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ARTISANAL GOLD MINING AND CONFLICT IN AFRICA

Isabel Maria de Carvalho Caldeira

Work Project carried out under the supervision of:

Professor Victoire Girard

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Abstract

It is estimated that 63 percent of people directly involved in artisanal and small-scale mining in Africa are committed to gold mining. We use georeferenced data (0.5×0.5 decimal degree level) on gold-suitable zones to document the impact of artisanal and small-scale gold mining (ASGM) on conflict in 54 African countries for the period 1997-2018. By exploiting exogenous variations in world prices, the results suggest that ASGM is associated with higher risk of conflict. A disaggregation of conflict into different types suggests that ASGM lowers the risk of larger and deadlier events but increases the risk of intermittent or less-lethal events.

Keywords: conflict, artisanal mining, gold, Africa, disaggregated data, natural resources.

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I. Introduction

Natural resources such as minerals and metals have long been viewed as a source of conflict. These resources require added attention due to being non-renewable and having various applications. In addition, population growth and the push for renewable energy and infrastructure imply that the demand for metals and minerals is accelerating (World Economic Forum 2023). As such, research on the economic, political, and social dimensions of minerals and metals remains relevant. Most literature has been dedicated to the impact of industrial and large-scale mining, partly as a result of its scale, economic significance and influence, and data accessibility. As such, there is a greater lack of understanding about artisanal and small-scale mining. This imbalance occurs despite the considerable growth artisanal mining has experienced in the past two decades. In fact, artisanal mining is not only an important source of minerals and metals but also a means of subsistence for millions of people (IGF 2017).

This Work Project attempts to document whether, and under which conditions, artisanal gold mining impacts conflict. We use georeferenced data at the 0.5×0.5 decimal degree level (corresponding to 55×55 kilometres at the Equator) to document the impact of artisanal and small-scale gold mining (ASGM) on conflict in 54 African countries for the period 1997-2018. The unit of observation is at the cell-year level. To proxy artisanal gold mining, we use a novel data set constructed by Girard, Molina-Millán and Vic (2022) on gold suitable zones, i.e., areas that are most suitable to host gold, and exploit the variation in the international price of gold. The latter allows us to mitigate endogeneity concerns between the occurrence of conflict and mining activity. Conflict data is sourced from the Armed Conflict Location & Event Data Project (ACLED). In addition, we report results using the Uppsala Conflict Data Program Georeferenced Event Dataset (UCDP GED).

The main dependent variable is a dummy variable equal to 1 if, at least, one conflict event is registered in a given cell and a given year. As such, we employ a linear probability model. The baseline specification includes cell and country-year fixed effects, and standard errors are clustered at the cell level. As a robustness exercise, we report estimations with cell and year fixed effects. In addition, we replicate results using a spatial HAC correction that allows for both cross-sectional spatial correlation and location-specific serial correlation (Conley 1999; Hsiang, Meng, and Cane 2011).

Results suggest that artisanal and small-scale gold mining is associated with higher risk of conflict. This is consistent with mechanisms linking natural resources to conflict through channels such as financial feasibility, rent-seeking or grievances (Berman et al. 2017; Berman, Couttenier and Girard 2023; Lujala, Gleditsch and Gilmore 2005; Rigterink 2020). A disaggregation of conflict into distinct types suggests that ASGM increases the risk of intermittent or less-lethal events such as riots but lowers the risk of larger and deadlier events such as battles. The latter is consistent with mechanisms such as income diversification, which increase the opportunity cost of conflict (Banchirigah and Hilson 2010; Bazillier and Girard 2020; Maconachie and Hilson 2018). In addition, by being a labour-intensive activity, artisanal mining can create incentives to safeguard labour so that illegal taxation is possible (Fourati, Girard and Laurent-Lucchetti 2022). Since lethal forms of violence are more likely to result in a loss of the labour force that is to be extorted, it is plausible that employing less lethal types of violence becomes preferred.

This Work Project contributes to the literature on natural resources and conflict in two ways. Firstly, it focuses on artisanal and small-scale mining. There is still a lack of understanding about the impacts of the latter since literature has been mostly dedicated to industrial and large-scale mining (Benshaul-Tolonen 2019; Benshaul-Tolonen 2022; Berman et al. 2017). By relying on empirical evidence, the findings of this Work Project help to fill the knowledge gap on an equally important form of mining. In particular, it suggests that artisanal mining can impact conflict risk despite existing at a lower scale. As such, it can help build more informed approaches on how to manage an activity that is still mostly informal, unregulated and unsupervised. Secondly, it presents a more nuanced analysis on the impacts of artisanal mining as it suggests that different theoretical effects may dominate depending on the type of conflict considered. Understanding the several drivers of conflict is essential in order to mitigate it and prevent it.

The Work Project is organized as follows. Section II contextualizes the problem and presents a summary of existing literature. Section III provides a description of the data, including sources and descriptive statistics. Section IV describes the methodology. Section V presents the empirical results and discussion. Lastly, Section VI concludes.

II. Literature Review

A. Background and Context

By being non-renewable and having a wide range of applications, minerals and metals are valuable natural resources. In fact, mining is an activity that can be traced back to primitive times (National Geographic Society 2022). Between 1995 and 2018, total global mineral wealth more than tripled and, within this period, the price of gold tripled (World Bank 2021). In fact, gold was the commodity experiencing the largest price increase by going from an average of $418 per troy ounce in 1995 to $1 247 in 2018 (World Bank 2021). However, like other natural resources, minerals and metals have been viewed as a source of conflict (Berman et al. 2017; Lujala, Gleditsch and Gilmore 2005; Rigterink 2020).

Artisanal and small-scale mining (ASM) differs from industrial and large-scale mining (LSM) in terms of the scale of operation, types of instruments used, and the level of regulation and supervision in place. ASM refers to the extraction of minerals using primarily manual techniques and simple instruments such as pickaxes. Consequently, it is a labour-intensive activity. Given its minimal capital requirements and low barriers to entry as a result of low regulation, ASM is more accessible to individuals or groups with limited resources (IISD n.d.). On the contrary, LSM relies on mechanized instruments and techniques which, in turn, make it a capital-intensive activity (Artisanal Gold Council n.d.). Since it is often carried out by multinational corporations or Governments, LSM is subject to stricter regulation and supervision.

ASM has experienced substantial growth in the past two decades, which can be partially explained by the increase of mineral prices (IGF 2017). It is estimated that 6 million people were directly involved in ASM in 1993, a number that increased to 49.5 million in 2022 (ASM Inventory 2023; IGF 2017).

