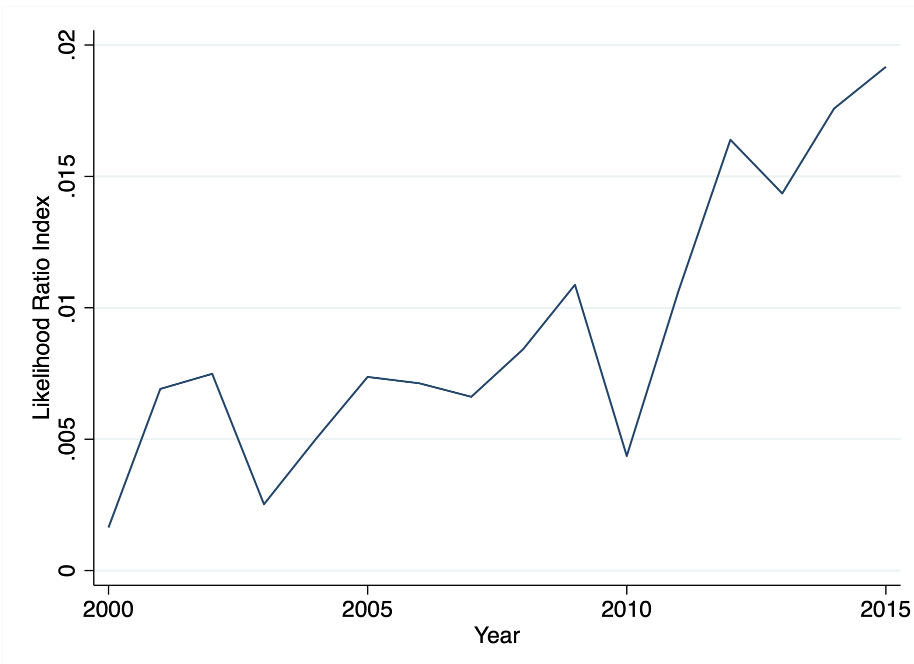


Notes: This figure decompose Figure 7 in the two components of the link coefficient:

$$\beta = \mathbb{E}[\text{Contact}_{iobt}|\text{Link}_{iobt} = 1, X_{iobt}] - \mathbb{E}[\text{Contact}_{iobt}|\text{Link}_{iobt} = 0, X_{iobt}]$$

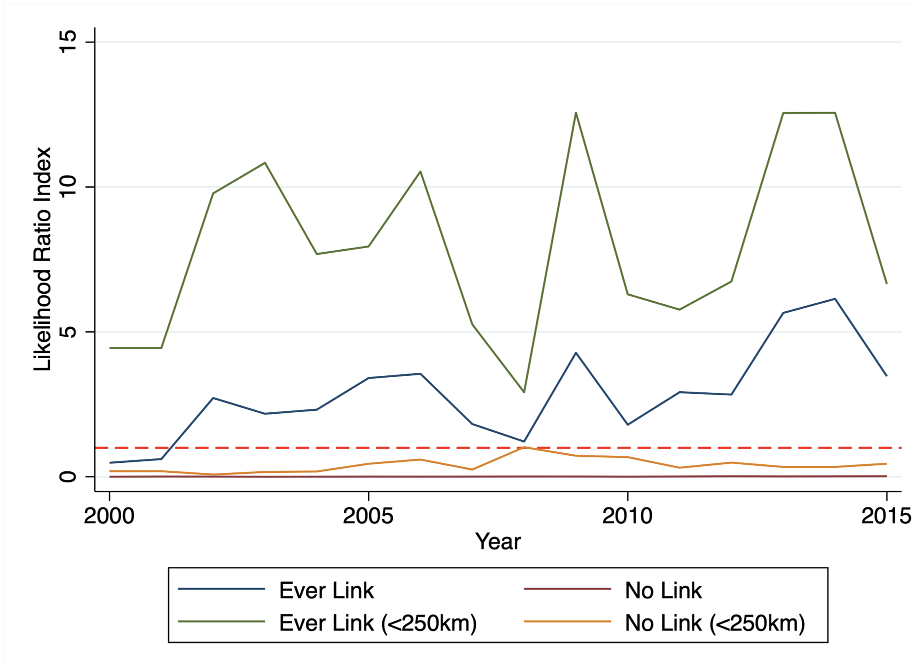
Hence, the figure presents the mean probability, together with 95% confidence intervals, of observing an armed band b (in percentage), with link (in blue), and without link (in red), in the Interest Zone i of owner o for different bins of Distance begin. We say that an armed band b and an owner o have a link in the Interest Zone i at time t if they had a contact in the past, in another Interest Zone of the same owner. An armed band b and a owner o have a contact at time t in the Interest Zone i if we observe a conflict event involving b in i at t. Distance begin is the distance between the centroid of the Interest Zone and the location we observe for the first time the armed band over the period from 2000 to 2015. As one can see, results shown in Figure 7 are entirely driven by $\mathbb{E}[\text{Contact}_{iobt}|\text{Link}_{iobt} = 1, X_{iobt}]$, while $\mathbb{E}[\text{Contact}_{iobt}|\text{Link}_{iobt} = 0, X_{iobt}]$ is virtually zero in almost all distance bins. Therefore the probability of observing the linked armed group is more or less stable across different distance bins.

Figure A5: Likelihood Ratio test - Full sample



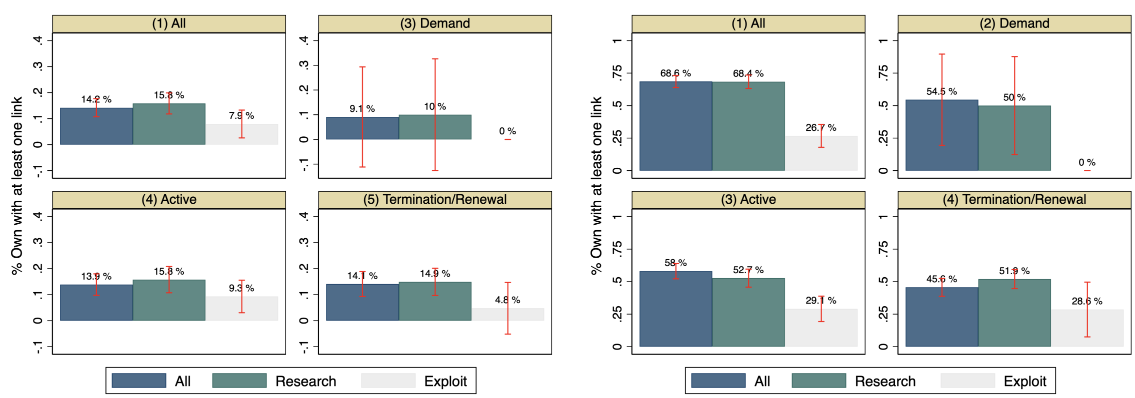
Notes: The figure presents the likelihood ratio indexes for owner-band dyads.

Figure A6: Likelihood Ratio Test - Distance Previous Period



Notes: The figure presents the likelihood ratio indexes for owner-band dyads with ever a link (blue), never a link (red), ever a link and closer than 250km (green), never a link and closer than 250km (yellow).

