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Land Conflicts in the Wake of Gold Mining Expansion in Colombia*

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Abstract

This paper provides quantitative evidence on the relationship between gold mining expansion and violent conflict in Colombia. Utilizing a two-stage least squares (2SLS) regression model, the study examines the effects of gold mining on violence using three different measures of gold mining activity across two distinct periods: the Gold Rush (2004-2014) and the post-Gold Rush (2014-2022). The exogeneity of international gold prices and geochemical anomalies is exploited to identify causal effects. During the Gold Rush period, strong effects of gold mining on violence are observed using machine learning and gold mining deforestation measures. In the post-Gold Rush period, mixed results were found, with significant effects primarily observed using the deforestation measure. The presence of armed groups and ethnic mining communities exacerbates the effects of gold mining on violence. However, using two different measures for institutions, such as judicial inefficiency and electoral risk, no significant influence on the impact of gold mining on violence was found. The findings highlight the role of armed groups and the targeting of ethnic communities in the expansion of gold mining areas, underscoring the need for policy interventions to address land disputes and the involvement of armed groups in the mining sector. The robustness of the results is confirmed through various measures of the dependent variables and different clustering methods for standard errors.

Key words: *Natural resources, gold mining, Colombia, conflict, violence.*

JEL Classification: D74, L72, Q34, O13.

1 Introduction

Numerous studies in economics have explored the relationship between natural resources and conflict, particularly focusing on how resource abundance and dependency can lead to income shocks in resource-rich regions. The available literature is diverse, and although there is consensus that these income shocks, often influenced by fluctuations in global commodity prices, may correlate with conflict, the specific channels and direction of causation remain ambiguous. This complexity emerges from the bidirectional relationship between mineral wealth or land fertility and conflict. While these resources can be catalysts for conflict, the presence of existing conflicts may, in turn, shape the methods and values associated with the extraction, trade, or valuation of those resources. To address this identification issue, most studies have employed instrumental variable approaches, using variables such as commodity prices, weather variations, trade patterns, or geological characteristics, which correlate with income shocks but not directly with conflict itself (Miguel et al., 2004; Brückner and Ciccone, 2010; Dube and Vargas, 2013; Bazzi and Blattman, 2014; Nunn and Qian, 2014).

These strategies help isolate the causal effect of income shocks on conflict, enabling researchers to draw more robust conclusions about the underlying mechanisms linking resource abundance to conflict dynamics. Commodity export prices are perhaps the most common instrument used in this literature, and for good reason: they are more volatile than manufactured goods exchanged in the global market and are not influenced by the decisions of an individual country. Moreover, in developing countries where commodity exports constitute a significant portion of GDP, and where internal conflicts prevail, external commodity prices become a relevant source of income shocks.

From a theoretical standpoint, the relationship between international commodity prices and conflict has been examined through three main lenses: the opportunity cost effect of fighting, the concept of the state as a prize, and the strength of democratic institutions (Giménez-Gómez and Zergawu, 2018). The opportunity cost perspective posits that higher wages may reduce conflict by lessening the labor supply available for armed groups since wages represent the opportunity cost of rebellion (Fearon and Laitin, 2003). The rapacity effect implies that a rise in government revenue from private sources such as rents can intensify conflict by making the gains from seizing control more attractive (Brückner and Ciccone, 2010; Dube and Vargas, 2013). Notably, Dube and Vargas (2013) integrate both of these aspects in an empirical analysis specific to Colombia. Finally, the third perspective contends that increased revenues could enhance the state's ability to defend itself, counteract insurgents,

or strengthen institutional capacity (Bazzi and Blattman, 2014; Brückner et al., 2012).

This study investigates the impact of the territorial expansion of mechanized gold mining activities in Colombia on community violence. It focuses on whether this expansion leads to land disputes, contributing to forced displacements, threats, homicides of social leaders, and terrorist attacks. The hypothesis is that, to expand gold mining territories, legal and illegal miners may encroach on lands occupied by communities that might oppose these activities. In many rural areas, these communities depend on extracting gold themselves or are concerned about the environmental consequences of mechanized mining, which threaten their livelihoods. In territories with prevalent armed conflict, miners, in alliance with armed groups, may use violence to expel people from these lands, increasing threats and killing representative figures (social leaders) within these communities.

This study uses a panel dataset that includes annual data from all municipalities in Colombia from 2004 to 2022. The analysis focuses on two distinct subperiods: the Gold Rush (2004-2014) and the Post-Gold Rush (2014-2022). During the Gold Rush, there was a significant increase in international gold prices and a high demand for gold mining titles. In contrast, the Post-Gold Rush period is characterized by a ceasefire with the largest guerrilla group (Revolutionary Armed Forces of Colombia–People’s Army - FARC-EP) and stabilization in both the price and demand for gold mining titles. Three different measures of gold mining activity are employed: machine learning estimations for 2004-2014, which predict mining activities based on satellite imagery (Romero and Saavedra, 2021); UNODC gold mining data for 2014-2022, derived from remote sensing of alluvial gold exploitation (UNODC, 2016); and gold mining deforestation for 2004-2021, which combines deforestation data with geospatial information on evidence of alluvial gold mining and mining titles and applications.

Following this data collection and characterization, the research employs a two-stage least squares (2SLS) regression model to address potential endogeneity in the relationship between gold mining and multiple violence indicators. The model leverages variation in international gold prices, interacted with the presence of geochemical anomalies indicative of gold deposits, as an instrumental variable to analyze the impact of gold mining expansion activities on various targeted violence indicators such as forced displacement, threats, and killings of social leaders. Additionally, the analysis examines the effects on homicide rates and rates of victims of terrorist attacks, such as bombings and clashes. The study also considers the differential impact on municipalities with the presence of armed groups.

This research presents a notable contribution to the literature on conflict and resource abun-

dance, particularly in the Colombian context. Compared to [Idrobo et al. \(2014\)](#), this study differs in several key aspects. Firstly, while [Idrobo et al. \(2014\)](#) measure illegal gold mining at a fixed point in time, this study employs three different methods to measure gold mining areas over time: machine learning estimations, UNODC gold mining data, and gold mining deforestation. Secondly, while [Idrobo et al. \(2014\)](#) find no significant effects on displacements, arguing that illegal mining is a labor-intensive activity, this study suggests that illegal mining, like legal mining, is a capital-intensive activity. Violence emerges from territorial disputes between mechanized miners (legal or illegal) and local communities. The results regarding terrorist attacks, which include victims of clashes, indicate that disputes can also emerge between different illegal armed groups involved in mining activities. Finally, this study specifically investigates targeted violence, including the killings of social leaders, which has not been analyzed in previous studies about mining in Colombia.

Additionally, this research offers a distinct perspective compared to [Dube and Vargas \(2013\)](#), which explore the rapacity effect in the context of oil, gold, and coal, demonstrating that increased contestable income from these resources can heighten violence through gains from appropriation. While [Dube and Vargas \(2013\)](#) provide a broad understanding of the relationship between natural resource prices and conflict in Colombia, this study focuses specifically on gold and the territorial expansion of capital-intensive mining driven by rising international gold prices. This expansion into new territories leads to increased violence against traditional miners and local communities who rely on the land for their livelihoods. By examining the territorial nature of mining expansion, this research contributes a detailed view of how rising gold prices provoke violence, addressing the complexities of land use and community displacement beyond mere revenue appropriation.

The paper is structured as follows: Section 2 provides the context, detailing the recent trajectory of the gold mining sector and its role in the Colombian armed conflict. Section 3 discusses the data on violence and gold mining, including information sources, and the data processing techniques used to prepare the variables necessary for the empirical strategy, which is outlined in Section 4. The results are presented in Section 5, and conclusions are drawn in Section 6.

2 Context

2.1 Gold mining in Colombia

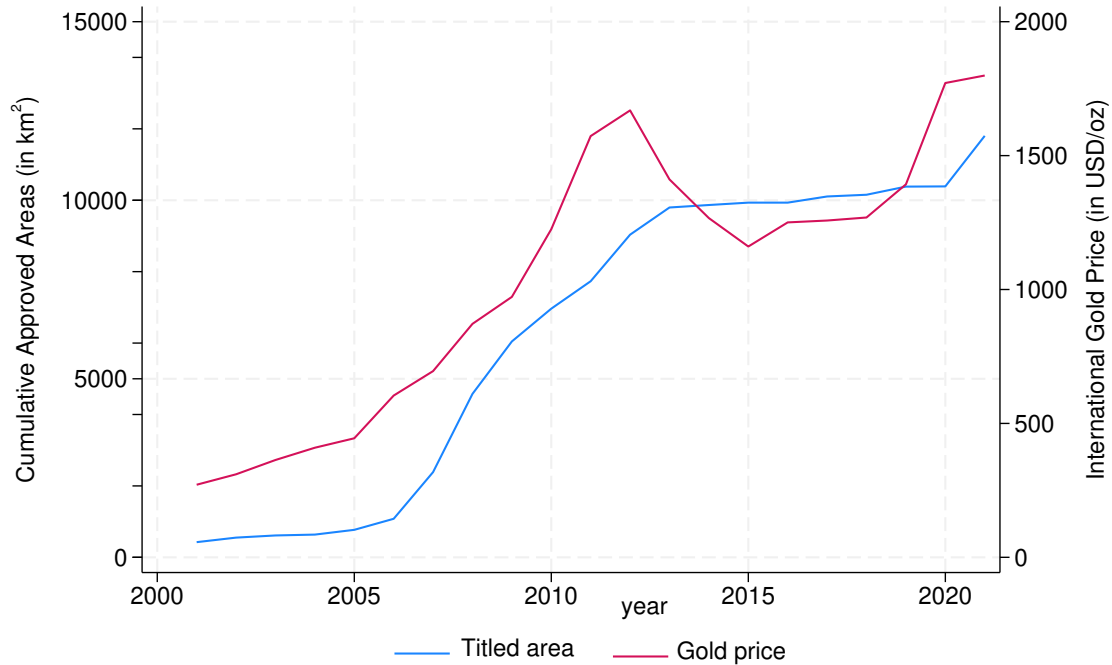
The legal framework for mining in Colombia is governed by the Mining Code (Law 685), established in 2001 with the goal of facilitating the granting of exploitation leases to attract foreign direct investment (FDI) into the sector (Echavarria, 2014). This reform marked a significant shift for the national government from acting as a mining entrepreneur to serving as a regulator and promoter of sectoral policies. The simplification of legal processes is characterized by three main aspects. First, the entire mining process—including exploration, construction, extraction, processing, and closure—was consolidated under the *mining concession title* as the sole legal figure. Second, distinctions between different scales of mining were abolished, and the application process for mining titles was standardized, making it uniform across all applicants regardless of their capacity or size. Finally, the reform streamlined administrative procedures by merging various mining agencies and reducing the number of officials involved in the sector’s administration (Echavarria, 2014; Ortiz-Riomalo and Rettberg, 2018).

