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Violence and Gold price shocks in the Brazilian Amazon: an exploratory analysis

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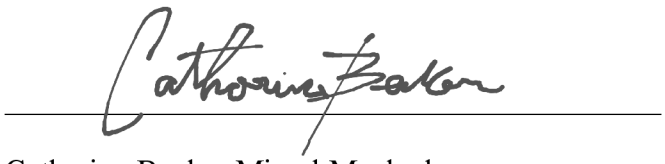
Supervisor: Pascale Combes Motel

Declaration

I declare in lieu of oath, that I wrote this thesis myself.
All information derived from the work of others has been acknowledged in the text and the list of references is given.



Catharina Becker Missel Machado

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Theses guidelines: Brazil is one of the most vulnerable countries to climate change: extreme temperatures, rising seas, heavy rainfall and droughts are already a reality in the country (UNDP, 2020), increasing demand and decreasing surface water availability (Hirata; Conicelli, 2012) as well as shortages in food production (Jelani, 2017). The environmental degradation, according to the neo-malthusian theory, combined with a rapid population growth is likely to lead to extreme levels of hunger and widespread violent conflict (Erlich, 1968; Kaplan, 1994). In this context, the present research seeks to contribute to the body of subnational empirical studies by analyzing the relationship between weather shocks and conflict incidence in Brazil, taking into account mining companies activities. In order to do that, the research will use quantitative data available by public and private sources to measure incidence of conflict, weather shocks and presence of mining industry activities. From the best of our knowledge, there is no dataset available yet that brings together weather shocks, conflict and mining activities in Brazil yet and building the dataset itself will be an important contribution to the field. Apart from that, we expect to contribute with descriptive statistics on the subject.

Recommended resources: Verpoorten (2012); Raleigh & Urdal (2007); Hidalgo et al. (2010); Harari & Ferrara (2017); Collier & Hoeffler (1998); Urdal (2005); Theisen (2008)

Supervisor's signature: Date: January 13, 2023

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Abstract

The rise in international commodity prices following the 2008 global financial crisis sparked a gold stampede in the Brazilian economy, particularly in the Amazon region, one of the main gold-rich zones in the country, making both legal and illicit mining a highly profitable and alluring business. It is believed that the increased illicit mining of gold has exacerbated violence in areas with abundant metals, becoming a new driving force in Brazilian conflicts. In this context, the present thesis is a preliminary investigation of the relationship between mining and conflict through an extensive microeconomic literature review and descriptive statistics on the gold surge's correlation and four different measures of violence, including homicide rate, firearm death rate, violent causalities, and aggregated rural violence. An entirely new dataset is created for Brazilian municipalities located in the Legal Amazon to determine those which are exposed to illegal mining and how they are affected by violence. To circumvent the paucity of data on illicit mining in Brazil, we use the location of protected areas, such as Indigenous Territories and Natural Conservation Areas, and deforestation rates as instruments to determine municipalities exposed to illegal mining. In protected areas, no mining of any kind is allowed, meaning that all mining activities in municipalities with these characteristics are illegal. We conclude by demonstrating that the municipalities exposed to illegal mining present 13.8% more incidences of homicide rate than municipalities exposed to legal mining and 63% more than municipalities not exposed to mining and that the violence indicators seem to be correlated with the international gold price.

Keywords: Amazon region, Illegal Gold mining, Violence, Gold price, Death Rate

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List of Abbreviations

ANM	National Mining Agency
FCB	Federal Constitution of Brazil
FUNAI	National Indian Foundation
FIRJAN.	Federation of Industries of the State of Rio de Janeiro
IBAMA	Brazilian Institute of the Environment and Renewable Natural Resource
IBGE	Brazilian Institute of Geography and Statistics
IBRAM	Brazilian Mining Institute
INCRA	National Institute for Colonization and Agrarian Reform
PLG	Permissão Lavra Garimpeira

