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IFPRI Discussion Paper 01193

June 2012

Mineral Resources and Conflicts in the Democratic Republic of the Congo

A Case of Ecological Fallacy

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PARTNERS AND CONTRIBUTORS

IFPRI gratefully acknowledges the generous unrestricted funding from Australia, Canada, China, Denmark, Finland, France, Germany, India, Ireland, Italy, Japan, the Netherlands, Norway, the Philippines, South Africa, Sweden, Switzerland, the United Kingdom, the United States, and the World Bank.

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ABSTRACT

Civil wars inflict considerable costs on countries which may be trapped in vicious cycles of violence. To avoid these adverse events, scholars have attempted to identify the roots of civil wars. Valuable minerals have been listed among the main drivers of civil conflicts. Yet, despite the large body of literature, the evidence remains mixed. This paper provides a spatially nuanced view of the role of mineral resources in civil wars in the particular case of the Democratic Republic of the Congo. We estimate the impact of geolocated new mining concessions on the number of conflict events between January 1997 and December 2007. Instrumenting the variable of interest with historical concessions interacted with changes in mineral international prices, we unveil an *ecological fallacy*: Whereas concessions have no effect on the number of conflicts at the territory level (lowest administrative unit), they do foster violence at the district level (higher administrative unit). We develop a theoretical model wherein the incentives of armed groups to exploit and protect mineral resources explain our empirical findings. A spatial analysis of the effect of mining concessions on conflict backs our proposed theoretical explanation.

Keywords: conflict, natural resources, Democratic Republic of the Congo

JEL Classification: Q34, O13, Q32, N57

ACKNOWLEDGMENTS

For their helpful suggestions and comments, we would kindly like to thank Jean-Francois Carpantier, Olivier Dagnelie, Jan Fidrmuc, Peter Heudtlass , Francois Libois, Fergal McCann, Edward Miguel, Jo Swinnen, the IFPRI DP Editor and participants of the IFPRI Brown Bag Seminar and the Center for the Study of African Economies Conference 2012.

1. INTRODUCTION

Civil wars inflict considerable costs on countries that may get trapped into vicious cycles of violence (World Bank 2011). To avoid these adverse events, scholars have attempted to identify the roots of civil wars. Valuable minerals have been listed among the main drivers of civil conflicts. Yet, despite the large body of literature addressing this topic, the evidence remains mixed (Blattman and Miguel 2010; van der Ploeg 2011).

Collier and Hoeffler (2004) showed that countries with larger shares of primary commodity exports are more likely to experience civil wars. However, several shortcomings of Collier and Hoeffler's (2004) study have been highlighted. First, primary commodities are not homogeneous. As underlined by specialists of the field, there is an urge to categorize the various types of natural resources into diffuse resources, such as agricultural production, and point resources, such as mineral resources (Le Billon 2001; Wick and Bulte 2006), with the latter being seen as more conflictive (Ross 2004). On theoretical grounds, point resources, as opposed to diffuse resources, attract violent entrepreneurs who compete for the control of the rents (Mehlum, Halvor, and Torvik 2002). Recognizing the specificities of mineral resources, a series of papers has sought to identify the specific effect of mineral resources on civil conflicts. The initial evidence, based on cross-country analyses, pointed at the indisputable role played by mineral resources in both igniting and sustaining civil conflicts (Lujala, Gleditsch, and Gilmore 2005; Ross 2006; Lujala 2010).

Second, the relationship between mineral resources and conflict is potentially endogenous. For instance, mineral resource dependence may be a direct consequence of actual or expected civil war (Brunnschweiler and Bulte 2008, 2009).[1] The confounding role of institutions is another source of endogeneity. Fearon and Laitin (2003) and Fearon (2005) emphasized the role of oil revenues in weakening state capacity. More recently, Besley and Persson (2010) formalized this argument by proposing a model of endogenous state capacity formation. They showed that natural resource-rich countries will underinvest in state capacity formation and will therefore be more prone to experiencing civil conflicts.

Third, the cross-country nature of the early contributions to this debate fails to capture the effects of within-country uneven distribution of resources. Moreover, this level of aggregation may fail to account for unobserved heterogeneity. More recent studies adopted a microfounded approach by exploiting within-country variations. By working with subnational units of analysis, researchers can draw more accurate causal inferences. Proceeding likewise, Buhaug and Rod (2006), Angrist and Kugler (2008), and Dube and Vargas (2008) all identified a positive effect of the presence of natural resources on the occurrence of conflict events. Using georeferenced data on a 100-square-kilometer grid, Buhaug and Rod (2006) found a positive effect of the presence of oil and diamonds on the likelihood of civil conflict. Both Angrist and Kugler (2008) and Dube and Vargas (2008) studied the impact of exogenous commodity price shocks on the level of violence in Colombia. The former showed that positive price shocks on cocaine increased violence at the department level, whereas the latter showed that at the municipality level, the effect of oil and coffee price increases have had a positive and negative effect, respectively, on the number of violent events.[2]

Findings from two recent studies suggest that mineral resources could work as a catalyst for peace, thus casting doubt upon the generalization of the aforementioned relationship between resources and conflict. Bellows and Miguel (2009) and Ziemke (2008) studied the civil conflicts of Sierra Leone and Angola, respectively, and concluded, on the basis of georeferenced data, that the presence of diamonds contained the level of violence.

[1] By properly dealing with endogeneity issues, Brunnschweiler and Bulte (2008, 2009) showed that the presence of natural resources does not affect civil war.

[2] The opportunity cost mechanism, according to which profitable alternative economic opportunities may reduce the incentives to engage in predatory activities, is well-known in the theoretical literature on conflicts (Grossman 1991; Dal Bó and Dal Bó 2011).

This paper contributes to these microfounded approaches by focusing on the conflicts in the Democratic Republic of the Congo (DRC). More precisely, we estimate the impact of geolocated granted mining concessions in DRC between January 1997 and December 2007 on the location of conflict events. Beyond data availability, anecdotal evidence (presented in Section 2) suggests that the granting of concessions is a particular momentum for armed groups to obtain kickbacks or down payments from mining companies. Estimating this relationship would produce biased results, however, because of endogeneity issues. Indeed, the actual and the expected violent events are likely to directly affect the decision of granting a concession. Moreover, some common underlying political process could affect both variables.[3] We therefore instrument for the granting of concessions by exploiting georeferenced data on historical concessions, coupled with changes in international prices of minerals, to assess the causal relationship between mining concessions and conflict.[4] By implementing this two-stage least-square estimation at two geographical levels of analysis—that is, the territory and the district levels—we derive an interesting finding: Although granted concessions do not affect the number of conflict events at the territory level, they do increase the frequency of conflicts at the district level. This finding of an *ecological fallacy* is of the outmost importance in the study of violent conflicts.[5] Our analysis sheds light on seemingly contradictory findings in the literature and highlights the role of the spatial dimension in the empirical literature on conflicts.

We propose a theoretical mechanism to rationalize our empirical findings, owing much to the literature on crime displacement (Repetto 1976, Barr and Pease 1990, Johnson et al. 2012). In our model, violence affects negatively mining profitability, thus providing strong incentives for mining companies to keep fighting activities far from the production sites.[6] This mechanism, which we name the *protection effect*, helps explain the ecological fallacy identified in our empirical analysis. Revisiting our econometrics by allowing for a heterogeneous spatial effect of mining concessions on conflict validates the theoretical findings.

In Section 2, we briefly describe the conflict in DRC and its alleged relationship to mining activities. In Section 3, we present our empirical findings and the paper's central result—the ecological fallacy. Section 4 develops the theoretical model underpinning the empirical findings of an ecological fallacy. In Section 5, we revisit the econometric strategy by incorporating the spatial dimension identified in the theoretical framework, and we establish the plausibility of our theoretical explanation.

[3] For a more general discussion on the endogeneity of natural resources and conflict, see Brunnschweiler and Bulte (2008, 2009).

[4] Our Instrumental Variable strategy closely follows the one adopted by Brückner and Ciccone (2010).

[5] The ecological fallacy refers to the erroneous assumption that relationships between variables at the aggregate level imply the same relationships at the individual level. It has also been called a problem of ``aggregation bias'' or a ``modifiable area unit problem'' (Wong 2009).

[6] For the case of DRC, see Vlassenroot and Raeymaekers (2004) and Raeymaekers (2010).

2. BACKGROUND

Since 1996, the Democratic Republic of the Congo (DRC) has experienced a succession of wars and lower-scale conflicts that, according to a survey of the International Rescue Committee, have been the cause of more than 5 million deaths from 1998 to 2008 (IRC 2008) and an estimated 1.7 million internally displaced people (Internal Displacement Monitoring Center 2011). Whether or not these exact figures are biased (Spiegel and Robinson 2010), their magnitude is indicative of the lethality of these conflicts. The causes of the Congo Wars are multiple, complex, and intermingled. In the aftermath of the Rwandan genocide in 1994, the DRC became home to an estimated 1.2 million Hutu refugees fleeing the retaliation of the new Tutsi-led Rwandan government's armed branch, the Rwandan Patriotic Army (RPA). In the fall of 1996, the Congolese president, Mobutu Sese Seko, gave orders for various government-sponsored groups to stigmatize and perpetrate violent acts against the Banyamulenge minority, a primarily Tutsi-Rwandan-origin population that had migrated to eastern Congo. By early September, the RPA commandos were stealthily penetrating the Congolese territory, arming the Banyamulenge and perpetrating coordinated attacks in South Kivu province. Soon afterward, supported by the foreign governments of Rwanda, Uganda, and other neighboring countries, the rebel movement *Alliance des Forces Démocratiques pour la Libération du Congo* (AFDL) was created and led by Laurent-Désiré Kabila. Kabila then seized the opportunity of the Rwandan incursion in eastern DRC to contest Mobutu's leadership, thus beginning the first Congolese war (1996–1997).[7] The second Congolese war (1998–2003) had a more international dimension, since rival countries and factions saw in the conflict-hit DRC a convenient ground for waging proxy wars. Although the end of the second war meant a retreat of international actors from the battlefield, it did not lead to the dissolution of the numerous rival armed groups and gangs that had formed over the course of the seven years of wars. In fact, the violence in DRC continues to affect the country's stability, especially in its eastern regions.