According to the Colombian constitution, subsoil resources, including minerals, are owned by the central government, which is responsible for issuing mining concession titles based on environmental approvals and setting royalty taxes for mineral extraction. Mining titles holders are required to pay an annual fee equivalent to the daily minimum wage per hectare. Additionally, they must pay royalties calculated based on the gross value and type of minerals extracted (Saavedra and Romero, 2021).

Along with the implementation of the Mining Code, legislative and tax policies, including a series of tax exemptions, were enacted between 2004 and 2007 to enhance the attractiveness of Colombia’s mining sector to foreign investors (Ortiz-Riomalo and Rettberg, 2018; Betancur, 2019). Simultaneously, since the early 2000s, the international gold price began a significant ascent, culminating in historic highs after the 2008 financial crisis. The price of gold rose from \$350 per ounce in 2001 to around \$1500 per ounce by 2012. This scenario, driven by both regulatory reforms and escalating gold prices, spurred a wave of investments in the sector and a high demand for mining concessions as illustrated in Figure 1. The most notable increase in the cumulative concessioned area occurred between 2004 and 2014, a period now referred to as the *Colombian Gold Rush* (Bonilla Mejía, 2020). During this time, the area formally designated for gold exploitation expanded from less than 500 square kilometers in 2004 to nearly 10,000 square kilometers by 2014. However, this burgeoning

demand led to a speculative environment, marked by a scarcity of free areas, venture capital investors negotiating licenses, and the frequent abandonment of concession areas during the exploration stage. Many investors, in turn, adopted a strategy to hold their titles with the aim of selling at higher prices in the future (Echavarría and González, 2016).

Figure 1: Cumulative legally granted areas for gold mining and international gold price (2001-2021)



Author' calculations based on data from the National Agency of Mining. Cumulative titled area is expressed in km^2 . Gold prices are expressed in US dollars per Troy Once.

In 2003, aligned with the goal of promoting mining activities and taking a resolute stance against guerrilla insurgency, the Colombian government launched a security approach focused on military presence, known as the “territorial consolidation process.” Led by President Uribe (2002-2010), this initiative aimed to fortify the presence of the Armed Forces and National Police in selected regions, thus fostering an environment conducive to investments in natural resource extraction and agribusiness. While his successor, the Santos’ administration, adopted a different security approach by advocating for a peace agreement with the FARC-EP (the largest guerrilla group) in 2016, the focus on the mining sector remained central to policy. Through offering incentives and upgrading infrastructure to back the sector, the government continued to encourage growth within the energy-mining industry (McNeish, 2016).

Given the low entry barriers to gold mining, miners in Colombia can choose between labor-intensive or capital-intensive extraction methods (Snyder, 2006). Labor-intensive activities are undertaken by artisanal miners, also known as traditional, barequeros, or small-scale miners. These miners work individually or in small groups using traditional alluvial mining techniques, including panning and sluicing with handheld tools. Their gold extraction, primarily for subsistence, is limited by law to a small annual amount. These subsistence activities are often rooted in communities that have practiced agro-mining livelihoods for generations. While they do not need a mining title to operate, they must be registered to sell the gold they collect to gold trading houses (Veiga and Marshall, 2019; Vélez-Torres, 2014; Vélez-Torres and Agergaard, 2014). Artisanal and small-scale gold mining in Colombia is heavily reliant on mercury for the extraction process. The use of mercury involves amalgamation, where the amalgam consists of 40-50% mercury and 50-60% gold. This process results in significant mercury contamination during direct manipulation, amalgam burning, and environmental spills. In Colombia, the average annual mercury loss from artisanal and small-scale mining is estimated at 175 tons, making the country the third-largest global emitter of mercury. The environmental and health impacts of this contamination are profound, affecting aquatic and terrestrial ecosystems and posing severe risks to human health (Vélez-Torres and Méndez, 2022).

Legal miners use capital-intensive techniques for gold extraction, possess the required environmental licenses and mining titles, and pay royalties and taxes as mentioned before. In contrast, capital-intensive activities without a mining title are conducted by miners often labeled as illegal or illicit, employing heavy machinery such as excavators and dredgers (UNODC, 2022). These illegal miners do not pay royalties or taxes, and their extraction techniques can result in substantial environmental degradation. The mining census conducted by the Ministry of Mines and Energy between 2010 and 2011 found that 63% of the surveyed mining units were operating without a title (Echavarría, 2014). This situation appears to have remained relatively unchanged. Data from 2021, sourced from UNODC (2022) using satellite imagery and remote sensing tools, revealed that 65% (63,984 ha) of the EVOA were located in non-titled exploitation areas. Additionally, half of the EVOA on land were situated in Excluded Mining Areas.

The significant degree of informality prevalent in the mining sector can be traced back to the 2001 Mining Code, which inadvertently created an asymmetrical environment for awarding mining concessions. This code failed to account for the varied scales of mining operations, thereby disadvantaging artisanal miners in securing their right to exploit gold (Vélez-Torres,

2014; Echavarría, 2014). Although the Mining Code established the legal figure of Special Reserve Areas (ARE, for its Spanish acronym), which allows traditional mining communities to maintain their operations if they can demonstrate a history of artisanal activities within designated territories, these regions often have restricted access. A significant portion of these lands is held under exploration concessions by mining companies, and a multitude of applications from artisanal and illegal miners are still pending (Echavarría, 2014; Massé and Billon, 2018).

Efforts to combat illegal mining in Colombia have been significantly shaped by Decree 2235 of 2012, which authorized law enforcement to seize and destroy machinery used in unauthorized mining activities. This measure aimed to dismantle illegal operations and protect the environment from severe degradation. In parallel, efforts to reduce mercury use in artisanal and small-scale mining have included several initiatives. Law 1658 of 2013 aimed to eliminate mercury use in mining by 2023, providing technical assistance and financial incentives to support miners in transitioning to mercury-free methods. Additionally, Colombia ratified the Minamata Convention in 2018, which aims to reduce and eventually ban mercury use in all mining activities. Despite these efforts, challenges such as the illegal mercury trade and the involvement of organized crime continue to pose significant obstacles (Díaz et al., 2020).

2.2 Gold mining and internal armed conflict

Colombia has faced a complex and long-lasting internal conflict, spanning approximately six decades. It has involved multiple actors, including leftist guerrilla groups such as the Revolutionary Armed Forces of Colombia (FARC) and the National Liberation Army (ELN), right-wing paramilitary groups, drug cartels, and state security forces. The conflict has had a devastating impact on the Colombian population, leading to widespread violence, forced displacement, human rights abuses, and a breakdown of the rule of law. During the administration of Juan Manuel Santos (2010-2018), peace negotiations with the FARC started in 2012, a ceasefire was declared in 2014, and the negotiations culminated in a signed agreement on November 24, 2016, with around 85% of FARC members endorsing the deal. Meanwhile, negotiations with the ELN also began under Santos but remain ongoing, as a comprehensive peace agreement has yet to be reached.

The origin of this conflict dates back to the mid-1960s with the creation of FARC and ELN. These guerrilla groups positioned themselves as representatives of the economically

disadvantaged rural population and engaged in confrontations with the government, aiming for its overthrow. In certain municipalities, they even established local governance structures that provided basic services and handled disputes (Prem et al., 2020, 2022). While the conflict was relatively low in intensity during the 1980s, the situation escalated dramatically in the 1990s. This escalation was driven by multiple factors, such as guerrilla groups resorting to the illicit drug trade as their primary funding source and the emergence of paramilitary organizations (Dube and Vargas, 2013; Bautista-Céspedes et al., 2021).

According to Massé and Billon (2018), numerous factors have contributed to deepening the conflict, including disputes over land ownership, the illegal drug trade, and the availability of valuable natural resources such as oil and gold. As described in the previous section, the surge in gold prices, which began in the early 2000s, promoted the proliferation of both legal and illegal miners who started to explore new territories. Many of these territories were traditionally associated with artisanal and small-scale mining, potentially generating disputes over these areas (Bonilla Mejía, 2020; Echavarria, 2014). The remote locations of these mining areas make state presence weak, allowing illegal activities to flourish and increasing the vulnerability of local populations to human rights abuses (Massé and Billon, 2018).

Various armed groups have also found opportunities to diversify their illicit activities within the gold production chain, some of which have previously been involved in illegal farming of crops (Rettberg and Ortiz-Riomalo, 2016; Echavarria, 2014). These groups have leveraged the gold supply chain, employing methods such as extortion, tax fraud, and control of the market for mining supplies (such as explosives and mercury), the trade in gold, and agreements with large-scale mining companies for security services. They have become engaged in the smuggling of illegal gold and have even used profits from unlawful activities to buy machinery to start their mining operations. Gold’s characteristics—its high value, far-reaching market, and difficult traceability—have made it an attractive instrument for hiding substantial earnings from illegal activities like drug trafficking, resulting in more instances of money laundering (Márquez and Salcedo, 2012; Goñi et al., 2014; OECD, 2017; Massé and Billon, 2018; Betancur, 2019).

Furthermore, the military securitization during Uribe’s administration (2002-2010) has been influenced by a multitude of factors. Not only was it formed by the legal military forces and official defense strategies but also shaped by illegal entities such as paramilitary groups.¹

¹Recently referred to as BACRIM which is an acronym that stands for “Criminal Bands” or “Bandas Criminales” in Spanish. It is a term used in Colombia to refer to criminal organizations that emerged after

These groups, particularly the AUC (Autodefensas Unidas de Colombia) paramilitaries between 2000 and 2004, started to safeguard the private economic interests of domestic and foreign companies operating in mining areas, contributing to the militarization of local mining environments (Vélez-Torres, 2014; Vélez-Torres and Agergaard, 2014). This complex situation, coupled with the national challenge of enforcing existing legal regulations and the lack of means to deal with the pressures stemming from the widespread entry of diverse actors into the gold mining sector, has resulted in the expansion of gold mining being accompanied by a rise in displacement, threats, and human rights violations, particularly towards community leaders and advocates (Rettberg and Ortiz-Riomalo, 2016; OECD, 2017; Ortiz-Riomalo and Rettberg, 2018; Massé and Billon, 2018; Betancur, 2019).

The situation previously described positions traditional communities at a crossroads. They find themselves trapped between militarized and illegal armed groups on one side, and on the other, an absence of formalized land titles or legal status to defend their territories against mechanized miners. The role of weak property rights has significantly exacerbated forced displacement dynamics in Colombia, as the lack of legal land tenure makes it easier for powerful actors to forcibly displace small farmers and seize their lands (Weitzner, 2012; Millán-Quijano and Pulgarín, 2023). Presumably, the primary repercussions of gold mining have been the forced displacement of residents and threats directed at social leaders. Such outcomes arise because these communities and their leaders frequently challenge diverse economic and political interests, including the endeavors of armed groups to dominate strategic regions. Environmental advocates in mining areas are particularly at risk (Prem et al., 2022).