1 Introduction

Over the past decade, the Brazilian Amazon Region[1] has become increasingly violent, contrasting with other Brazilian states. Despite a significant decline in violence in 2018 and 2019[2], Amazon's homicide rate increased by approximately 100% between 2005 and 2015 in contrast with other Brazilian states (Deluchey & Santos, 2018). The rising homicide rate in the Amazon occurs at an already lofty point - in 1996, three-quarters of national homicides occurred in the Amazon Region (Simmons, 2005) – turning the area into one of the most hazardous in the country. According to the ranking of the most dangerous countries in the world from Statista[3], if the North of Brazil[4] were a country, its homicide rate of 33 per 100,000 inhabitants (Fórum Brasileiro de Segurança Pública, 2022) would make it the eleventh most dangerous in the world, ahead of Mexico, Colombia, and Nigeria (Fabio, 2022) (Statista, 2022).

The causes of this peculiar increase include illegal resource exploration (Pereira & Pucci, 2021), regulation on the trade of specific resources (Chimeli & Soares, 2017), land disputes (Simmons, 2005), and the absence of well-established institutions (Duchelle, Cronkleton, Kainer, & Guanacoma, 2012) (Alston, Libecap, & Schneider, 1995). Despite these traditional explanations, we will discuss a second, largely unexplored source of conflict. We believe that illegal gold mining, fueled by the boom in gold prices, explains at least a portion of the observed increase in violence in the Amazon region during the 2000s.

The Brazilian Legal Amazon comprises 321 identified points of illicit, active, and inactive mines, distributed across 132 areas in the nine states comprising the Amazon

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[1] In the present study the terms Brazilian Amazon region, Amazon region, Amazon basin, and Legal Amazon will be used interchangeably. More specifically, we are referring to the nine states part of the socio-geographic division of the Legal Amazon: Acre, Amapá, Amazonas, Pará, Rondônia, Roraima, Tocantis, Mato Grosso, and the western part of Maranhão. (IBGE, 2021)

[2] Cerqueira (2014) conducted arguably the most exhaustive empirical analysis of homicide trends in Brazil, which is recommended for understanding the factors that could explain the significant decrease in the Brazilian homicide rate throughout 2019. The author argues that between 2011 and 2007, homicide rates in Brazil decreased in tandem with reductions in inequality, increases in income, a smaller proportion of young men, and increases in incarceration rates (Cerqueira D. R., 2014). To read further: > https://web.bndes.gov.br/bib/jspui/handle/1408/1922> . Accessed on May 5, 2023. <.

[3] Statista is a private online platform that provides statistics and reports for several industries, including data on crime and law enforcement across the globe. For more information regarding their statistics: < https://www.statista.com/markets/411/topic/546/crime-law-enforcement/#overview>

[4] The Brazilian North region comprises seven states – Acre, Amapá, Amazonas, Pará, Rondônia, Roraima and Tocantins -, and all of them are part of the Legal Amazon. (IBGE, 2021)

Basin (Deutsche Welle, 2018), and much of the deforestation in 2020 is attributed to illegal mining (Fellet, 2019).[5] The phenomenon exemplifies the plausibility of our hypothesis that homicides can be associated with the illegal exploration of gold in the Brazilian Amazon, especially in periods of high international gold prices. If our assumption is correct, we expect to see higher homicide rates in areas more exposed to gold deposits when prices for gold in the international market go up.

In Latin America and Africa, the increase in gold prices attracted organized criminal groups that perceived illegal gold extraction as a new profitable business which can be a plausible explanation for the connection between illegal gold mining and higher levels of violence in the Amazon municipalities (Wagner & Hunter, 2020). In light of this, the present study will pay close attention to the criminal networks operating behind illegal gold mining in the Amazon.

The Brazilian Amazon is a hub for the multiple relationships that are established on the regional/global market for drug and armaments trafficking. Due to its location, it must be viewed in a broader context in terms of the forms of occupation and use of its territory by the organized criminal networks and illegal activities that operate there (Fórum Brasileiro de Segurança Pública, 2022). In this environment of high international gold prices, non-state armed groups shift from their traditional markets, such as drugs and human trafficking, and specialize in the trade of minerals and the illegal extraction of gold (Nellemann, et al., 2016).

