Property rights under selective enforcement: How mining cadastres relate to conflict in low income countries

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Abstract

This paper investigates the impact of property rights on resource conflicts in ten sub-Saharan countries. Using original data and Difference-in-Difference estimates, the paper finds that property rights only reduce conflict if they limit direct political influence over mining activities. Since this is often not the case, the overall effect of mining cadastres under weak enforcement on conflict levels is limited. The results emphasize the importance of political conditions on the effectiveness of policies that address administrative capacity constrains in low income countries.

Introduction

Do property rights reduce resource conflicts in countries with weak enforcement? Resource extraction relates to multiple types of conflict, especially in low income countries. Climate change exacerbates this conflict potential, as the global demand for mining commodities is increasing and artisanal and small-scale mining (ASM) gains importance to

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the livelihoods of many [1]. For decades, donors and scholars have been advocating for property rights in low income countries and finance efforts to establish them. If properly enforced, mining licenses create investment incentives, lower transaction costs and reduce the thread of expropriation. But their strength depends on rulers and bureaucracies, which may prioritize political survival and personal access to rents over an efficient allocation of resources. Despite significant efforts to increase administrative capacities in the mining sector of low income countries, little is known how theses investments relate to political processes and local conflict.

This paper examines with a rigorous empirical approach the proposition that robust investment in property rights within the mining sector holds the potential to mitigate conflict over valuable resources by establishing clear ownership frameworks and fostering stakeholder cooperation. I argue, and show with original data, that this is only the case where formalization of mining activities unambiguously reduces the direct political influence. Since this is often not the case, sole property right reforms have little to no effect on local conflict levels under weak enforcement, but intricate the relationship between the mining sector and political processes.

Studying the effects of property rights empirically is a difficult task, especially in low income countries. For one, access to administrative data is often constrained. A second challenge are issues of endogeneity. The allocation of resources to formalize ownership over an asset class is typically based on factors like economic wealth, state capacity, historic roots or cultural norms. This makes it particularly challenging to understand how policies that aim to strengthen domestic property rights can reduce mining related conflict.

Using original data from administrative records in the Democratic Republic of the Congo (DRC) and its neighboring countries, this paper examines how mining licensees moderate the effect of resource extraction on conflict. To distinguish between administrative constrains for property rights and political motives to exclude certain types of mining from rights or enforcement, I leverage exogenous variation in the donor preference of aid payments, which enabled multiple countries to formalize their mining sector at low costs.

[1] ASM helps to subside or even replace agricultural incomes during droughts. Already today, the livelihoods of 130 to 270 million people depends on ASM (Girard et al. 2022)

To examine the extent of political independence conferred by a mining license, a comparison is made between minerals regulated by the Dodd-Frank Act section 1502 and other minerals post-2010. This unique quasi-experimental setting allows for an analysis of how different types of mining licenses moderate the impact of resource conflicts in ten low-income countries.

The primary argument put forth in this paper is that property rights within the mining industry only reduce local conflict levels if mining licenses effectively diminish direct political influence over a mine. Two main reasons may explain why this is not always the case. Firstly, there are administrative constraints that create gaps between actual mining activities, formal documentation, and the enforcement of rights. Secondly, and perhaps more significantly, powerful political actors deliberately maintain gaps between property rights and their enforcement in relation to mines. This mechanism resembles what Albertus (2021) refers to as "property right gaps" in land reforms. In other words, varying levels of political influence among mining stakeholders sustain the potential for conflict in resource extraction, even if administrative capacities improve the documentation of ownership.

My empirical analysis supports this argument. In general, the formalization of mining licenses leads to increased conflict levels in the corresponding areas. However, when examining the economic value of mining activities independently from their legal status, I observe different patterns. Specifically, while the overall impact of licenses on conflict is not significant, mining licenses that clearly reduce political influence over a mine tend to decrease local conflict levels.

Before presenting the analysis and its underlying data in detail, the following section elaborates in which way property rights can solve existing mining related conflicts and how such licenses are subject to political preferences. Next, I elaborate how the Dodd-Frank-Act and technical innovation allow to observe exogenous variation in administrative constrains and the political value of mining licenses. The final sections concludes in which cases the findings of this paper applies.

Theory: How property right gaps relate to mining conflict

The literature finds great potential in the establishment of strong and universal property rights. Scholars attribute them with lower risks of expropriation (Besley and Ghatak 2010), higher firm value (Berkowitz et al. 2015), more investment (Goldstein and Udry 2008) and long term economic growth (Acemoglu and Johnson 2005). Empirical evidence supports this perspective (e.g. Galiani and Schargrodsky (2010) and Ho (2021)), but is limited to countries with somewhat sufficient levels of state capacity and domestic initiatives to establish property rights.

The potential of property rights is particular promising in context of resource extraction, as this sector is not only economically crucial to many low income countries, but also relates to multiple types of conflict. Without exploring this mechanism in detail, early quantitative work conceptualizes mining conflicts between rebels groups and government actors (e.g. (Berman et al. 2017; Collier and Hoeffler 2004)). To observe exogenous variation in the economic value of mining activities, most studies in the mining conflict literature considers commodity prices as exogenous factors.

