Mineral Resources and Conflicts in DRC: A Case of Ecological Fallacy*

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Abstract

The present paper provides a spatially-nuanced view on the role of mineral resources in civil wars in the particular case of the Democratic Republic of Congo (DRC). We estimate the impact of geo-located new mining concessions on the number of conflict events between January 1997 and December 2008. Instrumenting the variable of interest with historical concessions interacted with changes in mineral international prices, we unveil an *ecological fallacy*: concessions have no effect on the number of conflicts at the territory level (lowest administrative unit), while they foster violence at the district level (higher administrative unit). We develop a theoretical model where 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
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1 Introduction

Civil wars inflict considerable costs on countries which 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).

In a popular paper of Collier and Hoeffler (2004) it is shown that countries with larger shares of primary commodity exports are more likely to experience civil wars. 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 as is the case for 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 that contest for the control of the rents (Mehlum et al. 2002). Recognizing the specificities of mineral resources, a series of papers have sought to identify the specific effect of mineral resources on civil conflicts. The inital evidence based on cross-country analyses pointed at the undisputable role played by mineral resources in both igniting and sustaining civil conflicts (Lujala et al. 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 (Bunnschweiler and Bulte 2008; 2009).[1] The confounding role of institutions is another source of endogeneity. Fearon and Laitin (2003) and Fearon (2005) emphasize the role of oil revenues in weakening state capacity. More recently, Besley and Persson (2010) formalize this argument by proposing a model of endogenous state capacity formation. They show that natural resource-rich countries will under-invest 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 micro-founded approach by exploiting within country variations. Working with sub-national units of analysis allows to draw more accurate causal inference. Proceeding likewise, Buhaug and Rod (2006), Angrist and Kugler (2008), and Dube and Vargas (2008) all identify a positive effect of the presence of natural resources on the occurence of conflict events. Using geo-referenced data at the 100 square kilometer grid, Buhaug and Rod (2006) find a positive effect of oil and diamonds presence on the likelihood of civil conflict. Both Angrist and Kugler (2008) and Dube and Vargas (2008) study the

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

impact of exogenous commodity-price shocks on the level of violence in Colombia. The former show that positive price shocks on cocaine generated increased violence at the department level, while the latter show that at the municipality level the effect of oil and coffee prices increases have, respectively, a positive and negative effect 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 doubts upon the generalization of the above relationship between resources and conflict. Bellows and Miguel (2009), and Ziemke (2008) study, respectively, the civil conflicts of Sierra Leone and Angola, and conclude on the basis of georeferenced data that the presence of diamonds contained the level of violence.

The present paper contributes to these latter micro-founded approaches by focusing on the conflicts in the Democratic Republic of Congo (DRC). More precisely, we estimate the impact of geo-located granted mining concessions in DRC between January 1997 and December 2008 on the location of conflict events. Estimating this relationship would produce biased results, however, since actual or expected violent events could directly affect the decision of granting a concession, while some common underlying political process could affect both variables. [3] We therefore instrument for the granting of concessions by exploiting geo-referenced data on historical concessions coupled with changes in mineral international prices 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, the territory and the district levels, we derive a striking finding: while granted concessions do not affect the number of conflict events at the territory level, they 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 it highlights the role of the spatial dimension in the empirical literature on conflicts.

We develop a theoretical model where the incentives of armed groups to exploit and protect mineral resources explain our empirical findings. Violence has a negative effect on 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

[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)).

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

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

[5]The ecological fallacy refers to situations where an erroneous assumption is made that relationships between variables at the aggregate level imply the same relationships at the individual level.

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

"protection effect" helps explaining 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 the next section, 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 etablish the plausibility of our theoretical explanation.

2 Background

Since 1996 the 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 five million deaths over the 1998-2008 period (IRC 2008) and an estimated number of 1.7 million internally displaced people (Internal Displacement Monitoring Center 2011). Whether or not these exact figures are biased (Spiegel and Robinson 2010), its 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 Rwandese Patriotic Army (RPA). In the Fall of 1996 the Congolese president, Mobutu Sese Seko, had given orders for various government-sponsored groups to stigmatize and perpetrate violent acts against the *Banyamulenge* minority - a primarily Tutsi-Rwandese origin population having migrated in Eastern Congo at various times in history - for electoral motives. By early September, the RPAs commandos were stealthily penetrating the Congolese territory, arming the *Banyamulenge*, and perpetrating coordinated attacks in South Kivu. Shortly later, 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 who would seize the opportunity of the Rwandan incursion in Eastern DRC to contest Mobutu's leadership. The First Congo War (1996-1997) had started.[7] The Second Congo war (1998-2003) had a more international dimension since rival countries and factions saw in the conflict-hit DRC a propice ground for waging proxy-wars. The end of the war meant a retreat of the interna-

[7]Structural analyses of the Congolese wars also point to the historical grievances fueled by the "divide and rule" policy applied by the Belgian colonizers, the exploitative legacy from the same colonizers and 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).

tional actors from the battle field, but it did not imply the dissolution of the numerous rival armed groups and gangs that had formed over the course of the 7 years wars. In fact the violence in DRC continues affecting the stability of the country, especially in its Eastern regions.

Congo's natural wealth in mineral resources (e.g. diamonds, coltan...) has often been identified as the main driver of the violence, either as a way to finance warring parties or a warfare objective in itself (Congdon Fors and Olsson 2004, Turner 2007, Stearns 2011, International Alert 2010, Gambino 2011).[8] Over the years the United Nations has repeatedly issued reports of experts, of the Security Council, and of the Secretary General underlining that natural resources have fuelled the conflicts in 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 analysis of the Congo Wars, and Vlassenroot and Raeymaekers's (2004) work on the Ituri conflict provide a more nuanced picture, however, since they

[8]For instance, Stearns (2011) refers 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. These countries and the Congolese army were also highly involved in large-scale looting of mineral resources through which "soldiers, commanded by an officer" were reported to force the mines' managers to "open the coffers and doors. The soldiers were then ordered to remove the relevant products and load them into vehicules". A report from the International Crisis Group Africa (ICG 2006) also reports the smuggling of major minerals such as refined tin (also called cassiterie) or other derived metal from the tin group (coltan, niobium and tungsten) through the Rwandan borders, gold through the Ugandan border.

[9]These reports, including the one from a panel of experts on the "*Illegal Exploitation of Natural Resources and Other Forms of Wealth of the Democratic Republic of Congo*" (April 12, 2001) have documented the way 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 were shareholders, taking kickbacks on numerous contracts with terms unfavorable to the state, and large-scale smuggling (see International Crisis Group report). Official statements have also been released, see e.g. the Presidential statements of the U.N. S/PRST/2000/20, S/PRST/2001/3, and S/PRST/2003/2.