Multiple studies have documented the unequal effects of the influx of miners on black and indigenous communities. These groups have been left without formalized rights to their lands and without state protection, leading to increased land loss, environmental damage, human rights violations, and a dearth of sustainable employment opportunities. Both legal and illegal mining have contributed to these problems (Vélez-Torres and Méndez, 2022; Guerrero et al., 2012). In response, some communities have attempted to safeguard themselves by forming community councils for collective ownership over their territories, though this approach has encountered obstacles in regions rich in gold deposits.

the demobilization of paramilitary groups in the mid-2000s (Massé and Billon, 2018)

3 Data

A panel that includes all municipalities in Colombian territory was created, providing annual data on violence rates and gold mining activity from 2004 to 2022, as shown in the summary statistics in Table 1. Although the current number of municipalities in Colombia totals 1,122, only 1,090 municipalities were used for all regressions, following the panel employed by [Saavedra and Romero \(2021\)](#). This adjustment ensures consistency across regressions, given that three different measures of gold mining activity were used. In the Colombian administrative structure, a “municipio” is analogous to a U.S. county, encompassing both urban centers and their surrounding rural areas. “Departamentos,” the primary administrative divisions in Colombia, are similar to states in the U.S., with a total of 32. Nested within these departments are divisions known as “provincia” or subregion, which facilitate the joint provision of public services because municipalities within these groups might share similar geography.

3.1 Violence

The dependent variable data, which encompass various indicators of violence such as the number of victims of homicides, threats, forced displacements, and terrorist attacks at the municipal level, were obtained from the Registro Único de Víctimas (RUV). This dataset is based on self-reported accounts by victims of the conflict, which introduces certain limitations. While government officials validate each case, some individuals may register to receive government benefits even if they were not forcibly displaced by violent actions ([Millán-Quijano and Pulgarín, 2023](#)). Additionally, significant under-registration exists due to various factors. Many victims are unaware of the program, fear being identified, or face accessibility issues. It is estimated that about 30% of internally displaced persons do not register for these reasons ([Ibáñez and Velásquez, 2009](#)), leading to the potential underreporting of forced internal displacement rates ([Saldarriaga and Hua, 2019](#)). This data specifically relates to violence within the context of the internal conflict, excluding instances of common violence such as everyday threats or homicides resulting from robberies and similar incidents. Two specific categories within the scope of victims of forced displacement are considered: “Forced Displacement” and “Forced Abandonment or Forced Dispossession of Lands.” The measure of terrorist attacks refers to the number of victims from various types of conflict-related violence, including attacks or bombings, combat incidents, clashes or confrontations, and sieges. This dataset has been used by [Saldarriaga and Hua \(2019\)](#), [Bonilla Mejía \(2020\)](#) and [Millán-Quijano and Pulgarín \(2023\)](#).

Data on the annual number of assassinated social leaders are obtained from the records of *Somos Defensores*, a human rights NGO in Colombia. This organization has documented these incidents since 2002, aiming to consistently present statistics on this form of violence to pressure national authorities and raise awareness of what they describe as systematic and intentional acts. Their database, enriched by contributions from a vast network of over 500 human rights organizations throughout Colombia, especially in conflict-affected regions, ensures that each case is detailed with the date, the municipality of occurrence, the victim’s name, the suspected perpetrator, and a brief account of the event. *Somos Defensores* offers a blend of protection measures, ranging from direct protective mechanisms, including both national and international relocations through internships, to regional support during humanitarian crises. The designation “social leader” broadly includes members of local community councils, representatives of ethnic communities (e.g., indigenous and Afro-Colombian groups), unionists, environmental activists, and other advocates. This data has been used by Prem et al. (2022).

3.2 Gold mining

This section presents an overview of the data available on gold mining in Colombia and discusses three methods for estimating the geographical spread of gold mining addressed in this paper. Accurately determining the extent of this territorial spread is complicated by the informal nature of much of the mining activity and the limited data on the output from legally operating mines. The three approaches highlighted here focus on open pit gold mines which utilize large machinery to remove surface material, as these methods are grounded in analyzing satellite imagery to detect landscape changes such as alterations in water bodies, deforestation, and soil disturbance from vegetation loss. Consequently, this approach does not capture artisanal, non-mechanized mining activities or underground vein mining.

Annual gold production data at the municipal level has only been consolidated since 2017. For legal mining, the Ministry of Mines and Energy of Colombia provides information on mining titles and applications since 1990. This includes data on the application and approval dates, as well as the exact location and size of the mining concessions that intend to extract gold among other minerals. However, possession of a mining title does not necessarily indicate active extraction; many title holders use these titles primarily for speculation, eventually transferring them to mining firms prepared to exploit the land. Thus, a mining title does not serve as a reliable indicator of gold extraction.

Table 1: Summary statistics

	N	mean	sd	min	max
<i>Panel A: Violence. Victims per 100,000 individuals</i>					
Homicide (SL)	20,710	0.218	1.659	0	89.45
Displacement	20,710	1,126	3,078	0	93,266
Homicide	20,710	53.86	136.2	0	3,107
Terrorist Acts	20,710	14.14	134.2	0	6,473
Threat	20,710	95.44	247.1	0	6,872
<i>Panel B: Gold mining. Hectares</i>					
Machine learning (2004-2014)	11,959	27.10	120.8	0	2,592
UNODC gold mining (2014-2022)	7,630	83.26	555.7	0	8,842
Gold mining deforestation (2004-2021)	19,620	3.813	42.33	0	1,657
<i>Panel C: Instrument</i>					
Gold Price (Pesos)	20,710	2.535	1.375	0.931	5.485
Gold Price (USD)	20,710	2.448	0.772	1	3.756
Anomalies	20,710	0.238	0.426	0	1
<i>Panel D: Controls</i>					
Coca crops (ha)	20,710	39.30	360.6	0	22,082
Farc presence	20,710	0.114	0.318	0	1
Other armed groups presence	20,710	0.156	0.363	0	1
Farc or other armed groups	20,710	0.227	0.419	0	1

Note: This table covers the period from 2004 to 2022 and includes 1,090 municipalities.

In terms of comprehensive data that includes both legal and illegal mining sites, the Ministry on Mining conducted a census in 2010, but this information has not been updated since. Nevertheless, this data has been employed by [Idrobo et al. \(2014\)](#) to measure illegal mining at a specific time and by [Saavedra and Romero \(2021\)](#) to estimate gold mining activity from 2004 to 2014 using a machine learning technique. The estimates by [Saavedra and Romero \(2021\)](#) will be used as one measure of gold mining in this paper, as explained below.

Information on historical geochemical anomalies provided by INGEOMINAS consolidates data from geochemical projects prior to 2008. Geochemical anomalies pinpoint regions where specific elements, such as gold, exist at concentrations exceeding their natural background levels. The compilation of historical geochemical data, dating back to INGEOMINAS' founding in 1917, was completed in 2008. Over 4,000 documents, including geology reports, mineral and geochemical exploration, and laboratory analyses from INGEOMINAS libraries and external institutions were reviewed during this consolidation process. From this data, maps of geochemical potential were created to identify areas suitable for mining projects. According to the summary statistics in table 1, in about 24% of the municipalities geochemical anomalies of gold have been detected. This data has been used by [Idrobo et al. \(2014\)](#) and [Bonilla Mejía \(2020\)](#), and will also be used in this paper as part of the identification strategy as explained in Section 4.

Machine learning estimations for 2004-2014:

For the period that corresponds to 2004 to 2014, data from [Romero and Saavedra \(2021\)](#) on gold mining in Colombia is employed, derived using a machine learning model. The 2010 Colombian Mining Census, provided by the Ministry of Mines, serves as the foundational dataset. This census includes the locations of both legal and illegal mining operations across half of the Colombian municipalities. Municipalities included in the census are comparable to those not included regarding changes in royalties, mineral production, the presence of central government institutions, and the presence of armed groups, ensuring a correct randomization of the sample. The data primarily encompasses open-pit mines, facilitating observable satellite detection for subsequent analysis.

The model training involved several key steps. Initially, high-resolution satellite imagery was prepared for compatibility with machine learning applications. A crucial phase of the process was the calibration of a machine learning algorithm using data from the 2010 census, designed to distinguish mined from non-mined pixels based on a 30×30 m grid. Each pixel was labeled for mining activity and analyzed for various satellite surface-reflectance measures,

deforestation data, and ecosystem types. The training set comprised 75% of the data, with the remaining 25% reserved for testing the model’s accuracy. Post-training, the algorithm predicted mining activities from 2004 to 2014, with further steps including legal verification against mining permits, identification of the mined minerals using National Mining Agency resources, and aggregation of the data at the municipal level for detailed regression analysis. According to the authors, the machine learning model developed to predict mining activities has a precision rate of 79%. In Table 1, this variable is referenced as “Machine learning (2004-2014).” The average annual area estimated for gold mining for each municipality from 2004 to 2014 was 27.1 hectares.

Alluvial Gold Exploitation. Evidence from Remote Sensing (UNODC):

Data from the United Nations Office on Drugs and Crime is used for the second part of the analyzed period, spanning 2014-2022 (UNODC, 2016). It utilizes satellite imagery and remote sensing to detect areas of alluvial gold exploitation. This process involves the analysis of changes in land and water bodies that indicate mining activities. Notably, regions defined by this method exclude non-mechanized gold extraction areas, such as artisanal sites and underground exploitations, due to their non-detectability via satellite imagery. The detected areas are then verified through field visits and cross-referenced with additional data sources such as the National Mining Agency and environmental records to confirm the presence of mining activities. Through the Information Access System (SAI-EVOA), the United Nations Office on Drugs and Crime, in agreement with the Ministry of Mines and Energy of Colombia, provides the estimated area in hectares at the municipal level for the years 2014, 2016, 2018, 2019, 2020, 2021, and 2022. This measure will be referred to in this document as “UNODC gold mining.” As shown in Table 1, the average annual gold mining area per municipality was 83.26 hectares.

Gold mining deforestation:

Due to the recent availability of UNODC data and data from Saavedra and Romero (2021) limited to the gold rush period (2004-2014), there is interest in developing independent estimations for the entire period to contrast with the first two measures. UNODC (2016) offers evidence of alluvial gold mining in two forms: a consolidated measure at the municipal level, referred to as “UNODC gold mining” for 2014-2022, and annual geospatial data comprising 1km×1km polygons that have undergone alluvial gold mining (EVOA). This latter data, along with deforestation records and potential gold mining sites from mining titles, applications, and Special Reserved Areas, is used for the third gold mining estimation referred to

as “gold mining deforestation.”