Conducting a meta-analysis of 46 natural experiments, Blair et al. (2021) find that price changes for lootable artisanal minerals provoke conflict, while commodity price changes, on average, do not change conflict risks. More recent work points out that mining conflict often emerge between civil actors and industrial mines. Christensen (2019/ed) finds that mining relates to conflict due to incomplete information – a common cause of conflict in industrial and international relations. This mechanism rationalizes why mining induces often protest, instead of full-fledged battles between belligerents. The study suggests that transparency dampens the relationship between prices and protest. Rigterink et al. (2023) provide evidence that competition between artisanal and industrial miners is also an important source of natural resources related conflict. They find the impact of price shocks on violent conflict is roughly three times as large in locations with industrial mining where artisanal mining is feasible as it is in places with industrial mining but no

potential for artisanal mining.

This raises the question which incentives political leaders have to withhold property rights in the mining sector, and maintain an inefficient allocation of resources, especially if foreign donors are willing to invest in administrative capacities to document mining licenses. Addressing a similar question in the context of land reforms, the term *property rights gaps* refers to the disparities or inequalities in the legal recognition and protection of property rights among different individuals or groups within a society. These gaps occur when certain individuals or groups enjoy secure and enforceable property rights, while others, often marginalized or disenfranchised populations, have limited or insecure rights to own, control, or transfer property. Scholars on land reforms find in property right gaps an import reason why land reforms often do not lead to the desired results (Albertus 2021). The literate provides two potential explanations for theses gaps. The first one is weak state capacity. Even if foreign donors provide technical solutions for mining cadastres, domestic bureaucracies still need to maintain these registries and enforce compliance. If administrative capacities are missing, property rights are simply not awarded (Joireman 2007; Toulmin 2009). A second type of gap emerges if political powerful actors deliberately tailor, award or enforce property rights in the interest of their own political survival. To maintain their political power, both democratic and authoritarian leaders have incentives to reward allies or exclude rivals (Hassan and Klaus 2023). In the context of resource extraction, propoerty rights can regulate market access, investment incentives or the probability of expropriation. Since property rights are irrevocable, leaders have an incentive to reward long term allies rather then short term supporters with legal recognition of mining activities. Finally, property right gaps can help political powerful mining companies to protect their assets against other stakeholders. Recent work highlights the importance of conflict dynamics between large scale miners (LSM) and ASM (Rigterink et al. 2023) or local population (Christensen 2019/ed).

To summarize, property rights gaps are state capacity- or deliberate created constrains, that exclude some actors via access to rights or their selective enforcement. This implies that property rights become a club- rather than a public good. This causes not

only welfare losses, but also political spillovers. Such spillovers can be new reasons for conflict or power sharing mechanisms to maintain rule.

While it is beyond the scope of this paper to distinguishing between every sub type of property gap, I consider the sum of such factors and analyse the way actually awarded mining licenses related to local conflict around mines. Exploring the underlying mechanisms, property gaps provide a plausible explanation why the actual effects of mining licenses under weak enforcement differ from the textbook idea of property rights.

Context: The Dodd-Frank Act section 1502 and its effects

The issue of murky property rights in the mining sector is a significant challenge in the DRC and its neighboring countries. While many large scale mines (LSM) operate since colonial rule and are arguably more established than their national governments, many mines operates as artisanal or small-scale miners (ASM) without legal documentation.

One instance of the social costs of theses weak property rights became evident during the second Congo War from 1998 to 2003, were military groups gained revenue by controlling ASM in the eastern Kivu region. These mines operate under devastating inhumane conditions and fiances armed conflicts, which coinded the term *conflict minerals*. While the conflict in the eastern DRC has multiple causes, the issue of conflict minerals gained much attention among stakeholder in high-income countries. Addressing these social issues, the Dodd-Frank Act of 2010, specifically Section 1502, (hereafter DFA) requires public companies in the U.S. to disclose their use of tin, tungsten, tantalum and gold (3TGs) in their products and determine if they are sourced in an ethical manner. These minerals are abundant in the DRC and are crucial elements in the supply chain of electronic devices. [2] Since small-scale mining remains a crucial income stream for millions of people in the DRC and neighboring countries, a full embargo on conflict minerals has never been implemented.

[2]Following the US initiatives, entities such as the OECD, the Chinese Chamber of Commerce, and the European Union passed similar regulation.

Instead, donors financed and supported efforts to formalize the mining sector in the affected countries and require due diligence reporting from private companies on the origin of the 3TG they use. To provide the necessary administrative capacities to document ownership, bilateral- and multilateral donors financed and supported the creation of mining cadastres. These cadastre systems document not only beneficial ownership of mines, but also provide the administrative back-end infrastructure to fulfill other bureaucratic tasks, such as tax collection or environmental regulations.

Compared to other African countries, countries affected by the DFA received significantly more aid payment to improve administrative capacities in the mining sector.