Artisanal and small-scale gold mining (ASGM) is the main form of ASM. It is estimated that 37 percent of the 49.5 million people directly involved in ASM in 2022 are committed to gold mining. In Africa, this number rises to approximately 63 percent (ASM Inventory 2023). Moreover, the gold extracted through artisanal mining accounts for 20 percent of global supply (IGF 2017).

B. Literature

Financial feasibility, rent-seeking and grievances are among the major channels linking natural resources such as minerals and metals to higher levels of conflict. Natural resources can elevate the risk of conflict by increasing the financial feasibility of violent actors, i.e., looting resources eases financial constraints, helping to spur or sustain conflict (Lujala, Gleditsch and Gilmore 2005). Moreover, valuable resources increase the rents to be captured if territories are taken over, creating incentives for rent-seeking (Collier and Hoeffler 2004). Finally, the exploration of natural resources can have negative impacts, namely related to environmental degradation, displacement of communities (Downing 2002; Hilson 2002) or ethnic fragmentation, which can fuel conflict by creating or aggravating grievances among actors. For instance, Girard, Molina-

Millán and Vic (2022) explore the impacts of ASGM by assembling a novel geological map of gold suitable areas in Africa, i.e., areas that are most suitable to host gold, and use it as a proxy for ASGM activity. The authors find that an increase in the gold price accounts for 8 percent of the increase in deforestation in Africa between 2001 and 2018, a number that rises to 28 percent in areas that are gold-suitable (Girard, Molina-Millán and Vic 2022). Moreover, Berman, Couttenier and Girard (2023) suggest that mineral exploitation in a group's historical homeland intensifies the strength of an ethnic group identity relative to national identity. This is partly rooted in feelings of relative deprivation and grievances, which may occur if the extraction of natural resources degrades the status or welfare of local groups or yields benefits that are not perceived by these groups.

The characteristics of ASM and LSM make it so that natural resources explored under these methods can be classified as lootable and non-lootable, respectively. Lootable resources are more susceptible to smuggling due to being extracted through elementary methods and tools by individuals or small groups (Le Billon 2009; Lujala, Gleditsch and Gilmore 2005). Contrarily, non-lootable resources are harder to extract or transport and thus, are less likely to be appropriated.

Lootable resources are often associated with higher levels of conflict as these can act as a source of funding to armed groups, rebels or locals (Lujala, Gleditsch and Gilmore 2005; Rigterink 2020). Lujala, Gleditsch and Gilmore (2005) focus on the relationship between diamonds and armed conflict, finding that the geological form of diamond deposits impacts conflict incidence. The authors distinguish between primary diamonds, a non-lootable resource, and secondary diamonds, a lootable resource. It is suggested that secondary diamonds are positively related to conflict incidence, whereas primary diamonds make incidence less likely (Lujala, Gleditsch and Gilmore 2005).

Although ASM is likely associated with higher levels of conflict, this relationship can vary depending on the types of conflict considered. Fourati, Girard and Laurent-Lucchetti (2022) employ a geographically disaggregated analysis covering all African countries from 1997 to 2018 and find that artisanal mining increases non-lethal violence. Centred on the argument that the source of funding for armed actors is the illegal taxation of resources, by being a labour-intensive activity, artisanal mining creates incentives to safeguard labour and prefer to employ non-lethal over lethal violence. The opposite would occur for industrial mining, i.e., industrial mining only increases lethal violence, which the authors prove empirically.

The increase in the number of people directly involved in ASM can also be explained by an "increasing difficulty of earning a living from agriculture and other rural activities" (IGF 2017, 1). This has been aggravated by negative economic shocks related to climate such as floods or droughts (UNECA 2003). By destroying crops that are crucial for the livelihood of farmers, such negative shocks have been linked to increases in conflict by decreasing the opportunity cost of conflict relative to labour market participation, which portrays conflict as more desirable (Collier and Hoeffler 1998; Dal Bó and Dal Bó 2011; Harari and La Ferrara 2018). Harari and La Ferrara (2018) employ a geographically disaggregated analysis covering African countries from 1997 to 2018 to examine the hypothesis that droughts are linked to conflict through losses in agricultural production and farmers' income. The authors find evidence that droughts during crop growing season affect conflict incidence but droughts outside growing season do not.

Since the opportunity cost mechanism seems to operate through negative economic shocks such as income losses, ASM has the potential to mitigate the relation between such shocks and conflict through income diversification. This can be especially valuable for low-income households (Banchirigah and Hilson 2010; Maconachie and Hilson 2018).

In particular, ASGM has been associated to positive economic spillovers, namely at the level of consumption, wealth and night-time light emissions (Bazillier and Girard 2020; Girard, Molina-Millán and Vic 2022). By using the gold boom in Burkina Faso as a quasi-natural experiment, Bazillier and Girard (2020) find that an increase in the gold price increases the consumption of households living near artisanal mines. However, the effect dissipates when considering industrial gold mines.

This Work Project attempts to document whether, and under which conditions, artisanal gold mining impacts conflict. The access to artisanal gold mining doesn't allow for a clear effect from the outset. On the one hand, the income diversification channel allows for positive economic spillovers (Banchirigah and Hilson 2010; Bazillier and Girard 2020; Girard, Molina-Millán and Vic 2022; Maconachie and Hilson 2018), which would increase the opportunity cost of conflict, thus reducing conflict levels. On the other hand, the artisanal element is seemingly associated with higher levels of conflict, namely through the channels of financial feasibility, rent-seeking and grievances (Berman et al. 2017; Berman, Couttenier and Girard 2023; Lujala, Gleditsch and Gilmore 2005; Rigterink 2020). The net effect will depend on the strength of each outcome.

III. Data

We use georeferenced data at the 0.5×0.5 decimal degree level (corresponding to 55×55 kilometres at the Equator) from several sources to construct a data set covering 54 African countries from 1997 to 2018. The data doesn't depend on administrative divisions, which rules out endogeneity concerns between the unit of observation at the cell-year level and conflict incidence, the main dependent variable. This section is divided in two parts: the first part conveys information on the different data sets used and the second part provides descriptive statistics.

A. Data Sources

1. Conflict data

The main data on conflict comes from the Armed Conflict Location & Event Data Project (ACLED) (Raleigh et al. 2010). The ACLED is a widely used data set (Berman et al. 2017; Fourati, Girard and Laurent-Lucchetti 2022; Harari and La Ferrara 2018) that provides disaggregated data on conflict events such as date, location, number of fatalities and actors. The data is obtained from local, regional and national sources, which can raise concerns over reporting bias. To lessen such concerns, we control for cell and country-year fixed effects. In addition to ACLED, and similar to Berman et al. (2017) and Harari and La Ferrara (2018), we report and discuss the results using the Uppsala Conflict Data Program Georeferenced Event Dataset (UCDP GED) (Davies, Pettersson & Öberg 2022; Sundberg and Melander 2013).