The EVOA data, available only for recent years, are intersected with annual deforestation data from 2001-2021 to trace historical gold mining activity. It is assumed that past gold mining occurred near the recently detected EVOA areas because of the large size of the 1km×1km polygons. Recognized by [UNODC \(2016\)](#) and [Saavedra and Romero \(2021\)](#), mechanized gold mining invariably involves deforestation. Global Forest Watch provides deforestation data with an approximate resolution of 30×30 meters, covering global tree cover loss annually from 2001-2021 ([Hansen et al., 2013](#)). However, overlaying EVOA and deforestation data might capture deforestation from other activities such as agriculture or cattle ranching. Thus, mining titles, applications, and Special Reserve Areas (AREs), which hold information about gold deposits, are utilized. Given the costs associated with acquiring and maintaining a mining title, firms are unlikely to invest in non-prospective areas, suggesting that such titles likely indicate the presence of gold deposits. This assumption also applies to AREs, where mining communities invest to secure exclusive rights to mine these areas artisanally.

In processing the geospatial data, EVOA polygons from 2018 to 2021 were merged into a single layer, and a 1.5 km buffer was applied to account for mining activities prior to 2018. This layer was then overlaid with selected mining titles and applications specifically aimed at gold extraction, along with AREs in process and approved. Subsequently, all the deforestation occurring annually on this combined layer was aggregated at the municipality level from 2004 to 2021. [Figure 2](#) visually demonstrates this methodology. Prominent yellow areas on the map indicate EVOAs, associated with gold mining regions. Dark red/purple polygons represent mining titles, while orange areas show applications that may lead to gold extraction upon approval. AREs are depicted as brown segments. Dark green patches, composed of minute squares or pixels, represent deforestation events, with each 30m×30m pixel reflecting a year’s worth of data. To establish the gold mining deforestation measure, instances of deforestation within the legal mining titles, applications, and AREs were totaled, provided these occurred within the overarching EVOA regions.

3.3 Other data

The international gold price in real terms was sourced from the World Bank Commodity Prices dataset. The exchange rate from the US dollar to Colombian pesos was obtained from the Colombian Central Bank (Banco de la República). Both the real prices in Colombian

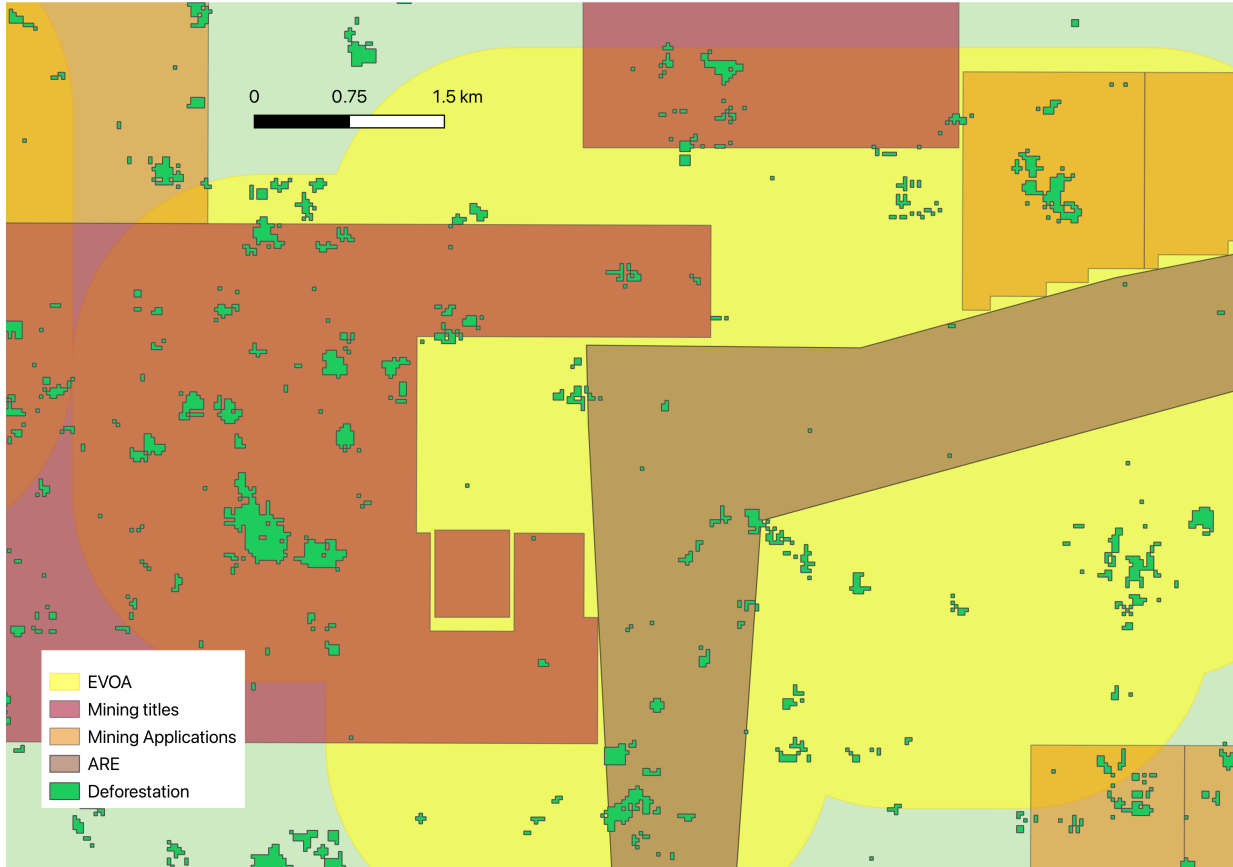


Figure 2: Evidence of Alluvial Gold Exploitation, mining titles, mining applications, Special Reserve Areas (ARE), and deforestation. Municipality: Tarazá, Antioquia.

pesos and dollars were normalized, using 2004 as the base year. Estimates of coca crops in hectares were obtained from the Ministry of Justice and Law in partnership with the United Nations Office on Drugs and Crime through the [Integrated System for Illicit Crop Monitoring \(SIMCI\)](#). Estimations of armed presence groups, specifically the FARC and other groups, for the years 2011 to 2014 were taken from [Prem et al. \(2022\)](#).

4 Empirical Strategy

The evidence outlined in section 2 suggests that the territorial expansion of capital-intensive gold mining may specifically target local communities resistant to their gold extraction activities, to gain access to land for gold exploitation. Specifically, heightened rates of violence, including threats, displacement, and homicides, among other types of violence, might be ex-

pected. However, analyzing the relationship between the territorial expansion of gold mining and violence rates is challenging due to potential endogeneity, which can lead to biased estimators and obscure true causal relationships. Endogeneity emerges because gold mining expansion might be correlated with unobservable factors affecting the count of violence victims. For instance, municipalities with weak governance or lax regulatory environment might increase the risk of displacement and indiscriminate deforestation derived from gold mining.

In addressing this identification problem, the following approach aligns with seminal research that explores the intersection of resource abundance and conflict (Brückner et al., 2012; Brückner and Ciccone, 2010; Dube and Vargas, 2013). Specifically, the two-stage least squares (2SLS) model, complemented with year and municipality fixed effects, is adopted to tackle the endogeneity concern.

The interaction of international gold prices and gold geochemical anomalies is used as the instrumental variable (IV) to address potential biases from simultaneous effects. This technique, as documented in Bonilla Mejía (2020) and Idrobo et al. (2014), has been previously applied to the Colombian context to estimate the effects of gold mining activity on educational outcomes and violence. The reasoning underpinning this IV choice revolves around two main points:

1. Increases in gold prices can indeed catalyze mining activities; however, there is no direct evidence to suggest they automatically lead to an uptick in violence. Their impact on mining primarily stems from economic incentives rather than sociopolitical dynamics.
2. Geochemical anomalies, which are natural geological formations, designate areas abundant in gold deposits. This makes mining activities in these specific regions particularly reactive to gold price variations. Importantly, these anomalies, being products of millions of years of geological processes, are inherently exogenous. Their distribution and existence are not influenced by human actions, economic interests, or social dynamics within or outside the municipality.

The international prices of commodities, including gold, are largely insulated from the decisions or interventions of an individual nation. This assertion holds particular weight for countries with a modest contribution to global production, such as Colombia, which accounts for under 2% of worldwide gold output (Bonilla Mejía, 2020). Given Colombia's minor role in the global gold marketplace, it further substantiates our confidence in the exogeneity of the

international gold price, assuring its independence from domestic Colombian dynamics.

As noted by [Idrobo et al. \(2014\)](#), if illegal gold mining leads to increased violence, then higher international gold prices should disproportionately affect violence in municipalities with geographic features that suggest a higher likelihood of gold deposits. Although geographic characteristics might influence violence through other mechanisms, the instrument used combines these characteristics with the international gold price. This interaction helps ensure that the exclusion restriction is less likely to be violated.

The two-stage least squares (2SLS) estimation is articulated in the subsequent manner:

First stage:

$$\text{Ln}(MinedArea_{it}) = \alpha + \gamma_1 \text{Ln}(GoldPrice_t) \times GeoAnom_i + \gamma_2 X_{it} + \mu_i + \lambda_t + \epsilon_{it} \quad (1)$$

Second stage:

$$\text{Ln}(Violence_{it}) = \alpha + \beta_1 \text{Ln}(\widehat{MinedArea}_{it}) + \beta_2 X_{it} + \mu_i + \lambda_t + \epsilon_{it} \quad (2)$$

Where:

- Municipalities and years are indexed by i and t respectively.
- $MinedArea_{it}$ represents the estimated mined area of gold within municipality i in year t . This variable has three measures, as explained in the data section.
- $GoldPrice_t$ represents the international gold price in Colombian pesos for year t .
- $GeoAnom_i$ is a binary variable, set to 1 if geochemical anomalies are detected in municipality i .
- $Violence_{it}$ includes various metrics of violence, such as the number of victims of displacement, threats, killings of social leaders, homicides, and terrorist attacks per 100,000 individuals, for municipality i during year t .
- X_{it} includes a set of control variables.
- Municipality and year fixed effects are represented by μ_i and λ_t respectively.
- The error term is captured by ϵ_{it} .

The area dedicated to coca cultivation is incorporated as a control variable. Areas, where

coca is cultivated, are often linked to illegal activities like drug trafficking, which lead to conflicts and forced migrations (Rettberg and Ortiz-Riomalo, 2016; Angrist and Kugler, 2005). By controlling for these factors, the focus is maintained on the violence directly related to gold mining without the interference of these other sources of conflict.