Consequently, it is essential to recognize the significance of criminal organizations to regional criminal dynamics. The relative weight of these organizations in Brazil's illicit sector, particularly in the Amazon region, is substantial. Since agents operating in unlawful markets cannot rely on the legal system to enforce contracts, protect property rights, or settle internal disputes, they employ violence as a means of commitment and arbitration (Chimeli & Soares, 2017). According to the Council of Europe (2000), some of the fundamental characteristics of a criminal organization consist of the use of violence for intimidation and control (Council of Europe, 2000).

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[5] More specifically, Amazon deforestation grew by 25% in the first half of 2020 and much of it is attributable to illegal mining. In the first half of 2019, the state of Roraima, home to the Yanomami, exported 288 kilograms of gold legally, despite the absence of an authorized mine for gold extraction in Roraima (Fellet, 2019).

In Brazil, the connection between illegal mining and organized crime has recently captured the attention of governments and the media, nationally and internationally. Recent reports by Instituto Igarapé[6], Lagesa[7], WWF[8], and Instituto Escolhas[9] have highlighted the detrimental effects of illegal gold mining on Brazil's level of criminality, deforestation, and violence. Internationally, media outlets such as Financial Times[10], Aljazeera[11]and The New York Times[12] also report the harmful effects of illegal mining on the country's socio-development. Even the United States Treasury imposed sanctions on Brazilian criminal organizations to combat narcotics trafficking[13]. However, with limited exceptions, very few academic studies have already examined the effects of the mining surge on violence in Brazil, the present thesis topic of research.

Given that gold is the second-most exported mineral in Brazil (Risso, Sekula, Brasil, Schmidt, & Assis, 2021) and that the mining sector has the potential to expand further, the debate regarding gold extraction and violence is crucial. According to the IBRAM (Brazilian Mining Institute)[14], approximately 95 tons of gold (US$ 2.8Bn) were exported in 2018 (Risso, Sekula, Brasil, Schmidt, & Assis, 2021). Moreover, the country's vast size suggests the possibility of significant mining developments in the near to medium future, turning the country into a global and national center for gold extraction (Costa & Rios, 2022). Currently, industrial mining operations in Brazil produce roughly 2,000 kilograms of gold from more than 80 mines (Costa & Rios, 2022), and relatively new gold-frontier areas have been established in the Amazon region. Minas Gerais, which is not part of the Amazon Region, has historically been the most important Brazilian state for gold extraction and still has a significant number of mines. Nonetheless, Amazonian areas - especially in the surroundings of the Serra dos Carajás, Tapajós, Alta Floresta-

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[6]Available at: < https://igarape.org.br/wp-content/uploads/2021/12/2021-12-08-Illegal-mining-guide-EN.pdf>. Accessed on April 28, 2023.

[7] Available at <http://www.lagesa.org/wp-content/uploads/documents/Manzolli_Rajao_21_Illegal_gold.pdf>. Accessed on April 28, 2023.

[8] Available at < https://d3nehc6yl9qzo4.cloudfront.net/downloads/mineracao_na_amazonia_legal_web.pdf>. Accessed on April 28, 2023.

[9] Available at https://www.escolhas.org/wp-content/uploads/Gold-under-the-microscope-more-than-200-tons-of-brazilian-gold-are-potentially-illegal.pdf. Accessed on April 28, 2023.

[10] Available at <https://www.ft.com/content/20fb5c77-baf1-45ab-a886-51cac68cfd4e.>. Accessed on April 28, 2023

[11] Available at <https://www.aljazeera.com/news/2021/6/14/indigenous-reel-from-brazil-illegal-gold-mining> Accessed on April 28, 2023

[12] Available at< https://www.nytimes.com/interactive/2022/08/02/world/americas/brazil-airstrips-illegal-mining.html>. Accessed on April 28, 2023

[13] Available at < https://br.usembassy.gov/u-s-department-of-treasury-targets-narcotics-traffickers-and-their-supporters-using-enhanced-counter%E2%80%AFnarcotics-authorities/>. Accessed on May 9, 2023.