Although comparable in terms of structure, the main difference between the ACLED and the UCDP GED is the definition of events included. The UCDP GED focuses on events resulting in more than 25 fatalities in a given year, whereas the ACLED includes non-fatal and non-violent events (Eck 2012; Raleigh et al. 2010; Högbladh 2022). Thus, the UCDP GED is less exhaustive than the ACLED. However, by recording only large and deadly events, reporting bias is less plausible in the UCDP GED.

2. Mining data

To proxy artisanal gold mining, we use the novel data set constructed by Girard, Molina-Millán and Vic (2022) on gold suitable zones, i.e., areas that are most suitable to host gold, in Africa and multiply it by the yearly international price of gold. Each cell is assigned a value ranging from 0 (non-suitable) to 1 (fully suitable), corresponding to the share of the cell that is gold suitable. Not all gold suitable zones will record ASGM and even if a cell is assigned value 1, it is not fully certain that artisanal mining is recorded. Nonetheless, if ASGM occurs, it will be most successful within these zones (Girard, Molina-Millán and Vic 2022). In addition, gold suitable zones can also be suitable for industrial and large-scale gold mining (LSGM), even if only a portion of gold deposits are profitable enough for the capital requirements associated with LSGM. For instance, Girard, Molina-Millán and Vic (2022) suggest that only 3 percent of gold-suitable cells record an industrial mine at some point between 1987 and 2018. Regardless, it is important to separately control for both types of mining activities. Data on the price of gold and other commodities is sourced from the World Bank Commodities Prices Data Set (World Bank 2023). These refer to annual prices in real 2010 U.S. dollars.

To distinguish the effects of artisanal and industrial gold mining, we use data from Berman et al. (2017) on the location of large-scale mines. The data is based on information from Raw Material Data, and small-scale and illegally operated mines are not included. Berman et al. (2017) cover the period 1997-2010 and employ a dummy variable which equals 1 if, at least, one active large mine is recorded in a given cell during the year. Given that we cover the period 1997-2018, we assumed that each mine's status remained constant for all the years after 2010, i.e., if there was an active large mine open (closed) in 2010, it remains open (closed) until 2018.

4. Other data

Similar to Almer, Laurent-Lucchetti and Oechslin (2017) and Harari and La Ferrara (2018), we use the Standardized Precipitation-Evapotranspiration Index (SPEI) to capture the effect of climate events (Vicente-Serrano et al. 2010). The SPEI is expressed in units of standard deviations from the long-run average of water balance. By construction, it has mean 0 and standard deviation 1 (Vicente-Serrano et al. 2010). A negative SPEI is associated with drier conditions, whereas a positive SPEI is associated with wetter conditions. Besides taking into account precipitation, the SPEI considers variables such as temperature and potential evapotranspiration. As such, it is more complete than indices such as the Standardised Precipitation Index (SPI) or the Palmer Drought Severity Index (PDSI).

The PRIO-GRID data set developed by Tollefsen, Strand and Buhaug (2012) provides other cell-specific variables such as distances between the centre of the cell to the closest landcontiguous neighbouring country and to the national capital city. Since the sample covers the period 1997-2018, these are not accounted for using cell fixed effects due to border changes following the independence of South Sudan from Sudan in 2011.

Finally, data on ethnic fractionalization is sourced from Reynal-Querol (2014).

B. Descriptive Statistics

The sample covers 54 countries from the period 1997-2018, which consists of approximately 10 678 cells across time. Table 1 reports descriptive statistics for both the ACLED and UCDP GED samples.

1. ACLED Sample

From the 54 countries, only 5 experience no conflict event over the 22-year period and 9 have no cells that are gold suitable. The probability of occurring at least one conflict event in a given cell and a given year is approximately 10.08 percent. This probability is higher in gold suitable cells at about 12.35 percent, which decreases to 8.47 percent in non-suitable cells.

Figure 1 shows the average of conflict events in each year in cells that are gold suitable and non-suitable for the ACLED sample. The average incidence in gold-suitable and non-suitable cells report a similar trend which, in turn, follow the trend in the gold price. The average remains below 0.04 until 2010, continuously increasing thereon after until 2018. Between 1997 and 2008, and in 2010, 2013 and 2014, average incidence is higher in gold-suitable cells. In other years, average incidence is higher in non-suitable cells.

2. UCDP GED Sample

From the 54 countries, 8 experience no conflict event over the 22-year period. This is higher than in the ACLED sample, which was expected due to ACLED being less restrictive on the inclusion of conflict events. As such, the probability of occurring at least one conflict in a given cell and a given year is also lower at approximately 3.47 percent. This probability remains higher in gold suitable cells at about 3.84 percent, which decreases to 3.84 percent in non-suitable cells.

The average incidence in gold-suitable and non-suitable cells reports a similar trend, although the difference between gold-suitable and non-suitable cells increases from 2008 onwards more prominently than in the ACLED sample (Figure 2). Moreover, the average is lower than in the ACLED sample. Whereas the average in the ACLED sample remains below 0.04 until 2010, the average remains below 0.04 for the 22-year period in the UCDP GED sample. Regardless, it also experiences a continuous increase in conflict events after 2010. With the exception of 1997, 1998, 2001, 2003 and 2006, average incidence is higher in cells that are not gold suitable.

Finally, the SPEI has a mean of -0.26, suggesting the weather in the sample has been drier than the long-run average over the 22-year period.

Table 1 – Descriptive Statistics

Variables	(1) No. Obs.	(2) Mean	(3) Std. Dev.	(4) Min	(5) Max
Conflict ACLED Sample	234,916	0.101	0.301	0	1
Conflict UCDP GED Sample	234,916	0.0347	0.183	0	1
Events ACLED Sample					
Battles	234,916	0.0298	0.170	0	1
Explosions/Remote Violence	234,916	0.00464	0.0680	0	1
Violence Against Civilians	234,916	0.0280	0.165	0	1
Riots	234,916	0.0136	0.116	0	1
Gold suitability	234,916	0.178	0.299	0	1
SPEI	232,298	-0.260	1.009	-6.776	7.280
SPEI, Lag 1	232,298	-0.264	1.013	-6.776	7.280
SPEI, Lag 2	232,298	-0.262	1.015	-6.776	7.280
Industrial Mines	227,274	0.020	0.140	0	1
Ethnic fractionalization	200,353	0.640	0.235	0.050	0.959
Distance to border	228,470	169.14	138.50	.0034	1971.66
Distance to capital city	234,828	645.57	416.04	3.703	2482.53

Figure 1 - Mean conflict in gold suitable and non-suitable cells and gold price (per 1000 troy ounce), ACLED Sample, 1997-2018.