In the presentation of our empirical results, particular attention is given to the reporting of the Kleibergen-Paap rk Wald F statistic. This choice is aligned with our model specification, which accounts for heteroskedasticity and employs clustered standard errors at the municipality level. Essentially, this F statistic measures the strength of the relationship between the instrumental variable and the endogenous regressor (gold mining), providing insight into the instrument’s relevance. Given that our empirical strategy emphasizes the robustness of the IV method, reliance on the Kleibergen-Paap rk Wald F statistic ensures consistency in our analysis and bolsters the validity of our findings.

5 Results

To present the results, the analysis period has been divided into two segments based on the three gold mining estimations available and the context described in section 2. The first period, from 2004 to 2014, is marked by a significant increase in the gold price and a high demand for mining titles, which is identified as the Colombian gold rush. The results for this period are presented in Panel A of each results table. The post-gold rush period, characterized by a more stable dynamic in terms of the gold price and the titled areas expansion, spans from 2014 onwards and is presented in Panel B. This stability may be attributed to land scarcity following the rush in the first period. Additionally, some authors have argued that the conflict dynamic in Colombia underwent a significant transformation following the FARC insurgency’s permanent ceasefire in 2014 (Prem et al., 2020, 2022).

For gold mining, the regressor of interest, three different measures have been used as explained in section 3.2. Estimations using gold mining deforestation have also been divided into these two periods to compare the results with the other two measures included in the analysis: the machine learning estimations (ML estimation for 2004-2014) and the EVOA estimation made by UNODC since 2014. Given that the outcome variables are measured as the natural logarithm of the rate (where the rate is the number of victims per 100,000 population), the coefficients represent elasticities. Specifically, a coefficient indicates the percentage change in the violence rate associated with a 1 percent change in the area mined. Clustered robust standard errors at the municipality level are reported in parentheses, ensuring that

the standard errors account for potential correlation within municipalities. Additionally, regressions using the rate as the dependent variable, rather than its logarithm, are included in the appendix in section 7 for comparison.

Table 2 presents the OLS estimates of the impact of gold mining on various measures of violence. During the Gold Rush period, as shown in Panel A, the machine learning estimation indicates that a 1% increase in gold mining activity is associated with a 0.14% increase in the displacement rate, a 0.05% increase in the homicide rate of social leaders, a 0.10% rise in the threat rate, and a 0.22% increase in the rate of terrorist acts, all significant at the 1% level. General homicide rates decrease by 0.10%, significant at the 5% level. Similarly, the gold mining deforestation measure shows positive and significant effects on displacement (0.12%), threats (0.06%), and terrorist acts (0.13%) at the 1%, 5%, and 5% levels respectively, while the general homicide rate increases by 0.18%, significant at the 1% level.

In the Post-Gold Rush period, as shown in Panel B, the UNODC measure of gold mining shows no statistically significant effect on displacement, homicides of social leaders, or threats, but a negative effect on the general homicide rate of 0.17%, significant at the 5% level. The deforestation measure indicates significant increases in displacement (0.09%) and threats (0.09%), both at the 1% level, while the rate of terrorist acts decreases by 0.17%, significant at the 5% level. Additionally, in the appendix (Table A1), OLS regressions using the rate of each violence indicator as the dependent variable instead of the logarithm of the rate are reported. These results show no significant effect on the displacement rate for any period. For homicides and threats, significant effects are found only during the Gold Rush period, with negative coefficients on the homicide rate. Significant positive effects on terrorist acts are observed with the machine learning estimation during the first period.

It is important to note that endogeneity might be an issue with these OLS results, potentially leading to biased estimates. To address this concern, the instrumental variable (IV) specification will be used. This approach will help mitigate endogeneity issues and provide more reliable estimates of the causal impact of gold mining on violence. The results of the reduced form estimations are presented in Tables A2 and A3. Table A2 shows that during the Gold Rush period, an increase in the international gold price has positive effects on displacement, homicides of social leaders, threats, and terrorist attacks. In the post-Gold Rush period, positive effects are observed on displacement, homicides of social leaders, and general homicides. In contrast, Table A3 shows no significant effects on displacement in any period. During the Gold Rush period, positive effects are found for homicides of social leaders, threats, and terrorist acts, while in the post-Gold Rush period, positive effects are

Table 2: OLS Estimates of the Impact of gold mining on Violence

	(1)	(2)	(3)	(4)	(5)
	Displacement	Homicide	Threat	Homicide	Terrorist
		(SL)			Acts
A. Gold Rush					
ML estimation (2004-2014)	0.14*** (0.03)	0.05*** (0.01)	0.10*** (0.04)	-0.10** (0.05)	0.22*** (0.04)
Coca crops (ha)	0.02** (0.01)	0.00 (0.01)	0.03 (0.02)	0.04* (0.02)	0.00 (0.02)
Constant	6.55*** (0.20)	-6.55*** (0.09)	0.87*** (0.27)	1.93*** (0.34)	-2.91*** (0.28)
Observations	11,959	11,959	11,959	11,959	11,959
Gold mining deforestation (2004-2014)	0.12*** (0.02)	0.04* (0.02)	0.06** (0.03)	0.18*** (0.04)	0.13** (0.06)
Coca crops (ha)	0.02** (0.01)	0.00 (0.01)	0.03 (0.02)	0.04* (0.02)	0.00 (0.02)
Constant	6.51*** (0.16)	-6.54*** (0.15)	0.69*** (0.24)	3.64*** (0.33)	-3.37*** (0.43)
Observations	11,990	11,990	11,990	11,990	11,990
B. Post - Gold Rush					
UNODC gold mining (2014-2022)	-0.08 (0.05)	-0.00 (0.05)	-0.03 (0.04)	-0.17** (0.07)	0.03 (0.08)
Coca crops (ha)	0.03*** (0.01)	0.07*** (0.02)	0.01 (0.01)	0.06** (0.03)	-0.00 (0.02)
Constant	3.76*** (0.34)	-6.28*** (0.32)	1.54*** (0.28)	-5.11*** (0.45)	-3.36*** (0.49)
Observations	7,629	7,630	7,630	7,630	7,630
Gold mining deforestation (2014-2021)	0.09*** (0.03)	0.06 (0.07)	0.09*** (0.03)	-0.01 (0.08)	-0.17** (0.07)
Coca crops (ha)	0.02* (0.01)	0.04* (0.02)	0.01 (0.01)	0.04 (0.03)	0.02 (0.03)
Constant	4.77*** (0.21)	-6.02*** (0.43)	2.33*** (0.20)	-4.21*** (0.52)	-4.44*** (0.44)
Observations	8,719	8,720	8,720	8,720	8,720

Note: Clustered robust standard errors at the municipality level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Violent crime rates are expressed as the natural logarithm of the number of victims per 100,000 individuals. Each column represents a regression that includes all 1,090 municipalities.

Table 3: First-Stage Regression: Predicting Gold Mining through international gold prices and Geochemical Anomalies

	(1)	(2)	(3)	(4)
	ML estimation	UNODC	Gold mining deforestation	Gold mining deforestation
	(2004-2014)	(2014-2022)	(2004-2014)	(2014-2021)
Anomalies×Gold Price	1.92*** (0.22)	-0.60*** (0.22)	1.26*** (0.19)	0.34*** (0.10)
Coca crops (ha)	0.00 (0.01)	-0.00 (0.01)	0.01 (0.01)	0.01 (0.01)
Constant	-4.14*** (0.09)	-5.43*** (0.10)	-6.59*** (0.06)	-6.26*** (0.06)
Observations	11,959	7,630	11,990	8,720

Note: Clustered robust standard errors at the municipality level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Each column represents a regression that includes all 1,090 municipalities.

observed on homicides of social leaders and general homicides.

The first-stage regression results, presented in Table 3, test the relevance condition of the instrument by examining the effect of international gold prices in municipalities with high concentrations of gold (anomalies). During the Gold Rush period (2004-2014), the instrument shows a positive and significant correlation with the mined area across all measures, as seen in columns (1) and (3). However, in the Post-Gold Rush period (2014-2022), there is a surprising negative correlation between the instrument and the area mined as measured by UNODC, as shown in column (2). This finding challenges the rationale behind the selection of the instrument, which presumes that an increase in international gold prices should expand the mined areas in municipalities with gold deposits, eventually affecting violence indicators. The negative coefficient in column (2) contradicts this expectation. However, the Kleibergen-Paap rk Wald F statistic for this period is below the threshold of 10, indicating that the instrument is weak for this period. Overall, the instrument appears much weaker in the second period for both the UNODC measure and gold mining deforestation.

Table 4 presents the instrumental variable (IV) estimates of the effect of gold mining on various measures of violence. These IV estimates are more reliable than the OLS results due to their ability to address potential endogeneity. For the Gold Rush period (2004-2014), columns 1, 2, 3, and 5 show significant positive effects on the displacement rate, homicide

rate of social leaders, threat rate, and the rate of victims of terrorist acts. Notably, the general homicide rate in column 4 is not statistically significant, indicating that the violence is more targeted. The Kleibergen-Paap rk Wald F statistics of 72.977 and 43.34 for the ML estimation and gold mining deforestation measures, respectively, confirm the strength of the instrument during this period. The increase in terrorist acts is likely due to more clashes or confrontations between armed groups vying for control over mining areas.

In contrast, for the Post-Gold Rush period (2014-2022), the UNODC measure shows negative coefficients, but these results are unreliable due to a weak instrument (Kleibergen-Paap rk Wald F statistic of 7.146). The gold mining deforestation measure, with a stronger instrument (Kleibergen-Paap rk Wald F statistic of 10.972), shows higher and more coherent coefficients. These differences may stem from the specificity of gold mining deforestation, which focuses on variations in gold mining titles and community mining areas (AREs), leading to disputes and increased violence. The targeted focus of the gold mining deforestation measure captures differences in mining activity in highly localized areas of interest to different types of miners.

For the results using the rate of violence indicators as the dependent variables, presented in Table A4, the findings are generally consistent with those using the logarithm of the rate. Stronger effects are observed during the Gold Rush period, while the post-Gold Rush period shows weaker and less significant effects. A notable difference is the lack of a significant effect on the displacement rate during the Gold Rush period.

Although the discrepancies in the effects observed between Panel A and Panel B may be due to the decreased relevance of the instrument in the second period, it is also possible that the dynamics of violence have shifted in the post-conflict scenario following the ceasefire with the FARC group and the emergence of what has been termed the “pax mafiosa” in some regions. Indeed, violence rates have substantially declined in most categories, except for homicides of social leaders, which have more than tripled, and threats, which have increased by 30% in the second period.