Congo's natural wealth in mineral resources has often been identified as the main driver of the violence, either as a way to finance warring parties or as a warfare objective in itself (CongdonFors and Olsson 2004; Turner 2007; Stearns 2011; International Alert 2010; Gambino 2011).[8] Over the years, the United Nations has repeatedly issued reports from experts, the UN Security Council, and the UN Secretary General underlining that natural resources have fueled the conflicts in the DRC.[9] Among others, coltan—a high-value mineral used in the manufacturing of electronic devices—has been designated as one of the main culprits of the Congo Wars (Jackson 2001; Montague 2002).[10] Prunier's (2009) thorough

[7] Structural analyses of the Congolese wars also point to the historical grievances fueled by the *divide and rule* policy that had been applied by the Belgian colonizers, the exploitative legacy from the same colonizers, the associated lack of investment in human and physical capital, the role of external powers during the Cold War, and the patronage system inherited from Mobutu's long-standing rule (Turner 2007).

[8] For instance, Stearns (2011) referred to several deals made between mining companies and rebel groups in the form of "advance taxes" or "down payments." Such minerals are also reported to have motivated the military support received by neighboring countries, such as Burundi, Rwanda, and Uganda. A report from International Crisis Group Africa (ICG 2006) also described the smuggling of major minerals, such as refined tin (also called cassiterite) or other derived metals from the tin group (such as coltan, niobium, and tungsten), through the Rwandan borders and of gold through the Ugandan border.

[9] These reports, including the study titled "Illegal Exploitation of Natural Resources and Other Forms of Wealth of the Democratic Republic of Congo" (April 12, 2001), have documented how mining activities can provide financial resources to conflict—mainly by offering monopolies in exchange for kickbacks, embezzling from state-run companies, creating joint ventures in which politicians are shareholders, taking kickbacks on numerous contracts with terms unfavorable to the state, and large-scale smuggling. Official statements have also been released, including the residential statements of the United Nations (S/PRST/2000/20; S/PRST/2001/3; S/PRST/2003/2).

[10] Stearns (2011) reported the interview of a pilot highly involved in military and mineral transportation during the Congolese wars: "The initial profits [in the first years of the second Congolese war], however, were nothing compared to what was to come. Everything changed in 2000, when the coltan price soared [said the interviewee]. It was a fluke. That year, the information technology bubble coincided with heightened demand for cell phones and the Christmas release of a Sony PlayStation console. Demand for tantalum, the processed form of coltan, had been rising steadily for years, but now the market got caught up in a buying frenzy. Within months, the local market price for tantalum shot up from $10 to $380 per kilo, depending on the percentage of ore content, while the world price peaked at $600 per kilo of refined tantalum. [. . .] Exports from

analysis of the Congo Wars and Vlassenroot and Raeymaekers's (2004) work on the Ituri conflict provide a more nuanced picture, however. Both studies present a detailed account of the extreme complexity of the situation that sparked and sustained violent conflicts in the DRC's Great Lakes region. Violence is described there as being the consequence of an unfortunate explosive mix of inherited grievances, ethnic polarization, land scarcities, regional control by foreign powers, and natural wealth. Austesserre (2012) even argued that the international community's overemphasis of mineral exploitation as a cause of conflict has led to inappropriate action and the exacerbation of violence. It is hardly deniable, however, that many Congolese mining locations have been looted and the minerals exported illegally over the years by both Congolese and foreign rebels, as well as by neighboring countries' militias (Montague 2002; CongdonFors and Olsson 2004; Prunier 2009; Freedman 2011). To explore the mineral resources–conflict nexus, the next section proceeds with an empirical investigation of the question.

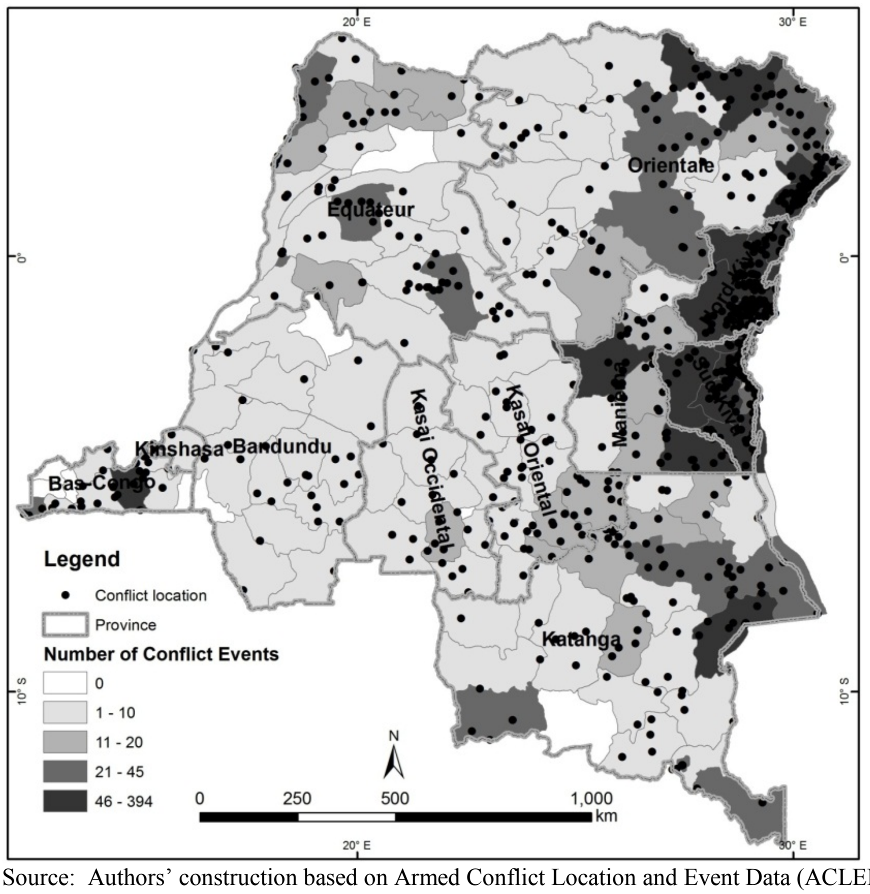
the eastern Congo and Rwanda soared to somewhere between $150 and $240 million in 2000 alone, and profit margins were high. [. . .] The profits facilitated the war" (299).

3. BASELINE ANALYSIS

Data

The empirical analysis is mainly based on the monthly variations of three variables. First, the dependent variable is the monthly sum of conflict events by territories or districts, using the Armed Conflict Location and Event Data (ACLED; Raleigh et al. 2010) from January 1997 to December 2007. More than 3,300 conflict events occurred during that period, including 2,898 violent events. As can be seen from Figure 3.1, most conflict events were concentrated in Orientale and North and South Kivu provinces. Conflict events were also concentrated in the territory of Pweto (Haut-Katanga district) in Katanga province, as well as in Kinshasa. The geographical dispersion of the data tracks the degree to which various areas of the Democratic Republic of the Congo (DRC) have been affected by conflict, thus giving us confidence regarding the data quality.

Figure 3.1—Distribution of conflict events in Democratic Republic of the Congo (DRC), 1997-2007



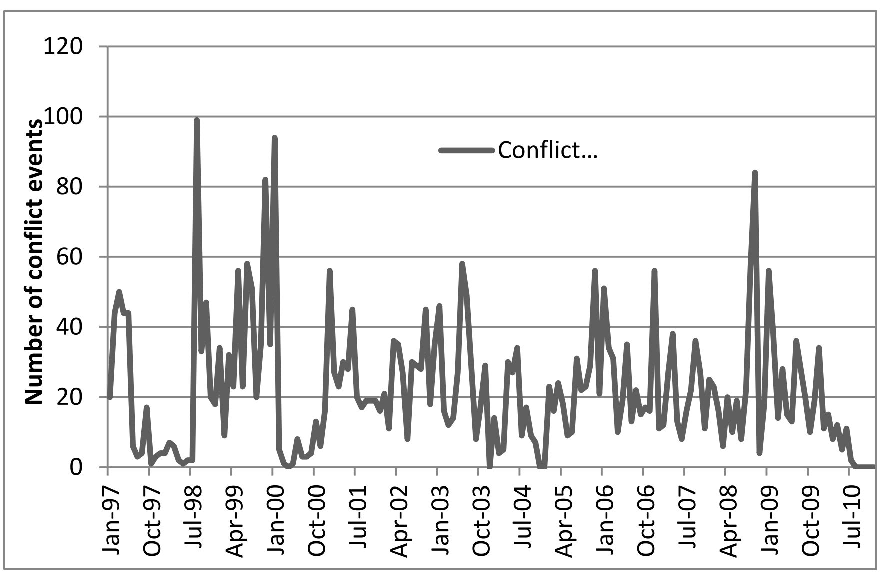
Source: Authors' construction based on Armed Conflict Location and Event Data (ACLED, Raleigh et al. 2010).
Note: Points represent the raw ACLED events.

North and South Kivu have been heavily exposed to conflict because of the presence of the *Forces Democratiques de Liberation du Rwanda* (FDLR)—a rebel group consisting of Rwandan Hutus who participated in the Rwandan genocide—and the willingness of the Rwandan government to seek revenge or eradicate this potential threat. In addition, since 2004, the *Congrès National pour la Défense du Peuple* (CNDP), led by Laurent Nkunda, has been present in the region. Note that the CNDP is allegedly supported by Rwanda to maintain that country's influence in the resource-rich eastern DRC. Orientale province—in particular, the districts of Ituri, Haut-Uele, and Bas-Uele and the territory of

Bafwasende—continues to suffer from the presence of the Ugandan Lord's Resistance Army and other armed groups, as well as from the emergence of ethnic local conflicts in Ituri (Spittaels and Hilgert 2010). Pweto is a small fishing village that, in 2000, witnessed one of the most important battles of the second Congolese war between the Congolese army of Laurent-Désiré Kabila (supported by foreign contingents from Zimbabwe, Angola, and Namibia) and Rwandan and Burundian troops (Stearns 2011). The main strategic value of this area is that it allows control of Lubumbashi, "the country's mining capital" (Stearns 2011, 272). The reason for violence in Kinshasa is explained by the strategic and political importance of the capital city in the Congolese conflicts. Our results are nonetheless robust to the exclusion of the Kinshasa district (or related territories) from the analysis.