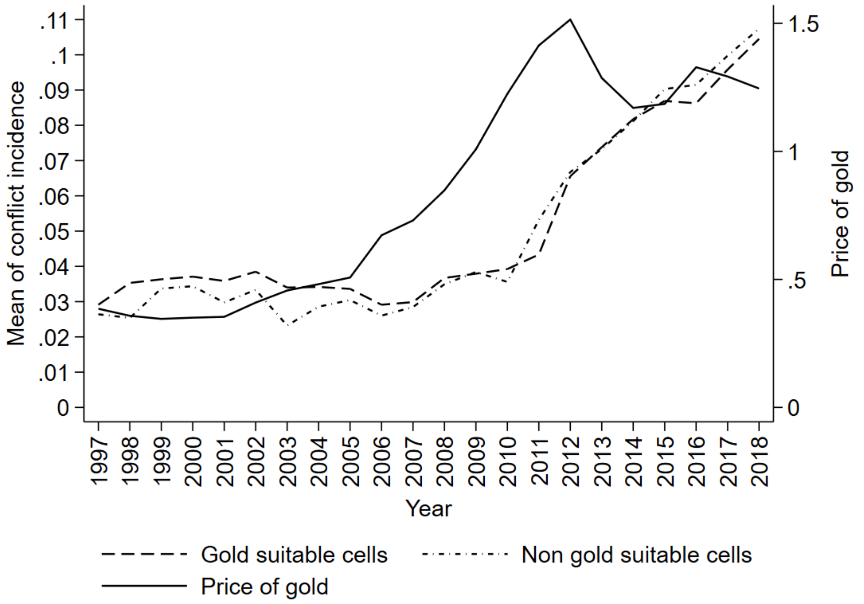
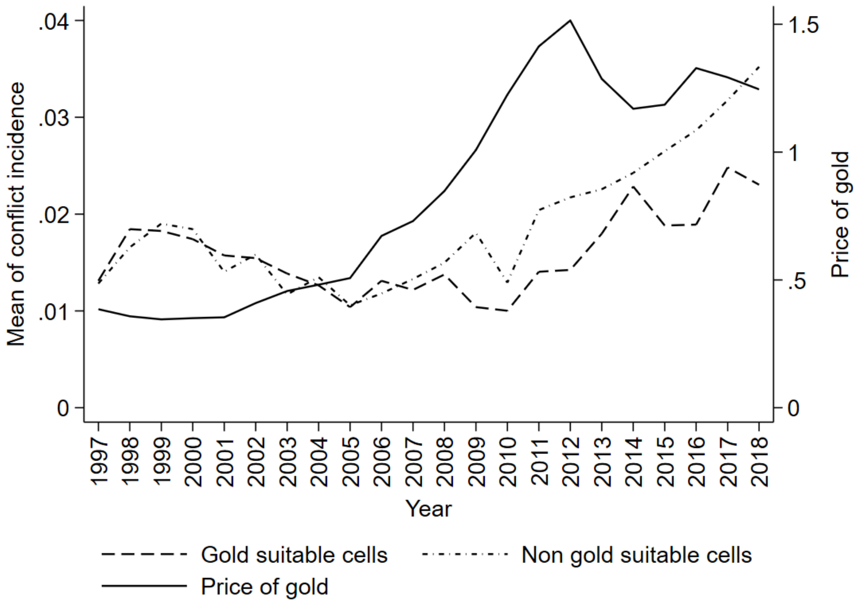


Figure 2 - Mean conflict in gold suitable and non-suitable cells and gold price (per 1000 troy ounce), UCDP GED Sample, 1997-2018.



IV. Methodology

We resort to a linear probability model to estimate the following specification:

$$Conflict_{it} = \alpha + \gamma \; Gold\ suitability_i \times Gold\ price_t + \theta \; Controls_{it} + FE_i + FE_{ct} + \varepsilon_{it}$$

The main dependent variable, $Conflict_{it}$, is a dummy variable equal to 1 if, at least, one conflict event is recorded in cell i in year t. This variable is used in both the ACLED and the UCDP GED samples.

The main independent variable of interest is the interaction $Gold\ suitability_i \times Gold\ price_t$, which is the proxy for the presence of artisanal gold mining in cell i. $Gold\ suitability_i$ is sourced from Girard, Molina-Millán and Vic (2022). The $Gold\ price_t$ refers to the international price of gold in year t, which captures the potential revenues of ASGM. It is plausible that local miners lack the capacity to influence international prices and thus, are considered price-takers in the international market. Exploiting the variation in the international price also allows us to abstract from endogeneity concerns between the occurrence of conflict and mining activity, in particular regarding reverse causality. In this case, γ measures the change in the probability of occurring a conflict event when gold suitability changes, holding other factors fixed. Thus, a negative γ indicates that the more gold suitable a zone is, the lower the likelihood of conflict. A positive γ indicates that the more gold suitable a zone is, the higher the likelihood of conflict. However, since gold suitable zones can host artisanal gold mining and large-scale gold mining, it is important to control for the latter. As such, we include a dummy variable equal to 1 if, at least, one active large mine is recorded in cell i during year t, in the set of controls. In addition, all specifications include the following controls: the SPEI and two respective lags, distance to the country border and to the national capital city, ethnic fractionalization and interactions between commodity prices and the dummy variable for the presence of active large mines.

The benchmark specification includes cell fixed effects, FE_i, and country-year fixed effects, FE_{ct}. Cell fixed effects are included to control for time-invariant determinants of conflict and artisanal mining at the cell level, e.g., cell's land characteristics such as area, elevation or area equipped for irrigation. Country-year fixed effects are included to control for country level time-varying determinants of conflict and artisanal mining such as property rights. In addition, we report results using cell and year fixed effects, FE_t. The latter are included to control for time-varying determinants of conflict and mining.

Baseline results are reported with standard errors clustered at the cell level due to possible spatial correlation within cells. As a robustness exercise, given the spatial resolution of the data set, we account for spatial correlation beyond the dimensions of the cells (corresponding to 55×55 kilometres at the Equator). Thus, we also report estimations with a spatial HAC correction which allows for both cross-sectional spatial correlation and location-specific serial correlation (Conley 1999; Hsiang, Meng, and Cane 2011). Spatial correlation is assumed to vanish after 500 kilometres and temporal correlation among observations is assumed to vanish after 100000 years, i.e., infinite horizon (Colella et al. 2020).

In addition, we disaggregate the main dependent variable into conflict types using the ACLED sample. As such, the dependent variable becomes $ConflictType_{it}$. This is a dummy variable equal to 1 if, at least, one type of conflict event is recorded in cell i in year t. It is not possible to replicate this exercise using the UCDP GED sample as the latter doesn't categorize events by type.