[10]Stearns (2011: 299) reports 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 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".

present a detailed account of the extreme complexity of the situation that sparked and sustained violent conflicts in the Great Lakes region. Violence is described as being the consequence of an unfortunate explosive mix of inherited grievances, ethnic polarization, land scarcities, regional control by foreign powers, and natural wealth. It is hardly deniable, however, that many Congolese mining locations have been looted and the minerals exported illegaly over the years by both Congolese and foreign rebels and by neighboring countries' militias (Montague 2002, Congdon Fors and Olsson 2004, Prunier 2009, Freedman 2011). To explore the mineral resources-conflict nexus we next proceed with an empirical investigation of the question.

3 Baseline Analysis

Our analysis exploits month-year (month m and year m) and geographical (i) variations in the occurrence of conflict events ($Conflicts_{i,m,y}$) and granting of mining concessions ($Concessions_{i,m,y}$) between January 1997 and December 2008 to draw causal inference on the role of new or future mining activities on the level of violence in DRC. The period under investigation is dictated by data availability. As described below, this also implies that our analysis is limited to the incidence of local conflict events rather than on the onset of the first Congolese war (end of 1996). Using sub-national 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:

$$Conflicts_{i,m,y} = \alpha_i + \alpha_{m,y} + \theta t + \beta Concessions_{i,m,y} + \epsilon_{i,m,y} \quad (1)$$

Yet, as emphasized in the Introduction, 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 reasons, as mining companies might be less likely to invest in conflict-prone areas, but also because of omitted factors since the granting of concessions may be driven by local politics that could equally directly influence the occurence of conflict. Lastly, measurement problems, in particular for the reported conflict events, are likely to correlate with conflict events thereby introducing additional biases. To deal with that methodological challenges, our estimation relies on an instrumentalization strategy close 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. In particular, we use the normalized[11] international prices of the minerals ($P_{j,m,y}$, j designating the mineral) the mining concessions extract or aim at extracting, as time-varying exogenous

[11] The prices are normalized to 100 for the first month of 1997.

shocks on the probability to grant a new mining concession of a particular mineral type and at a specific geograpical location. The constructed index may be expressed as follows: [12]

$$\begin{aligned} PriceIndex_{i,m,y} &= \sum_j \omega_{i,j} P_{j,m,y} \\ \text{where} \quad \omega_{i,j} &= PastConc_{i,j} \end{aligned} \tag{2}$$

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 as non-linear methods in a two-stage framework imply strong specification assumptions (Angrist and Krueger 2001). Accordingly, our estimating equation is the following:

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

Although it does not alter the main results of this paper, we also control for rainfall anomalies to control for changes in the opportunity cost to fight, unrelated to mining concessions. To control for other unobserved factors, our estimates introduce territory/district fixed effects, a time trend and a series of month-year time dummies.

3.1 Data

The dependent variable is the monthly sum of conflict events by territories or districts, using the Armed Conflict Location and Event Data (ACLED), from January 1997 to December 2008. There were more than 3,300 conflict events during that period, including 2,898 violent events. As can be seen from Figure 1, most conflict events are concentrated in Orientale, North and South Kivu provinces. Conflict events are also concentrated in the territory of Pweto (Haut-Katanga district) in the Katanga province as well as in Kinshasa. The geographical dispersion of the data tracks the degree by which various areas of the DRC have been affected by conflict, thus reconforting us regarding the data quality. 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

[12]Notice that similar results are found when considering instead $\omega_{i,j} = \frac{PastConc_{i,j}}{\sum_j PastConc_j}$.

Rwandan government to seek revenge or eradicate this potential threat but also because of the presence since 2004 of the Congres National pour la Defense du Peuple (CNDP) led by Laurent Nkunda. Note that this last group is reported to be supported by Rwanda to maintain its influence in the resource-rich Eastern DRC. The Orientale province and in particular, the districts of Ituri, Haut-Uele, Bas-Uele and the territory of Bafwasende continue to suffer from the presence of the Ugandan Lord's Resistance Army, other armed groups and the emergence of ethnic local conflicts in Ituri (Spittaels and Hilgert 2010). Pweto is a small fishing village whose area is known to have witnessed in 2000, one of the most important battles of the second Congolese war between the Congolese army of Kabila, supported by foreign contingents from Zimbabwe, Angola and Namibia against Rwandan and Burundian troops (Spears 2010). The main strategic value of this area was to get control on "Lubumbashi, the country' mining capital" (Spears 2010: 272). The case of Kinshasa may be peculiar given the strategic and political importance of the capital in the Congolese conflicts. Our results are nonetheless robust to the exclusion of the related territory or district from the analysis. Overtime, the evolution of conflict events show large monthly variations. As illustrated in Figure 2, several peaks can be observed in May 1997, January 2001, June 2003, November 2005, January 2006, December 2006 and in particular, in August 1998, November 1999, January 2000 and October 2008. We can note that conflict events occurring after 2008 are no included in our sample due to other data constraints. This period records much lower levels of conflicts. The observed peaks track well-documented increases of violence in DRC (see e.g. Turner 2007). We also define an alternative dependent variable by restricting the dependent variable to violent conflict events.

The main variable of interest relates to the mining concessions. Based on data provided by the Ministry of Mining (6,860 mining concessions granted over the period), we construct the monthly sum of mining concessions granted by territory or district. We will also use the size of these new concessions as an alternative proxy. A logarithm transformation is applied to the concession-related variables to ease interpretation, although results will be shown robust to the omission of such transformation.[13] According to our data, concessions were granted between 1994 and 2008, with the exception of the information on past concessions described below. Figure 3 indicates that mining concessions are mainly granted in Eastern and Southern DRC, which is largely consistent with any geological map of the country. Figures 1 and 3 also suggest that mining concessions are at least partly and spatially correlated with the highest concentration of conflict events. However, our discussion of the literature suggests not to interpret such correlation as causation.

To be able to draw causal inference, we construct the instrumental variable, described

[13] Young and Young (1975) seminally showed that adding the value 0.1 to a variable to avoid the missing values generated by the logarithm transformation of zero values may have some drawbacks.