Appendix **??** elaborates in this policy shift and its exogenous character. As a result, seven out of ten countries affected by the DFA have today public available online repositories of their mining licenses. Evaluations the effects of these efforts, scholars draw a mixed picture. On one hand did the documentations of mining ownership increase significantly in recent year. Today, a significant share of 3T is certified as "conflict free" minerals [3]

Unfortunately, these efforts did reduce the conflict level in the DRC (Parker and Vadheim 2017), qualitative evidence suggest that licensing schemes of formal property rights introduced a new avenue of political influence over the supply chain of minerals (Johnson 2013) including mining certification fraud and cross border smuggling[4]. Transnational networks also play a crucial role in the second Congo War and sub sequential conflicts (König et al. 2017). This suggests that political alliance became increasingly useful, if one actor can provide legal documentation for the origin of T3 minerals. The price of T3 minerals without documentation of origin dropped up to 80 percent compared to world market (**carischCONFLICTGOLDCRIMINAL2012**).

[3]Gold as a substantial informal markets, which limits the effectiveness of due diligence reporting

[4]For instance, a recent report by the organization Global Witness documents how informal T3 from the DRC enters the mineral licensing scheme via smuggling routs to Rwanda

Measurement and Data: Mining activities and their legal status

This section outlines the methodology used to measure the effects of property rights on resource extraction in ten low income countries. To insulate the effect of property rights in the mining sector, two types of measures are needed: The location of relevant mining sides and the legal documentation of each side over time. To oberve the former, existing studies use proprietary data sets to identify the location of industrial mines (e.g.Berman et al. (2017) and Christensen (2019/ed)). While these measures capture economically important extraction sites, they ignore informal mines even if they contribute significantly to a countries production capacities. Addressing this constrain, recent studies combine remote sensing and geological data (e.g. Girard et al. (2022) and Rigterink et al. (2023) to identify areas that are suitable for extraction. These measure define areas suitable for ASM, but do not localize unique mining sides or consider factors such as market access or labor availability in their measurement of ASM. This paper introduces therefore both a new observational approach to observe formal and informal mines as well as mining licenses over time.

Actual mining activities

To identify formal and informal mining sites, I utilize the Minerals Yearbook, volume III, published by the National Minerals Information Center at the United States Geological Survey (USGS). This publication provides a comprehensive overview of mineral resources available in each country, including their geological and geographical characteristics, production and trade statistics, and information on exploration and development activities. Formal mining sites are located individually, while artisanal and small-scale mining (ASM) sites for specific commodities are aggregated on district (adm2) or province level (adm1). To disaggregate ASM further, I merge the Yearbook data with additional data sets for each country, which list the location of unique ASM mines. The references for these additional data sets are listed in Appendix 4. Compared to existing measures,

Table 1: Mining: Production side and licenses.

	Number
ø mine size (ha)	9
ø license size (ha)	2951
ASM sides	3947
LSM sides	275
Unique commodities	34
Prodcution licenses	4074
Exploration licenses	8412

this approach increases the sample size significantly and list a total of 4270 unique ASM and 258 unique LSM in the ten countries of interest. Figure 2(b) plots the locations of each mine.

Legal status of mines

To identify property rights for both ASM and LSM, I parse the mining cadastres of each country. While these portals are public, the underlying data is unstructured and does not allow for bulk download. To overcome this constrain, we[5] leverage the framework memorious to scrape each mining portal. Even though the first mining cadastres went online in 2008, each portal includes existing paper-based documentation of mining licenses. This approach provides all formally-mined licenses since independence for each country. Seven out of ten countries affected by the DFA publish their entire mining cadastres online. To consider potential selection issues, Appendix **??** discuses reasons why Angola, Burundi and the Central African Republic did not formalize their mining sector before 2022.

Comparing the actual mining sites to mining licenses, the licenses are on average more than 980 times larger. Table 1 lists descriptive statistics for production sites and mining licenses. Figure 1 lists the annually activated mines per country. Map 2(b) plots the locations of actual mining sites and the locations of mining licenses for all countries affected by the DFL.