V. Results and Discussion

We are interested in understanding whether, and under which conditions, access to artisanal gold mining impacts conflict. As such, the main variable of interest is the proxy for the presence of artisanal gold mining. This section is divided in three parts: the first part reports results using the ACLED sample, the second part reports results using the UCDP GED sample, and the third and final part reports results for different types of conflict using the ACLED sample.

A. ACLED Sample

Table 2 reports the baseline results for the ACLED sample. The dependent variable is a dummy variable equal to 1 if, at least, one conflict event is recorded in cell i in year t. Thus, it is an indicator of conflict incidence. As previously mentioned, benchmark estimations include cell and country-year fixed effects. Standards errors are clustered at the cell level. In addition, we report results using cell and year fixed effects.

In all columns, the proxy for the presence of artisanal gold mining is positive and significant at the 1 or 5 percent level. This suggests that the more gold suitable a zone is, the higher is the risk of conflict. This would be aligned with theories linking natural resources to higher conflict incidence through channels like financial feasibility, rent-seeking and grievances (Berman et al. 2017; Berman, Couttenier and Girard 2023; Lujala, Gleditsch and Gilmore 2005; Rigterink 2020).

Columns 1 and 3 report estimations without controls. Although the coefficients of interest are positive, these should be interpreted with caution due to omitted variable bias. In particular, industrial mining is likely a catalyst of conflict (Berman et al. 2017) and the former might correlate with artisanal mining. Moreover, it seems that climatic conditions can be drivers of conflict (Almer, Laurent-Lucchetti and Oechslin 2017; Harari and La Ferrara 2018) and might also correlate with artisanal mining as some methods of extraction depend, for instance, on water availability (e.g., gold panning refers to the process of separating gold from soil particles using water in a recipient which is agitated by the miner and this process often occurs near riverbeds (EPA 2023)).

Columns 1 and 2 report results using cell and year fixed effects, and columns 3 and 4 report results using cell and country-year fixed effects. The positive relationship between artisanal gold mining and conflict is slightly more significant when using cell and year fixed effects. Regardless, the magnitude of the coefficient is small in both cases.

Table 2 – Conflict and gold suitability, ACLED Sample

Estimator	Linear Probability Model			
Dependent variable	Conflict Incidence			
Sample	ACLED			
Variables	(1)	(2)	(3)	(4)
Gold suitability x Gold price	0.0285***	0.0260***	0.0222***	0.0172**
	(0.00795)	(0.0087)	(0.00757)	(0.0083)
Constant	0.0965***	0.3013***	0.0974***	0.1726****
	(0.00119)	(0.0198)	(0.00114)	(0.0366)
Controls	No	Yes	No	Yes
Cell FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	No	No
Country-Year FE	No	No	Yes	Yes
Observations	234,916	195,000	234,828	194,935
R-squared	0.408	0.416	0.408	0.465

Notes: Dependent variable is a dummy variable equal to 1 if, at least, one conflict event occurs in a cell in a given year. Controls include: the SPEI, along with two lags; a dummy variable equal to 1 if there is, at least, one large mine in the cell; ethnic fractionalization at the country level; distance to the border of the nearest land and to the national capital city in kilometres; and interactions between commodity prices and the dummy variable for the presence of active large mines. The gold price is expressed per 1000 troy ounce. Robust standard errors (clustered at the cell level) in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

The estimations using the spatial HAC correction which allows for both cross-sectional spatial correlation and location-specific serial correlation (Conley 1999; Hsiang, Meng, and Cane 2011) yield similar results but there is a slight loss in significance as standard errors increase (Appendix, Table 6).

The proxy for artisanal gold mining was built using information on the contours, age and chemical composition of geological bedrocks in Africa (Girard, Molina-Millán and Vic 2022). Gold suitability is based on two criteria: geological strata and lithology. Firstly, the geological layers corresponding to geological ages during which gold mineralization occurred were isolated. Secondly, the lithologies, i.e., the physical characteristics, for which composition is suitable for hosting gold were identified. To be suitable for artisanal gold mining, a bedrock needs to satisfy both criteria (Girard, Molina-Millán and Vic 2022). The gold suitability of a cell, i.e., the value ranging from 0 (non-suitable) to 1 (fully suitable), is assigned by calculating the share of the cell that overlaps with the bedrocks suitable for artisanal gold mining.

As a robustness exercise, and given the novelty of the data set, we use different specifications of gold suitability to test the hypothesis that artisanal mining increases conflict risk. Table 3 reports the baseline results for the ACLED sample using the various specifications of gold suitability. Despite a loss in significance, the results point towards a positive relationship between artisanal gold mining and conflict.

In columns 1 and 2, cells' share of gold suitability is multiplied by the logarithm of the international price of gold. The proxy for the presence of artisanal gold mining remains positive and significant at the 1 or 5 percent level. However, the magnitude of the coefficients decreases.

Columns 3 to 6 report estimations using a dummy variable for gold suitability instead of using cells' share of gold suitability. The dummy variable takes value 1 if the cell is suitable for gold. Thus, as long as the cell has some degree of gold suitability, i.e., is not assigned a value of 0 (non-suitable), the dummy variable takes value 1. Coefficients remain positive in all specifications, but their magnitude and significance become progressively smaller.

Table 3 – Conflict and different specifications of gold suitability, ACLED Sample

Estimator	Linear Probability Model					
Dependent variable	Conflict Incidence					
Sample	ACLED					
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Gold suitability x Log Gold price	0.0195***	0.01254**				
	(0.00651)	(0.00624)				
Gold suitability dummy x Gold price			0.0072	0.00752*		
			(0.00493)	(0.00454)		
Gold suitability dummy x Log Gold price					0.0049	0.00552
					(0.00373)	(0.00343)
Constant	0.306***	0.1763***	0.303***	0.1740***	0.3064***	0.1775***
	(0.020)	(0.037)	(0.0198)	(0.037)	(0.020)	(0.037)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Cell FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	No	Yes	No	Yes	No
Country-Year FE	No	Yes	No	Yes	No	Yes
Observations	195,000	194,935	195,000	194,935	195,000	194,935
R-squared	0.416	0.465	0.416	0.465	0.416	0.465

Notes: The gold price is expressed per 1000 troy ounce. Robust standard errors (clustered at the cell level) in parentheses. *** p<0.01, ** p<0.05, * p<0.1

B. UCDP GED Sample

Similar to Berman et al. (2017) and Harari and La Ferrara (2018), we replicate the baseline results using the UCDP GED data set as a robustness exercise. These results can be found in Table 4.