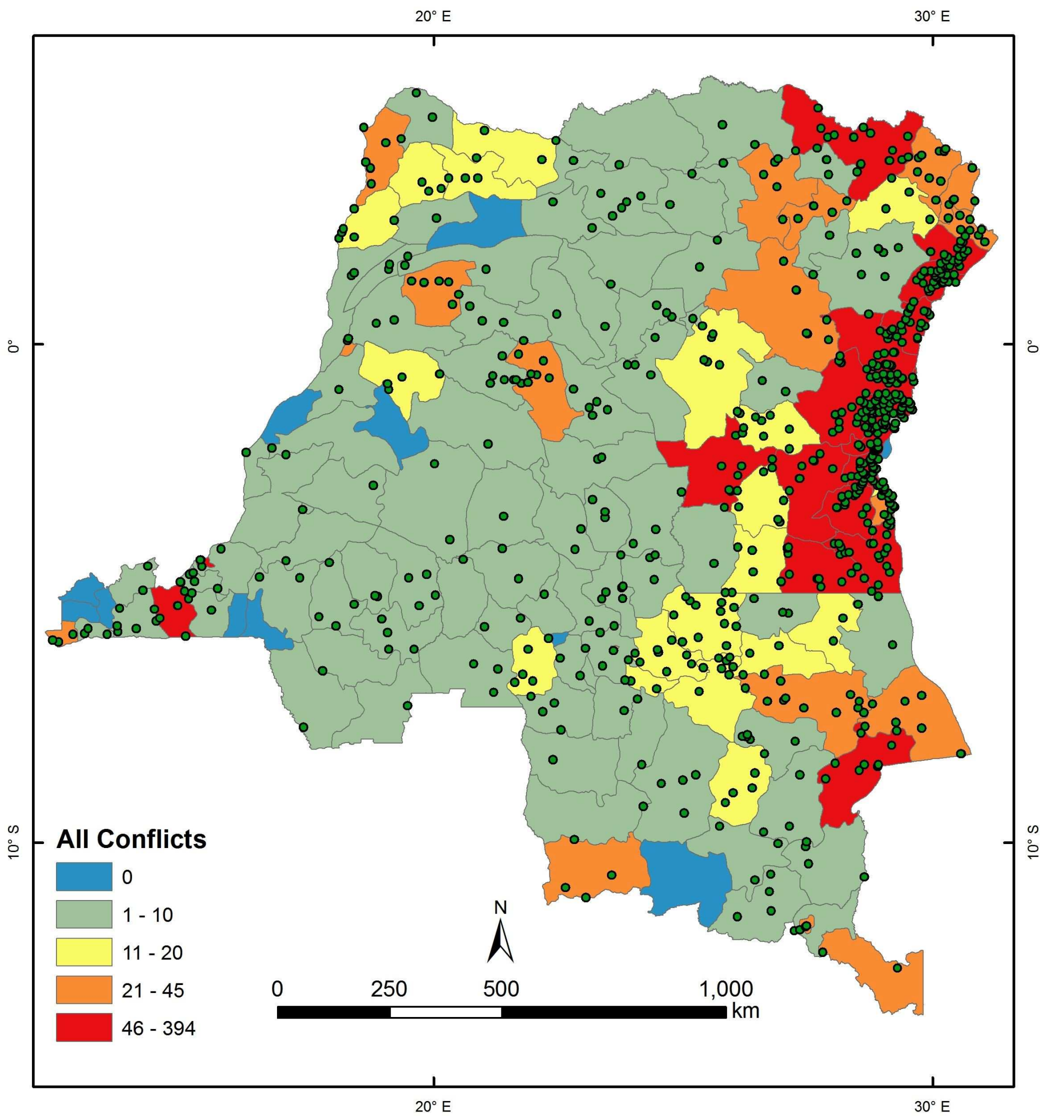

Figure 1: Source : Armed Conflict Location and Event Data (ACLED). Green points represent the raw ACLED events.

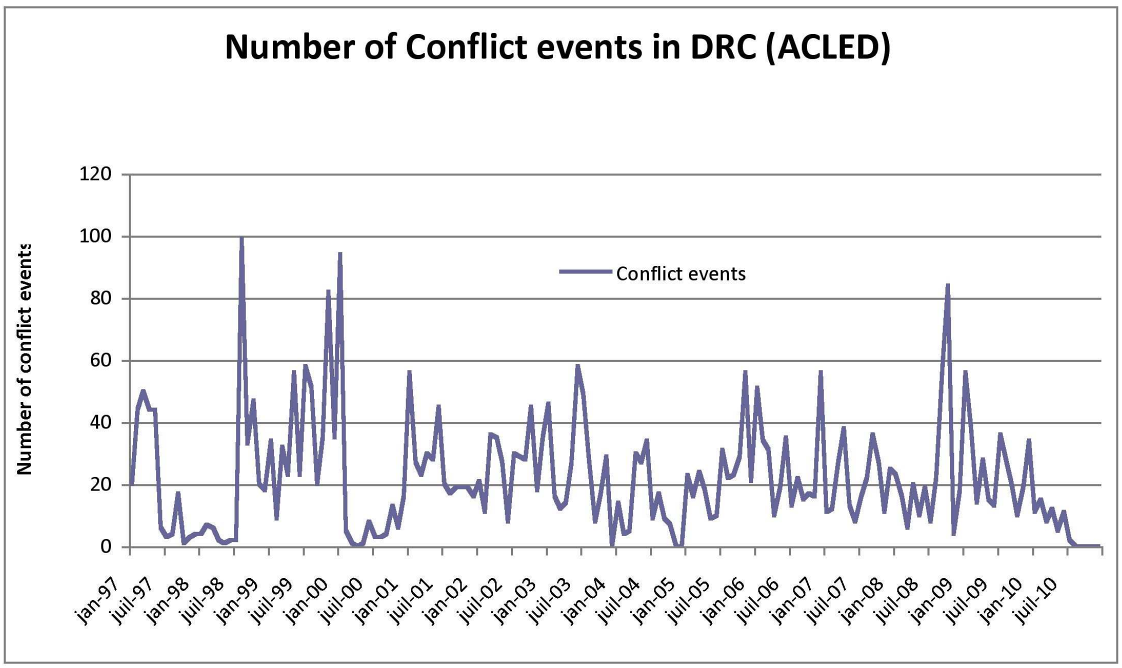

Figure 2: Source : Armed Conflict Location and Event Data (ACLED)