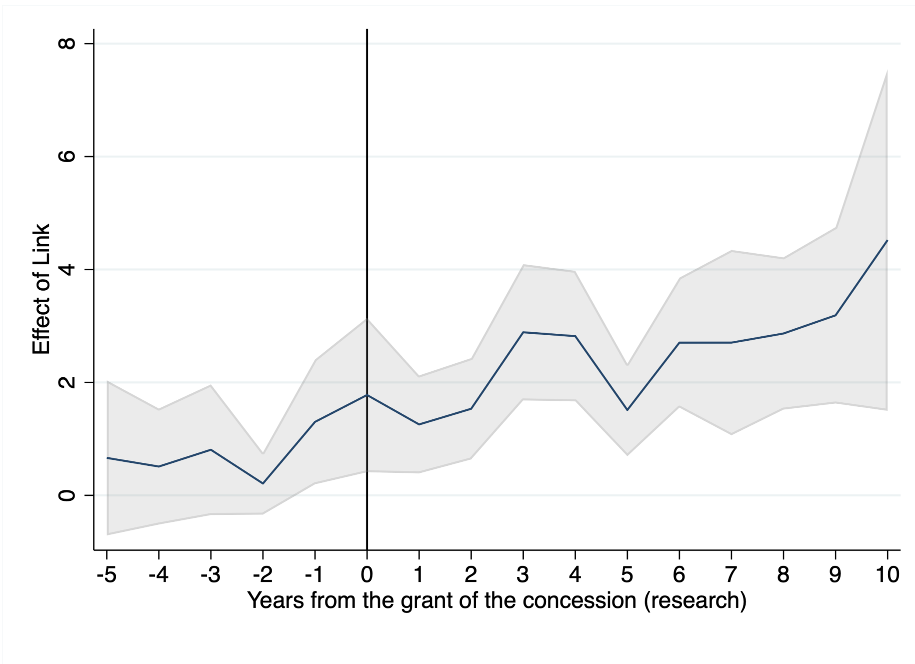
Figure A7: Owner contacts - Extensive Margin



Data Residual

Notes: These figures present the frequency of owners with at least one contact with an armed band. An armed band b and a owner o have a contact at time t in the Interest Zone i if we observe a conflict event involving b in i at t. In sub-figure (b) we control for Region FE. Each sub-figure is divided in four graphs. Graph (1) considers all concessions, (2) only those in the demand phase, (3) only those active and (4) those in the termination/renewal phase. Finally, in each graph three frequency are shown: (i) comprehensive one, (ii) considering only research concessions and (iii) considering only exploitation concessions.

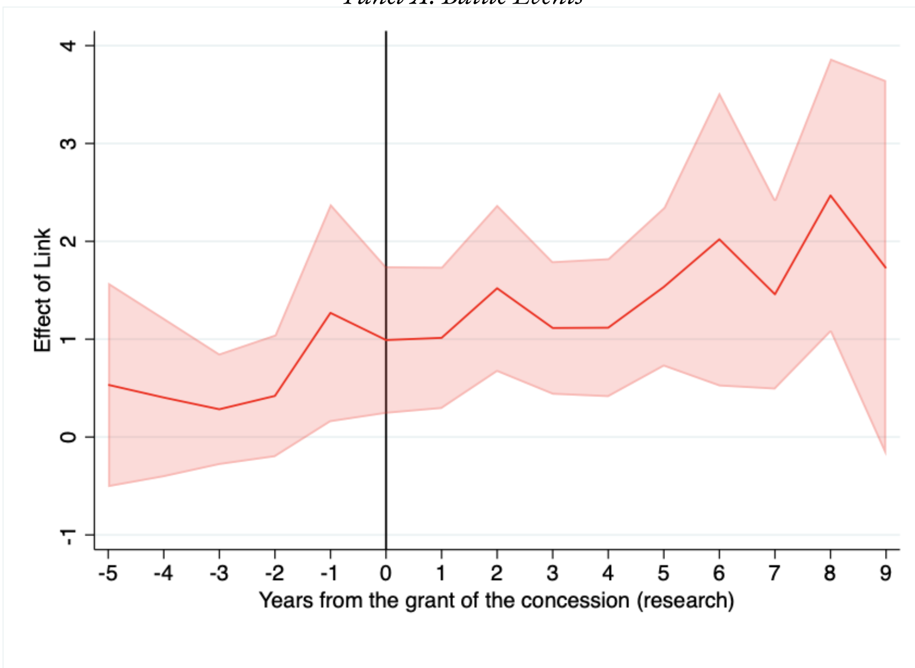
Figure A8: Link and opening of the concession



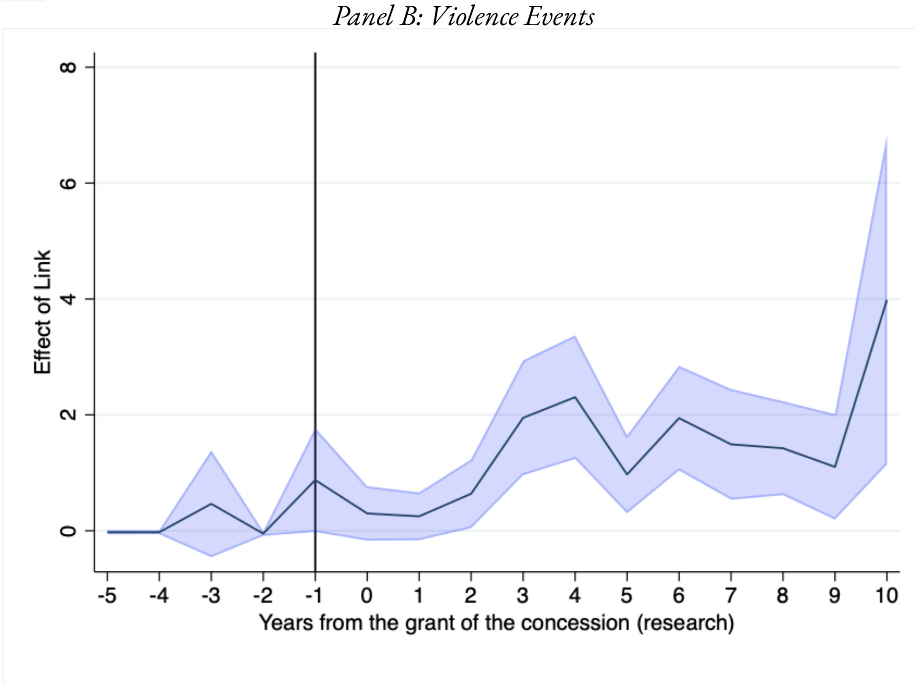
Notes: The figure presents the 95% confidence interval together with the point estimate of Link's coefficient in model (3) of Table 3 restricted at different years from the grant of the concession. Sample restricted only to research concessions.