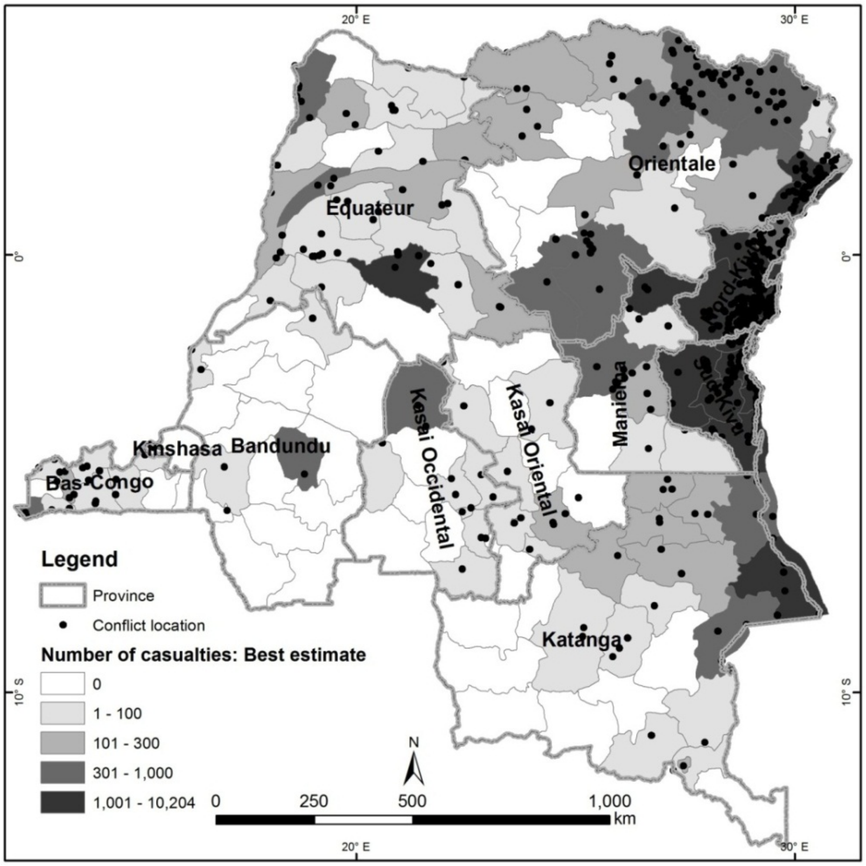
The evolution of conflict events exhibits large monthly variations. As illustrated in Figure 3.2, several peaks can be observed: in May 1997, January 2001, June 2003, November 2005, January 2006, and December 2006 and especially in August 1998, November 1999, January 2000, and October 2008. Conflict events occurring after 2007 are not included in our sample due to other data constraints. Since 2007, however, the recorded levels of conflicts were much lower. The observed peaks track well-documented increases of violence in DRC (see, for example, Turner 2007). We also define alternative dependent variables by either restricting the dependent variable to violent conflict events based on the ACLED dataset or computing the number of conflicts based on the Uppsala Conflict Data Program's (UCDP's) georeferenced events datasets (Sundberg et al. 2010). The UCDP data adopt a more restrictive definition of conflict events and only comprise events reporting at least one direct death. Over the period investigated, UCDP recorded 793 conflict events, in contrast to the 2,898 violent events in the ACLED dataset. Despite the difference of coding, the geographical distribution of UCDP conflict events in Figure 3.3 provides a fairly similar picture to the one depicted in Figure 3.1.

Figure 3.2—Number of conflict events in the Democratic Republic of the Congo (DRC), 1997–2010



Source: Authors' construction based on Armed Conflict Location and Event Data (ACLED, Raleigh et al. 2010).

Figure 3.3—Distribution of conflict events in the Democratic Republic of the Congo (DRC), 1997-2007

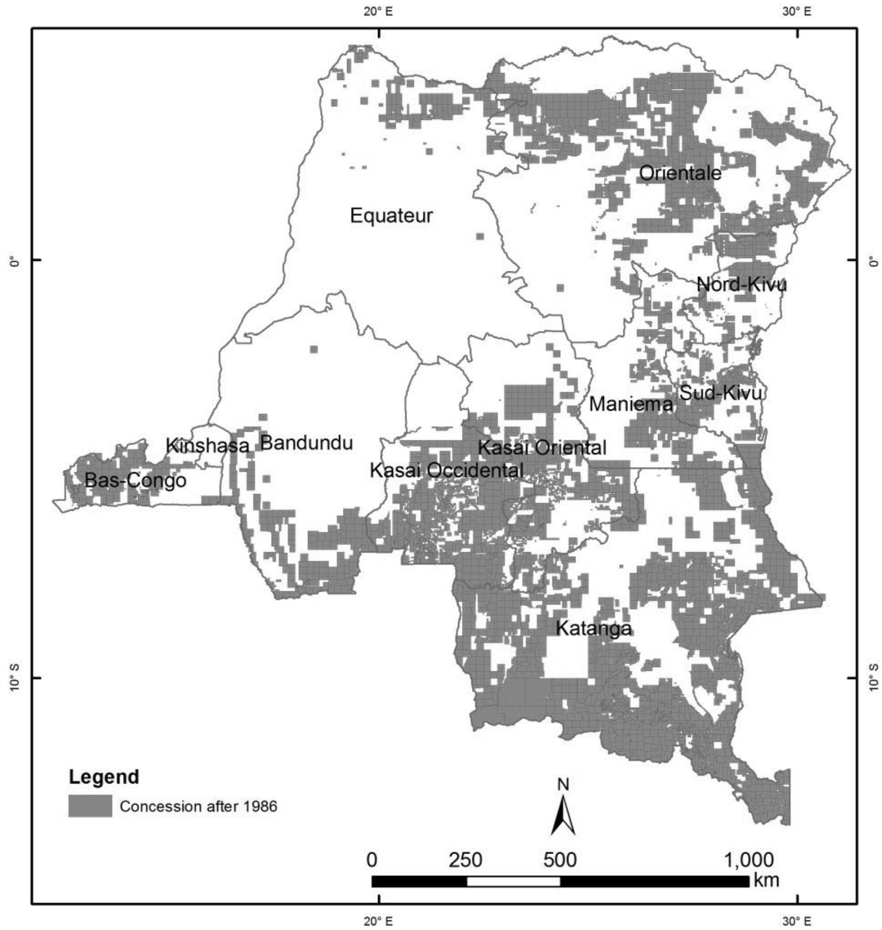


Source: Authors' construction based on Uppsala Conflict Data Program (UCDP, Sunderg et al. 2012).
Note: Points represent the raw UCDP events.

Second, the main variable of interest relates to the mining concessions. Based on data provided by the DRC Ministry of Mining (5,963 mining concessions granted between 1997 and 2007), we construct the monthly sum of mining concessions granted by territory or district. We also use the size of these new concessions as an alternative proxy. The minerals involved include gold, copper, diamonds, lead, silver, tin, zinc, palladium, tungsten, and iron ore. There are several types of mining concessions with different permits and associated fees. Due to sample size limitations, we do not distinguish between the two broad categories: research and operating.[11] A logarithm transformation is applied to the concession-related variables (adding the value 0.1 when there is no concession) to ease interpretation; results are still robust even without such transformation. In our database, concessions were granted between 1994 and 2007, with the exception of past concessions granted in 1968, 1969, and 1979, plus one concession in 1986. No concession was granted between 1986 and 1994. Figure 3.4 indicates that mining concessions were mainly granted in eastern and southern DRC, which is consistent with the country's geological conditions. Figures 3.1, 3.3, and 3.4 also suggest that mining concessions may be spatially correlated with the concentration of conflict events. However, our review of the literature advises us not to interpret such an imperfect correlation as causation.

[11] The research permit confers to its owner the exclusive right to conduct, within the scope of which it is established and for the duration of its validity, the research work of the mineral substances classified as mines for which the permit is granted. The operating permit gives its owner the exclusive right to perform, inside the perimeter on which it is established and for the duration of its validity, the research, development, construction, and exploitation of minerals for which the permit is established.

Figure 3.4—Distribution of mining concessions in the Democratic Republic of the Congo (DRC)



Source: Authors' construction based on data provided by the DRC Ministry of Mining.

Third, rainfall data are used to improve the efficiency of our estimates, since this variable is likely to capture opportunity cost effects that are unrelated to mining activities. Indeed, Miguel, Satyanath, and Sergenti (2004) used rainfall data to control for the climate-induced changes in agricultural income (in poorly irrigated countries) and the resulting changes in the incentives to participate in armed groups. Rainfall data are measured by the National Aeronautics and Space Administration (NASA), using a one-degree latitude-longitude grid. We follow a standard approach to transform rainfall data into anomalies—that is, deviations from normal rainfall conditions. More specifically, the anomalies are computed at the unit of observation (territory or district) and measure the deviations from the long-term monthly mean, divided by its monthly long-run standard deviation.[12] The monthly basis is chosen to correct for seasonality patterns of rainfall data, whereas the long-run period is defined by the longest period of available data (1997–2010). We introduce the quadratic term of rainfall anomalies to allow for a detrimental impact of excessive rainfall deviations as compared with normal conditions. Our central results are shown to depend neither on the inclusion of that variable nor on its quadratic term.