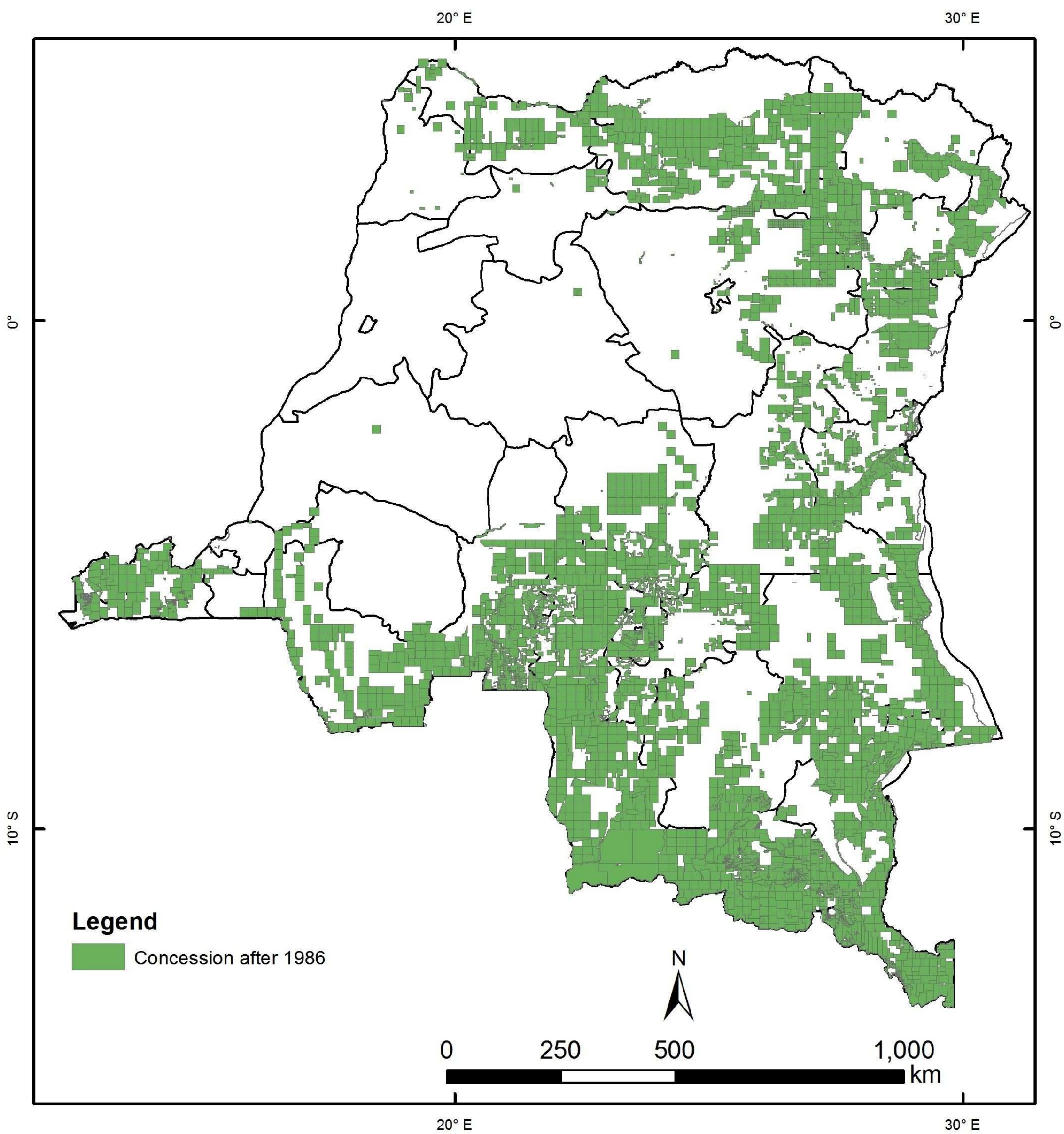

Figure 3: Source : DRC Ministry of Mines

in the previous Section. We exploit the information on mining concessions granted in the years 1968, 1969 and 1970 and one concession in 1985 (in our data, no concession was granted between 1986 and 1994). The minerals characterizing these mining concessions are Silver, Gold, Copper, Manganese, Tin and Tungsten. Note that these minerals, in particular Gold, Copper, Manganese and Tin, have been argued to fuel local conflicts in DRC. As explained above, the use of time-varying international prices, coupled with historical concessions, provides an exogenous shock on the probability to grant 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 Democratic Republic of Congo cannot alone affect the international prices of these minerals. However, changes in international prices may change the incentives to acquire a mining concessions. Indeed, an increase in international prices should increase the attractiveness of obtaining a new mining concession, given 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 to the physical presence of that minerals but also to the necessary inputs to exploit that minerals such as the infrastructure, the local input-output linkages, the presence of the needed labor force, the existing contractual arrangements, etc. Anecdotal evidence suggests that changes in prices may have an immediate impact on mining exploitation and request for concessions.[14]

Our identification strategy strongly relies on the validity of our instrumental variable. And while the relevance of that instrument may be directly tested, the exclusion restriction may be questionned. 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 rather acceptable assumption. On the other hand, however, we assume that the unobserved political discretionary rules affecting the granting of mining concessions are different for the contemporaneous mining concessions (1997-2008) and for the historical concessions granted in 1968, 1969 and 1970. This assumption which amounts to stating that the change of regime from Mobutu's rule to the reign of Laurent Désiré Kabila, and his succeeding son, Joseph Kabila, merits some additional justifications. Notice 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 later) suggests that the rules of discretion in the granting of concessions are unlikely to have been the same in the two periods. Anecdotal evidence about the way mining concessions have been granted in the two periods seems to confort us in making this assumption. Under Mobutu ruling, the mining sector was entirely nationalized and mining

[14]For example, *The Economist* reports how mining companies came from all over the world to deal with the Governor of Katanga, home to about 5 percent of the world's copper and nearly half its cobalt, following the record rises in prices for these minerals (The Economist, Congo's outback: Mr Copper, August 18, 2011).

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 in infrastructure and development" (Stearns 2011: 289). The rules of the game gradually changed in 1995 when Mobutu allowed his prime minister, Kenga wa Dondo, to gradually privatize the mining sector (Stearns 2011). In 1997, "the rebelion [led by Laurent-Desire 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). We also note that the economic conditions surrounding the mining concessions experienced important changes between the two periods. At the end of the seventies, 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, Stearns (2011) reports that both detrimental economic conditions such as the decreased copper prices (largely due increased supply from Chile and decreased world demand) and years of mismanagement dampened the profitability of mining activities. "Exports 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." (Stearns 2011: 289)

Finally, rainfall data is used to improve the efficiency of our estimates, since this variable is likely to capture opportunity cost effects that are unrelated with mining activities. Indeed, Miguel et al. (2004) use rainfall data to control for the climate-induced changes in agricultural income (in lowly irrigated countries) and the resulting changes in the incentives to participate to armed groups. Rainfall data are derived from National Aeronautics and Space Administration (NASA, satellite and modeled derived solar and meteorological data) based on a one degree latitude-longitude grid. We follow a standard approach to transform rainfall data into anomalies or 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. The monthly basis is chosen to correct for seasonality pattern of rainfall data, while data availability limits the definition of the long-run reference to the average over the sample (1997-2010 period). Our central results are shown not to depend on the inclusion of that variable which nevertheless allows us to draw some interesting policy conclusions.