[5]The data scraping of mining licensees is joint work with Alan Jones

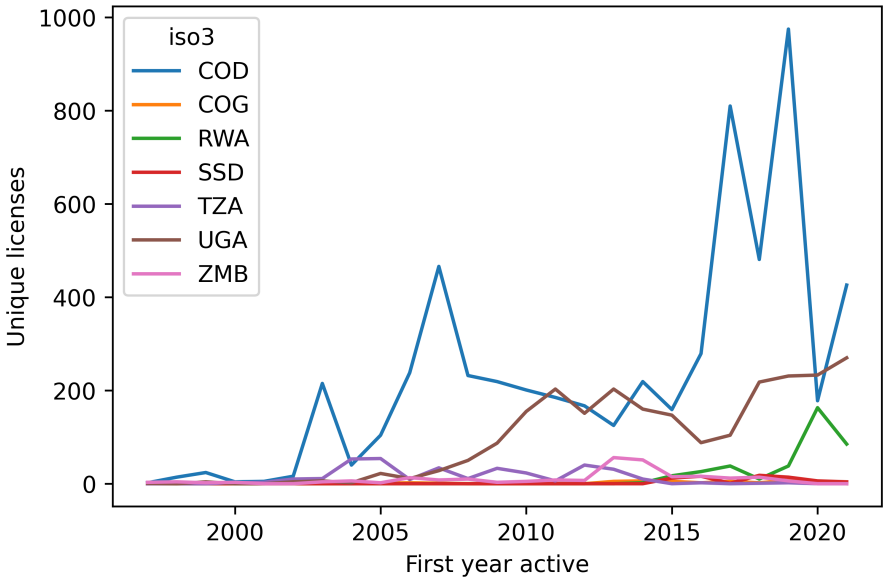
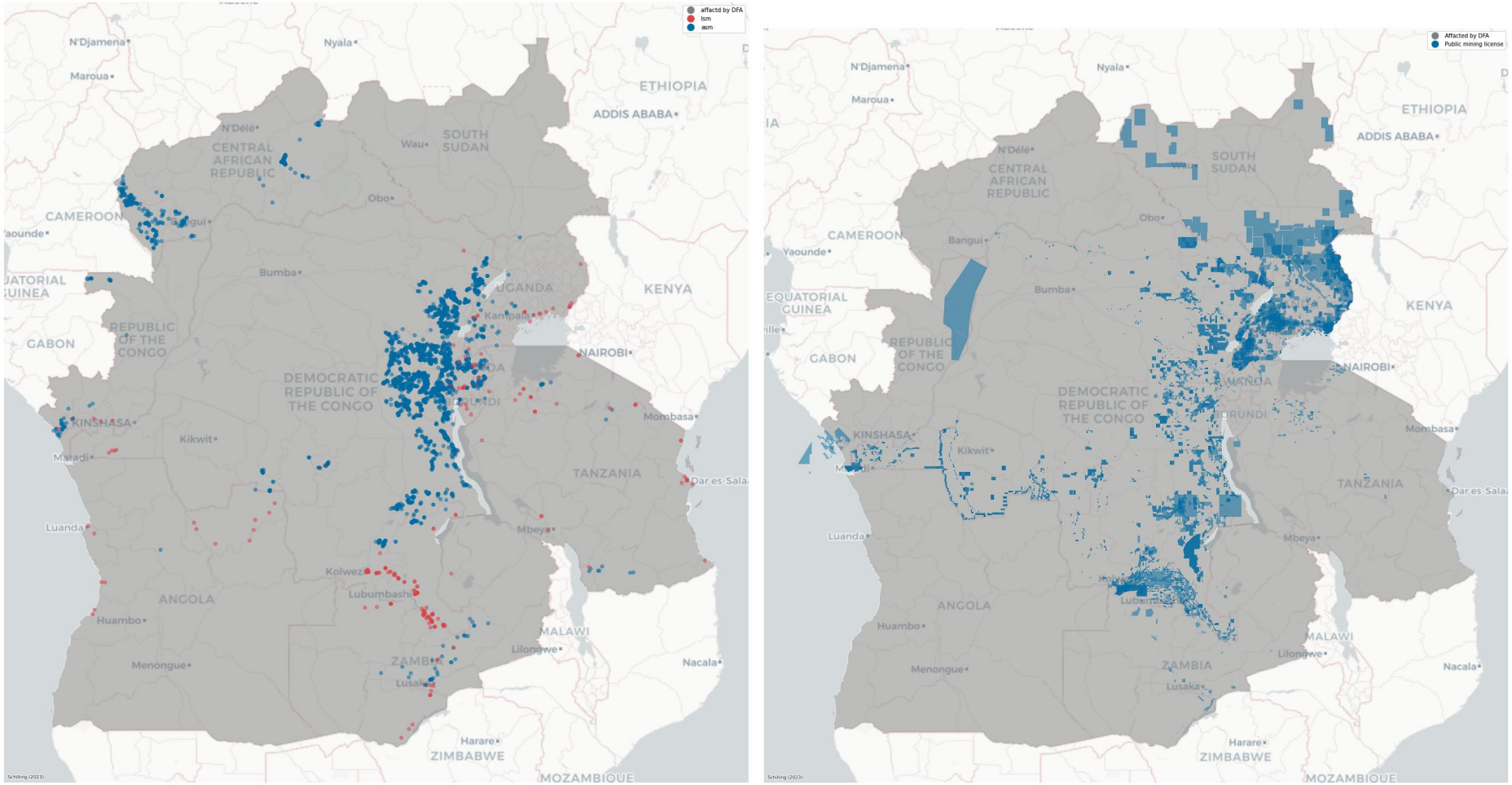


Figure 1: Newly established mining licenses per country 1997- 2021



(a) ASM (blue) and LSM (red) mining sides

(b) Mining license locations

Figure 2: Location of artisanal or small-scale mining (ASM) and large-scale mining (LSM) sides as well as mining licenses. The dark grey areas marks the territory of countries that are affected by the Dodd-Frank Act (DFA) section 1502 after 2010. Angola and the Central African Republic do not have and online available mining register. Burundi publish only a static repository of mining licenses in 2014.

Identification

To understand how public documented mining licenses moderate local conflict levels, I first draw on a Difference in Difference (DID) identification approach with staggered treatment across units, as each mining license get active at different points in time. To address potential contamination of coefficients on leads and lags of the treatment, I draw on an estimator proposed by Sun and Abraham (2021).

While changing aid patterns after the DFA in 2010 remove endogenously the budget or administrative constrains of mining licenses, political actor are still able to model the design of property right policies and thus selected treated individuals. In the first identification approach, the treatment includes both the effect of property right as well as the economic value and access to rent potential that mines provide regardless of their legal status.