Table 3.1 provides the descriptive statistics of these variables. Given the relatively long period used, the nonstationary nature of our variables may be a point of concern, leading to possible spurious relationships (Maddala and Wu 1999). We perform the Fisher panel data unit root test on the dependent

[12] A positive (negative) anomaly therefore signals abnormally high (low) rainfall.

and explanatory variables (see Table 3.2). The test rejects the null hypothesis that the series in the panel contains a unit root. All series are stationary at any reasonable level of confidence.[13]

Table 3.1—Descriptive statistics

Level of Analysis: Territory					
Variable	Observations	Mean	Std. Dev.	Minimum	Maximum
Conflict number (ACLED)	19,800	0.153636	1.024244	0	41
Violent conflict Number (ACLED)	19,800	0.132677	0.960466	0	41
Conflict number (UCDP)	19,800	0.046818	0.336929	0	11
Mining concessions	19,800	0.280253	1.756388	0	46
Rainfall anomalies	19,800	1.08E-09	0.953487	-2.7708	3.003923
Price index	19,650	506.0248	2,965.579	0	57,774.78
Level of Analysis: District					
Variable	Observations	Mean	Std. Dev.	Minimum	Maximum
Conflict number (ACLED)	5,016	0.606459	2.44326	0	43
Violent conflict Number (ACLED)	5,016	0.523724	2.241598	0	43
Conflict number (UCDP)	5,016	0.184809	0.849571	0	16
Mining concessions	5,016	1.10626	5.46692	0	103
Rainfall anomalies	5,016	-3.09E-09	0.915527	-2.5412	2.990951
Price index	4,978	1,997.466	7,107.281	0	63,507.28

Source: Compiled by authors.
Note: The prices of copper, nickel, zinc, and lead are not available for April 1998, which explains the slight reduction of observations for the price index compared with other variables.

Table 3.2—Panel unit root test

Level of Analysis	Territory	District
Conflict number (ACLED)	6,470.20*	1,489.460*
Violent conflict number (ACLED)	6,432.27*	1,503.910*
Conflict number (UCDP)	5,069.57*	1,517.041*
Mining concessions (number)	5,223.01*	1,317.530*
Mining concessions (number, log)	4,390.79*	1,035.360*
Mining concessions (size)	5,818.43*	1,517.970*
Mining concessions (size, log)	4,403.62*	1,063.390*
Rainfall anomalies	62.03*	1,573.520*
Price index	0.193	0.174

Source: Compiled by authors, based on Maddala and Wu (1999).
Note: * $p < 0.01$.

Identification Strategy

Our analysis exploits monthly (t) and geographical (i) variations in the occurrence of conflict events $(Conflicts_{i,t})$ and the granting of mining concessions $(Concessions_{i,t})$ between January 1997 and December 2007 in order to draw causal inferences about the role of new or future mining activities on the level of violence in DRC. The period under investigation is dictated by data availability, which implies that our analysis is limited to the incidence of local conflict events, rather than to the onset of the first

[13] Note, on the other hand, that the instrumental variable has a unit root. This is not surprising given the previously described construction, and it does not threaten our identification strategy.

Congolese war (end of 1996). Using subnational within-variations, we are mainly capturing the local dynamics of the relationship between mining concessions and conflicts, while failing to capture the wider geopolitical dimensions. Ideally, we would like to estimate the following equation:

$$Conflicts_{i,t} = \alpha_i + \alpha_t + \theta t + \beta Concessions_{i,t} + \epsilon_{i,t} \quad . \tag{1}$$

Yet, despite the introduction of territory and district fixed effects (α_i), a time trend (θt), and a series of month-year time dummies (α_t) in estimating (1), we are likely to face severe endogeneity problems (Brunnschweiler and Bulte 2008, 2009). In our case, the granting of mineral concessions may be highly endogenous because of simultaneity as mining companies might be less likely to invest in conflict-prone areas) or because of omitted factors, since the granting of concessions may be driven by local politics that could equally directly influence the occurrence of conflict. In addition, measurement problems, in particular with the reported conflict events, are likely to correlate with conflict events, thereby introducing additional biases.

To deal with these methodological challenges, our estimation relies instead on an instrumentalization strategy similar to Brückner and Ciccone (2010). We exploit historical concessions, coupled with changes in mineral international prices, to assess the causal relationship between mining concessions and conflict. *Historical concessions* are defined as those granted in 1968, 1969, and 1970, plus one in 1985. Mineral-specific international prices from the UN Conference on Trade and Development's (UNCTAD's) commodity price statistics are normalized.[14] A price index is then constructed by interacting the number of past concessions of mineral j in location i ($PastConc_{i,j}$) with the time-varying international prices of the mineral j that the mining concessions extractor aims to extract ($P_{j,t}$). The constructed index may be expressed as follows:[15]

$$PriceIndex_{i,t} = \sum_j PastConc_{i,j} P_{j,t} \quad . \tag{2}$$

The two-stage least-square estimation is implemented at two geographical levels of analysis: the territory and the district levels. A linear specification is adopted, because nonlinear methods in a two-stage framework imply strong specification assumptions (Angrist and Krueger 2001). Accordingly, our estimating equations are the following:

$$\begin{aligned} Conflicts_{i,t} &= \alpha_i + \alpha_t + \theta t + \beta_1 \widehat{Concessions}_{i,t} + \beta_2 Rainfall_{i,t} + \epsilon_{i,t} \\ Concessions_{i,t} &= \alpha_i + \alpha_t + \theta t + \gamma_1 PriceIndex_{i,t} + \gamma_2 Rainfall_{i,t} + \epsilon_{i,t} \end{aligned} \quad . \tag{3}$$

Although it does not alter the main results of this paper, we also control for rainfall anomalies ($Rainfall_{i,t}$) to control for changes in the opportunity cost to fight that are unrelated to mining concessions. To control for other unobserved factors, our estimates introduce territory and district fixed effects (α_i), a time trend (θt), and a series of month-year time dummies (α_t).

The use of time-varying international prices, coupled with historical concessions, provides an exogenous shock on the probability of granting a new mining concession of a particular mineral type. The rationale for using international prices as an exogenous variation is that conflicts in one particular territory or district of the DRC cannot alone affect the international prices of these minerals.[16] However,

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[14] If reported by UNCTAD to be traded internationally on different markets, we select the U.S. market as the reference. The prices are normalized to 100 for the first month of 1997. The prices of copper, nickel, zinc, and lead are not available for April 1998, which explains the slight reduction of observations for the price index compared with other variables (see Table 3.1).

[15] Notice that similar results are found when the price index is expressed as a proportion—that is, when $PastConc_{i,j}$ is divided by $\sum_j PastConc_j$.

[16] The price of coltan is excluded from the construction of the price index to ensure the exogenous nature of the price index as an instrument. DRC is one of the major coltan producers, producing in 2001 about 4 percent of the world's production (Roskill

changes in international prices may change the incentives to acquire mining concessions. Indeed, an increase in international prices should increase the attractiveness of obtaining a new mining concession, given the higher expected revenues. This is particularly true in areas where concessions of similar minerals have been granted in the past. The reasons may be related not only to the physical presence of these minerals but also to the investments needed to exploit these minerals, such as investments in infrastructure, as well as the local labor market conditions and the existing contractual arrangements. Anecdotal evidence suggests that changes in prices may have an immediate impact on mining exploitation and demand for concessions.[17]

Our identification strategy strongly relies on the validity of instrumental variable. While the relevance of that instrument may be directly tested, the exclusion restriction may be questioned. Our assumption is that the constructed price index is uncorrelated with the error terms, which implies that this index affects conflicts exclusively through the contemporaneous granting of concessions. Asserting that the international prices of minerals are exogenous is a reasonable assumption. Our exclusion restriction, however, also requires that the unobserved political discretionary rules affecting the granting of mining concessions are different for the contemporaneous mining concessions (1997–2007) and for the historical concessions granted in 1968, 1969, and 1970. This assumption, which amounts to stating that the change of regime from Mobutu Sese Seko's rule to the reign of Laurent-Désiré Kabila (and his succeeding son, Joseph Kabila), merits some additional justifications.

First, the different geographical origin (Orientale province for Mubutu and Katanga province for Kabila) and ethnic group origin (Ngbandi for the former and Luba for the latter) suggest that the rules of discretion in granting concessions are unlikely to have been the same in the two periods. Anecdotal evidence about the way mining concessions were granted in the two periods seems to support that assumption. Under Mobutu's rule, the mining sector was entirely nationalized, and mining concessions were largely under the control of the centralized and authoritarian regime. Mining revenues were largely used to "fund Mobutu's patronage network, instead of reinvesting earnings into infrastructure and development" (Stearns 2011, 289). The rules of the game gradually changed in 1995, when Mobutu allowed his prime minister, Léon Kenga Wa Dondo, to gradually privatize the mining sector. In 1997, "the rebellion [led by Kabila] applied its half-Marxist, half-liberal approach to mining, adopting a slipshod policy that imposed harsh conditions on large foreign companies, while favoring shadowy investors who often lacked the resources and expertise necessary to develop mining concessions" (Stearns 2011, 290).

Second, the economic conditions surrounding the mining concessions experienced important changes between the two periods. At the end of the 1970s, with the mineral prices for copper, gold, and cobalt being high, the mining sector was the largest source of employment and income in DRC. In the 1990s, however, both detrimental economic conditions, such as the decreased copper prices (largely due to an increased supply from Chile and a reduced world demand), and years of mismanagement dampened the profitability of mining activities. According to Stearns (2011), "Exports [of copper] declined from a high of 465,000 tons in 1988 to 38,000 tons just before the war, while cobalt production slipped from 10,000 to 4,000 tons in the same period. Similar trends affected all other mineral exports" (289).

Information Services 2002). However, the results remain unaltered when the price of coltan is included in the price index. Coltan prices are derived from Roskill Information Services (2002) and the U.S. Geological Survey. We thank Olivier Dagnelie for sharing those data.