The concept of “pax mafiosa,” as discussed by [Massé and Billon \(2018\)](#), provides a framework for understanding these shifts in violence dynamics. Under this concept, armed groups enforce a period of relative peace by involving local communities more deeply in the gold mining business instead of expelling them. These groups aim to avoid drawing attention from authorities by reducing overt violence, thereby creating a more stable environment for their operations. This inclusion minimizes violent conflicts and associated human rights abuses, as

Table 4: Instrumental variable effect of gold mining on violence

	(1)	(2)	(3)	(4)	(5)
	Displacement	Homicide	Threat	Homicide	Terrorist
		(SL)			Acts
A. Gold Rush					
ML estimation (2004-2014)	1.21*** (0.17)	0.18*** (0.06)	0.55*** (0.17)	-0.01 (0.20)	1.15*** (0.23)
Observations	11,959	11,959	11,959	11,959	11,959
Kleibergen-Paap rk Wald F statistic	76.977	76.977	76.977	76.977	76.977
Gold mining deforestation (2004-2014)	1.84*** (0.32)	0.28*** (0.10)	0.81*** (0.27)	-0.03 (0.30)	1.76*** (0.37)
Observations	11,990	11,990	11,990	11,990	11,990
Kleibergen-Paap rk Wald F statistic	43.34	43.34	43.34	43.34	43.34
B. Post - Gold Rush					
UNODC gold mining (2014-2022)	-1.41** (0.65)	-0.87* (0.45)	0.02 (0.40)	-1.34** (0.68)	1.26* (0.68)
Observations	7,629	7,630	7,630	7,630	7,630
Kleibergen-Paap rk Wald F statistic	7.146	7.146	7.146	7.146	7.146
Gold mining deforestation (2014-2021)	3.60*** (1.28)	1.61** (0.68)	0.77 (0.81)	2.84** (1.28)	-3.00** (1.25)
Observations	8,719	8,720	8,720	8,720	8,720
Kleibergen-Paap rk Wald F statistic	10.972	10.972	10.972	10.972	10.972

Note: Clustered robust standard errors at the municipality level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Violent crime rates are expressed as the natural logarithm of the number of victims per 100,000 individuals. Each column represents a regression that includes all 1090 municipalities, with coca crops used as a control variable in all regressions.

rival groups and state interventions are limited. Consequently, this enforced peace can lead to fewer displacements and human rights violations in gold mining areas, as the dominant group's control fosters a more predictable and less violent setting. This shift in the nature of violence may explain why the coefficients for the second period differ from those of the Gold Rush period.

5.1 Heterogeneous effects of gold mining expansion during the Gold Rush period

To study the potential mechanisms behind the increased violence derived from the expansion of gold mining, heterogeneous effects will be estimated based on a range of municipal characteristics. Specifically, the presence of armed groups, institutional factors, and traditional mining activities will be analyzed to understand how these factors exacerbate the impacts of gold mining on the violent outcomes of interest during the Gold Rush period.

The presence of armed groups is measured using a dummy variable that equals one for municipalities with at least one violent incident attributed to FARC or other armed groups (such as neo-paramilitary criminal bands and ELN guerrilla) from 2011 to 2014, as detailed in Prem et al. (2022). The results in Table 5 indicate that the presence of armed groups (FARC or other armed groups) during the Gold Rush period (2004-2014) exacerbates the effects of gold mining on all types of violence analyzed. In Table A5, where the dependent variables correspond to the rates for each violent indicator, the presence of armed groups significantly increases the effects of gold mining on displacement, threats, and terrorist acts rates, while the effects on homicides of social leaders and general homicides are less consistent. These findings are consistent with section 2.2, which documents how armed groups have been involved in gold mining operations, both directly and indirectly, through extortion, managing mining operations, and exerting control over mining regions, thereby exacerbating violence and criminality.

Institutional factors are examined through measures of judicial inefficiency and electoral risk, both taken from Prem et al. (2022). Judicial inefficiency is measured as the share of justice employees under disciplinary investigations, indicating the effectiveness and integrity of the judicial system. Electoral risk is a dummy variable that takes the value of one if the municipality exhibited abnormal behavior during the previous three congressional elections, which can suggest collusion between armed groups and political institutions or abnormal control exerted by armed groups. The results in Tables 6 and 7 indicate that there are no

Table 5: Instrumental Variable Effect of Gold Mining’s Impact on Violence in Areas with Armed Groups during the Gold Rush (2004-2014)

	(1)	(2)	(3)	(4)	(5)
	Displacement	Homicide (SL)	Threat	Homicide	Terrorist Acts
ML estimation (2004-2014)	1.13*** (0.17)	0.15** (0.06)	0.46*** (0.17)	-0.19 (0.20)	0.98*** (0.22)
ML estimation (2004-2014) × Farc or other armed groups	0.40** (0.16)	0.16** (0.08)	0.41*** (0.13)	0.81*** (0.15)	0.76*** (0.24)
Coca crops (ha)	0.01 (0.02)	0.00 (0.01)	0.02 (0.02)	0.04* (0.02)	-0.00 (0.03)
Kleibergen-Paap rk Wald F statistic	38.589	38.589	38.589	38.589	38.589
Observations	11,959	11,959	11,959	11,959	11,959

Note: Clustered robust standard errors at the municipality level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Violent crime rates are expressed as the natural logarithm of the number of victims per 100,000 individuals. Each column represents a regression that includes all 1090 municipalities, with coca crops used as a control variable in all regressions.

significant differential effects of gold mining on violence based on these institutional measures. This suggests that neither judicial inefficiency nor electoral risk significantly influence the impact of gold mining on violence outcomes during the Gold Rush period. Essentially, this means that regardless of the quality of institutions, judiciary mechanisms, or independent local governance, the effects of violence derived from gold mining were consistent across municipalities.

As discussed in section 2.2, mechanized miners often encroach upon areas traditionally occupied by artisanal miners or ethnic mining communities, leading to disputes over land and control. These conflicts can escalate into violence as different groups vie for dominance over valuable mining areas. To test this hypothesis, the existence of ethnic mining zones will be examined to determine if they exacerbate the effects of gold mining expansion on violence during the Gold Rush period. The presence of ethnic mining zones is captured with a dummy variable indicating their existence in the municipality. This measure was taken from the Agencia Nacional de Minería (National Mining Agency) and comes from a 2018 version. Since these are traditional communities, it can be assumed that these individuals have been engaged in mining during the study period and have been present in these areas for many years.

Table 6: Instrumental Variable Effect of Gold Mining’s Impact on Violence in Areas with Judicial Inefficiency during the Gold Rush (2004-2014)

	(1)	(2)	(3)	(4)	(5)
	Displacement	Homicide (SL)	Threat	Homicide	Terrorist Acts
ML estimation (2004-2014)	1.00*** (0.15)	0.16*** (0.06)	0.51*** (0.15)	-0.11 (0.17)	1.13*** (0.24)
ML estimation (2004-2014) × Judicial Inefficiency	-0.27 (0.44)	-0.01 (0.17)	0.10 (0.40)	0.36 (0.48)	0.25 (0.68)
Coca crops (ha)	0.01 (0.01)	0.00 (0.01)	0.02 (0.01)	0.03* (0.02)	-0.00 (0.03)
Kleibergen-Paap rk Wald F statistic	37.854	37.854	37.854	37.854	37.854
Observations	11,959	11,959	11,959	11,959	11,959

Note: Clustered robust standard errors at the municipality level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Violent crime rates are expressed as the natural logarithm of the number of victims per 100,000 individuals. Each column represents a regression that includes all 1,090 municipalities.

Table 7: Instrumental Variable Effect of Gold Mining’s Impact on Violence in Areas with Electoral Risk during the Gold Rush (2004-2014)

	(1)	(2)	(3)	(4)	(5)
	Displacement	Homicide (SL)	Threat	Homicide	Terrorist Acts
ML estimation (2004-2014)	1.22*** (0.17)	0.19*** (0.06)	0.59*** (0.16)	0.01 (0.20)	1.17*** (0.22)
ML estimation (2004-2014) × Electoral risk	-0.11 (0.23)	-0.04 (0.09)	-0.39 (0.24)	-0.18 (0.23)	-0.18 (0.34)
Coca crops (ha)	0.01 (0.02)	0.00 (0.01)	0.03 (0.02)	0.04* (0.02)	-0.00 (0.03)
Kleibergen-Paap rk Wald F statistic	37.739	37.739	37.739	37.739	37.739
Observations	11,959	11,959	11,959	11,959	11,959

Note: Clustered robust standard errors at the municipality level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Violent crime rates are expressed as the natural logarithm of the number of victims per 100,000 individuals. Each column represents a regression that includes all 1,090 municipalities.

The results depict that the presence of ethnic mining zones exacerbates the effects of gold mining expansion on violence. In Table 8, significant effects are observed in homicides of social leaders, general homicides, and terrorist acts (columns 2, 4, and 5). When considering the rate of violent events as the dependent variable, Table A6 shows significant effects on homicides of social leaders, threats, and terrorist acts (columns 2, 3, and 5). Overall, these results suggest that the presence of ethnic mining zones intensifies the violence associated with gold mining expansion during the Gold Rush period, indicating potential land disputes over gold-rich areas. The results are consistent with the anecdotal evidence that representatives of ethnic (indigenous and Afro-Colombian) communities have been targeted for opposing extractive activities in their territories (Prem et al., 2022). Despite the existence of legal protections like “Zonas mineras étnicas” (ethnic mining zones) to recognize and safeguard these communities, actors involved in mining continue to commit human rights violations to pursue their objectives (Vélez-Torres, 2014).

Table 8: Instrumental Variable Effect of Gold Mining’s Impact on Violence in municipalities with Ethnic Mining Zones during the Gold Rush (2004-2014)

	(1)	(2)	(3)	(4)	(5)
	Displacement	Homicide (SL)	Threat	Homicide	Terrorist Acts
ML estimation (2004-2014)	1.20*** (0.19)	0.12** (0.05)	0.53*** (0.19)	-0.31 (0.23)	1.01*** (0.25)
ML estimation (2004-2014) ×	0.04 (0.15)	0.17* (0.09)	0.06 (0.13)	0.77*** (0.16)	0.37* (0.21)
Ethnic mining zones	0.01 (0.02)	0.00 (0.01)	0.02 (0.02)	0.03 (0.02)	-0.01 (0.02)
Coca crops (ha)	32.156	32.156	32.156	32.156	32.156
Kleibergen-Paap rk					
Wald F statistic					
Observations	11,959	11,959	11,959	11,959	11,959

Note: Clustered robust standard errors at the municipality level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Violent crime rates are expressed as the natural logarithm of the number of victims per 100,000 individuals. Each column represents a regression that includes all 1,090 municipalities.

5.2 Robustness checks

As a robustness check, the instrumental variable regression results were re-estimated with standard errors clustered at the province level, as presented in Table A7. Despite the larger standard errors, the main conclusions about the impact of gold mining on violence during

the Gold Rush period remain consistent. The coefficients retain their significance in most cases, indicating that the observed effects of gold mining on displacement, homicides of social leaders, threats, and terrorist acts are robust to this alternative clustering specification.