Table 1 provides the descriptive statistics of the above variables. Given the relatively long time period used, the non-stationary 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 and the explanatory variables (see Table 2). The tests show that all series are stationary at any reasonable level of confidence.[15]

[15]Note that on the contrary, the instrumental variable has a unit root, which is not surprising

3.2 Empirical Results

In Table 3, we implement the two-stage least square estimation, described above. At both levels of analysis (territory and district), the price indices appear to be highly relevant in the sense that they strongly affect the probability to receive a mining concession. The F-Test on excluded instrument as well as the Cragg-Donald Wald tests allow us to unambiguously dismiss the risk of weak instruments (F statistics well above the Stock and Yogo weak identification test critical values at 10% or larger maximal IV size). Turning to the second-stage equations at the territorial level (Regressions (1) to (4) of Table 3) reveals that granted mining concessions, both in terms of number and size, do not affect the risk of conflict, including violent ones. However, at the district level, the instrumented mining concessions significantly increase the risk of conflict and in particular of violent conflicts (Regressions (5) to (8) of Table 3).[16] These results are robust to the use of the alternative definition of the mining concessions evaluated the basis of the years of demand, and not proceeding to the logarithmic transformation does not alter the results either. Lastly, our fingings are also robust to the reduction of the sample by excluding Kinshasa or by restricting the time span to the second Congolese war that took place between 1998 and 2004.

This contrasting result constitutes a case of *ecological fallacy* or aggregation problem, i.e. a misleading assumption that the relationship observed at an aggregated level (e.g. district) implies the same relationship at different level of aggregation (e.g. territory). 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 the next section we develop a theoretical model that aims at identifying these mechanisms.

4 Theoretical Framework

We consider a region represented by a unit-length line inhabited by a uniformily 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 the incumbent, I, and we assume without loss of generality that the concessions are located at the origin of the line representing the region. The incumbent attempts to retain

given its construction but should not threaten our identification strategy.

[16]Note that, such results hold when violence against civilians and violent confrontations between armed groups are used instead of the violent conflicts variable. In turn, mining concessions do not seem to have an effect on non-violent events. Although not shown for presentation purpose, note also that a *naive* regression, assuming that the mining concessions are exogenous, indicates that the endogeneity of mining concessions is likely to introduce a downward bias: the granting of mining concessions significantly decreases the level of conflict at both the territory and the district levels.

control over the mining profits, while a challenger endeavors taking over the mining concession. Labour constitutes the unique input of the mining activity, and we assume that the mining company is a local monopsonist on the labour 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:

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

where φ is the unit return to labour from mining, which we assume concave in the number of workers active in the mine, x_m. The parameter n captures the size or number of mining concessions.[17] The workers are remunerated at the (endogenous) wage of y_m. The monopsonist will therefore determine the demand for mining labour. Regarding the supply side of the labour market, the individuals of this society have two occupational choices: mining (x_m), and farming ($x_f = 1 - x_m$). The farming activity yields an income y_f. Mining is remunerated at the 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 location of the mine. 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 derives its entire income from the mining activity and to maximize his payoff he takes two decisions on top of the profit-maximizing labour decisions: (i) the amount of soldiers to bring along from his headquarters to face a potential opponent, x_i, given their exogenous unit cost $\bar{y}$[18], and (ii) the extent of the territory over which to deploy its army, d_v, given an increasing and convex deployment cost $c(d_v)$.[19] We describe the probability that the incumbent beats the challenger in fighting by the product $p(x_i, x_c)e(d_v)$, with x_c standing for the challenger's number of soldiers, and the fighting technology satisfying some very general assumptions as in Skaperdas (1996):

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

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:

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

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

[18]Making the fighters' remuneration endogenous would unecessarily 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.

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

Since the labour force, x, has two occupational choices and that the commuting costs, τ, are incured by the workers, it follows that for a mining wage y_m, any individual lying on the $[0, d_m]$ interval will prefer joining the mining sector rather than farming, where d_m is defined as:

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

We thus have that the mining labour supply equals:

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

It follows that the inverse labour 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 then write the incumbent's maximization problem as:

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

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 in 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 the above bracketed expression, the third term is negative. A sufficient condition for establishing the unicity of x_m^* is that $\partial\pi(x_m)/\partial x_m \leq 0 \Rightarrow \varphi^{'}(x_m) < \tau(1-d_v) < 0$

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

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

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

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

And since 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 SOCs are given by:

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

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

The sign of the last expression is a consequence of $p_{x_i x_i} \leq 0$, which can straightforwardly be computed.

The challenger's optimization problem is analogously given by:

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

Optimizing gives the following F.O.C.:

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

And 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 et al. 1995, proposition $8.D.3$). Moreover, by combining equations (9) and (14), we can deduce that $x_i = x_c$. Equipped with the above 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:

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

This result is very intuitive: since the size of the mining sector affects the profitability of the mining activity in a linear manner, 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 means not, however, that the industry has not become more profitable, since the incumbent will see his profits increase proportionally to the size of the mines he controls

Proceeding likewise with condition (8) we obtain:

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

This expression can be re-written as:

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

And using the FOC (8), it is immediate to deduce that the numerator of (16) is positive, thus implying that $\partial d_v^*/\partial n > 0$.

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

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

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

To visualize the above findings, and their implications in terms of the effect of number or size of mining sites on the violence in society, it is useful to proceed to a graphical representation. To that end, we first describe the shape of the fighting location and fighting intensity reaction functions.

Fixing $x_m = x_m^*$, and $x_c = x_c^*$, we can show that $d_v(x_i)$ 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 the change of equilibrium following a change in n. A very interesting observation is that in the neighbourhood 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 incentivize the incumbent to increase their aggressiveness. The underlying explanation of the former effect is that as the incumbent mobilizes more fighters, the likelihood of controlling the mines is increased, thus pushing the incumbent to deploy his combatants farther away from the mining site, and therefore to improve the sector's profitability. The latter effect mirrors the former. Indeed, since remoteness increases the value of the contested pie, when the combat location is farther away from the mining site, the incentives to increase one own's fighting efforts are higher.