[17] For example, *The Economist (2011)* reports how following record rises in mineral prices, mining companies came from all over the world to deal with the governor of Katanga, a province that is home to about 5 percent of the world's copper and nearly half its cobalt.

Empirical Results

In Table 3.3, we implement the two-stage least-square (2SLS) estimation described in the preceding section. At both levels of analysis (territory and district), the price indices appear to be highly relevant in the sense that they strongly and positively affect the probability of receiving a mining concession. The F test on excluded instruments allows us to unambiguously dismiss the risk of weak instruments. We also use a just-identified equation, which is known to be approximately unbiased. The second-stage regressions at the territorial level (regressions (1)–(6) of Table 3.3) reveal that granted mining concessions, in terms of both number and size, do not affect the risk of conflict. This finding holds true whether using the ACLED database or the (more selective) UCDP dataset.

At the district level, however, the instrumented mining concessions significantly increase the risk of conflict—in particular, of violent conflicts (regressions (7)–(12) of Table 3.3).[18] At the district level, given the mean number of conflict events reported in Table 3.1, a 10 percent increase in both the number and the size of mining concessions would increase the likelihood of conflict by about 29 and 11 percent, respectively.[19] These results are robust to the use of the alternative definition of *mining concessions,* evaluated on the basis of the years of demand (instead of the years of granting). Not proceeding to the logarithmic transformation does not alter the results. In addition, our findings are robust to the exclusion of the capital district (or two territories), Kinshasa, from the sample.

This result constitutes a case of *ecological fallacy,* or an aggregation problem—that is, it is a misleading assumption that the relationship observed at an aggregated level (for example, the district level) implies the same relationship at a different level of aggregation (for example, the territory level). This observed ecological fallacy calls for a better understanding of the underlying mechanisms in order to fully evaluate the impact of mining concessions on conflict. In Section 4, we develop a theoretical model that aims at identifying these mechanisms.

[18] Such results hold when violence against civilians and violent confrontations between armed groups (only possible with the ACLED dataset) are used instead of the violent conflicts variable. In turn, mining concessions do not seem to have any effect on nonviolent events. Although not shown for presentation purposes, a naive regression that assumes the mining concessions are exogenous indicates that the (potential) endogeneity of mining concessions is likely to introduce a downward bias—that is, the granting of mining concessions significantly decreases the level of conflict at both the territory and the district levels.

[19] These effects are computed based on regressions (7) and (10) of Table 3.3. Using, respectively, the violent events from the ACLED and the UCDP databases, similar changes in the number of concessions would increase the likelihood of conflict by 31 and 48 percent (regressions (8) and (9)), respectively. The equivalent figures when modifying the size of the concessions are 11 and 17 percent (regressions (11) and (12)).

Table 3.3—Baseline results: A case of ecological fallacy

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Level of Analysis	Territory						District					
	Second-Stage Regressions											
Dependent Variable	Conflicts ACLED	Violent conflicts ACLED	Conflicts UCDP	Conflicts ACLED	Violent conflicts ACLED	Conflicts UCDP	Conflicts ACLED	Violent conflicts ACLED	Conflicts UCDP	Conflicts ACLED	Violent conflicts ACLED	Conflicts UCDP
Concessions (log)	-0.104	0.013	0.089				1.752**	1.64**	0.885**			
	[0.165]	[0.137]	[0.054]				[0.802]	[0.718]	[0.361]			
Concessions Size (log)				-7.3e-10	9.4e-11	6.2e-10				0.642**	0.601**	0.324**
				[1.2e-09]	[9.7e-10]	[4.1e-10]				[0.290]	[0.260]	[0.131]
Rainfall Anomalies	-0.025**	-0.023**	-0.008**	-0.026***	-0.023**	-0.008**	-0.162**	-0.144**	-0.052*	-0.168***	-0.15**	-0.055*
	[0.009]	[0.009]	[0.003]	[0.009]	[0.009]	[0.004]	[0.063]	[0.058]	[0.029]	[0.063]	[0.058]	[0.029]
Rainfall Squared Anomalies	-1.3e-04	10.5 e-04	-3.7e-04	-8.3e-04	11.4e-04	2.26e-04	0.078	0.069	0.027	0.081*	0.072	0.028
	[0.006]	[0.006]	[0.002]	[0.007]	[0.006]	[0.003]	[0.049]	[0.046]	[0.022]	[0.048]	[0.045]	[0.021]
Month Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Territory/District Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	19,650	19,650	19,650	19,650	19,650	19,650	4,978	4,978	4,978	4,978	4,978	4,978
Number of Territories/Districts	150	150	150	150	150	150	38	38	38	38	38	38
Underientification	24.2***	24.2***	24.2***	8.186***	8.186***	8.186***	26.99	26.99	26.99	27.42	27.42	27.42
Root Mean Square Error	0.98	0.92	0.33	1.008	0.92	0.39	2.81	2.61	1.18	2.73	2.54	1.18

Table 3.3—Continued

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Level of Analysis	Territory						District					
	First-Stage Regressions											
Dependent Variable	Concessions (log)	Concessions (log)	Concessions (log)	Concessions Size (log)	Concessions Size (log)	Concessions Size (log)	Concessions (log)	Concessions (log)	Concessions (log)	Concessions Size (log)	Concessions Size (log)	Concessions Size (log)
Price Index	4.73e-05***	4.73e-05***	4.73e-05***	6,723***	6,723***	6,723***	4.6e-05***	4.6e-05***	4.6e-05***	0.00013***	0.00013***	0.00013***
	[8.31e-06]	[8.31e-06]	[8.31e-06]	[2,142]	[2,142]	[2,142]	[7.45e-06]	[7.45e-06]	[7.45e-06]	[1.92e-05]	[1.92e-05]	[1.92e-05]
Rainfall Anomalies	0.016**	0.016**	0.016**	1.14e+06	1.14e+06	1.14e+06	0.029	0.029	0.029	0.088	0.088	0.088
	[0.008]	[0.008]	[0.008]	[3.38e+06]	[3.38e+06]	[3.38e+06]	[0.021]	[0.021]	[0.021]	[0.056]	[0.056]	[0.056]
Rainfall Squared Anomalies	-0.009*	-0.009*	-0.009*	-2.29e+06	-2.29e+06	-2.29e+06	-0.033**	-0.033**	-0.033**	-0.093**	-0.093**	-0.093**
	[0.005]	[0.005]	[0.005]	[2.71e+06]	[2.71e+06]	[2.71e+06]	[0.015]	[0.015]	[0.015]	[0.038]	[0.038]	[0.038]
Month Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Territory/District Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	19,650	19,650	19,650	19,650	19,650	19,650	4,978	4,978	4,978	4,978	4,978	4,978
R squared	0.21	0.21	0.21	0.068	0.068	0.068	0.306	0.306	0.306	0.297	0.297	0.297
Number of Territories/ Districts	150	150	150	150	150	150	38	38	38	38	38	38
F-Test	12.11***	12.11***	12.11***	3.172***	3.172***	3.172***	7.194***	7.194***	7.194***	7.422***	7.422***	7.422***
F-Test on excluded Instruments	32.37***	32.37***	32.37***	9.86***	9.86***	9.86***	38.97***	38.97***	38.97***	43.67***	43.67***	43.67***

Source: Authors' estimations.

Notes: *** p < 0.01, ** p < 0.05, * p < 0.1.
Robust standard errors are in brackets.

4. THEORETICAL FRAMEWORK

We consider a region represented by a unit-length line and inhabited by a uniformly distributed continuum of individuals of unit mass. These individuals are each endowed with a unit amount of time. All mining concessions operating in this territory are under the control of a mine-extraction company, which is controlled by incumbent I. We assume, without loss of generality, that the concessions are located at the line's origin. The incumbent attempts to retain control over the mining profits, while a challenger endeavors taking over the region with the mining concessions. Labor constitutes the unique input of the mining activity, and we assume that the mining company is a local monopsonist on the labor market. The profits, π, which are (negatively) influenced by fighting between the incumbent and the challenger over the control of the resources, read as follows:

$$\pi(x_m, d_v; A) = (\varphi(x_m) - y_m(x_m, d_v))\, n x_m \quad , \tag{4}$$

where φ is the unit return to labor from mining, which we assume to be concave in the number of workers active in the mine, x_m. The parameter n captures the size or number of the mining concessions.[20] The workers are remunerated at the (endogenous) wage of y_m. The monopsonist will therefore determine the demand for mining labor.

Regarding the supply side of the labor market, the individuals of this society have two occupational choices: mining (x_m) or farming ($x_f = 1 - x_m$). The farming activity yields income y_f. Mining is remunerated at wage y_m, yet the miners have to incur the unit commuting cost of $(1 - d_v)\tau$ to move from their initial location to the mining company, where d_v is the location of conflict with respect to the mine's location. An individual i located at a distance d_i from the mine will therefore prefer working in the mining sector instead of farming if $y_m \geq y_f + (1 - d_v)\tau d_i$.

The incumbent maximizes his profits with respect to three choice variables: (i) the number of miners x_m, (ii) the amount of soldiers to deploy against the challenger, x_i, given the exogenous unit cost $\bar{y}$ of the soldiers,[21] and (iii) the extent of the territory, d_v, over which to deploy his army given an increasing and convex deployment cost, $c(d_v)$[22]. We describe the probability that the incumbent beats the challenger in fighting by the product $p(x_i, x_c)e(d_v)$, where x_c is the challenger's number of soldiers and where the fighting technology satisfies some very general assumptions, as in Skaperdas (1996):

$$p(x_i, x_c) = \frac{g(x_i)}{g(x_i) + g(x_c)} \;\; , \;\; ,g'(x_j) > 0 \;\; , \;\; ,g''(x_j) < 0 \;\; , \;\; j = \{i, c\} \quad .$$

The fighting efficiency dimension is captured by the function $e(d) \in [0, 1]$, with $e'(d) < 0, e'' < 0, e(0) = 1$, and $e(1) \geq 0$.