To disagreed the legal status and economic value of a each mine, I extend this specification with an well established measure of economic value of mining actities. This approach leverages variation in world market prices for commodities to observe exogenous variation of the economic value of a mine and is often used in the mineral conflict literature. To validate the assumption that prices are indeed exogenous to the countries of interest, Appendix B examines the market power each commodity holds. To estimate commodity prices as accurate as possible, I consider the modal price ration between value and weight of trade flows in the the BACI trade statistics dataset (Gaulier and Zignago 2010). Compared to existing measures, this time series spans a larger time period. To validate this price measures, Appendix 5 compares this measure to prices spot market data from Bloomberg.

While existing research estimates the economic values for each grid cell based on the modal extracted commodity, I consider the sum of T3, cobalt and copper (2C), gold and diamond production for each cell. This approach allows for a more granular compassion of cell and a distinction between the political value of property rights over each type of resource, i.e. I compare T3 licenses to other types of mining licenses. Furthermore this measure is more suitable to account for geological clustering, as many commodities

are extracted at the same mine[6]. Additionally, I distinguish between ASM and LSM as described in the measurement section . In sum, I derive four treatment variables for economic value: T3 under ASM, T3 LSM, other minerals ASM and other minerals LSM. Each of theses measures is estimate with equation:

$$ECON_{itm} = \sum_{c=1}^{C} M_c \times ln(Pct) \tag{1}$$

Where M_c represent a dummy for an ASM or LSM site that extracts the commodity c. $ln(Pct)$ captures the log or world market price for c in year t. To distinguish between T3 and other minerals to summarize the economic value for T3, where $c \in \{tin, tungsten, tantalum\}$ and other minerals.

Based on this measure of economic mining value per cell, I now examine how public documented property rights moderate the effects of mining activities on local conflict levels. Here, I interact each of the economic value types with a dummy whether the territory of the mine lays within an active mining prodcution license. As start and end date of each mining differ, the treatment becomes heterogeneous. Equation 2 expresses this relation:

$$y_{it} = \alpha_i + \beta_1 Prod_{it} + \beta_2 Prod_{it} \times ECON_{itm} + \beta_3 ECON_{itm} + \gamma_t + \epsilon_{it} \tag{2}$$

Where $Prod_{it}$ presents a dummy for any active mining license at cell i in year t. To account for spatial auto correlation, I cluster the standard errors for both regression using Conley (1999) and controll for cell FE α_i and year FE γ_t.

To compare the institutional conditions mines operate in, I use ACLED as measure of local conflict. This measure documents on very granular measure investment incentives and the thread of expropriation. This includes not only rebel attacks and looting, but also state actors. The unit of analysis are for both regressions $5km^2$, the obvervation period is 1997- 2018 (curently last year for known commodity prices).

[6]Tungsten, tin and tantalum as well as cobalt and copper are often extracted in the same mine

Results

This section presents two sets of results. First I compare based on the event study approach how newly established mining production licenses affect the local conflict level. Table 2 lists the unconditional probabilities for all treatment variables.

	labels	values
1	active license	0.0043
2	T3 ASM	0.0144
3	T3 LSM	0.0003
4	other mining ASM	0.0124
5	other mining LSM	0.0014

Table 2: Unconditional probability of treatment variables

To derive a deeper understanding of the mechanism between due diligence reporting and local conflict, table 3 presents the results of regression 2 examining the effect of different mining activities with or without formal ownership on the likelihood of conflict between 1997 and 2020. The dependent variable is again the probability of at least on conflict, for each production and commodity type a separate specification. Model 1 and 3 indicates hat both ASM and LSM mines that extract T3 experience a weaker relation between commodity prices and conflict. However, theses effects balance out the increasing conflict of effect of active licenses only marginal.