Figure A9: Link and opening of the concession - Battle and Violence

Panel A: Battle Events

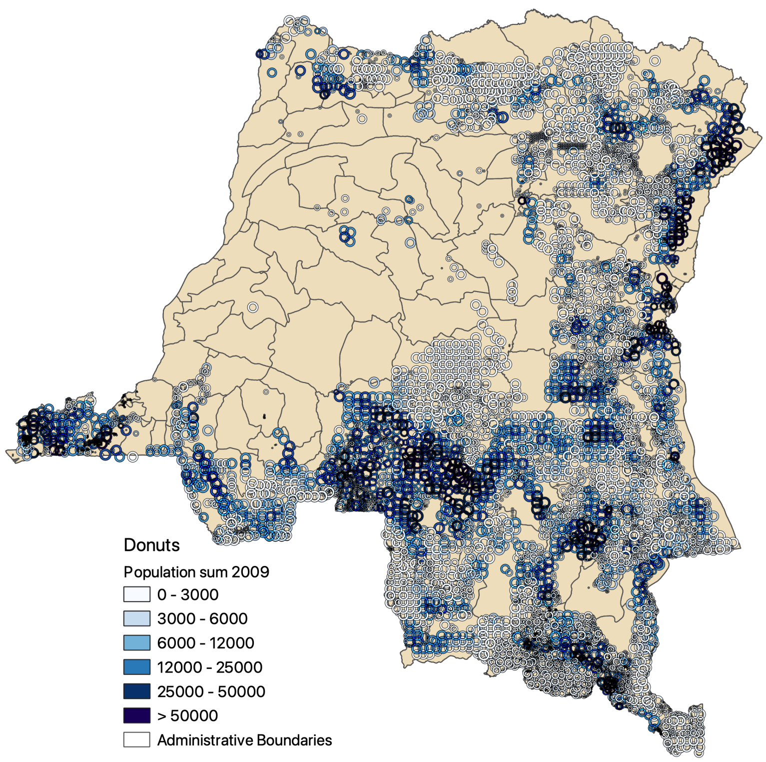


Panel B: Violence Events



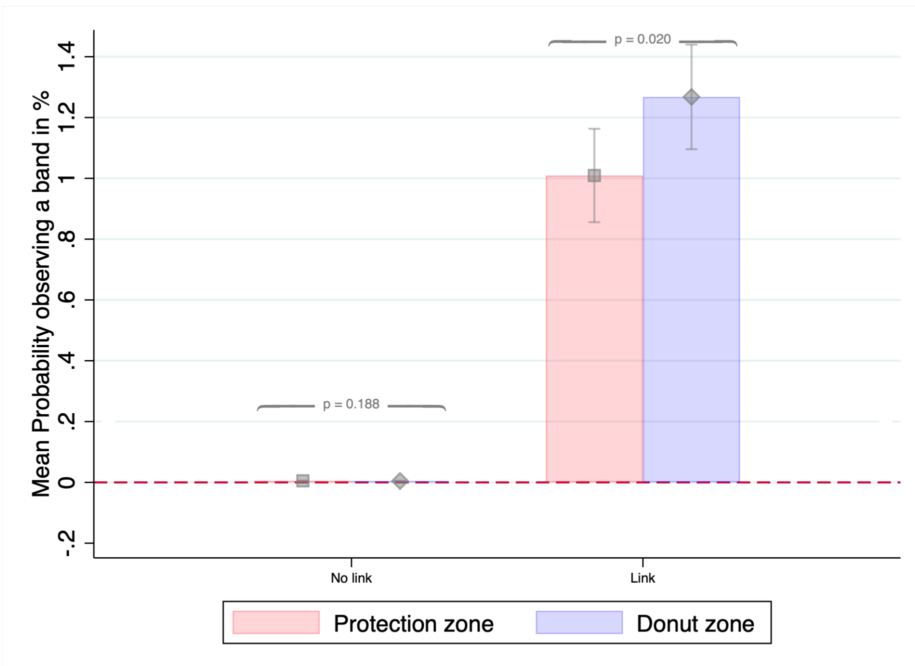
Notes: The figure presents the 95% confidence interval together with the point estimate of Link's coefficient in model (3) of Table 3, using as dependent variable a dummy indicating a battle, panel A, and violence against civilians, panel B, ACLED event in the interest zone involving the armed band, restricted at different years from the grant of the concession. Coefficients are multiplied by 100. Sample restricted only to research concessions.

Figure A10: Map zones



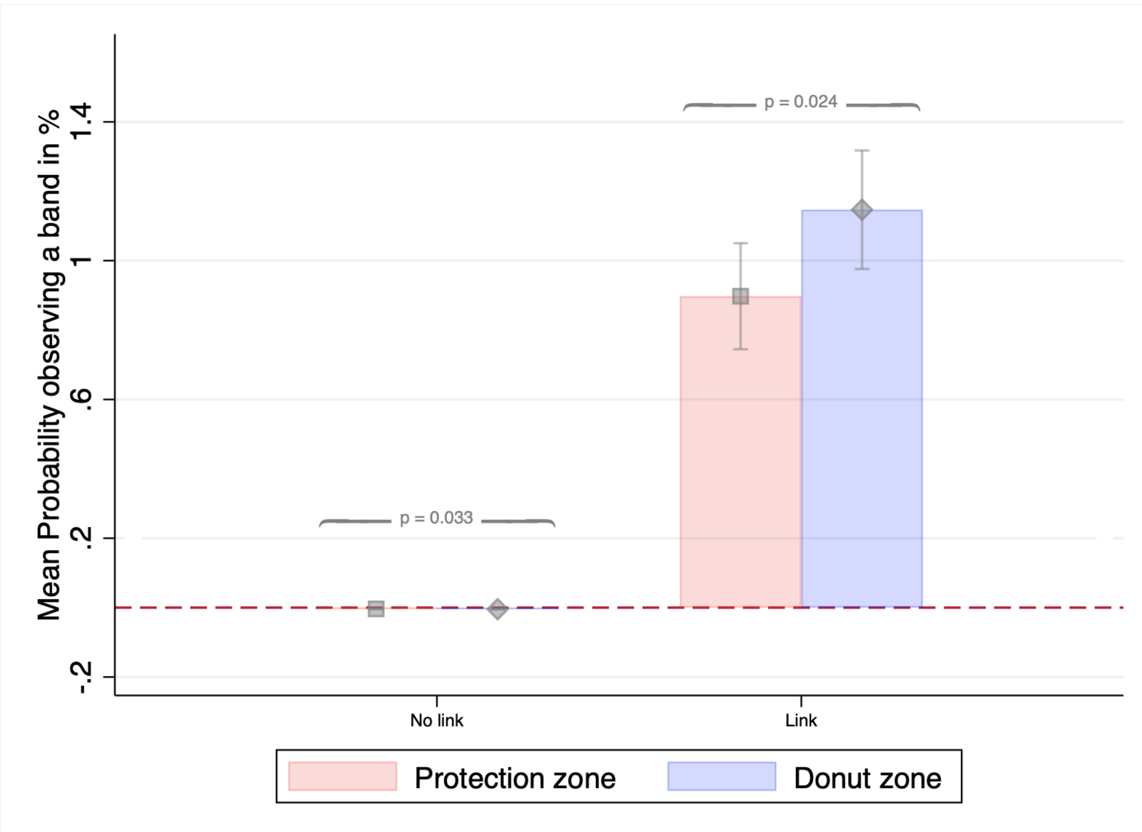
Notes: The figure presents Donut zones, color coded for the population in 2009.

Figure A11: Probability by link and zone



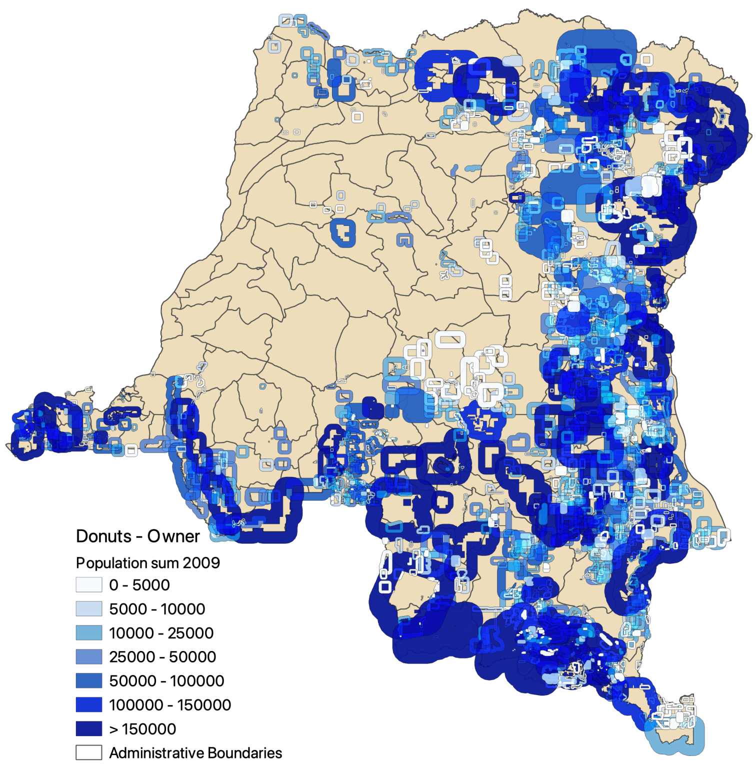
Notes: The Figure presents the mean probability, as well as the 95% confidence interval, of observing the armed band b in the Protection Zone (in red), or the Donut Zone (in blue), composing Interest Zone i of owner o, whether the armed group and the owner have a link or not. We say that an armed band b and an owner o have a link in the Interest Zone i at time t if they had a contact in the past, in another Interest Zone of the same owner. An armed band b and a owner o have a contact at time t in the Interest Zone i if we observe a conflict event involving b in i at t. Figure A12 replicates this controlling for the log of distance between the centroid of the Interest Zone and the location we observed for the first time the armed group, rainfall, nightlights, Concession FE, Year FE and Band FE.