Contrary to the baseline results in the ACLED sample, in all columns, the proxy for the presence of artisanal gold mining is negative and unsignificant. Although coefficients are of small magnitude (even smaller than in the ACLED sample), this would suggest that the more gold suitable a zone is, the lower is the risk of conflict. This would be aligned with theories linking natural resources to lower conflict incidence through channels like income diversification which, by allowing positive economic spillovers (Banchirigah and Hilson 2010; Maconachie and Hilson 2018; Bazillier and Girard 2020), would increase the opportunity cost of conflict, thus reducing it.

Table 4 – Conflict and gold suitability, UCDP GED Sample

Estimator	Linear Probability Model			
Dependent variable	Conflict Incidence			
Sample	UCDP GED			
Variables	(1)	(2)	(3)	(4)
Gold suitability x Gold price	-0.00771	-0.0047	-0.00391	-0.0014
	(0.00570)	(0.00646)	(0.00491)	(0.00552)
Constant	0.0359***	0.1250***	0.0353***	0.0347***
	(0.000857)	(0.0167)	(0.000739)	(0.0294)
Controls	No	Yes	No	Yes
Cell FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	No	No
Country-Year FE	No	No	Yes	Yes
Observations	234,916	195,000	234,916	194,935
R-squared	0.291	0.295	0.339	0.344

Notes: The gold price is expressed per 1000 troy ounce. Robust standard errors (clustered at the cell level) in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

The discrepancy in results between the two data sets can be attributed to multiple factors. Firstly, it is possible that the suggested positive relationship between artisanal gold mining and conflict found in the ACLED sample is not replicable in other contexts. This poses a threat to the external validity of our study, meaning findings and policy implications cannot be generalized. Secondly, as previously mentioned, although comparable in terms of structure, the ACLED and the UCDP GED have different definitions of conflict event. Whereas the ACLED includes smaller, non-fatal and non-violent events, the UCDP GED focuses on large and deadly events. This could suggest that the impact of artisanal gold mining on conflict is conditional on the types of conflict events considered. For instance, Fourati, Girard and Laurent-Lucchetti (2022) find that artisanal mining increases non-lethal violence and that industrial mining increases lethal violence. Since the two data sets are not fully comparable, this can only be partially tested by disaggregating the main dependent variable into different types of conflict events. However, the UCDP GED doesn't categorize events by type, meaning this exercise can only be performed using the ACLED sample. Finally, the fact that coefficients become smaller and insignificant could arguably be explained by the lower variation in the dependent variable of the UCDP GED sample when compared to the ACLED sample (Table 1).

C. Conflict by Type, ACLED Sample

Table 5 reports the results for different types of conflict using the ACLED sample. The dependent variable is a dummy variable equal to 1 if, at least, one type of conflict event is recorded in cell i in year t. The disaggregation of the main dependent variable into different types of conflict events allows for a more nuanced analysis and can provide insights to possibly explain the different results obtained in the ACLED and UCDP GED samples.

Four types of events are considered: Battles, Explosions/Remote Violence, Violence Against Civilians and Riots. Battles concern any "violent interaction between two politically organized armed groups" (ACLED 2019, 7), which includes armed clashes and territorial disputes. Explosions/Remote Violence involve "one-sided violent events in which the tool for engaging in conflict creates asymmetry by taking away the ability of the target to respond" (ACLED 2019, 9), which includes, among others, the use of chemical weapons, and air or drone strikes. Violence Against Civilians refers to "violent events where an organised armed group deliberately inflicts violence upon unarmed non-combatants" (ACLED 2019, 11), which includes harm attempts such as beating, shooting or raping, and forced disappearance acts such as kidnapping. Finally, Riots relate to "violent events where demonstrators or mobs engage in disruptive acts" (ACLED 2019, 13) like property destruction. The probability of occurring at least one conflict event in a given cell and a given year is approximately: 2.98 percent for

Battles, 2.8 percent for Violence Against Civilians, 1.36 percent for Riots and 0.464 percent for Explosions/Remote Violence (Table 1). Based on the total number of fatalities, Battles are the most lethal form of violence and Riots are the least lethal. (Appendix, Table 8). However, it is difficult to quantify the degree of lethality of each type of conflict based only on fatality data as the latter is typically biased. The ACLED is unable to verify the accuracy of this data, meaning it can only be considered as reported fatality (ACLED 2019). Regardless, based on the description of each event type, it is plausible that events like Battles would result in more deaths than events like Explosions/Remote Violence or Riots.

The proxy for the presence of artisanal gold mining is negative and significant at the 5 percent level for Battles. For Explosions/Remote Violence, Violence Against Civilians and Riots, the proxy is positive and significant at the 1 or 10 percent level (Table 5). The estimations using cell and year fixed effects and estimations using the spatial HAC correction yield similar results (Appendix, Tables 9-11). All effect sizes are of small magnitude, but these are largest for Violence Against Civilians and Battles.

Since the UCDP GED focuses on fatal events related to civil wars resulting in more than 25 deaths, it is plausible that such events would fall under the Battles category in the ACLED sample. This can help explain the different signs obtained in the ACLED and UCDP GED samples when considering all types of conflict events. As such, artisanal gold mining lowers the risk of larger and deadlier conflict events. On the contrary, artisanal gold mining increases the risk of intermittent or less-lethal conflict events such as Riots or Violence Against Civilians. This would be akin to the findings of Fourati, Girard and Laurent-Lucchetti (2022) suggesting that, by being a labour-intensive activity, artisanal mining creates incentives to safeguard labour so that illegal taxation is possible. Lethal forms of violence are more likely to result in a loss of the labour force to be extorted. As such, it becomes preferable to employ non-lethal violence.

Table 5 – Types of conflict and gold suitability, ACLED Sample (Cell and Country-Year Fixed Effects)

Estimator	Linear Probability Model			
Dependent variable	Conflict Incidence by Type of Conflict			
Sample	ACLED			
Variables	Battles	Explosions/ Remote Violence	Violence Against Civilians	Riots
	(1)	(2)	(3)	(4)
Gold suitability x Gold price	-0.0108**	0.00525***	0.0198***	0.00564*
	(0.00455)	(0.00198)	(0.00481)	(0.00289)
Constant	0.0851***	-0.0295*	0.0564***	0.0174***
	(0.0299)	(0.0163)	(0.0217)	(0.00604)
Controls	Yes	Yes	Yes	Yes
Cell FE	Yes	Yes	Yes	Yes
Year FE	No	No	No	No
Country-Year FE	Yes	Yes	Yes	Yes
Observations	194,935	194,935	194,935	194,935
R-squared	0.203	0.114	0.204	0.174

Notes: Dependent variable is a dummy variable equal to 1 if, at least, one type of conflict event occurs in a cell in a given year. The gold price is expressed per 1000 troy ounce. Robust standard errors (clustered at the cell level) in parentheses. *** p<0.01, ** p<0.05, * p<0.1

VI. Conclusion

Artisanal and small-scale gold mining (ASGM) is crucial for the livelihoods of millions of people and the gold extracted through this activity accounts for 20 percent of global supply (ASM Inventory 2023; IGF 2017). However, there is still a lack of understanding about the impacts of this activity, and it is hard to access reliable statistical data on the matter. As such, investigating and understanding ASGM can help policymakers develop relevant strategies to enhance its positive impacts and mitigate the negative ones.