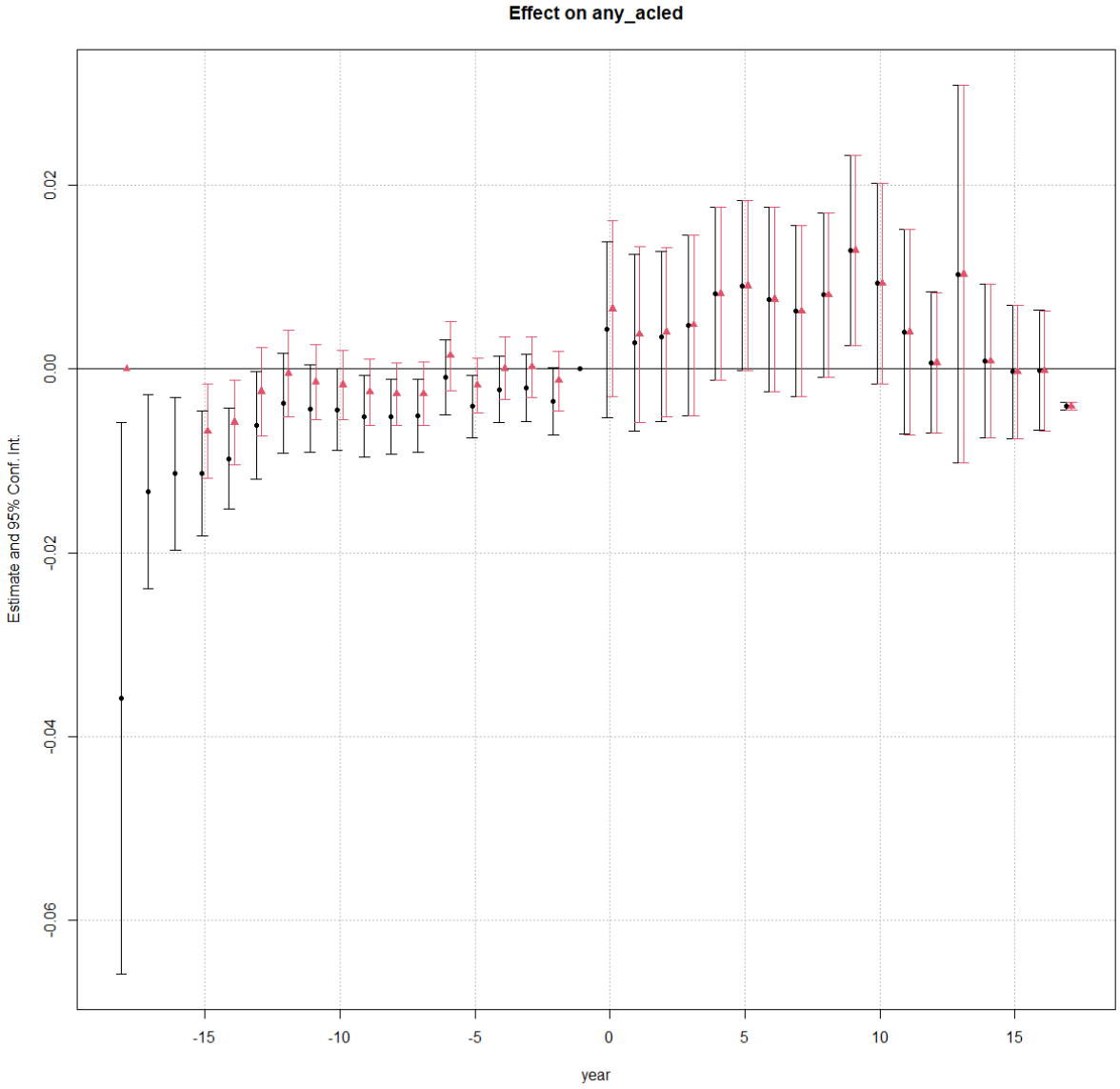


Figure 3: Effects of mining production licenses on the probability of conflict events per grid cell 2000-2020 in the DRC. The black line takes the first year and the year before the treatment the reference period. The red lines shows the same estimation with the first tree periods before the treatment

Table 3: Effect of different mining actities on likelihood for conflict with or without Production license 1997-2020

Dependent Variable:	P(any ACLED event)			
Model:	(1)	(2)	(3)	(4)
Variables				
T3 ASM	0.0141***			
	(0.0031)			
active License	0.0011**	0.0010**	0.0009**	0.0009**
	(0.0005)	(0.0004)	(0.0004)	(0.0005)
T3 ASM w. active license	-0.0013**			
	(0.0006)			
T3 LSM		0.0329***		
		(0.0089)		
T3 LSM w. active license		-0.0045**		
		(0.0019)		
other ASM			0.0080***	
			(0.0019)	
other ASM w. active license			-3.94×10^{-5}	
			(0.0010)	
other LSM				0.0033
				(0.0046)
other LSM w. active license				0.0003
				(0.0009)
Fixed-effects				
Cell level (333,719)	Yes	Yes	Yes	Yes
Year (24)	Yes	Yes	Yes	Yes
Fit statistics				
R^2	0.22276	0.22271	0.22274	0.22270
Adjusted R^2	0.18896	0.18891	0.18894	0.18891
Observations	8,009,256	8,009,256	8,009,256	8,009,256

Conley (9.2km) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Conclusion

One import constrain to the socio economic utility of property right are property right gaps, i.e. cases where governments withhold access to formal ownership over assets due to state capacity constrains or political motives. This research note advances the literature on property right gaps, by examining their role in the context of resource extraction. I argue that property right gaps constrain efforts to formalize the mining sector of low income countries and efforts to reduce the conflict potential of resource extraction.

Empirically, I construct two novel data sets of mining activities as well as their legal status using original data from ten sub-Saharan countries. Using a difference in difference design, I show that formal mining licenses only reduce local conflict levels, if a license clearly increases the independence of mining activities from political actors. This implies that sole mining licenses have generally little effect on conflict levels under weak enforcement, since they do not necessary reduce political influence or even create new dependencies on political actors. I also demonstrate that number and types of unique mining activities are more larger and more heterogeneous that prior studies assume.