Figure A12: Probability by link and zone - residual



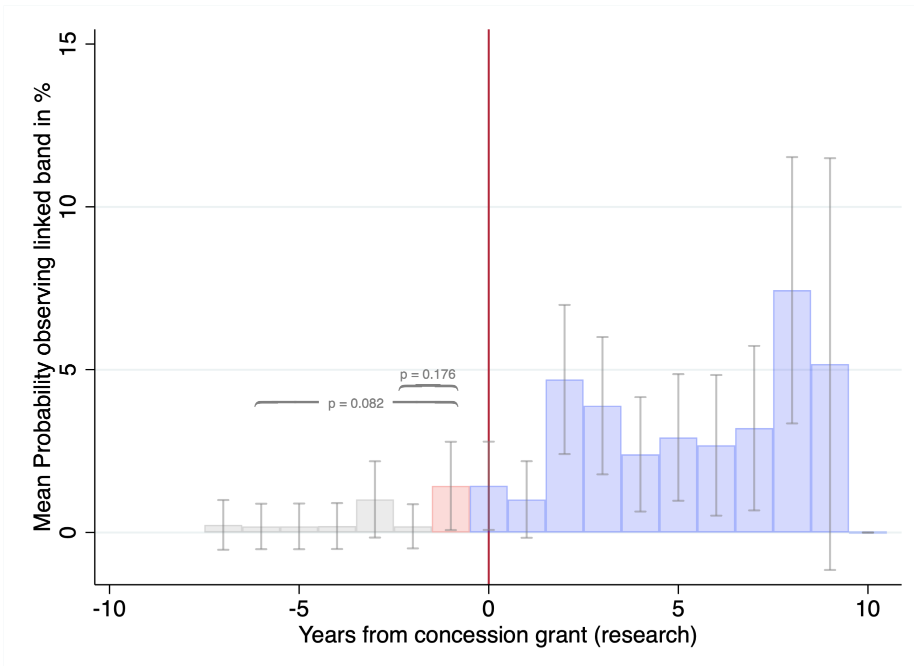
Notes: The Figure presents the mean probability, as well as the 95% confidence interval, of observing the armed band b in the Protection Zone (in red), or the Donut Zone (in blue), composing Interest Zone i of owner o, whether the armed group and the owner have a link or not. We say that an armed band b and an owner o have a link in the Interest Zone i at time t if they had a contact in the past, in another Interest Zone of the same owner. An armed band b and a owner o have a contact at time t in the Interest Zone i if we observe a conflict event involving b in i at t. We control for the log of distance between the centroid of the Interest Zone and the location we observed for the first time the armed group, rainfall, nightlights, Concession FE, Year FE and Band FE.

Figure A13: Map sensitivity zones



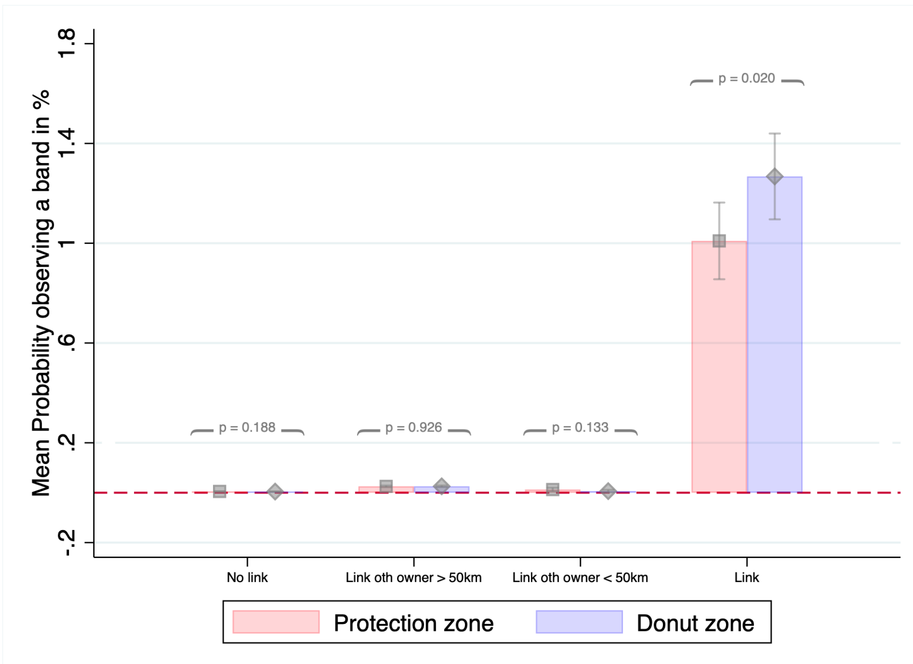
Notes: The figure presents sensitivity Donut zones, color coded for the population in 2009.

Figure A14: Probability linked band - sensitivity zones



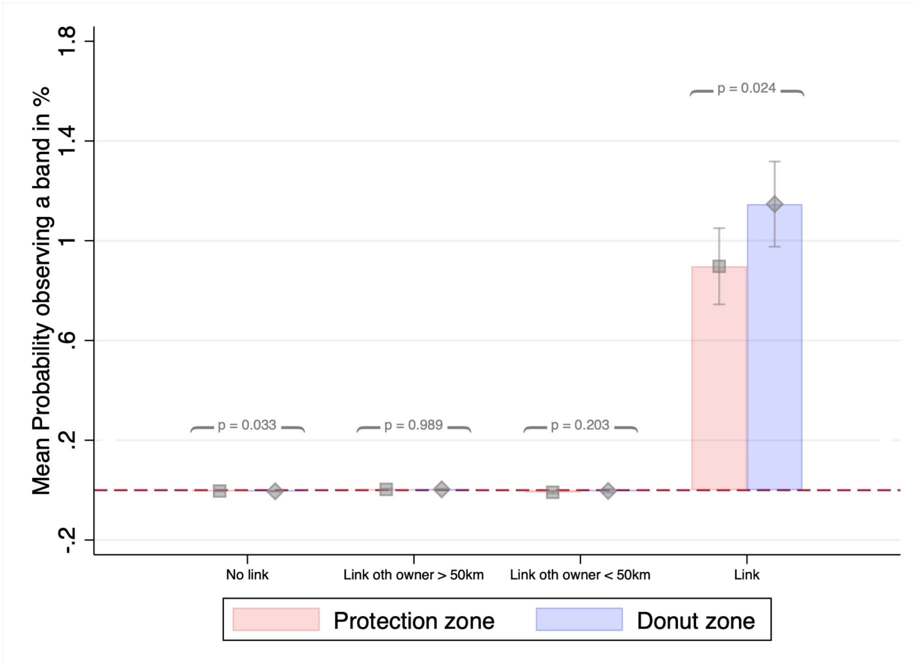
Notes: This Figure presents the mean probability, together with 90% confidence intervals, of observing the linked armed group b (in percentage) within the Interest Zone i of the owner o, for different years relative to the opening of the concession. Sample restricted to research concessions only. We say that an armed band b and an owner o have a link in the Interest Zone i at time t if they had a contact in the past, in another Interest Zone of the same owner. An armed band b and a owner o have a contact at time t in the Interest Zone i if we observe a conflict event involving b in i at t. We control for Concession, Band, and Year FE, log distance between the centroid of the concession and the location the first time we observe the armed group in the sample, rainfall, nightlights and population in the Interest Zone.

Figure A15: Probability by link and zone - placebo links



Notes: The Figure presents the mean probability, as well as the 95% confidence interval, of observing the armed band b in the Protection Zone (in red), or the Donut Zone (in blue), composing Interest Zone i of owner o, whether the armed group and the owner have a link, a link with another owner closer than 50km, a link with another owner beyond 50km, or no link. We say that an armed band b and an owner o have a link in the Interest Zone i at time t if they had a contact in the past, in another Interest Zone of the same owner. We say that an armed band b has a link with another owner, if it has had a contact with another owner in the past. We say that an armed band b has a link with another owner closer than 50km, if they had a contact with another owner, in the past, in a concession closer than 50km. An armed band b and a owner o have a contact at time t in the Interest Zone i if we observe a conflict event involving b in i at t. Figure A16 replicates the same graph controlling for the log of distance between the centroid of the Interest Zone and the location we observed for the first time the armed group, rainfall, nightlights, Concession FE, Year FE and Band FE.

Figure A16: Probability by link and zone - placebo links, residuals



Notes: The Figure presents the mean probability, as well as the 95% confidence interval, of observing the armed band b in the Protection Zone (in red), or the Donut Zone (in blue), composing Interest Zone i of owner o, whether the armed group and the owner have a link, a link with another owner closer than 50km, a link with another owner beyond 50km, or no link. We say that an armed band b and an owner o have a link in the Interest Zone i at time t if they had a contact in the past, in another Interest Zone of the same owner. We say that an armed band b has a link with another owner, if it has had a contact with another owner in the past. We say that an armed band b has a link with another owner closer than 50km, if they had a contact with another owner, in the past, in a concession closer than 50km. An armed band b and a owner o have a contact at time t in the Interest Zone i if we observe a conflict event involving b in i at t. We control for the log of distance between the centroid of the Interest Zone and the location we observed for the first time the armed group, rainfall, nightlights, Concession FE, Year FE and Band FE.