6 Conclusions

This paper provides quantitative evidence on the relationship between gold mining expansion and violent conflict in Colombia. The empirical strategy employed involves a two-stage least squares (2SLS) regression model, utilizing three different measures of gold mining activity. During the Gold Rush period, strong effects of gold mining on violence are observed using both machine learning and gold mining deforestation measures. In contrast, the post-Gold Rush period presents mixed results, with more pronounced effects observed using the gold mining deforestation measure. This discrepancy may be attributed to the localized nature of the deforestation measure, which focuses on strategic regions where gold mining titles have been approved and requested, and on special reserve areas designated for traditional mining communities, compared to the broader measure provided by the UNODC. The instrument's relevance is more pronounced during the first period.

Differential effects of gold mining on violence are evident in municipalities with the presence of armed groups and ethnic mining communities during the Gold Rush period. However, no significant differential effects are observed based on institutional factors such as judicial inefficiency and electoral risk. These findings suggest that institutional quality does not significantly influence the impact of gold mining on violence outcomes during the Gold Rush period. The consistency of violence effects derived from gold mining across municipalities, regardless of the quality of institutions, judiciary mechanisms, or local governance, underscores the significant role armed groups play in the gold mining sector and the differential targeting of ethnic communities by actors involved in extractive industries. The results indicate that mechanized miners, in their pursuit to expand gold exploitation areas, may form alliances with armed groups. These groups, often involved in mining activities themselves, target areas traditionally occupied by ethnic communities and commit acts of violence to seize these territories.

The robustness of the results is confirmed using different measures of the dependent variables and various clustering methods for the standard errors. These findings contribute to the understanding of how resource extraction, particularly gold mining, can drive violent conflict, emphasizing the need for policy interventions that address the underlying factors of land

disputes and the involvement of armed groups in the mining sector.

7 Appendix. Additional tables

Table A1: OLS Estimates of the Impact of Gold Mining on Violence (Rate as Dependent Variable)

	(1)	(2)	(3)	(4)	(5)
	Displacement	Homicide (SL)	Threat	Homicide	Terrorist Acts
A. Gold Rush					
ML estimation (2004-2014)	-11.64 (45.44)	0.04*** (0.01)	15.56*** (2.94)	-7.35*** (2.10)	6.34** (2.84)
Coca crops (ha)	-67.01* (36.29)	0.00 (0.01)	2.26 (1.42)	-3.90*** (1.37)	1.17 (1.20)
Constant	1,752.04*** (300.45)	0.28*** (0.09)	171.61*** (19.29)	147.85*** (15.66)	52.82*** (18.45)
Observations	11,959	11,959	11,959	11,959	11,959
Gold mining deforestation (2004-2014)	-125.75 (96.61)	0.02 (0.01)	14.10*** (4.04)	-7.47* (3.95)	3.68* (2.07)
Coca crops (ha)	-65.45* (35.96)	0.00 (0.01)	2.26 (1.41)	-3.89*** (1.36)	1.18 (1.21)
Constant	990.54 (686.42)	0.19* (0.10)	173.86*** (28.03)	140.16*** (27.58)	40.37*** (14.47)
Observations	11,990	11,990	11,990	11,990	11,990
B. Post - Gold Rush					
UNODC gold mining (2014-2022)	-55.71 (49.14)	-0.02 (0.04)	-12.13* (6.99)	-0.79 (0.62)	-2.00** (0.83)
Coca crops (ha)	-15.63 (27.66)	0.10*** (0.03)	-2.56 (3.70)	0.72 (0.45)	-0.72 (0.80)
Constant	545.43 (342.08)	0.58* (0.30)	82.60* (43.76)	11.37** (4.42)	13.04** (6.39)
Observations	7,629	7,630	7,630	7,630	7,630
Gold mining deforestation (2014-2021)	-81.20 (58.67)	0.03 (0.06)	6.49 (5.84)	1.30 (0.90)	-2.06 (2.25)
Coca crops (ha)	-25.30 (25.60)	0.08*** (0.03)	-3.79 (3.64)	0.93** (0.42)	0.77 (1.18)
Constant	323.19 (372.46)	0.77* (0.40)	190.65*** (36.78)	25.46*** (5.74)	20.32 (13.12)
Observations	8,719	8,720	8,720	8,720	8,720

Note: Clustered robust standard errors at the municipality level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Violent crime rates are expressed as the number of victims per 100,000 individuals. Each column represents a regression that includes all 1,090 municipalities.

Table A2: Reduced form effect of gold prices and geochemical anomalies on violence

	(1)	(2)	(3)	(4)	(5)
	Displacement	Homicide	Threat	Homicide	Terrorist
		(SL)			Acts
A. Gold Rush					
Anomalies \times Gold Price	2.32*** (0.21)	0.36*** (0.11)	1.02*** (0.30)	-0.03 (0.38)	2.22*** (0.36)
Coca crops (ha)	0.02** (0.01)	0.00 (0.01)	0.03 (0.02)	0.04* (0.02)	0.00 (0.02)
Constant	5.71*** (0.09)	-6.82*** (0.05)	0.26* (0.14)	2.48*** (0.16)	-4.22*** (0.15)
Observations	11,990	11,990	11,990	11,990	11,990
B. Post - Gold Rush					
Anomalies \times Gold Price	0.88*** (0.23)	0.56*** (0.16)	0.04 (0.24)	0.72*** (0.27)	-0.85*** (0.26)
Coca crops (ha)	0.03** (0.01)	0.05** (0.02)	0.02 (0.01)	0.04 (0.02)	0.00 (0.02)
Constant	4.13*** (0.11)	-6.43*** (0.13)	1.76*** (0.11)	-4.28*** (0.17)	-3.39*** (0.17)
Observations	9,809	9,810	9,810	9,810	9,810

Note: Clustered robust standard errors at the municipality level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Violent crime rates are expressed as the natural logarithm of the number of victims per 100,000 individuals. Each column represents a regression that includes all 1,090 municipalities.

Table A3: Reduced form effect of gold prices and geochemical anomalies on violence

	(1)	(2)	(3)	(4)	(5)
	Displacement	Homicide (SL)	Threat	Homicide	Terrorist Acts
A. Gold Rush					
Anomalies \times Gold Price	131.63 (450.61)	0.26*** (0.09)	148.02*** (23.73)	-86.19*** (21.82)	62.83*** (21.71)
Coca crops (ha)	-66.74* (36.29)	0.00 (0.01)	2.22 (1.40)	-3.86*** (1.34)	1.14 (1.20)
Constant	1,817.85*** (193.64)	0.06 (0.04)	80.09*** (8.12)	189.87*** (8.91)	15.73** (6.34)
Observations	11,990	11,990	11,990	11,990	11,990
Observations	11,990	11,990	11,990	11,990	11,990
B. Post - Gold Rush					
Anomalies \times Gold Price	-124.77 (218.75)	0.34* (0.18)	11.36 (27.01)	11.93*** (2.95)	-10.34 (9.52)
Coca crops (ha)	-0.20 (25.89)	0.08*** (0.03)	-1.34 (3.28)	0.62 (0.40)	0.16 (0.87)
Constant	986.27*** (144.05)	0.56*** (0.15)	161.40*** (20.76)	13.91*** (2.42)	31.47*** (6.55)
Observations	9,809	9,810	9,810	9,810	9,810

Note: Clustered robust standard errors at the municipality level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Violent crime rates are expressed as the number of victims per 100,000 individuals. Each column represents a regression that includes all 1090 municipalities.

Table A4: Instrumental variable effect of gold mining on violence

	(1)	(2)	(3)	(4)	(5)
	Displacement	Homicide (SL)	Threat	Homicide	Terrorist Acts
A. Gold Rush					
ML estimation (2004-2014)	60.44 (237.32)	0.13*** (0.05)	77.16*** (14.71)	-45.20*** (12.28)	32.89*** (11.98)
Observations	11,959	11,959	11,959	11,959	11,959
Kleibergen-Paap rk Wald F statistic	76.977	76.977	76.977	76.977	76.977
Gold mining deforestation	104.49 (358.56)	0.21*** (0.08)	117.50*** (23.49)	-68.42*** (19.59)	49.88*** (18.42)
Observations	11,990	11,990	11,990	11,990	11,990
Kleibergen-Paap rk Wald F statistic	43.34	43.34	43.34	43.34	43.34
B. Post - Gold Rush					
UNODC gold mining (2014-2022)	217.72 (363.77)	-0.44 (0.37)	1.08 (41.47)	-18.67** (8.31)	16.20 (19.74)
Observations	7,629	7,630	7,630	7,630	7,630
Kleibergen-Paap rk Wald F statistic	7.146	7.146	7.146	7.146	7.146
Gold mining deforestation	-293.57 (718.34)	1.40* (0.76)	49.56 (93.80)	47.44*** (17.72)	-29.71 (32.74)
Observations	8,719	8,720	8,720	8,720	8,720
Kleibergen-Paap rk Wald F statistic	10.972	10.972	10.972	10.972	10.972

Note: Clustered robust standard errors at the municipality level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Violent crime rates are expressed as the number of victims per 100,000 individuals. Each column represents a regression that includes all 1,090 municipalities, with coca crops used as a control variable in all regressions.

Table A5: Instrumental Variable Effect of Gold Mining's Impact on Violence in Areas with Armed Groups during the Gold Rush (2004-2014)

	(1)	(2)	(3)	(4)	(5)
	Displacement	Homicide (SL)	Threat	Homicide	Terrorist Acts
ML estimation (2004-2014)	-78.60 (244.10)	0.13** (0.05)	61.61*** (13.70)	-43.79*** (11.38)	25.67** (10.31)
ML estimation (2004-2014) × Farc or other armed groups	638.28*** (199.79)	0.02 (0.04)	71.34*** (18.23)	-6.48 (16.67)	33.15* (17.56)
Coca crops (ha)	-67.49* (35.94)	0.00 (0.01)	1.85 (1.60)	-3.65** (1.44)	0.99 (1.28)
Kleibergen-Paap rk Wald F statistic	38.589	38.589	38.589	38.589	38.589
Observations	11,959	11,959	11,959	11,959	11,959

Note: Clustered robust standard errors at the municipality level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Violent crime rates are expressed as the number of victims per 100,000 individuals. Each column represents a regression that includes all 1,090 municipalities.