[14] Available at: <https://ibram.org.br/en/>. Accessed on April 28, 2023

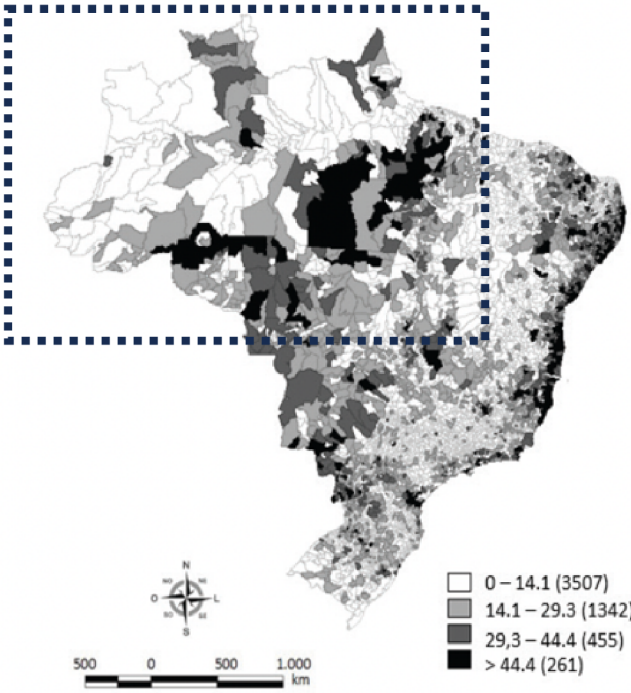
Peixoto de Azevedo, and Amapá regions - represent the frontier of new discoveries, with great potential for the future development of industrial gold mining. In the Amazonian state of Pará, the documented artisanal extraction prior to the 20th century is scarce and poorly documented. In contrast, the gold mining industry has exploded in the last fifty years, to the point where it is now one of the leading participants in the Brazilian gold market. Minas Gerais, which is home to the two largest gold mines in Brazil, remains the country's most important gold producer; however, the Amazon region is establishing itself as an irreversible leader in this field[15] (Costa & Rios, 2022).

In addition, the mining industry has received substantial federal support since the Brazilian government has recently publicly supported the activity. In this context, it is imperative that policymakers make the connection between illegal gold mining and violence a top priority, as the rising international price of gold affects both the legal (The World Bank, 2023) and illegal mining markets (Wagner & Hunter, 2020) (Risso, Sekula, Brasil, Schmidt, & Assis, 2021). In recent years, the increase in the international price of gold has led to an increase in the legal and illicit mining of gold in Brazil (The World Bank, 2023).

When the map of gold deposits in Figure 1 is juxtaposed with homicide rates in Figure 2, empirical indices of the correlation between violence and gold seem to emerge. We believe that when the price of gold rises, disputes over the control of a more lucrative resource lead to an increase in violence in these regions.