Figure A17: Artisanal Small Mines

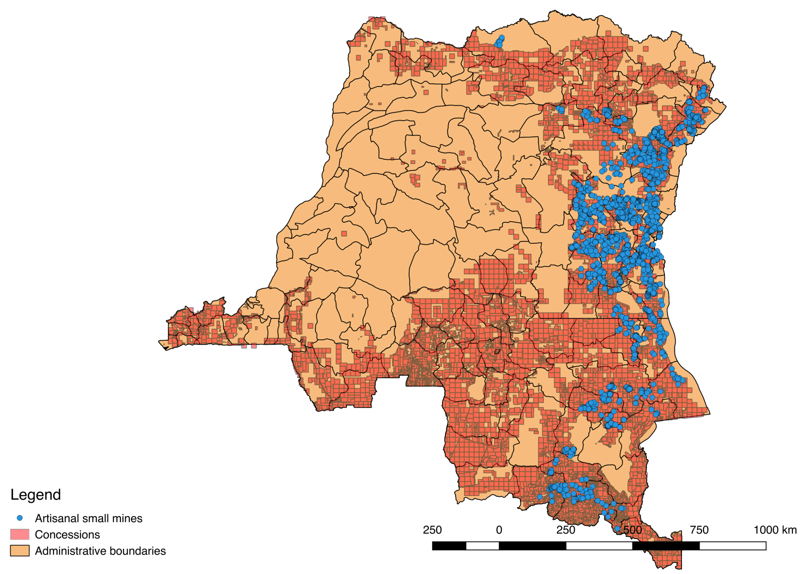
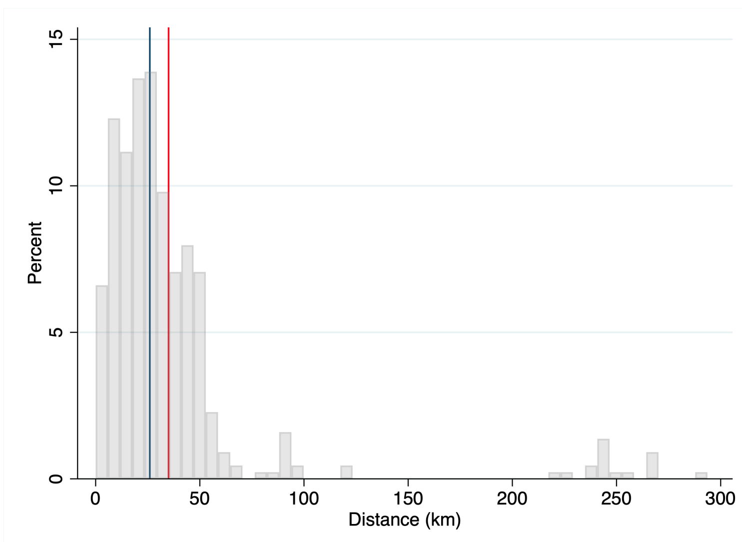


Figure A18: Distribution of the distance between armed group location in ACLED and in IPIS



Notes: The Figure shows the distribution of the 3-year moving average for the (minimum) distance between armed group locations in ACLED and in IPIS. The sample is restricted to the 26 armed groups present in both datasets. The red vertical line is the average, the blu line is the median.

C Extra Tables

Table A1: Descriptives CAMI data

	Mean	SD	Min	Max	Obs
Exploit	0.190620	0.392840	0	1	3966
Research	0.780635	0.413868	0	1	3966
Active	0.638679	0.480444	0	1	3966
Demand phase	0.016894	0.128889	0	1	3966
Other status	0.344428	0.475241	0	1	3966
Year starting date	2,007.622794	2.761184	1,994	2,015	3966
Year expiring date	2,013.589511	5.689124	1,998	2,043	3966
Number minerals extracted	3.525719	2.819446	0	19	3966
Area km^2	141.277988	143.968597	0.860551	405.322810	3966
Gold	0.560767	0.496356	0	1	3966
3T Minerals	0.273323	0.445722	0	1	3966
Number owners				679	
Avg # concessions per owner				20.89	
Avg length research concession				4.31	
Avg length exploit concession				12.57	

Table A2: Armed Bands

Allied Democratic Forces (ADF)	Mayi Mayi Militia (Bwasakala)
Alliance of Patriots for a Free and Sovereign Congo (APCLS)	Mayi Mayi Militia (Cheka)
Alur Ethnic Militia	Mayi Mayi Militia (Cmdt Jackson)
Anti-Balaka	Mayi Mayi Militia (Cmdt La Fontaine)
Bundu dia Kongo (BDK)	Mayi Mayi Militia (Ebu Ela)
Bafuliru Ethnic Militia	Mayi Mayi Militia (Fuliiru)
Bakata Katanga Communal Militia	Mayi Mayi Militia (Gedeon Kyungu Mutanda)
Bakwa	Mayi Mayi Militia (Guides)
Bana Mura	Mayi Mayi Militia (Gumino)
Bangadi Communal Militia	Mayi Mayi Militia (Hapa na pale)
Bangubangu Ethnic Militia	Mayi Mayi Militia (Kabido)
Bantu Ethnic Militia	Mayi Mayi Militia (Kidjangala)
Banyamulenge Ethnic Militia	Mayi Mayi Militia (Kifuafua)
Batwa Ethnic Militia	Mayi Mayi Militia (Leopard)
Bena	Mayi Mayi Militia (Luc Yabili)
Beni Communal Militia	Mayi Mayi Militia (Major Pierre Rashidi Ibulecho)
Biakatu Communal Militia	Mayi Mayi Militia (Malaika)
Bijombo Communal Militia	Mayi Mayi Militia (Manu)
Bulana Communal Militia	Mayi Mayi Militia (Mazembe)
Butembo Communal Militia	Mayi Mayi Militia (Morgan Ekasambaza)
CCU	Mayi Mayi Militia (Mwenyemali)
CNDD-FDD	Mayi Mayi Militia (Nyatura)
National Congress for the Defence of the People (CNDP)	Mayi Mayi Militia (PARECO)
National Coalition of the People for the Sovereignty of Congo (CNPSC)	Mayi Mayi Militia (Raia Mukombozi)
CNRD	Mayi Mayi Militia (Raia Mutomboki)
Cooperative for Development of the Congo's (CODECO)	Mayi Mayi Militia (Safisha Mabaya)
CRC	Mayi Mayi Militia (Simba)
Dibaya Communal Militia	Mayi Mayi Militia (Union of Patriots for the Defense of the Innocents)
Djugu Communal Militia	Mayi Mayi Militia (Yakutumba)
Armed Forces of the Congolese People (FAPC)	Mbororo Ethnic Militia
FDD	Militia (Alleluia)
Democratic Forces for the Liberation of Rwanda (FDLR)	Militia (Ditunga)
Front for the Liberation of Congo (FLC)	Militia (Elements)
Front for the Liberation of the Enclave of Cabinda (FLEC)	Militia (Gedeon)
Nationalist and Integrationist Front (FNI)	Militia (Kalamba Dilondo)
National Liberation Forces (FNL)	Militia (Kamwina Nsapu)
Popular Forces of Burundi (FOREBU)	Militia (Kem)
Popular Front for Justice in the Congo (FPJC)	Militia (Mbawu Nkanka)
Patriotic Resistance Front of Ituri (FRPI)	Militia (Mumbere Kasauti)
Haut-Uele Communal Militia	Miltia (Kawai Dewayo)
Hema	Movement for Claiming the Truth of the Ballot Box
Hunde Ethnic Militia	Mudundu 40
Hutu Ethnic Militia	Mukemuna Communal Militia
Idjwi Communal Militia	Nduma Defense of Congo-Renovated (NDC)
Interahamwe Militia	Nande Ethnic Militia
Youth of UNAFEC (JUNAFEC)	Ngiti Ethnic Militia
Kabongo Communal Militia	Ngumino Ethnic Militia
Kabeya Lumbu Communal Militia	Ntambwe Communal Militia
Kahesha Communal Militia	Nyatura
Kalambo Communal Militia	Okita Ndeke Communal Militia
Kande Communal Militia	Palipehutu-FNL
Kasuku	PERCI
Kelela Communal Militia	People's Party for Reconstruction and Democracy (PPRD)
Kuluna Communal Militia	Party for the Unity and Safeguarding of the Integrity of the Congo (PUSIC)
LC	Rally for Congolese Democracy (RCD)
Lord's Resistance Army (LRA)	Red Tabara
Lendu Ethnic Militia	Rwandan Rally for Unity and Democracy (RUD)
Luba	SPLA-IO
Lulunga Communal Militia	Tchele Communal Militia
M23	Tshiyoyo Militia
Movement for the Liberation of the Congo (MLC)	Twa Ethnic Militia (Burundi)
Military Revolutionary Committee (MRC)	Twiganeho Ethnic Militia
Rwandan Movement for Democratic Change (MRDC)	Union for Democracy and Social Progress (UDPS)
Mayi Mayi Militia (Akilimali)	UNAFEC
Mayi Mayi Militia (Bakata Katanga)	Union for Peace in the Central African Republic (UPC)
Mayi Mayi Militia (Bede)	
Mayi Mayi Militia (Biloze Bishambuke)	
Mayi Mayi Militia (Body of Christ)	
Mayi Mayi Militia (Buhirwa)	