The utility of the incumbent is therefore given by

$$u_i = p(x_i, x_c)e(d_v)\pi(x_m, d_v) - \bar{y}x_i - c(d_v) \quad . \tag{5}$$

[20] We assume that the production technology is linear in n, which results in the profits being homogeneous of degree 1 in size.

[21] Making the fighters' remuneration endogenous would unnecessarily complicate the model. Indeed, having assumed that the pool of workers is not influenced by the number of fighters recruited, the endogenous remuneration of the latter would simply amount to a rescaling of our results.

[22] All results remain qualitatively unchanged if we assume the deployment cost is linear.

Since the labor force, x, has two occupational choices and the commuting cost, τ, is incurred by the workers, it follows that for mining wage y_m, any individual lying on the interval $[0, d_m]$ prefers joining the mining to farming, where d_m is defined as:

$$d_m = \frac{y_m - y_f}{\tau(1 - d_v)}.$$

We thus have the mining labor supply as follows:

$$x_m^s = \begin{cases} \frac{y_m - y_f}{\tau(1-d_v)} & \text{if } \frac{y_m - y_f}{\tau(1-d_v)} \leq 1 \\ 1 & \text{otherwise} \end{cases}.$$

It then follows that the inverse labor supply function is given by:

$$y_m = \begin{cases} \tau x_m(1 - d_v) + y_f & \text{if } x_m^s \leq 1 \\ \tau(1 - d_v) + y_f & \text{otherwise} \end{cases}.$$

We can now write the incumbent's maximization problem as follows:

$$\max_{x_m, d_v, x_i} \left\{ \frac{g(x_i)}{g(x_i) + g(x_c)} e(d_v) \left[\varphi(x_m) - \tau x_m(1 - d_v) - y_f \right] n x_m - \bar{y} x_i - c(d_v) \right\}. \quad (6)$$

Optimizing yields the following first-order conditions:

$$\frac{\partial u_i}{\partial x_m} = p(x_i, x_c) e(d_v) n \left(\varphi(x_m) - y_f + \varphi'(x_m) x_m - 2\tau(1 - d_v) x_m \right) = 0 \quad (7)$$

$$\frac{\partial u_i}{\partial d_v} = p(x_i, x_c) \left(e'(d_v) \pi(x_m) + e(d_v) \tau n x_m^2 \right) - c'(d_v) = 0 \quad (8)$$

$$\frac{\partial u_i}{\partial x_i} = p_{x_i}(x_i, x_c) e(d_v) \pi(x_m, d_v) - \bar{y} = 0 \quad (9)$$

To show that the incumbent's best response consists of selecting a unique combination of $(x_m(x_c), d_v(x_c), x_i(x_c))$, we need to show that the incumbent's utility function is quasi-concave in his decision variables. Let us sequentially consider the second-order conditions:

$$\frac{\partial^2 u_i(x_m)}{\partial x_m^2} = p(x_i, x_c) e(d_v) n \left(2\varphi'(x_m) - 2\tau(1 - d_v) + \varphi''(x_m) x_m \right). \quad (10)$$

To establish the utility function's quasi-concavity, it is sufficient to show that $\partial\pi(x_m)/\partial x_m \leq 0) \Rightarrow \partial^2\pi(x_m)/\partial x_m^2 < 0$. Notice first that in this expression, the third term is negative. A sufficient condition for establishing the unicity of x_m^* is that

$$\partial\pi(x_m)/\partial x_m \leq 0 \Rightarrow \varphi'(x_m) < \tau\,(1 - dv) < 0.$$

We can next re-express $\partial\pi(x_m)/\partial x_m \leq 0$ as follows:

$$\varphi'(x_m) \leq 2\tau(1-d_v) - \frac{\varphi(x_m) - y_f}{x_m}.$$

Thus, to establish (strict) quasi-concavity, it is sufficient to show the following:

$$2\tau(1-d_v) - \frac{\varphi(x_m) - y_f}{x_m} < \tau(1-d_v) \Leftrightarrow \tau(1-d_v)x_m < \varphi(x_m) - y_f.$$

In addition, because this last inequality is always verified if $\pi(x_m) > 0$, we can deduce that there exists a unique $x_m(x_i, x_c, d_m)$.
The others second-order conditions are given by:

$$\frac{\partial^2 u_i}{\partial d_v^2} = p(x_i, x_c)\left(e''(d_v)\pi(x_m, d_v) + 2e'(d_v)\tau n x_m^2\right) - c''(d_v) < 0 \quad (11)$$

$$\frac{\partial^2 u_i}{\partial x_i^2} = p_{x_i x_i}(x_i, x_j)e(d_v)\pi(x_m, d_v) < 0 \quad (12)$$

The sign of expression (12) is a consequence of $p_{xixi} \leq 0$, which can be computed straightforwardly.
The challenger's optimization problem is analogously given by

$$\max_{x_c} u_c = p(x_i, x_c)e(d_v)\pi(x_m, d_v) - \bar{y}x_c. \quad (13)$$

Optimizing gives the following first-order conditions:

$$\frac{\partial u_c}{\partial x_c} = p_{x_c}(x_i, x_c)e(d_v)\pi(x_m, d_v) - \bar{y} = 0. \quad (14)$$

It is straightforward to show that the challenger's objective function is concave in x_c.
Having showed that the problem is well behaved, we can deduce that a Nash equilibrium for this game exists (see Mas-Collel, Whinston, and Green 1995, proposition 8D3). Moreover, by combining equations (9) and (14), we can deduce that $x_i = x_c$. Equipped with these results, we can now conduct comparative statics on the parameters of interest.

Comparative Statics: Changes in the Size of the Mining Industry

Using condition (7), we can derive the following expression:

$$\frac{dx_m^*}{dn} = -\frac{p(x_i, x_c)e(d_v)\partial\pi(x_m, d_v)/\partial x_m}{\frac{\partial^2 u_i}{\partial x_m^2}} = 0 \quad (15)$$

The numerator is nil as it equals the first-order condition in (7) up to a multiplicative term n.
Because the size of the mining sector linearly affects the profitability of the mining activity, modifying the mining sector size will not change the optimal number of hired miners, since both the marginal cost of hiring an additional worker and his marginal return for the company are unaffected by the increase in n.
This does not mean, however, that the industry has not become more profitable; rather, the incumbent will see his profits increase proportionally to the size of the mines he controls.
Proceeding likewise with condition (8), we obtain

$$\frac{dd_v^*}{dn} = -\frac{p(x_i, x_c)\left[e'(d_v)\partial\pi(x_m, d_v)/\partial n + e(d_v)\tau x_m^2\right]}{\frac{\partial^2 u_i}{\partial d_v^2}},$$

which can be rewritten as follows:

$$\frac{dd_v^*}{dn} = -\frac{p(x_i, x_c)\left[\frac{e'(d_v)\pi(x_m,d_v)+e(d_v)\tau n x_m^2}{n}\right]}{\frac{\partial^2 u_i}{\partial d_v^2}} \quad (16)$$

Using the first-order condition (8), we can immediately deduce that the numerator of (16) is positive, thus implying that $\partial d_v^*/\partial n > 0$.

Finally, we can derive the effect of a change in n on the intensity of conflict by using condition (9):

$$\frac{dx_i^*}{dn} = -\pi_{x_i}(x_i^*, x_c^*)e(d_v^*)\frac{\partial\pi(x_m, d_v)/\partial n}{\frac{\partial^2 u_i^*}{\partial x_i^2}} > 0 \quad (17)$$

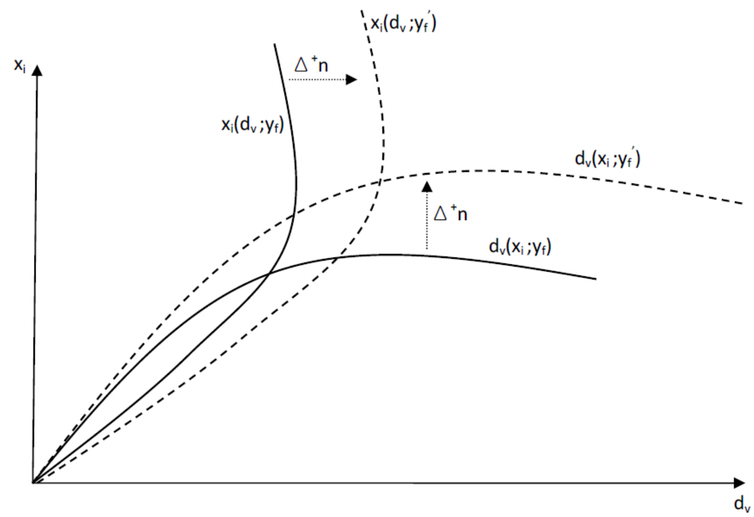
And since $x_i^* = x_c^*$, we have that $\partial x_c^*/\partial n > 0$.

To visualize the effect of number or size of mining sites on intensity and spatial location of violence, we proceed to a graphical representation. First, we describe the relationship between the fighting location and fighting intensity.

Fixing $x_m = x_m^*$ and $x_c = x_c^*$, we can show that the reaction functions $d_v(x_i)$ and $x_i(d_v)$ are both concave and cross each other on their increasing part. Using the comparative statics' results, we can therefore construct on Figure 4.1 the change of equilibrium following a change in n. Notice that in the neighborhood of the equilibrium, conflict remoteness and conflict intensity are strategic complements: intensifying fighting efforts gives the incumbent the incentives to push the conflict farther away, while more remote violent episodes induces the incumbent to increase conflict intensity. When the incumbent mobilizes more fighters, the likelihood of controlling the mines is increases, thereby inducing the incumbent to displace conflict farther away from the mining site to increase the profitability of mining.