Offering new data and empirical results, this paper opens avenues for future research for a broad set of cases where property rights intersect with a weak rule of law. These scope conditions of theses findings apply to a wide range how countries with economically valuable resources but low levels of domestic state capacity. The effects of climate change are likely to increase the subset of cases where this setting applies, as property rights are crucial to regulate access to excludable and sparse resource. This applies not only the extraction of minerals or access to land, but also resources like water or rights to CO_2 emissions. An important exemption of these scope conditions are cases where governments hold enough state capacity to create state monopolies, such as copper production in Chile. The findings of this research note demonstrate that foreign policies and aid can support efforts to strength administrative capacities to document property rights in low income countries, but can't bypass the domestic characteristics of the political landscape or the long term effects of colonial rule.

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Table 4: Refrences for ASM locations sides and licenses

iso3	asm	lsm	License source	Authority	ASM source
AGO	1	14	no online portal	Ministry of Mineral Resources, Oil and Gas	open street maps
BDI	58	20	url	Burundi Ministry of Energy and Mines	World Bank rport
CAF	540	0	no online portal	Ministre des Mines et de la Gologie	IPIS
COD	3376	86	url	DRC Cadastre Minier (CAMI)	IPIS
COG	44	5	url	Ministry of Hydrocarbons, Republic of Congo	open street maps
RWA	137	14	url	Government of Rwanda; Rwanda Mines, Petroleum and Gas Board (RMB)	ICGLR Database
SSD	1	0	url	South Sudan Ministry of Petroleum and Mining	open street maps
TZA	18	31	url	Ministry of Energy & Minerals	IPIS
UGA	61	18	url	Directorate of Geological Survey and Mines	UN environment report
ZMB	34	70	url	Zambia Ministry of Mines and Mineral Development	open street maps

A Mining Licenses and production side references

B Marketpower over global commodity

To ensure that commodity prices are exogenous to the actors in the sample, I examine in this section the market power of the DRC for the global cobalt production. If a single country dominates the global supply of a particular commodity, actors in the economy could set the market prices causing of endogenity. Across the minerals and countries in the sample, the market share of the DRC is by far the largest market share, making it the most likely case of a producer being a price setter in context of this study.

According to the USGS, the country accounts for roughly 70 % of the global market share. Cobalt is crucial for the global supply chain of lithium-iron batteries which face significant demand increase in recent years. In 2018 the government established the national agencia Enterprise Générale du Cobalt (EGC) the formal monolply to purchase and export cobalt.

However, despite this formal market dominance, the actual market power of DRC remains the defactovery limited. The major share of the fifteen production sides that extraction cobalt in the DRC are owned by Glencore, a multinational cooperation, approximately 30 % of the cobalt is extracted aritsanel. Yet, the no fully independent, economically relevant ASM sides are known . Instead the formal licenses of cobalt ASM are established in close proximity to LSM mining sides. The majority of domestic shareholder in cobalt industry are close to the ex president Kabliba (Deberdt 2021). Despite increasing demand, the global market prices did not increase substainly in recent years. In 2022 Glencore aggreed to pay $180mn to the DRC due to alleged corruption acts in the past ("Glencore to Pay DR Congo $180mn to Cover Corruption Claims" 2022).