Table A3: Descriptive statistics

	Mean	SD	Min	Max	Obs
ACLED[a]					
Interest - Event	0.010308	1.015207	0	1	8,566,560
Interest - Violence against civilians	0.004681	0.684162	0	1	8,566,560
Interest - Battle	0.003374	0.580816	0	1	8,566,560
Interest - Riot	0.000023	0.048318	0	1	8,566,560
Interest - Protest	0.000000	0.000000	0	0	8,566,560
Interest - Fatality	0.0046	0.6764	0	1	8,566,560
Protection - Event	0.005195	0.720718	0	1	8,566,560
Protection - Violence against civilians	0.002440	0.493929	0	1	8,566,560
Protection - Battle	0.003140	0.560359	0	1	8,566,560
Protection - Riot	0.000012	0.034166	0	1	8,566,560
Protection - Protest	0.000000	0.000000	0	0	8,566,560
Protection - Fatality	0.0022	0.4734	0	1	8,566,560
Donut - Event	0.005568	0.746180	0	1	8,566,560
Donut - Violence against civilians	0.002545	0.504452	0	1	8,566,560
Donut - Battle	0.003374	0.580816	0	1	8,566,560
Donut - Riots	0.000023	0.048318	0	1	8,566,560
Donut - Protest	0.000000	0.000000	0	0	8,566,560
Donut - Fatality	0.0026	0.5056	0	1	8,566,560
Contact and distances					
Link	0.002061	0.045354	0	1	8,566,560
Ever link	0.004839	0.069396	0	1	8,566,560
Previous distance km	976.435250	481.958614	1	2,247	725,778
Initial Distance	934.048536	477.772188	0.930331	2,229	5,457,216
Previous distance | Link & contact	181.889713	163.115606	9	1,793	392
Concessions					
Mine's area km2	141.277988	143.951580	0.860551	405.322810	63,456
Year starting date	2,007.622794	2.760857	1,994	2,015	63,456
Year expiring date	2,013.589511	5.688452	1,998	2,043	63,456
Number of minerals extracted	3.525719	2.819113	0	19	63,456
Gold	0.560767	0.496298	0	1	63,456
3T Minerals	0.273323	0.445669	0	1	63,456
Exploit	0.190620	0.392793	0	1	63,456
Research	0.780635	0.413819	0.	1	63,456
Open concession	0.352985	0.477902	0	1	63,456
Controls					
Sum population donut	4,431.666797	20,587.782646	0	730445	63,456
Sum population protection	3,901.413305	15,669.604673	0	429202	63,456
Mean rainfall donut	1,425.581587	308.126502	611.724886	2,975.807048	63,456
Mean rainfall protection	1,425.956325	308.182723	612.978333	2,961.183105	63,456
Mean nightlights donut	0.426261	2.548129	-0.016875	62	47,592
Mean nightlights protection	0.415171	2.556752	-0.014615	62.000148	47,592

[a] To ease the reporting of the descriptives, mean and standard deviation are multiplied by 100.

Table A4: Descriptive statistics

	Mean	SD	Min	Max	Obs
ACLED[a]					
Interest - Event	0.013658	1.168580	0	1	3,968,470
Interest - Violence against civilians	0.006955	0.833927	0	1	3,968,470
Interest - Battle	0.004410	0.664046	0	1	3,968,470
Interest - Riot	0.000000	0.000000	0	0	3,968,470
Interest - Protest	0.000000	0.000000	0	0	3,968,470
Interest - Fatality	0.005720	0.756291	0	1	3,968,470
Protection - Event	0.006627	0.814052	0	1	3,968,470
Protection - Violence against civilians	0.003477	0.589686	0	1	3,968,470
Protection - Battle	0.003553	0.596061	0	1	3,968,470
Protection - Riot	0.000000	0.000000	0	0	3,968,470
Protection - Protest	0.000000	0.000000	0	0	3,968,470
Protection - Fatality	0.002570	0.506971	0	1	3,968,470
Donut - Event	0.007585	0.870874	0	1	3,968,470
Donut - Violence against civilians	0.003855	0.620906	0	1	3,968,470
Donut - Battle	0.004410	0.664046	0	1	3,968,470
Donut - Riots	0.000000	0.000000	0	0	3,968,470
Donut - Protest	0.000000	0.000000	0	0	3,968,470
Donut - Fatality	0.003377	0.581077	0	1	3,968,470
Contact and distances					
Link	0.003807	0.061585	0	1	3,968,470
Ever link	0.006611	0.081038	0	1	3,968,470
Previous distance km	970.886975	486.616968	0.930331	2,247.105718	598,437
Initial Distance	933.711170	477.946949	0.930331	2,229.073690	3,968,470
Previous distance | Link & contact	191.748379	133.090241	11.874948	932.525285	261
Concessions					
Mine's area km2	141.277988	143.951580	0.860551	405.322810	63,456
Year starting date	2,007.622794	2.760857	1,994	2,015	63,456
Year expiring date	2,013.589511	5.688452	1,998	2,043	63,456
Number of minerals extracted	3.525719	2.819113	0	19	63,456
Gold	0.560767	0.496298	0	1	63,456
3T Minerals	0.273323	0.445669	0	1	63,456
Exploit	0.190620	0.392793	0	1	63,456
Research	0.780635	0.413819	0.	1	63,456
Open concession	0.352985	0.477902	0	1	63,456
Controls					
Sum population donut	4,431.666797	20,587.782646	0	730445	63,456
Sum population protection	3,901.413305	15,669.604673	0	429202	63,456
Mean rainfall donut	1,425.581587	308.126502	611.724886	2,975.807048	63,456
Mean rainfall protection	1,425.956325	308.182723	612.978333	2,961.183105	63,456
Mean nightlights donut	0.426261	2.548129	-0.016875	62	47,592
Mean nightlights protection	0.415171	2.556752	-0.014615	62.000148	47,592

[a] To ease the reporting of the descriptives, mean and standard deviation are multiplied by 100.