We use georeferenced data at the 0.5×0.5 decimal degree level (corresponding to 55×55 kilometres at the Equator) to document the impact of artisanal and small-scale gold mining on conflict in 54 African countries for the period 1997-2018. To proxy artisanal gold mining, we use a novel data set constructed by Girard, Molina-Millán and Vic (2022) on gold suitable zones, i.e., areas that are most suitable to host gold. By exploiting exogenous variations in world prices, the results suggest that ASGM is associated with higher risk of conflict. This is consistent with mechanisms linking natural resources to conflict through channels such as financial feasibility, rent-seeking or grievances (Berman et al. 2017; Berman, Couttenier and Girard 2023; Lujala, Gleditsch and Gilmore 2005; Rigterink 2020). A disaggregation of conflict into different types suggests that ASGM increases the risk of intermittent or less-lethal events but lowers the risk of larger and deadlier events. The latter is consistent with mechanisms such as income diversification, which increases the opportunity cost of conflict (Banchirigah and Hilson 2010; Bazillier and Girard 2020; Maconachie and Hilson 2018). Plus, by being a labour-intensive activity, artisanal mining can create incentives to safeguard labour so that illegal taxation is possible (Fourati, Girard and Laurent-Lucchetti 2022). Since lethal forms of violence are more likely to result in a loss of the labour force to be extorted, it becomes preferable to employ less lethal types of violence.

These findings have policy implications that are potentially relevant. It is likely that artisanal mining increases conflict by relaxing the financial constraints of armed groups or rebels, either through taxation or the resell of minerals. Plus, artisanal mining is still a largely unregulated and unsupervised activity. Thus, the formalization of the artisanal sector through legal and regulatory mechanisms is of relevance. For instance, this can be done by establishing or supporting institutions and organizations responsible for overseeing the sector. In doing so, the feasibility incentives that increase the risk of conflict are potentially lowered. In addition, artisanal mining has been linked to undesired effects such as deforestation (Girard, Molina-Millán and Vic 2022). The formalization of the sector can pave the way to the promotion of practices that minimize the sector's environmental harm. Finally, such measures have the potential to improve access to data on artisanal mining regarding, for instance, data on more accurate location, number and characteristics of miners, namely in terms of gender or education, production levels, and so on. Short-term strategies can include raising awareness or educating artisanal miners on conflicts and its mechanisms so that miners' bargaining power increases and their vulnerability to exploitation decreases.

While the aforementioned findings provide valuable insights, it is important to address their limitations. Firstly, no specific mechanisms relating artisanal mining to higher/lower conflict incidence are tested. Rather, this study focuses on the sign and magnitude of this relationship. Moreover, the distinction between lethal and non-lethal conflict events is mainly based on qualitative data rather than quantitative data due to reporting bias. Provided there is data available, these limitations can be addressed in future research. Moreover, the latter can include expanding this study to different regions or countries as artisanal mining is also a prevalent activity in places such as Asia and South America (ASM Inventory 2023). In addition, it is possible that the differences found in terms of conflict type are applicable to other dimensions such as the types of actors involved in conflict events.

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VIII. Appendix

A. Lists

List 1 - Countries: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Democratic Republic of Congo, Cote D'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, São Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Swaziland, Tanzania, Togo, Tunisia, Uganda, Zambia and Zimbabwe.

List 2 - Commodity prices: Aluminium, Copper, Lead, Tin, Nickel, Zinc, Gold, Platinum, Silver, Iron, Coal, Phosphate. All prices refer to annual prices in real 2010 U.S. dollars. Diamonds are not considered as it was not possible to find a unique market price.

B. Figures

Figure 3 - Mean conflict in gold suitable and non-suitable cells – Comparison between ACLED and UCDP GED Samples, 1997-2018.

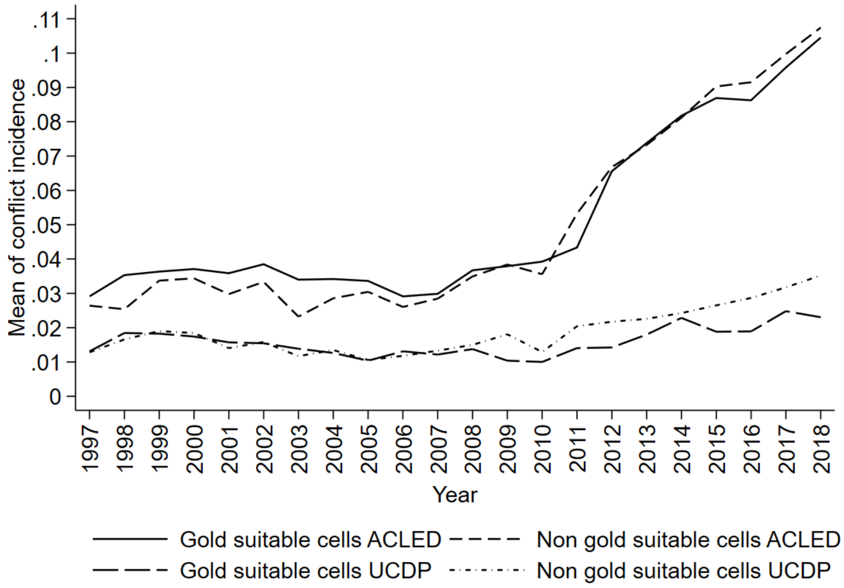
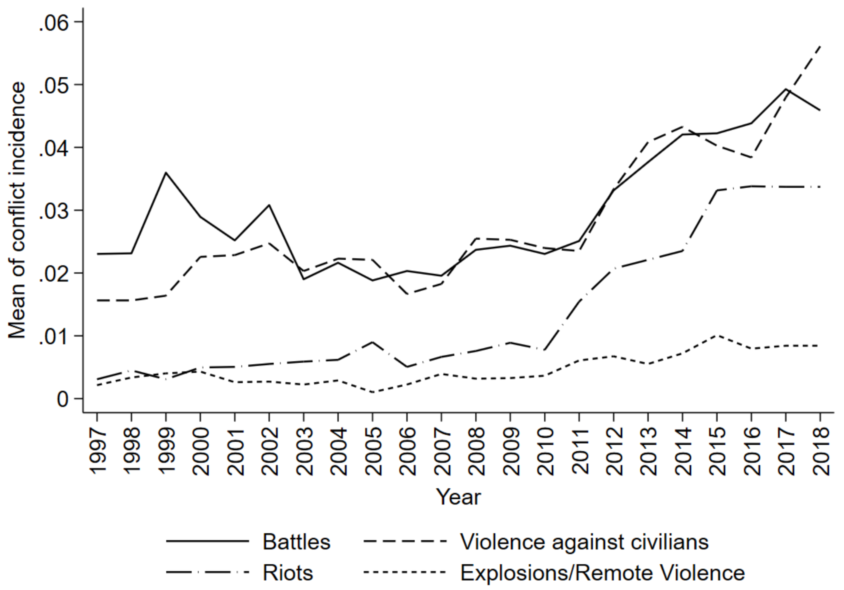


Figure 4 - Mean conflict by event type, ACLED Sample, 1997-2018.