An increase in the size, and therefore profitability, of the mining sector controlled by the incumbent has a positive effect on both d_v and x_i. Since the marginal return of protection increases, the incumbent will attempt to move the conflict location farther from the mining site, up to the point at which the marginal return equalizes the marginal cost of the operation. The impact of a larger mining sector on conflict intensity is naturally also positive: the larger the pie at stake in the conflict the more intense the fighting. Additionally, the above-described strategic interaction between d_v and x_i pushes the conflict location farther away from the mining location, and its intensity upwards.

Figure 4.1—Effect of an increase in agricultural yields on the location and intensity of conflict



Source: Authors' creation.

Comparative Statics: Changes in y_f

The level of farming income y_f has an impact on the opportunity cost of mining, and thus on the labor supply of miners, while also influencing the exit options of fighters who have the possibility of reconverting to mining or farming. Combined, these changes will affect the optimal number of miners, the fighting location d_v^*, and the intensity of conflict as measured by the number of fighters involved, x_i^* and x_c^*. The following comparative statics may be derived by applying the implicit functions theorem (IFT) to equation (7):

$$\frac{dx_m^*}{dy_f} = -\frac{\left[p_{x_i}e + p_{x_c}e + pe'\right] n \overbrace{\frac{\partial \pi}{\partial x_m}}^{=0} + pe\left(-1 + 2\tau x_m \frac{\partial d_v}{\partial y_f}\right) n}{\frac{\partial^2 u_i}{\partial x_m^2}} \quad . \qquad (18)$$

We thus have that $\frac{dx_m^*}{dy_f} < 0$ if

$$\frac{2\tau e' x_m^2}{e''\pi + 2\tau e' x_m^2} < 1 \Leftarrow e'' < 0 \quad .$$

If we look next at the effect of a change of y_f on d_v^*, we find that it is ambiguous. By applying the IFT to condition (8), we obtain

$$\frac{dd_v^*}{dy_f} = -\frac{p\left(-e' n x_m + e' \overbrace{\frac{\partial \pi}{\partial x_m}}^{=0} \frac{\partial x_m}{\partial y_f} + 2e\tau n x_m \frac{\partial x_m}{\partial y_f}\right) + \overbrace{\left(p_{x_i}\frac{\partial x_i}{\partial y_f} + p_{x_c}\frac{\partial x_c}{\partial y_f}\right)}^{=0}\left[e'\pi + e\tau n x_m^2\right]}{\frac{\partial^2 u_i}{\partial x_m^2}} \quad .$$

The sign of this expression is therefore the same as the sign of $nx_m\ (2e\tau\partial x_m/\partial y_f - e')$, which is nonsignable. The former term represents the increased incentives of the incumbent to bring the conflict closer to the mining location; for lower mining profits, the marginal utility of securing the labor force by pushing the conflict away is reduced. The second (positive) term captures the mitigating force of the lower marginal return to protecting the (now lower) profits, which in turn incentivizes the incumbent to push conflict farther away.

We finally explore the effect of a change of y_f on the conflict intensity as captured by the pair (x_i^*, x_c^*). Applying the IFT to (9) yields

$$\frac{\partial x_i^*}{\partial y_f} = -\frac{p_{x_i x_c}\frac{\partial x_c}{\partial y_f}e\pi + e'\frac{\partial d_v}{\partial y_f}p_{x_i}\pi + p_{x_i}e\left(-nx_m + \frac{\partial \pi}{\partial x_m}\frac{\partial x_m}{\partial y_f} + \frac{\partial \pi}{\partial d_v}\frac{\partial d_v}{\partial y_f}\right)}{\frac{\partial^2 u_i}{\partial x_i^2}} \quad . \qquad (19)$$

Using the fact that $x_i^* = x_c^* \Rightarrow p_{x_i x_c} = 0,$ and $\partial\pi\ /\ \partial x_m\ = 0,$ the sign of (19) is given by the sign of

$$e'\frac{\partial d_v}{\partial y_f}\pi - enx_m - e\frac{\partial \pi}{\partial d_v}\frac{\partial d_v}{\partial y_f} = \frac{\partial d_v}{\partial y_f}\underbrace{\left[e'\pi + e\pi'\right]}_{>0} - enx_m \quad , \qquad (20)$$

where the underbraced term is positive given FOC (8). According to the discussion on the effect of y_f on d_v^*, we can conclude that if $\partial d_v^*/\partial y_f\ \leq 0$, then an increase in agricultural yields will also reduce the intensity of violence. The intuition of this result is as follows: Higher agricultural yields modify the optimal location of fighting. If conflict is brought closer to the mining location, then the efficiency of the defending armed group increases, as do the mining profits. The former effect increases the marginal benefit of farming, whereas the latter has the opposite consequence. Yet, the latter effect is shown to always dominate the former. In addition, higher values of y_f have a direct negative effect on the profitability of mining (via the labor market), and lower profits reduce the incentives to arm. Thus, if higher agricultural yields push the incumbent entrepreneur to bring conflict closer to the mining site, all forces push the conflict intensity downward. If, however, , $\partial d_v^*/\partial y_f > 0$, then the net effect will be indeterminate.

We have therefore shown that an increase in the agricultural yields raises the exit options of mining workers, thereby translating to a reduction in labor supply, which, in turn, reduces the number of miners hired at equilibrium. In Section 5, we revisit the empirical strategy and confront our comparative statics results to the data.

5. REVISITING THE EMPIRICAL ANALYSIS

Our theoretical model suggests that the impact of mining concessions raises the risk of conflict is non-homogeneous across space. In particular, increasing the size or number of mining site(s) has the potential not only of increasing overall conflict intensity but also of displacing violent events farther from mineral deposits. Following Florax and Folmer (1992), we assess the role of spatially lagged mineral concessions. We apply the method to our panel analysis following Anselin (2002).[23] We augment equations (2) with a spatially lagged explanatory variable in the following way:

$$\begin{aligned} Conflicts_{i,t} &= \alpha_i + \alpha_t + \theta t + \beta_1 \widehat{Concessions}_{i,t} + \beta_2 W\widehat{Concessions}_{i,t} \\ &+ \beta_3 Rainfall_{i,t} + \epsilon_{i,t} \\ Concessions_{i,t} &= \alpha_i + \alpha_t + \theta t + \phi_1 PriceIndex_{i,t} + \phi_2 W PriceIndex_{i,t} \\ &+ \phi_3 Rainfall_{i,t} + \epsilon_{i,t} \\ WConcessions_{i,t} &= \alpha_i + \alpha_t + \theta t + \theta_1 PriceIndex_{i,t} + \theta_2 W PriceIndex_{i,t} \\ &+ \theta_3 Rainfall_{i,t} + \epsilon_{i,t} \end{aligned} \quad . \qquad (21)$$

We use a distance-based spatial matrix, based on the inverse distance decay function. $WConcessions_{i,t}$ and $WPriceIndex_{i,t}$ are weighted sums of the concession-based variables and price indices at other locations. We can, for instance, express the variable $WConcessions_{i,t}$ as follows:

$$WConcessions_{i,t} = \sum_{j \neq i} w_i j Concessions_{j,t} \quad \text{where} \quad w_i j = \frac{d_{ij}^{-\gamma}}{\sum_j d_{ij}^{-\gamma}}$$

and where γ takes the values 1 or 2, as these are the most common integers used in spatial econometrics (Anselin 2002).

Table 5.1—Lagrange Multiplier tests for spatial correlations

	(1)	(2)	(3)	(4)	(5)	(6)
Level of Analysis		Territory			District	
Dep. Var.	Conflicts ACLED	Violent Conflicts ACLED	Conflicts UCDP	Conflicts ACLED	Violent Conflicts ACLED	Conflicts UCDP
Tests			Lagrange Multiplier Test			
Variable of Interest			Concessions (number, log)			
Spatial Lag	73.69***	73.69***	390.098***	3.2	3.8	6.89***
Spatial Error	73.49***	73.49***	385.95***	2.7	3.4	6.38***
Variable of Interest			Concessions (size, log)			
Spatial Lag	90.98***	73.69***	390.098***	3.2	3.8	6.89***
Spatial Error	91.95***	73.49***	385.98***	2.7	3.4	6.38***

Source: Authors' estimations.
Note: ***p < 0.01.

[23] As shown in Table 5.1 (columns (1)–(3)), the LM tests performed at the territory level suggest significant spatial lags and error correlations. However, at the district level, only Uppsala Conflict Data Program (UCDP) variables display significant spatial correlation (column (6)). To account for spatial correlation, we estimate spatial panel models with time and location fixed effects, using Matlab routines and methods developed by Elhorst (2003, 2010). The estimation approach includes the bias correction procedure proposed by Lee and Yu (2011) if the spatial panel data models contain spatial and/or time-period fixed effects. Because of the absence of convincing evidence of the presence of spatial correlation at the district level, in addition to a possible small sample bias with respect to districts (only 38), we discuss only territory-level estimates.

Table 5.2 indicates that at the territory level (regressions (1)–(3)), the granting of mining concessions in the neighboring territory significantly increases the risk of conflict (especially violent conflicts), thus implying that the granting of concessions in neighboring territories exacerbates the intensity of conflict. The coefficient of the non-spatially lagged variable is negative and significantly different from zero (close to significant in regression (3)). Table 5.2 indicates that these results are robust to the use of an alternative spatial matrix of order 1 (instead of 2) and to the size of the concessions rather than to their number (regressions (4)–(12) in Table 5.2).

In Table 5.3, we report estimation results using explicit spatial models for panel data based on the methods developed by Elhorst (2003, 2010), along with the bias correction procedure proposed by Lee and Yu (2011), for spatial panel data models containing spatial and/or time-period fixed effects. The results suggest the existence of significant spillovers in conflict intensity in both the error term and the spatially dependent variable. In other words, conflicts erupting in territories are not independent from each other; consequently, any strategy to address these conflicts should be comprehensive and inclusive. Even with these spatial specifications, our estimates remain very stable, especially for the number of concessions.