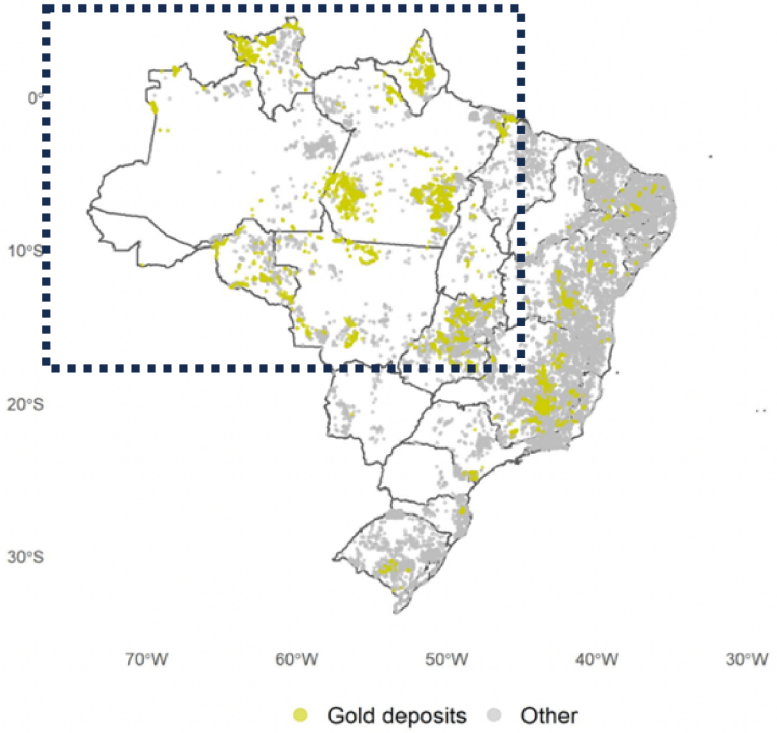
[15] To read more about the importance of the Amazonian minerals in the Brazilian national account: < https://ibram.org.br/noticia/amazonia-e-destaque-na-balanca-comercial-mineral/>. Accessed on May 19th, 2023

Figure 1: Homicide rate (per 1000 habitants) in Brazil in 2019



Source: *(Barros, Baggio, & Baggio, 2020)*

Figure 2: Gold deposits vs Other mineral deposits in Brazil



Source: (Pereira & Pucci, 2021)

In light of the aforesaid, the primary objective of this research project is to provide a preliminary examination of the increase in illicit gold extraction, the rising price of gold, and the level of violence in the gold-rich Amazon region. By conducting the research, we contribute to the literature in multiple ways. First, we study a largely unexplored link between violence and the abundance of gold deposits in the Amazon. To the best of our knowledge, Pereira & Pucci's (2021) analysis of the impact of market regulation on the incidence of violence in the Amazon region is the study closest to our objective but does not cover the effect of price shocks in the international gold market. Since they focus specifically on the regulatory change of the mining policy, they do not analyze commodity market effects that might affect the increase in illegal gold mining exploration as well, and consequently, in the incidence of mortalities.

Second, in contrast to other subnational analyses of the resource curse (Harari & Ferrara, 2018), we document information regarding the global prices of nonrenewable resources. Most subnational analyses use the existence of a natural resource extraction site as their independent variable, but they lack information on the output and value of this output. It is plausible to expect that a site's output value influences pertinent economic, political, and social outcomes, making this a potentially significant gap.

Third, to the best of our knowledge, we are the first to document a comprehensive review of the multiple conflict drivers in the Brazilian Amazon region using microeconomic literature. Fourth, we conduct original data collection on mining and violence to generate an entirely new dataset at the subnational level, compiling data from multiple sources. Fifth, there is an abundance of literature on violence in Brazil since the country has one of the highest homicide rates in the world (Ceccato, Kahn, & Vazquez, 2021).–Ceccato, Kahn, & Vazquez (2021) alone amassed over three thousand publications on the subject. However, despite the academic attention to the security issue on the national level, at the regional level academic investigations are scarce. In this context, this research seeks to contribute to Ceccato, Kahn, and Vazquez's (2021) call for a more systematic compilation of data on violence.

Therefore, its primary contribution is to introduce a preliminary investigation of the illegal mining boom on violence in Amazonian municipalities by describing the evolution of four measures of violence in municipalities exposed to illegal mining, legal mining, and municipalities non-exposed to mining activities from 2000 to 2019. We believe that illegal mining affects violence in the Legal Amazon through territorial control

disputes between illegal armed groups in regions of the country with abundant gold deposits.