Table A5: Links and Probability of observing the armed bands - different proximity measures

Dep. Variable:	$Contact = \mathbb{1}$ { armed band observed in Interest Zone of concession at t }						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Distance period $t-1$, non missing only if band is active in $t-1$							
Link	1.740***	1.735***	2.825***	2.825***	4.619***	9.569***	
	(0.237)	(0.240)	(0.383)	(0.383)	(0.806)	(1.349)	
Previous Distance (log)			-0.262***	-0.262***	-1.157***	-2.398***	-0.381***
			(0.0355)	(0.0355)	(0.262)	(0.264)	(0.0463)
Placebo link							0.0156
							(0.196)
Obs.	3968470	3968470	598437	598437	35377	39113	598437
R2	0.00841	0.0144	0.0549	0.0549	0.172	0.0902	0.0429
Mean Dep. | Link = 0	0.0070	0.0070	0.0398	0.0398	0.3834	0.6379	0.0398
Panel B: Distance last time a band is observed, non missing after band is active for the first time							
Link	1.740***	1.735***	1.719***	1.719***	2.647***	5.403***	
	(0.237)	(0.240)	(0.244)	(0.244)	(0.507)	(0.875)	
Distance Last (log)			-0.0899***	-0.0899***	-0.177	-0.820***	-0.116***
			(0.0130)	(0.0130)	(0.124)	(0.115)	(0.0153)
Placebo link							0.203
							(0.165)
Obs.	3968470	3968470	1392777	1392777	77029	91031	1392777
R2	0.00841	0.0144	0.0264	0.0264	0.115	0.0546	0.273
Mean Dep. | Link = 0	0.0070	0.0070	0.0170	0.0170	0.3834	0.2709	0.0170
Interest Zone FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Armed Band FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Population, Rain, Nightlights	No	No	No	Yes	Yes	Yes	Yes
Sample	Full	Full	Full	Full	<250km	Ever Band	Full

Notes: High Dimensional Fixed Effects Linear regression. Standard errors clustered at the interest zone level in parentheses. ***,**,* = indicate significance at the 1, 5, and 10% level, respectively. The dependent variable is a dummy indicating a generic ACLED event in the interest zone involving the armed band. To ease the reporting of the estimates, coefficients and mean dependent variable are multiplied by 100. Model (5) restricts the sample to armed bands closer than 250km from the interest zone considered in the previous period. Model (6) restricts the sample to Interest Zones with at least one contact over the entire sample (an armed band b and a owner o have a contact at time t in the Interest Zone i if we observe a conflict event involving b in i at t). Link is a dummy variable indicating whether, at time t, in Interest Zone i, the owner of the concession and the armed band have a link. We say that an armed band b and an owner o have a link in the Interest Zone i at time t if they had a contact in the past, in another Interest Zone of the same owner. Model (7) uses a placebo version of Link that is equal to 1 before the actual link takes place. In Panel A we use Log Previous Distance, that is the log of distance between the concession's centroid and the band in the previous period. In Panel B we use Log Distance Last, that is the log of distance between the concession's centroid and the band the last time we observed the latter.

Table A6: Sensitivity Table 3

	(1) Coefficient	(2) Standard error
S.e. clustered at interest level (**benchmark**)	1.732***	0.240
S.e. clustered at owner level	1.732***	0.441
S.e. clustered at region level	1.735***	0.280
S.e. clustered at band level	1.732***	0.343
Robust standard errors	1.732***	0.109
Interest × Band, Year FE	3.690***	0.566
Interest, Band, Region × Year FE	1.737***	0.241
Interest, Year FE	1.771***	0.241
Region, Year FE	1.735***	0.236

Notes: This table presents coefficient and standard error of Link's coefficient in model (3) of Table 3 using different clustering, and combinations of Fixed Effects. ***,**,* = indicate significance at the 1, 5, and 10% level, respectively.

Table A7: Link in different zones

	Donut Zone					Protection Zone				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Link	0.996***	0.996***	0.987***	0.987***	1.208***	0.804***	0.797***	0.791***	0.791***	0.466***
	(0.186)	(0.188)	(0.187)	(0.187)	(0.372)	(0.139)	(0.141)	(0.142)	(0.142)	(0.159)
Initial Distance (log)			-0.0130***	-0.0130***	-0.160***			-0.00756***	-0.00757***	-0.103***
			(0.00328)	(0.00328)	(0.0376)			(0.00282)	(0.00282)	(0.0290)
Obs.	3968470	3968470	3968470	3968470	260005	3968470	3968470	3968470	3968470	260005
R2	0.00496	0.0115	0.0115	0.0115	0.0297	0.00370	0.00825	0.00825	0.00825	0.0223
Concession FE	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Armed Band FE	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Year FE	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Population, Rain, Nightlights	No	No	No	Yes	Yes	No	No	No	Yes	Yes
Sample	Full	Full	Full	Full	<250km	Full	Full	Full	Full	<250km
Mean Dep. | Link = 0	0.0038	0.0038	0.0038	0.0038	0.0255	0.0035	0.0035	0.0035	0.0035	0.0193

Notes: High Dimensional Fixed Effects Linear regression. Standard errors clustered at the interest zone level in parentheses. ***,**,* = indicate significance at the 1, 5, and 10% level, respectively. The dependent variable is a dummy indicating a generic ACLED event in the Donut zone (1)-(5) and Protection zone (6)-(10) involving the armed band. To ease the reporting of the estimates, coefficients and mean dependent variable are multiplied by 100. Models (5) and (10) restricts the sample to armed bands closer than 250km from the zone considered in the previous period. Link is a dummy variable indicating whether, at time t, in Interest Zone i, the owner of the concession and the armed band have a link. We say that an armed band b and an owner o have a link in the Interest Zone i at time t if they had a contact in the past, in another Interest Zone of the same owner. An armed band b and a owner o have a contact at time t in the Interest Zone i if we observe a conflict event involving b in i at t. Proximity begin is a measure of how close were the concession and the band the first time we observe the latter.

Table A8: Link and Population - sensitivity population

	Different zones						Donut vs Protection	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Interest	Donut	Protection	Interest	Donut	Protection	-	-
Panel A: Population **same period**								
Link	1.722***	0.987***	0.791***	1.117***	0.536***	0.485***	0.491***	
	(0.239)	(0.187)	(0.142)	(0.209)	(0.156)	(0.104)	(0.0635)	
Population	0.0114	0.00538	0.00891	0.000454	-0.00207	0.00427	0.00888***	
	(0.00925)	(0.00736)	(0.00545)	(0.0105)	(0.00873)	(0.00508)	(0.00152)	
Link × Population				0.559***	0.400**	0.272***	0.270***	
				(0.212)	(0.178)	(0.0900)	(0.0451)	
Link × Population × Donut							0.134*	0.301***
							(0.0751)	(0.0739)
Obs.	3968470	3968470	3968470	3968470	3968470	3968470	7936940	7936940
R2	0.0145	0.0116	0.00828	0.0172	0.0143	0.00996	0.0100	0.539
Concession FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Armed Band FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Concession × Band × Year FE	No	No	No	No	No	No	No	Yes
Rain, Nightlights, Initial Distance (log)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Panel B: Population **previous period**								
Link	1.731***	0.981***	0.808***	1.184***	0.577***	0.514***	0.524***	
	(0.237)	(0.181)	(0.146)	(0.213)	(0.159)	(0.110)	(0.0659)	
Population	-0.00324	-0.00116	0.00252	-0.0134	-0.00819	-0.00185	0.00841***	
	(0.0119)	(0.00930)	(0.00633)	(0.0134)	(0.0107)	(0.00630)	(0.00167)	
Previous Contact × Population				0.524**	0.372**	0.269***	0.268***	
				(0.205)	(0.169)	(0.0938)	(0.0464)	
Previous Contact × Population × Donut							0.109	0.276***
							(0.0764)	(0.0753)
Obs.	3633500	3633500	3633500	3633500	3633500	3633500	7267000	7267000
R2	0.0149	0.0118	0.00868	0.0171	0.0140	0.0102	0.00988	0.541
Concession FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Armed Band FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Concession × Band × Year FE	No	No	No	No	No	No	No	Yes
Rain, Nightlights, Initial Distance (log)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Mean Dep. | Link = 0	0.0074	0.0040	0.0037	0.0074	0.0040	0.0037	0.0039	0.0039

Notes: High Dimensional Fixed Effects Linear regression. Standard errors clustered at the interest zone level in models (1) to (6), and interest,year,band level in models (7)-(8) in parentheses. ***,**,* = indicate significance at the 1, 5, and 10% level, respectively. The dependent variable is a dummy indicating a generic ACLED event in the Interest zone (1),(4),(7),(8), Donut zone (2),(5), Protection zone (3),(6), involving the armed band. To ease the reporting of the estimates, coefficients and mean dependent variable are multiplied by 100. Link is a dummy variable indicating whether, at time t, in Interest Zone i, the owner of the concession and the armed band have a link. We say that an armed band b and an owner o have a link in the Interest Zone i at time t if they had a contact in the past, in another Interest Zone of the same owner. An armed band b and a owner o have a contact at time t in the Interest Zone i if we observe a conflict event involving b in i at t. Donut is a dummy variable indicating the Donut zone with respect to the Protection one. In Panel A population is the number of people living in the area in the same period. In Panel B population is the number of people living in the area in the previous period.