C. Additional Results

Table 6 - Conflict and gold suitability, ACLED Sample using spatial HAC correction

Estimator	Linear Probability Model	
Dependent variable	Conflict Incidence	
Sample	ACLED	
Variables	(1)	(2)
Gold suitability x Gold price	0.0260*	0.0172
	(0.0136)	(0.0108)
Controls	Yes	Yes
Cell FE	Yes	Yes
Year FE	Yes	No
Country-Year FE	No	Yes
Observations	195,000	195,000

Notes: Dependent variable is a dummy variable equal to 1 if, at least, one conflict event occurs in a cell in a given year. Controls include: the SPEI, along with two lags; a dummy variable equal to 1 if there is, at least, one large mine in the cell; ethnic fractionalization at the country level; distance to the border of the nearest land and to the national capital city in kilometres; and interactions between commodity prices and the dummy variable for the presence of active large mines. The gold price is expressed per 1000 troy ounce. Conley (1999) and Hsiang, Meng, and Cane (2011) standard errors in parentheses: spatial correlation is assumed to vanish after 500 kilometres and temporal correlation among observations is assumed to vanish after 100000 years, i.e., infinite time horizon. *** p<0.01, ** p<0.05, * p<0.1

Table 7 - Conflict and gold suitability, UCDP GED Sample using spatial HAC correction

Estimator	Linear Probability Model	
Dependent variable	Conflict Incidence	
Sample	UCDP GED	
Variables	(1)	(2)
Gold suitability x Gold price	-0.00467	-0.00138
	(0.0109)	(0.00778)
Controls	Yes	Yes
Cell FE	Yes	Yes
Year FE	Yes	No
Country-Year FE	No	Yes
Observations	195,000	195,000

Notes: The gold price is expressed per 1000 troy ounce. Conley (1999) and Hsiang, Meng, and Cane (2011) standard errors in parentheses: spatial correlation is assumed to vanish after 500 kilometres and temporal correlation among observations is assumed to vanish after 100000 years, i.e., infinite time horizon. *** p<0.01, ** p<0.05, * p<0.1

Table 8 - Number of Reported Fatalities by Type of Conflict, 1997-1998, ACLED Sample

Sample	ACLED
	Total Number of Reported Fatalities
Battles	3 496 323
Explosions/Remote Violence	701 712
Violence Against Civilians	2 243 057
Riots	253 494

Table 9 – Types of conflict and gold suitability, ACLED Sample (Cell and Year Fixed Effects)

Estimator	Linear Probability Model			
Dependent variable	Conflict Incidence by Type of Conflict			
Sample	ACLED			
Variables	Battles	Explosions/ Remote Violence	Violence Against Civilians	Riots
	(1)	(2)	(3)	(4)
Gold suitability x Gold price	-0.0170***	0.000856	0.0261***	0.0139***
	(0.00458)	(0.00188)	(0.00486)	(0.00299)
Constant	0.152***	0.0115*	0.118***	-0.001***
	(0.0142)	(0.00669)	(0.0123)	(0.00306)
Controls	Yes	Yes	Yes	Yes
Cell FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Country-Year FE	No	No	No	No
Observations	195,000	195,000	195,000	195,000
R-squared	0.174	0.097	0.176	0.144

Notes: Dependent variable is a dummy variable equal to 1 if, at least, one type of conflict event occurs in a cell in a given year. The gold price is expressed per 1000 troy ounce. Robust standard errors (clustered at the cell level) in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 10 - Types of conflict and gold suitability, ACLED Sample using spatial HAC correction (Cell and Year Fixed Effects)

Estimator	Linear Probability Model			
Dependent variable	Conflict Incidence by Type of Conflict			
Sample	ACLED			
Variables	Battles	Explosions/ Remote Violence	Violence Against Civilians	Riots
	(1)	(2)	(3)	(4)
Gold suitability x Gold price	-0.0170***	0.000856	0.0261***	0.0139***
	(0.00658)	(0.00288)	(0.00737)	(0.00392)
Controls	Yes	Yes	Yes	Yes
Cell FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Country-Year FE	No	No	No	No
Observations	195,000	195,000	195,000	195,000

Notes: Dependent variable is a dummy variable equal to 1 if, at least, one type of conflict event occurs in a cell in a given year. The gold price is expressed per 1000 troy ounce. Conley (1999) and Hsiang, Meng, and Cane (2011) standard errors in parentheses: spatial correlation is assumed to vanish after 500 kilometres and temporal correlation among observations is assumed to vanish after 100000 years, i.e., infinite time horizon. *** p<0.01, ** p<0.05, * p<0.1

Table 11 - Types of conflict and gold suitability, ACLED Sample using spatial HAC correction (Cell and Country-Year Fixed Effects)

Estimator	Linear Probability Model			
Dependent variable	Conflict Incidence by Type of Conflict			
Sample	ACLED			
Variables	Battles	Explosions/ Remote Violence	Violence Against Civilians	Riots
	(1)	(2)	(3)	(4)
Gold suitability x Gold price	-0.0108**	0.00525*	0.0198***	0.00564*
	(0.00541)	(0.00309)	(0.00615)	(0.00297)
Controls	Yes	Yes	Yes	Yes
Cell FE	Yes	Yes	Yes	Yes
Year FE	No	No	No	No
Country-Year FE	Yes	Yes	Yes	Yes
Observations	195,000	195,000	195,000	195,000

Notes: Dependent variable is a dummy variable equal to 1 if, at least, one type of conflict event occurs in a cell in a given year. The gold price is expressed per 1000 troy ounce. Conley (1999) and Hsiang, Meng, and Cane (2011) standard errors in parentheses: spatial correlation is assumed to vanish after 500 kilometres and temporal correlation among observations is assumed to vanish after 100000 years, i.e., infinite time horizon. *** p<0.01, ** p<0.05, * p<0.1