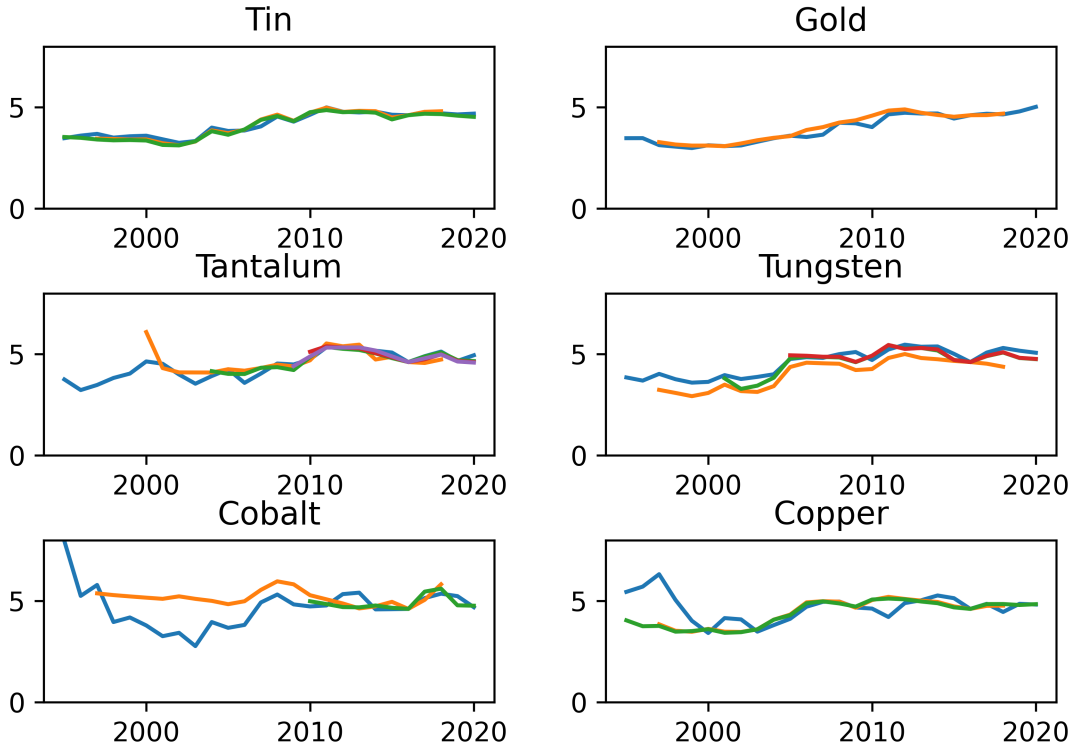

Figure 4: Commodity prices (ln, baseyear 2016) over time, comparing prices from Bloomberg (green, red and purple), BACI (blue), and metalary.com (orange). The Bloomberg data consists of the following prices indices: China Tantalum Concentrate Ta 205 30 % CIF, China Tantalum Metal 99.95 % FOB, China Tantalum Metal 99.95% Delivered US, Europe Tungsten APT 88.5 % In warehouse Rotterdam, China Tungsten APT 88.5 % FOB, LME TIN 3MO ($) UNF Comdty, LME COBALT SPOT ($) Comdty, LME COPPER SPOT ($) Comdty. The BACI prices index is the modular ration between quantity and value of all trade-flows per commodity type with at least one trade partner being affected by the DFA per year. Both BACI and metalary.com prices are deflated by prices real to 2016 and normalize by the natural log. This paper uses the BACI commodity prices for the analysis.

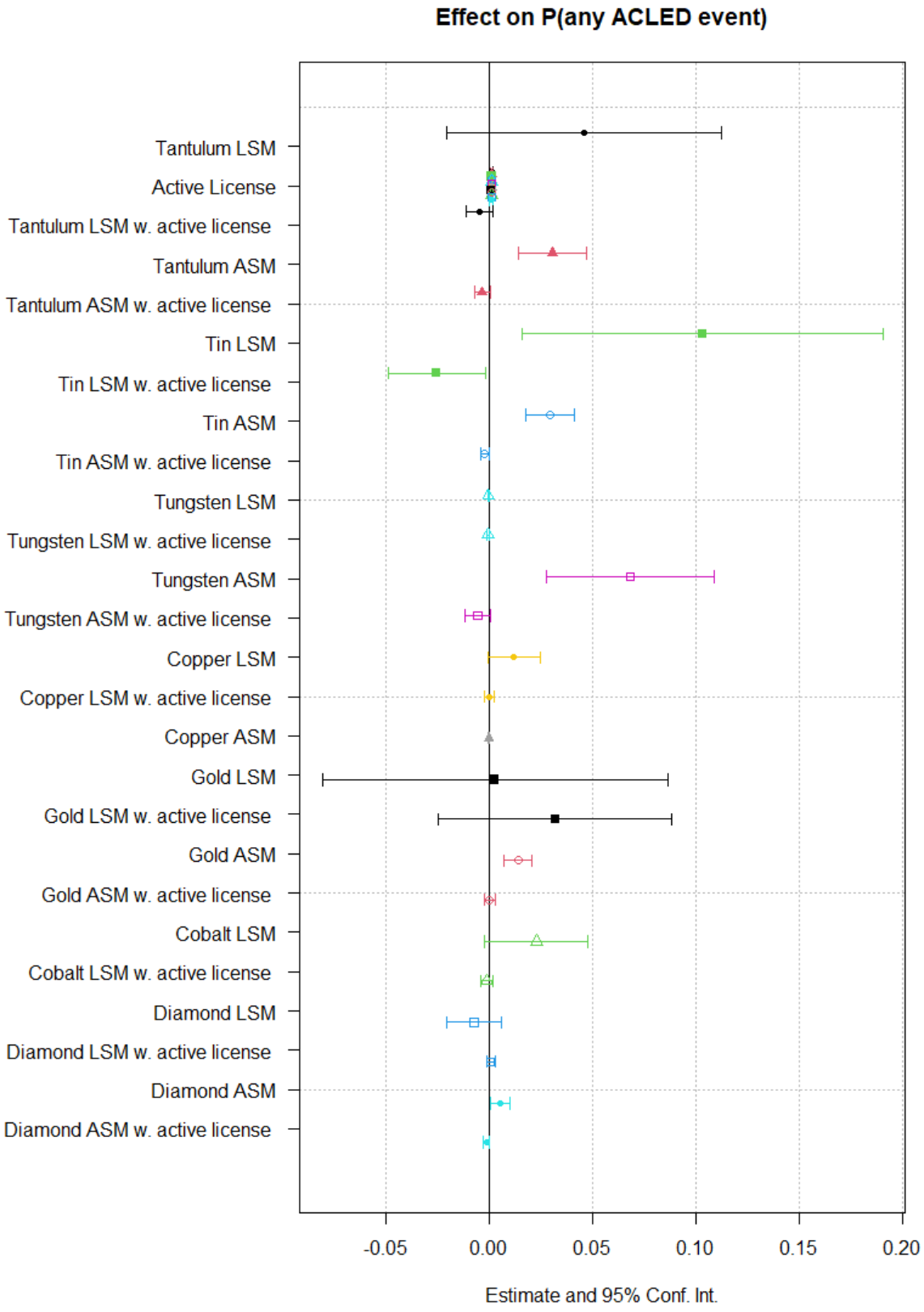

Figure 5: Effects of mining licenses per commodity type