Table A9: Links - IPIS bands

Dep. Variable:	*Contact* = 𝟙 { armed band observed in Interest Zone of concession at t }						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Sample restricted to **IPIS bands**							
Link	2.803***	2.780***	2.785***	2.784***	4.944***	9.132***	
	(0.438)	(0.444)	(0.445)	(0.445)	(1.015)	(1.477)	
Initial Distance (log)			-0.0138	-0.0138	-0.968**	-0.569**	0.0184
			(0.0265)	(0.0265)	(0.489)	(0.232)	(0.0182)
Placebo Link							-0.113
							(0.0837)
Obs.	507595	507595	507595	507595	11316	33264	507595
R2	0.0130	0.0403	0.0403	0.0403	0.213	0.0699	0.314
Interest Zone FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Armed Band FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Population, Rain, Nightlights	No	No	No	Yes	Yes	Yes	Yes
Sample	Full	Full	Full	Full	<250km	Ever Band	Full
Mean Dep. | Link = 0	0.0284	0.0284	0.0284	0.0284	0.7260	0.4468	0.0284
Panel B: Dep. Variable using **IPIS locations**							
Link	0.442***	0.445***	0.448***	0.448***	1.524***	3.322***	
	(0.0767)	(0.0777)	(0.0783)	(0.0783)	(0.285)	(0.501)	
Initial Distance (log)			0.00424***	0.00424***	-0.103	-0.0163	0.000457
			(0.00158)	(0.00158)	(0.0960)	(0.0324)	(0.00122)
Placebo Link							0.0373
							(0.0288)
Obs.	3968470	3968470	3968470	3968470	35377	90730	3968470
R2	0.00231	0.00453	0.00454	0.00455	0.0554	0.0412	0.00238
Interest Zone FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Armed Band FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Population, Rain, Nightlights	No	No	No	Yes	Yes	Yes	Yes
Sample	Full	Full	Full	Full	<250km	Ever Band	Full
Mean Dep. | Link = 0	0.0015	0.0015	0.0015	0.0015	0.0730	0.0673	0.0015

Notes: High Dimensional Fixed Effects Linear regression. Standard errors clustered at the interest zone level in parentheses. ***,**,* = indicate significance at the 1, 5, and 10% level, respectively. The dependent variable is a dummy indicating a generic ACLED event in the interest zone involving the armed band. To ease the reporting of the estimates, coefficients and mean dependent variable are multiplied by 100. Model (5) restricts the sample to armed bands closer than 250km from the interest zone considered in the previous period. Model (6) restricts the sample to Interest Zones with at least one contact over the entire sample (an armed band b and a owner o have a contact at time t in the Interest Zone i if we observe a conflict event involving b in i at t). Initial Distance (log) is the log of distance between the concession and the band the first time we observe the latter. Link is a dummy variable indicating whether, at time t, in Interest Zone i, the owner of the concession and the armed band have a link. We say that an armed band b and an owner o have a link in the Interest Zone i at time t if they had a contact in the past, in another Interest Zone of the same owner. Model (7) uses a placebo version of Link that is equal to 1 before the actual link takes place. Sample restricted to armed groups also present in the IPIS data in Panel A. In Panel B, dependent variable is constructed using IPIS locations rather than ACLED ones.

Table A10: Placebo links

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Real link										
Link	0.786***	2.340***	2.583***			0.304*	0.793***		0.391***	
	(0.138)	(0.542)	(0.481)			(0.168)	(0.0735)		(0.134)	
Link other band				-0.174***	-2.548***					
				(0.0271)	(0.530)					
Link × # Bands close						0.00330***				
						(0.00122)				
Link × Donut							0.191*	0.191*		-0.0570
							(0.106)	(0.106)		(0.0702)
Link × Population Begin									0.285***	
									(0.104)	
Link × Population × Donut										0.104*
										(0.0542)
Link with another owner										
Link	0.00337	-0.0499	0.0522			-0.00536**	0.00869***		0.00374	
	(0.00242)	(0.186)	(0.0352)			(0.00227)	(0.00169)		(0.00242)	
Link other band				0.0229	-1.555					
				(0.0502)	(2.563)					
Link × # Bands close						0.000133***				
						(0.0000405)				
Link × Donut							0.000728	0.000731		0.00102
							(0.00172)	(0.00172)		(0.00121)
Link × Population Begin									0.00729	
									(0.00510)	
Link × Population × Donut										0.00248
										(0.00404)
Link with another owner closer than 50km										
Link	-0.00501	-0.278*	-0.0325			0.00561	-0.00772**		-0.00239	
	(0.00394)	(0.161)	(0.0776)			(0.00540)	(0.00348)		(0.00444)	
Link other band				0.00503**	0.404**					
				(0.00233)	(0.190)					
Link × # Bands close						-0.000184				
						(0.000138)				
Link × Donut							-0.00685	-0.00684		-0.00244
							(0.00427)	(0.00427)		(0.00378)
Link × Population Begin									0.00207	
									(0.0113)	
Link × Population × Donut										0.00186
										(0.00960)
Obs.	3968470	35377	260064	3968470	35377	3968470	7936940	7936940	3968470	7936940
R2	0.513	0.563	0.518	0.00758	0.165	0.513	0.00774	0.539	0.514	0.770
Concession FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Armed Band FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Concession × Band × Year FE	No	No	No	No	No	No	No	Yes	No	Yes
Population, Rain, Nightlights, Previous Distance	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Sample	Full	<250km	Ever Band	Full	<250km	Full	Full	Full	Full	Full
Mean Dep. | Link = 0	0.0070	0.0425	0.1087	0.0070	0.0425	0.0070	0.0036	0.0036	0.0070	0.0036
Anticipation										
Year - Year Grant (Research)	-4	-3	-2	-1	0	1	2	3	4	5
Average probability linked band - *real*	0.154	0.484	0.246	0.791***	0.391*	0.627**	1.835***	1.822***	1.109***	2.091***
Average probability linked band - *other owner*	-0.009	-0.005	-0.007	-0.003	-0.004	-0.002	0.005	0.005	-0.007	0.010*
Average probability linked band - *other owner close*	-0.005	-0.010	-0.013	-0.013	-0.011	-0.011	-0.004	-0.004	-0.016	-0.005

Notes: High Dimensional Fixed Effects Linear regression. Standard errors clustered at the interest zone level in models (1) to (7) and (9), and interest,year,band level in models (8) and (10) in parentheses. ***,**,* = indicate significance at the 1, 5, and 10% level, respectively. The dependent variable is a dummy indicating a generic ACLED event in the Interest zone involving the armed band. To ease the reporting of the estimates, coefficients and mean dependent variable are multiplied by 100. Link is a dummy variable indicating whether, at time t, in Interest Zone i, the owner of the concession and the armed band have a link. We say that an armed band b and an owner o have a link in the Interest Zone i at time t if they had a contact in the past, in another Interest Zone of the same owner. An armed band b and a owner o have a contact at time t in the Interest Zone i if we observe a conflict event involving b in i at t. Donut is a dummy variable indicating the Donut zone with respect to the Protection one. # Bands close is the number of armed groups closer than 500km to the concession's centroid the first time we observe them. Link other band is a dummy variable indicating whether the owner of the concession has a link with another armed group. In this table we replicate the higher probability of observing the linked armed group - (1) to (3) - (Table 3), the comparison of this effect between the two zones - (7) and (8) - (Table 4), and the interaction with the population dimension - (9) and (10) - (Table 5). We also replicate in a synthetic way the specialization result (Figures 6, **??**, **??** and 8) by running the following regression:

$$\text{Band}_{i,o,t,b} = \alpha + \beta_1 \text{ Link}^{real}_{i,o,t,-b} + \beta_2 \text{ Link}^{other}_{i,o,t,-b} + \beta_3 \text{ Link}^{close}_{i,o,t,-b} + +X'_{iobt}\gamma + \mu_i + \mu_b + \mu_t + \epsilon_{i,o,t,b}$$

Results are shown in column (4). In column (5) we restrict the sample to armed groups closer than 500km to the centroid of the concession the first period we observe them in the sample, in the same fashion we did in Figures **??** and 8. In column (6) we replicate the third empirical fact. Finally, at the bottom of the table, we replicate the anticipation result, by showing the average probability of observing the linked band over different years relative to the grant year, controlling for Concession, Armed Band, Year FE, distance between the concession's centroid and the location in which we observe for the first time the armed group, rainfall, population and nightlights.