An increase in size, and therefore profitability, of the mining sector controlled by the incumbent impacts positively on both d_v and x_i. Since the marginal return of protection increases, the incumbent will attempt moving the conflict location farther from the mining site up to the point where the marginal return equalizes the marginal cost of this operation. On the other hand, the impact effect of a larger pie in terms of conflict intensity is naturally also positive. To these impact effects, one needs to add the above-described interaction effects that will eventually push the conflict location farther away, and its intesity upwards.

Comparative Statics - Changes in y_f

The level of farming income, y_f impacts on the opportunity cost of mining, and therefore on the labour 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^*, as well as 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 to equation (7) :

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

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

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

Looking next at the effect of a change of y_f on d_v^* is instead ambiguous. By applying the IFT to condition (8), we obtain:

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

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:

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

Using the fact that $x_i^* = x_c^* \Rightarrow p_{x_i x_c} = 0$, and $\partial\pi/\partial x_m = 0$, the above expression's sign is given by the sign of:

$$e^{'}\frac{\partial d_v}{\partial y_f}\pi - enx_m - e\frac{\partial\pi}{\partial d_v}\frac{\partial d_v}{\partial y_f} = \frac{\partial d_v}{\partial y_f}\underbrace{\left[e^{'}\pi + e\pi^{'}\right]}_{>0} - enx_m \tag{20}$$

where the underbraced term is positive given FOC (8). Following 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 the following. 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 and the mining profits rise as well. The former effect increases the marginal benefit of arming while the latter has the opposite consequence. Yet, the second effect is shown to always dominate the first one. Lastly, higher values of y_f have a direct negative effect on the profitability of mining (via the labour 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 downwards. 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 in a labour supply reduction, which, in turn reduces the number of miners hired at equilibrium. In the next section we revisit our empirical strategy and confront our comparative statics results to the data.

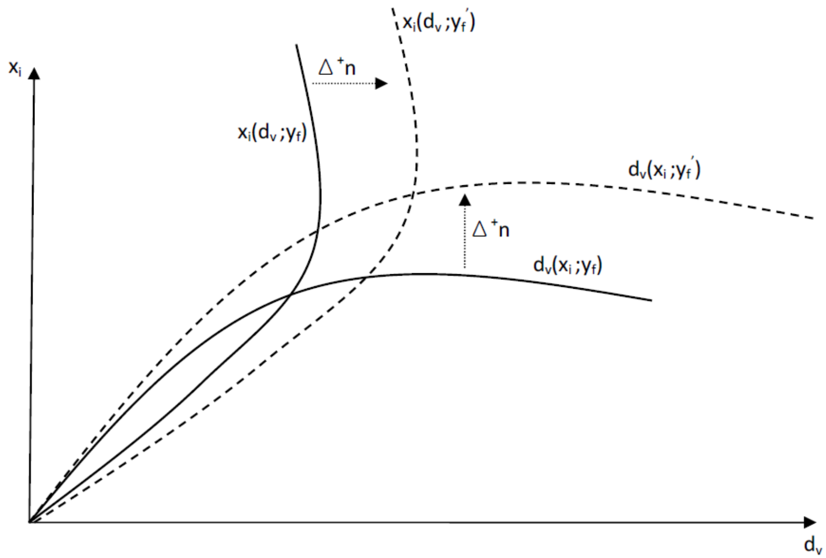

Figure 4: Effect of an increase in agricultural yields on the location and intensity of conflict.

5 Revisiting the empirical analysis

Our theoretical model suggests that the granting of mining concessions raises the risk of conflict in a non-homogeneous way across space. In particular, increasing the size or number of mining site(s) has been shown to increase overall conflict intensity but also to displace violent events farther from mineral deposits. To test our theoretical explanation, we follow Florax and Folmer (1992) in assessing the role of spatially lagged mineral concessions. We apply the method to our panel analysis, as this spatial econometric technique can be applied to such a panel setting (Anselin 2002). We augment equations (2) with a spatially lagged explanatory variable in the following way:

$$
\begin{aligned}
Conflicts_{i,m,y} &= \alpha_i + \alpha_{m,y} + \theta t + \beta_1 \widehat{Concessions}_{i,m,y} + \beta_2 W\widehat{Concessions}_{i,m,y} \\
&+ \beta_3 Rainfall_{i,m,y} + \epsilon_{i,m,y} \\
Concessions_{i,m,y} &= \alpha_i + \alpha_{m,y} + \theta t + \gamma_1 PriceIndex_{i,m,y} + \gamma_2 WPriceIndex_{i,m,y} \\
&+ \gamma_3 Rainfall_{i,m,y} + \epsilon_{i,m,y} \\
WConcessions_{i,m,y} &= \alpha_i + \alpha_{m,y} + \theta t + +\gamma_1 PriceIndex_{i,m,y} + \gamma_2 WPriceIndex_{i,m,y} \\
&+ \gamma_3 Rainfall_{i,m,y} + \epsilon_{i,m,y}
\end{aligned}
\tag{21}
$$

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

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

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

Table 4 indicates that, at the territory level, the granting of mining concessions in the neighbouring territory significantly increases the risk of conflict, in particular violent conflicts. The non-spatially lagged variable is negative and significantly different from zero, thus implying that the granting of concessions in neighbouring territories exacerbates the intensity of conflict.Table 4 indicates that these results are robust to the use of an alternative spatial matrix of order 1, instead of 2. At the district level, no spatial effect is found. Results presented in Table 4 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 logarithm transformation for the concession-based variables.

Overall, these result are consistent with the theoretical prediction according to which larger size/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 away from the mining site (potentially in a neighboring territory); and results in a higher level of violence at the aggregate level (adequately captured at the district level). Our results are therefore supportive of the spatial-based theoretical mechanisms emphasized in the previous section and likely to explain the case of ecological fallacy found in Section 3.2. 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 but increase the risk in neighboring territories. Increasing the number of mining concessions by 10% would result in a decrease of almost one conflict event in the same territory (-0.9 in regression (5) of Table 4) but an increase of more than two conflict events in the neighboring one (2.4 in the same regression). That in turn explains why a similar change in mining concessions would translate at a more aggregated effect (i.e. the district level) into an increase in conflict by almost two events (1.8 in regression (5) of Table 3).[20] Given the number of mining concessions granted in DRC, the magnitude of these results are 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 general picture, as the size of the new concessions features a similar spatial pattern. Finally, it should be noted that rainfall anomalies keep a significant and negative sign throughout the empirical analysis. A precise interpretation is tentative as this variable is only a proxy for agricultural income. Either case would imply that improved agricultural yields reduces 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 if the drop in profits resulting from the scarcer labour supply significantly reduces the incentives to fight for the control of the mine.