Based on regressions (1) and (4) of Table 5.3 and given the mean number of conflict events reported in Table 3.1, a 10 percent increase in the number and the size of mining concessions would respectively decrease the likelihood of conflict events by about 60 and 1 percent, respectively, in the same territory. However, a similar increase in the number and size of the concessions would also increase the number of conflicts by about 165 and 2 percent, respectively, in the neighboring territory. Although significantly different from zero, the much lower effect resulting from a change in the size of concessions, as compared with the number of concessions, may suggest that the size of the concessions is much less directly associated with an increase in mining profits. At the district level, no spatial effect is found. Results are robust to the use of alternative definitions of the mining concessions, such as those defined based on the years of demand and those not using a logarithmic transformation for the concession-based variables.

Overall, these results are consistent with the theoretical prediction that a larger size or number of mining sites increases the protection effect, thereby reducing violence around the mine(s); gives the incentives to the incumbent to move the conflict location farther from the mining site (potentially in a neighboring territory); and would result in a higher level of violence at the aggregate level (adequately captured at the district level). Our results are therefore supportive of the spatially based theoretical mechanisms emphasized in Section 4 and are likely to explain the case of ecological fallacy found in Section 3. In other words, the absence of a statistically significant relationship between mining concessions and (violent) conflicts at the territory level was driven by an omitted spatial effect, explained by the incumbent's incentives to better protect the mine. When spatial spillovers are taken into account, a mining concession tends to decrease the risk of conflict in the same territory, while increasing the risk in neighboring territories. This, in turn, explains why a change in mining concessions would translate to a more aggregated effect (that is, at the district level) into an increase in conflict intensity.

Given the potential for further exploitation of natural resources in DRC, the magnitude of these results is substantial. Furthermore, our results indicate that considering changes in the size of concessions, instead of changes in the number of concessions, would not modify the overall outcome, as the size of the new concessions features a similar spatial pattern, even though the magnitude of the effect on conflicts is much smaller.

Finally, it should be noted that rainfall anomalies retain a significant and negative sign throughout the empirical analysis. One should be cautious, however, in interpreting this result, because this variable is only a proxy for agricultural income. A tentative explanation would therefore be that improved agricultural yields reduce the intensity of conflict. Our theoretical predictions are consistent with this observation if either an increase of agricultural yields incentivizes the incumbent entrepreneur to improve his fighting capacity by moving his armed group closer to the production site, or the drop in profits resulting from the scarcer labor supply significantly reduces the incentives to fight for the control of the mine.

Table 5.2—Results with spatial dependency

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Level of Analysis	Territory						District					
Order of Spatial Matrix	2						1					
Dependent Variable	Conflicts ACLED	Violent Conflicts ACLED	Conflicts UCDP	Conflicts ACLED	Violent Conflicts ACLED	Conflicts UCDP	Conflicts ACLED	Violent Conflicts ACLED	Conflicts UCDP	Conflicts ACLED	Violent Conflicts ACLED	Conflicts UCDP
Concessions	-0.542**	-0.404*	-0.109				-0.911**	-0.737**	-0.194*			
(log)	[0.276]	[0.234]	[0.0793]				[0.416]	[0.363]	[0.115]			
Neighboring	3.337***	3.105***	1.441***				2.367***	2.175***	0.807***			
Concessions (log)	[1.102]	[1.009]	[0.362]				[0.794]	[0.740]	[0.258]			
Concessions				-3.4e-09*	-2.4e-09	-6.12e-10				-5.6e-09	-4.5e-09	-1.1e-09
Size (log)				[1.9e-09]	[1.6e-09]	[5.36e-10]				[3.6e-09]	[3.0e-09]	[9.34e-10]
Neighboring				0.400**	0.378***	0.180***				0.630*	0.579**	0.216**
Concessions				[0.163]	[0.140]	[0.048]				[0.337]	[0.287]	[0.0927]
Size (log)												
Rainfall	-0.032**	-0.03**	-0.011**	-0.037**	-0.0349**	-0.0128**	-0.046***	-0.043***	-0.015***	-0.054*	-0.0502*	-0.0168**
Anomalies	[0.013]	[0.012]	[0.004]	[0.018]	[0.015]	[0.005]	[0.016]	[0.0149]	[0.005]	[0.0305]	[0.0259]	[0.0083]
Rainfall Squared	0.0033	0.004	0.0009	0.0037	0.0049	0.0023	0.0002	0.0007	-0.0003	0.0052	0.0063	0.0024
Anomalies	[0.008]	[0.007]	[0.0027]	[0.013]	[0.0107]	[0.0035]	[0.009]	[0.008]	[0.0029]	[0.0202]	[0.0169]	[0.0049]
Month Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Territory Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000
Number of Territories	150	150	150	150	150	150	150	150	150	150	150	150
Underidentification test	19.7***	19.7***	19.7***	6.103***	6.103***	6.103***	15.31***	15.31***	15.31***	3.211***	3.211***	3.211***
Root Mean Squared Errors	1.147	1.072	0.39	1.601	1.363	0.458	1.357	1.248	0.42	2.41	2.054	0.62

Source: Authors' estimations.
Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Robust standard errors are in brackets.

Table 5.3—Results with spatial dependency, including spatially lagged dependent and independent variables and a spatially correlated error terms

	(1)	(2)	(3)	(4)	(5)	(6)
Level of Analysis		Territory			District	
Order of Spatial Matrix		1			1	
Dep. Var.	Conflicts ACLED	Violent Conflicts ACLED	Conflicts UCDP	Conflicts ACLED	Violent Conflicts ACLED	Conflicts UCDP
Spatially Lagged	0.102949***	0.093942***	0.213974***	0.099997***	0.095996***	0.213974***
Dep. Var.	(8.962629)	(8.145395)	(19.680156)	(8.842622)	(8.330796)	(19.680155)
Concessions	-0.929731***	-0.780477***	-0.200213***			
(log)	(-8.2032)	(-7.4076)	(-5.7447)			
Neighboring	2.534542***	2.254936***	0.655634***			
Concessions (log)	(12.8281)	(12.2776)	(10.7929)			
Concessions				-0.010269*	-0.275182***	-0.070541***
Size (log)				(-1.6496)	(-7.4116)	(-5.7447)
Neighboring				0.030875***	0.794126***	0.230999***
Concessions				(2.8409)	(12.26997)	(10.7929)
Size (log)						
Rainfall	-0.02583	-0.02072	-0.01201	1.041329***	-0.02153	-0.01222
Anomalies	(-1.0626)	(-0.9045)	(-1.5069)	(701.3836)	(-0.94)	(-1.5333)
Rainfall	0.002528	0.001049	-0.00196	-0.00048	0.000378	-0.00213
Squared	(0.1824)	(0.0803)	(-0.4303)	(-0.1822)	(0.02897)	(-0.4686)
Neighboring	-0.0108	-0.0121	0.004163	-0.09241***	-0.00969	0.004848
Rainfall	(-0.381)	(-0.4531)	(0.4479)	(-7.5419)	(-0.3628)	(0.5217)
Neighboring	-0.01858	-0.01547	-0.00371	-0.00086	-0.01352	-0.00314
Rainfall squared	(-1.0826)	(-0.9572)	(-0.66)	(-0.26576)	(-0.83755)	(-0.5599)
Spatial Error	0.28152***	0.294532***	0.341217	0.496263***	0.294326***	0.341217***
Correlation	(12.716)	(12.7599)	(12.930)	(13.6522)	(12.7592)	(12.9305)
Month Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Territory Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Time Trend	Yes	Yes	Yes	Yes	Yes	Yes
Observations	19,800	19,800	19,800	19,800	19,800	19,800
Number of Territories	150	150	150	150	150	150
Log Likelihood	-502	-476	-8,027	-289	-291	-802

Source: Authors' estimations.

Notes: * p < 0.01, *** p < 0.1; Asymmetric T-statistics are in parentheses.

6. CONCLUSION

We explore the mineral resources–conflict nexus by focusing on the mineral-rich and conflict-ridden Democratic Republic of the Congo (DRC) from 1997 to 2007. Using georeferenced data, we investigate whether the DRC government's granting of mineral concessions in particular geographical areas has had an impact on the intensity of conflict. To overcome endogeneity concerns, we instrument concessions granted over the period of analysis by the interaction of historical concessions and the prices of mineral resources. Our study reveals a case of ecological fallacy: At the territory level, granting concessions does not affect the level of conflict; at the district level, however, the right to exploit mineral wealth is shown to exacerbate the level of violence.

To rationalize this finding, we construct a theoretical explanation that relies on the incentives of violent entrepreneurs to protect the mining activities by avoiding armed confrontations with competing entrepreneurs near the mining activity. Securing a peaceful environment in the vicinity of the mining concession enhances the mining laborers' security, thereby reducing the cost of the labor force for the entrepreneurs in control of the mining location. A larger number of mining sites in a particular geographical location is shown to increase the intensity of conflict and to provoke a displacement of conflict to more remote locations. With respect to agricultural yields, positive shocks are shown to reduce the mining labor supply and therefore the mining sector's profits. As the contested prize's value diminishes under some conditions, conflict will tend to occur closer to the mine, even as the intensity of conflict declines.

Our paper brings forward a crucial element in the understanding of the roots of conflicts—namely, the importance of the geographical unit of observation. Neglecting this dimension may have devastating policy consequences. Indeed, we have shown that natural resources may constitute a blessing for populations located in the vicinity of mineral wealth, because resource-greedy entrepreneurs will deploy means to protect their source of income. The same resources, however, can be characterized as a curse for the wider geographical area, because the intensity of conflict in surrounding areas is likely to experience an increase. This spatially nuanced view of the conflictive role of mineral activities suggests that policies aimed at increasing transparency of mineral resources (for example, Section 1502 of the 2010 Dodd-Frank Wall Street and Consumer Protection Act) and possibly at reducing the exploitation of mineral resources may reduce conflict at the global level while at the same time generating tensions at the local level. Such regulations need to be accompanied at the local level by improved alternative income. Our results regarding rainfall anomalies suggest that support to the agricultural sector may well constitute such a complementary policy action.

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