Table A6: Instrumental Variable Effect of Gold Mining's Impact on Violence in municipalities with Ethnic Mining Zones during the Gold Rush (2004-2014)

	(1)	(2)	(3)	(4)	(5)
	Displacement	Homicide (SL)	Threat	Homicide	Terrorist Acts
ML estimation (2004-2014)	-55.37 (246.43)	0.09** (0.04)	59.79*** (15.22)	-44.39*** (12.40)	15.88* (9.32)
ML estimation (2004-2014) × Ethnic mining zones	298.43 (274.80)	0.12* (0.07)	44.74*** (14.54)	-2.08 (15.11)	43.85** (17.50)
Coca crops (ha)	-69.89* (36.15)	-0.00 (0.01)	1.49 (1.50)	-3.63** (1.45)	0.64 (1.22)
Kleibergen-Paap rk Wald F statistic	32.156	32.156	32.156	32.156	32.156
Observations	11,959	11,959	11,959	11,959	11,959

Note: Clustered robust standard errors at the municipality level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Violent crime rates are expressed as the number of victims per 100,000 individuals. Each column represents a regression that includes all 1,090 municipalities.

Table A7: Instrumental variable effect of gold mining on violence. Clustered errors at the province level

	(1)	(2)	(3)	(4)	(5)
	Displacement	Homicide	Threat	Homicide	Terrorist
		(SL)			Acts
A. Gold Rush					
ML estimation (2004-2014)	1.21***	0.18***	0.55**	-0.01	1.15***
	(0.28)	(0.07)	(0.24)	(0.33)	(0.38)
Coca crops (ha)	0.01	0.00	0.02	0.04	-0.00
	(0.02)	(0.01)	(0.02)	(0.03)	(0.02)
Observations	11,959	11,959	11,959	11,959	11,959
Kleibergen-Paap rk Wald F statistic	35.67	35.67	35.67	35.67	35.67
Gold mining deforestation	1.84***	0.28***	0.81**	-0.03	1.76***
	(0.47)	(0.10)	(0.38)	(0.51)	(0.56)
Coca crops (ha)	0.01	0.00	0.02	0.04	-0.01
	(0.03)	(0.01)	(0.02)	(0.03)	(0.03)
Observations	11,990	11,990	11,990	11,990	11,990
Kleibergen-Paap rk Wald F statistic	22.275	22.275	22.275	22.275	22.275
B. Post - Gold Rush					
UNODC gold mining (2014-2022)	-1.41	-0.87	0.02	-1.34	1.26
	(0.92)	(0.61)	(0.47)	(0.86)	(0.99)
Coca crops (ha)	0.02	0.06***	0.01	0.05	0.00
	(0.02)	(0.02)	(0.01)	(0.03)	(0.03)
Observations	7,629	7,630	7,630	7,630	7,630
Kleibergen-Paap rk Wald F statistic	3.168	3.168	3.168	3.168	3.168
Gold mining deforestation	3.60**	1.61**	0.77	2.84**	-3.00**
	(1.57)	(0.63)	(0.99)	(1.40)	(1.32)
Coca crops (ha)	-0.02	0.03	0.00	0.00	0.06*
	(0.03)	(0.02)	(0.02)	(0.04)	(0.03)
Observations	8,719	8,720	8,720	8,720	8,720
Kleibergen-Paap rk Wald F statistic	8.948	8.948	8.948	8.948	8.948

Note: Clustered robust standard errors at the province level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Violent crime rates are expressed as the as the natural logarithm of the number of victims per 100,000 individuals. Each column represents a regression that includes all 1,090 municipalities.

References

- Angrist, J. D. and Kugler, A. D. (2005). Rural Windfall or a New Resource Curse? Coca, Income, and Civil Conflict in Colombia. *The Review of Economics and Statistics*, 90(2):191–215.
- Bautista-Cespedes, O. V., Willemen, L., Castro-Nunez, A., and Groen, T. A. (2021). The effects of armed conflict on forest cover changes across temporal and spatial scales in the Colombian Amazon. *Regional Environmental Change*, 21(3).
- Bazzi, S. and Blattman, C. (2014). Economic shocks and conflict: Evidence from commodity prices. *American Economic Journal: Macroeconomics*, 6(4):1–38.
- Betancur, M. S. (2019). Minería del oro, territorio y conflicto en colombia. *Retos y recomendaciones para la protección de los derechos humanos y del medio ambiente*.
- Bonilla Mejía, L. (2020). Mining and human capital accumulation: Evidence from the Colombian gold rush. *Journal of development economics*, 145:102471–.
- Brückner, M., Ciccone, A., and Tesei, A. (2012). Oil price shocks, income, and democracy. *Review of Economics and Statistics*, 94(2):389–399.
- Brückner, M. and Ciccone, A. (2010). International commodity prices, growth and the outbreak of civil war in sub-saharan africa. *The Economic journal (London)*, 120(544):519–534.
- Brückner, M., Ciccone, A., and Tesei, A. (2012). Oil price shocks, income, and democracy. *The review of economics and statistics*, 94(2):389–399.
- Diaz, F. A., Katz, L. E., and Lawler, D. F. (2020). Mercury pollution in colombia: challenges to reduce the use of mercury in artisanal and small-scale gold mining in the light of the minamata convention. *Water international*, 45(7-8):730–745.
- Dube, O. and Vargas, J. F. (2013). Commodity price shocks and civil conflict: Evidence from colombia. *The Review of economic studies*, 80(4 (285)):1384–1421.
- Echavarría, C. (2014). What is legal? formalising artisanal and small-scale mining in colombia. *IIED, London and ARM, Colombia*, 79.
- Echavarría, E. and González, N. (2016). La formalización de la pequeña minería en Colombia: experiencias desde el territorio. *Serie sobre la MAPE Responsable*, 9.

- Fearon, J. D. and Laitin, D. D. (2003). Ethnicity, insurgency, and civil war. *American political science review*, 97(1):75–90.
- Giménez-Gómez, J.-M. and Zergawu, Y.-Z. (2018). The impact of social heterogeneity and commodity price shocks on civil conflicts. *Journal of Policy Modeling*, 40(5):959–997.
- Goñi, E. A., Sabogal, A., and Asmat, R. (2014). Minería informal aurífera en Colombia.
- Guerrero, L., Herrera, L., García, M., Coronado, S., Cadena, A., Figueroa, M., and Yépez, A. (2012). Minería, conflictos sociales y violación de derechos humanos en Colombia. *Segundo informe especial CINEP. Bogotá, Colombia.*
- Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., Thau, D., Stehman, S. V., Goetz, S. J., Loveland, T. R., et al. (2013). High-resolution global maps of 21st-century forest cover change. *science*, 342(6160):850–853.
- Ibáñez, A. M. and Velásquez, A. (2009). Identifying victims of civil conflicts: An evaluation of forced displaced households in Colombia. *Journal of Peace Research*, 46(3):431–451.
- Idrobo, N., Mejia, D., and Tribin, A. M. (2014). Illegal gold mining and violence in colombia. *Peace Economics, Peace Science and Public Policy*, 20(1):83 – 111.
- Márquez, F. and Salcedo, C. (2012). Defensa del territorio y resistencia afrocolombiana en el norte del Cauca. *C. Toro Péres, J. Fierro Morales, S. Coronado Delgado, & T. Roa Avendaño, Minería Territorio y Conflicto en Colombia*, pages 427–436.
- Massé, F. and Billon, P. L. (2018). Gold mining in Colombia, post-war crime and the peace agreement with the FARC. *Third World Thematics: A TWQ Journal*, 3(1):116–134.
- McNeish, J.-A. (2016). Extracting justice? Colombia’s commitment to mining and energy as a foundation for peace. *The International Journal of Human Rights*, 21(4):500–516.
- Miguel, E., Satyanath, S., and Sergenti, E. (2004). Economic shocks and civil conflict: An instrumental variables approach. *Journal of political Economy*, 112(4):725–753.
- Millán-Quijano, J. and Pulgarín, S. (2023). Oiling up the field. forced internal displacement and the expansion of palm oil in colombia. *World Development*, 162:106130.
- Nunn, N. and Qian, N. (2014). US food aid and civil conflict. *American Economic Review*, 104(6):1630–1666.
- OECD (2017). Due diligence in Colombia’s gold supply chain. <https://doi.org/10.1787/9789264279899-en>.

- Ortiz-Riomalo, J. and Rettberg, A. (2018). Minería de oro, conflicto y criminalidad en los albores del siglo XXI en Colombia: Perspectivas para el posconflicto colombiano. *Colombia. int.* 2018; 93: 17-63.
- Prem, M., Rivera, A. F., Romero, D. A., and Vargas, J. F. (2022). Selective Civilian Targeting: The Unintended Consequences of Partial Peace. *Quarterly journal of political science*, 17(3):317–354.
- Prem, M., Saavedra, S., and Vargas, J. F. (2020). End-of-conflict deforestation: Evidence from Colombia’s peace agreement. *World Development*, 129:104852.
- Rettberg, A. and Ortiz-Riomalo, J. F. (2016). Golden Opportunity, or a New Twist on the Resource–Conflict Relationship: Links Between the Drug Trade and Illegal Gold Mining in Colombia. *World Development*, 84:82–96.
- Romero, M. and Saavedra, S. (2021). Replication Data for: Local Incentives and National Tax Evasion: The Response of Illegal Mining to a Tax Reform in Colombia.
- Saavedra, S. and Romero, M. (2021). Local incentives and national tax evasion: The response of illegal mining to a tax reform in Colombia. *European Economic Review*, 138:103843.
- Saldarriaga, J. F. and Hua, Y. (2019). A gravity model analysis of forced displacement in Colombia. *Cities*, 95:102407.
- Snyder, R. (2006). Does lootable wealth breed disorder? A political economy of extraction framework. *Comparative political studies*, 39(8):943–968.
- UNODC (2022). Alluvial Gold Exploitation in Colombia: Evidence from Remote Sensing as Dated 2021. Technical report, United Nations Office on Drugs and Crime.
- UNODC, G. (2016). Explotación de oro de aluvión: evidencia a partir de percepción remota. *Oficina de las Naciones Unidas contra la Droga y el Delito (UNODC) y Gobierno de Colombia*. Dataset: Sistema de Acceso a la Información (SAI) EVOA.
- Veiga, M. M. and Marshall, B. G. (2019). The Colombian artisanal mining sector: Formalization is a heavy burden. *The Extractive Industries and Society*, 6(1):223–228.
- Vélez-Torres, I. (2014). Governmental extractivism in Colombia: Legislation, securitization and the local settings of mining control. *Political Geography*, 38:68–78.
- Vélez-Torres, I. and Agergaard, J. (2014). Political remittances, connectivity, and the trans-

local politics of place: An alternative approach to the dominant narratives on displacement in Colombia. *Geoforum*, 53:116–125.

Vélez-Torres, I. and Méndez, F. (2022). Slow violence in mining and crude oil extractive frontiers: The overlooked resource curse in the Colombian internal armed conflict. *The Extractive Industries and Society*, 9:101017.

Weitzner, V. (2012). *Holding Extractive Companies to Account in Colombia: An Evaluation of CSR Instruments Through the Lens of Indigenous and Afro-descendant Rights*. North-South Institute.