6 Conclusion

In this paper we explore the mineral resources-conflict nexus by focusing on the mineral-rich and conflict-ridden Democratic Republic of the Congo over the 1997-2008 period. Using geo-referenced data, we investigate whether granting mineral concessions in particular geographical areas by the central government of DRC 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 present mineral resources' prices. Our study reveals a case of ecological fallacy: while at the territory level granting concessions does not impact on the level of conflict, at the district level the right to exploit mineral wealth is shown to exacerbate the level of violence.

To rationalize this finding, we construct a theoretical explanation which relies on the incentives of violent entrepreneurs to protect the mining activities by avoiding armed confrontations with competing entrepreneurs nearby the mining activity. Securing a peaceful environment in the vicinity of the mining concession enhances the mining labourers' security, thereby reducing the cost of the labour force for the entrepreneurs in control of the

[20] Using the robustness Tables 5 and 6, where no logarithm transformation is used, would suggest a similar reduction in conflict events in the same territory (-0.7 in regression (5) of Table 6) but more than 8 additional conflict events in the neighboring one (8.4 in the same regression).

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 labour 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, while the intensity of conflict will decline.

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 since 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 since the intensity of conflict in surrounding areas is likely to experience an increase. This spatially-nuanced view on the conflictive role of mineral activities suggest that policies aiming at increasing transparency on mineral resources (e.g. the section 1502 of the 2010 Dodd-Frank Wall Street and Consumer Protection Act) and possibly reducing the exploitation of mineral resources need to be accompanied by strong support to the agricultural sector and other sources of alternative income.

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7 List of tables

Table 1: Descriptive Statistics

	Level of analysis: Territory				
Variable	Obs	Mean	Std. Dev.	Minimum	Maximum
Conflict Number	19800	0.1536364	1.024244	0	41
Violent Conflict Number	19800	0.1326768	0.9604655	0	41
Mining Concessions	19800	0.2802525	1.756388	0	46
Rainfall Anomalies	19800	1.08E-09	0.9534867	-2.770797	3.003923
Price Index	19650	506.0248	2965.579	0	57774.78
	Level of analysis: District				
Variable	Obs	Mean	Std. Dev.	Minimum	Maximum
Conflict Number	5016	0.6064593	2.44326	0	43
Violent Conflict Number	5016	0.5237241	2.241598	0	43 472.4957
Mining Concessions	5016	1.10626	5.46692	0	103
Rainfall Anomalies	5016	-3.09E-09	0.9155268	-2.541199	2.990951
Price Index	4978	1997.466	7107.281	0	63507.28

Table 2: Panel Unit Root Test (Maddala and Wu 1999)

Level of Analysis	Territory	District
Conflict Number	6470.2***	1489.46***
Violent Conflict	6432.27***	1503.91***
Mining Concessions (number)	5223.01***	1317.53***
Mining Concessions (number, log)	4390.79***	1035.36***
Mining Concessions (size)	5818.43***	1517.97***
Mining Concessions (size, log)	4403.62***	1063.39***
Rainfall Anomalies	62.03***	1573.52***
Price Index	0.193	0.174

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$;

Table 3: Baseline results : A case of ecological fallacy

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Level of Analysis	Territory	Territory	Territory	Territory	District	District	District	District
Sd-STAGE								
Dep. Var.	Number of Conflicts	Number of violent conflicts	Number of Conflicts	Number of violent conflicts	Number of Conflicts	Number of violent conflicts	Number of Conflicts	Number of violent conflicts
Concessions (log)	-0.104 [0.165]	0.0132 [0.137]			1.749** [0.800]	1.637** [0.717]		
Concessions Size (log)			-0.0169 [0.0267]	0.00214 [0.0223]			0.327** [0.148]	0.306** [0.133]
Rainfall Anomalies	-0.0249*** [0.009]	-0.0227*** [0.009]	-0.0246*** [0.009]	-0.0227*** [0.009]	-0.126** [0.055]	-0.112** [0.051]	-0.133** [0.056]	-0.119** [0.051]
Yr-Mth FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Territory/district FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	19,650	19,650	19,650	19,650	4,978	4,978	4,978	4,978
Nbr of Territoy/ Districts	150	150	150	150	38	38	38	38
Underid test	24.182***	24.182***	24.087***	24.087***	26.976***	26.976***	26.839***	26.839***
Weak id stat (a)	32.41	32.41	32.591	32.591	39.088	39.088	40.731	40.731
Root MSE	0.98	0.92	0.98	0.92	2.806	2.608	2.802	2.605
1St-STAGE								
Dep. Var.	Concessions (log)	Concessions (log)	Concessions Size (log)	Concessions Size (log)	Concessions (log)	Concessions (log)	Concessions Size (log)	Concessions Size (log)
Price Index	4.73e-05*** [8.32e-06]	4.73e-05*** [8.32e-06]	0.000292*** [5.11e-05]	0.000292*** [5.11e-05]	4.66e-05*** [7.45e-06]	4.66e-05*** [7.45e-06]	0.000249*** [3.90e-05]	0.000249*** [3.90e-05]
Rainfall Anomalies	0.0117 [0.007]	0.0117 [0.007]	0.0896** [0.045]	0.0896** [0.045]	0.014 [0.02]	0.014 [0.02]	0.096 [0.107]	0.096 [0.107]
Yr-Mth FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Territory/district FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	19,650	19,650	19,650	19,650	4,978	4,978	4,978	4,978
R sq.	0.21	0.21	0.21	0.21	0.306	0.306	0.294	0.294
Nbr of Territoy/ Districts	150	150	150	150	38	38	38	38
F-Test	12.19***	12.19***	13.06***	13.06***	7.24***	7.24***	8.07***	8.07***
F-test on excl. IV	32.41***	32.41***	32.59***	32.59***	39.09***	39.09***	40.73***	40.73***

**** $p< 0.01$, ** $p< 0.05$, * $p< 0.1$; (a) <10% Robust standard errors between brackets. (a) indicates that the Kleibergen-Paap Wald rk F statistic is larger than the Stock and Yogo statistics provided for a 10% maximal IV size.*

Table 4: Results with spatial dependency

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Level of Analysis	Territory	Territory	Territory	Territory	Territory	Territory	Territory	Territory
Sd-STAGE								
Order of Spatial Matrix	2	2	2	2	1	1	1	1
Dep. Var.	Number of Conflicts	Number of violent conflicts	Number of Conflicts	Number of violent conflicts	Number of Conflicts	Number of violent conflicts	Number of Conflicts	Number of violent conflicts
Concessions (log)	-0.543** [0.276]	-0.405* [0.234]			-0.911** [0.415]	-0.738** [0.363]		
Neighboring Concessions (log)	3.340*** [1.104]	3.109*** [1.011]			2.367*** [0.794]	2.175*** [0.740]		
Concessions Size (log)			-0.0816* [0.044]	-0.0594[0.110] [0.037]			-0.131** [0.066]	-0.104* [0.057]
Neighboring Concessions Size (log)			0.209*** [0.071]	0.194*** [0.065]			0.335*** [0.123]	0.307*** [0.114]
Rainfall Anomalies	-0.0301** [0.012]	-0.0284*** [0.011]	-0.0335** [0.015]	-0.0318** [0.014]	-0.0460*** [0.015]	-0.0429*** [0.014]	-0.0458** [0.022]	-0.0429** [0.021]
Yr-Mth FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Territory FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000
Nbr of Territories	150	150	150	150	150	150	150	150
Underid test	19.758***	19.758***	27.775***	27.775***	15.379***	15.379***	16.24***	16.24***
Weak id stat (a)	11.38	11.38	14.117	14.117	7.971	7.97	7.396	7.396
Root MSE 2d stage	1.147	1.072	1.435	1.334	1.357	1.248	2.048	1.877

**** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; (a) <10% Robust standard errors between brackets. (a) indicates that the Kleibergen-Paap Wald rk F statistic is larger than the Stock and Yogo statistics provided for a 10% maximal IV size.*

Table 5: Robustness of baseline results (without logarithm transformation)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Level of Analysis	Territory	Territory	Territory	Territory	District	District	District	District
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sd-STAGE								
Dep. Var.	Number of Conflicts	Number of violent	Number of Conflicts	Number of violent	Number of Conflicts	Number of violent	Number of Conflicts	Number of violent
Concessions	-0.0852 [0.136]	0.0108 [0.112]			0.629* [0.362]	0.588* [0.329]		
Concessions Size			-7.31E-10 [1.16e-09]	9.25E-11 [9.67e-10]			4.3e-09 [0.105] [2.67e-09]	4.05e-09* [2.43e-09]
Rainfall Anomalies	-0.0260*** [0.00888]	-0.0226*** [0.00838]	-0.0261*** [0.00905]	-0.0226*** [0.00838]	-0.0832 [0.0718]	-0.0718 [0.0673]	-0.0569 [0.0880]	-0.0472 [0.0825]
Yr-Mth FE Territory/district FE Time trend	Yes Yes Yes	Yes Yes Yes	Yes Yes Yes	Yes Yes Yes	Yes Yes Yes	Yes Yes Yes	Yes Yes Yes	Yes Yes Yes
Obs. R sq. Nbr of Territory/ Districts	19,650 -0.002 150	19,650 0.013 150	19,650 -0.051 150	19,650 0.012 150	4,978 -1.946 38	4,978 -2.005 38	4,978 -3.536 38	4,978 -3.637 38
Underid test Weak id stat (a)	11.79*** 13.19	11.79*** 13.19	8.197*** 9.881	8.197*** 9.88	7.489*** 8.172	7.489*** 8.172	5.333** 5.902**	5.333** 5.902**
Root MSE	0.92	0.92	1.008	0.92	3.733	3.48	6.632	4.322
1St-STAGE								
Dep. Var.	Concessions	Concessions	Concessions Size	Concessions Size	Concessions	Concessions	Concessions Size	Concessions Size
Price Index	5.78e-05*** [1.59e-05]	5.78e-05*** [1.59e-05]	6,738*** [2,144]	6,738*** [2,144]	4.66e-05*** [7.45e-06]	4.66e-05*** [7.45e-06]	0.000249*** [3.90e-05]	0.000249*** [3.90e-05]
Rainfall Anomalies	0.00119 [0.0157]	0.00119 [0.0157]	101,379 [2.996e+06]	101,379 [2.996e+06]	0.014 [0.0203]	0.014 [0.0203]	0.096 [0.107]	0.096 [0.107]
Yr-Mth FE Territory/district FE Time trend	Yes Yes Yes	Yes Yes Yes	Yes Yes Yes	Yes Yes Yes	Yes Yes Yes	Yes Yes Yes	Yes Yes Yes	Yes Yes Yes
Obs. R sq. Nbr of Territoy/ Districts	19,650 0.119 150	19,650 0.119 150	19,650 0.067 150	19,650 0.067 150	4,978 0.306 38	4,978 0.306 38	4,978 0.294 38	4,978 0.294 38
F-Test F-test on excl. IV	5.18*** 13.19***	5.18*** 13.19***	3.19*** 9.88***	3.19*** 9.88***	2.43*** 8.17***	2.43*** 8.17***	1.71*** 5.90**	1.71*** 5.90**

*** $p< 0.01$, ** $p< 0.05$, * $p< 0.1$; *(a) <10% Robust standard errors between brackets.*

Table 6: Robustness for results with spatial dependency (without logarithm transformation)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Level of Analysis	Territory	Territory	Territory	Territory	Territory	Territory	Territory	Territory
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sd-STAGE								
Order of Spatial Matrix	2	2	2	2	1	1	1	1
Dep. Var.	Number of Conflicts	Number of violent	Number of Conflicts	Number of violent	Number of Conflicts	Number of violent	Number of Conflicts	Number of violent
Concessions	-0.405* [0.221]	-0.301 [0.186]			-0.734* [0.391]	-0.600* [0.339]		
Neighboring Concessions	21.38*** [7.470]	20.41*** [6.784]			8.393*** [3.232]	7.810*** [2.937]		
Concessions Size			-3.19e-09* [1.94e-09]	-2.29E-09 [1.60e-09]			-6.65E-09 [4.36e-09]	-5.42E-09 [3.69e-09]
Neighboring Concessions Size			1.54e-07*** [5.99e-08]	1.46e-07*** [5.22e-08]			7.31e-08* [3.80e-08]	6.72e-08** [3.26e-08]
Rainfall Anomalies	-0.0339*** [0.0131]	-0.0310*** [0.0118]	-0.0324** [0.0156]	-0.0297** [0.0136]	-0.0500** [0.0195]	-0.0456*** [0.0173]	-0.0591* [0.0318]	-0.0539** [0.0274]
Yr-Mth FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Territory FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000
Nbr of Territories	150	150	150	150	150	150	150	150
Underid test	10.129***	10.129***	6.495**	6.495**	6.387**	6.387**	2.902*	2.902*
Weak id stat (a)	5.381	5.381	3.694	3.694	3.196	3.196	1.482	1.482
Root MSE 2d stage	1.258	1.146	1.548	1.333	1.701	1.514	2.72	2.336

**** $p< 0.01$, ** $p< 0.05$, * $p< 0.1$; (a) <10% Robust standard errors between brackets.*