Our findings indicate that municipalities exposed to illegal mining present a higher incidence of violence for all four violence measures in comparison with municipalities exposed to legal mining or not exposed to any mining activity. The findings are consistent with the academic literature on the so-called "natural resource curse," in which the abundance of a natural resource is associated with higher violence rates during conflicts (Paul Collier, 1998) (Fearon & Laitin, 2003) (Collier & Hoeffler, 2004), and more specifically to the "local resource curse" which focus specifically on the effects of natural endowments in terms of social conflicts on counties, regions, and localities (Sexton, 2020) (Loayza, Teran, & Rigolini, 2013). We believe that the recent gold rush become a new propelling force in the country's violence statistics. As a consequence of the unprecedented increase in the profitability of gold extraction (Rettberg & Ortiz-Riomalo, 2016), both non-state armed groups and informal and illegal miners have been embroiled in territorial control conflicts over gold mines, exacerbating violence in certain regions of the country.

We conduct the study in three main parts. First, we present stylized facts to illustrate the trend of violence in the Amazon and later discuss the causes for such a trend using relevant academic literature on violence in the Brazilian Amazon as a guideline. As we are interested in understanding the gold price shock on the incidence of violence in the Amazon, we add a subsection for presenting the main findings in the literature on natural resources and violence, especially the relationship between commodity price fluctuations and violence. Second, we present and describe our entirely new dataset for violence and mining status for municipalities located in the Legal Amazon. Third, we present stylized facts to provide adequate data visualization on the relationship between violence and mining exposure. Finally, we conclude with the main findings regarding gold price shocks and violence in the Brazilian Amazon.

2 Literature Review

The present section develops further on violence in the Brazilian Amazon. Firstly, we provide a brief context of the violence trend in the Amazon municipalities using stylized facts. Secondly, we present the main academic studies that attempt to explain what pushes violence upward in the region. Thirdly, we put natural resources and

violence into perspective and discuss the relevant literature on the natural resources curse, with a focus on commodity price fluctuations.

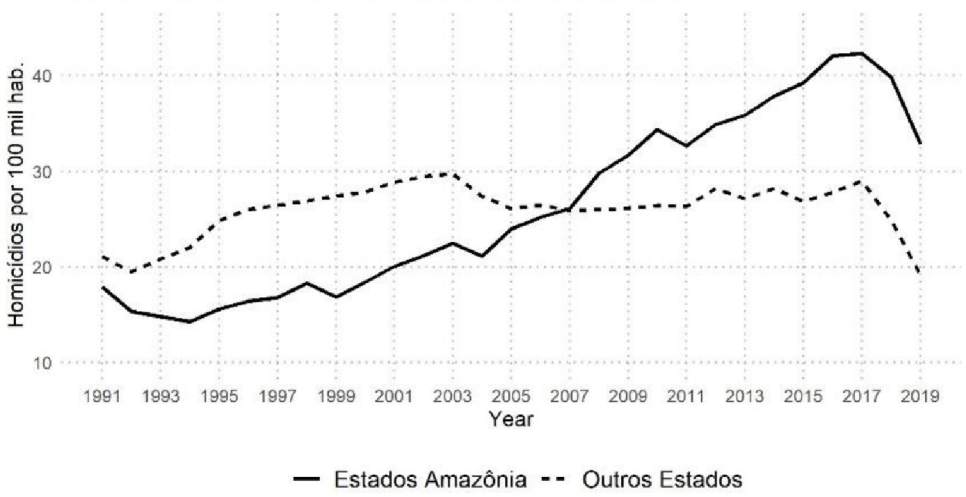
2.1 Violence in the Amazon Region

In contrast with recent findings which demonstrate that there is a higher risk for homicidal violence in Brazilian urbanized areas (Wanzinack, Signorelli, & Reis, 2022), the participation of urban homicides in the Amazon total has decreased progressively. In 1997, approximately 43% of homicides occurred in Amazonian metropolitan areas, ten years later, this proportion fell to 34.6%; and in 2019, it dropped to 22.2% (Cerqueira, et al., 2019). Even having a low percentage of urbanization, the homicide rate in Amazonian municipalities increased by 62% in 2021, while the national average decreased by 9.3% (Fórum Brasileiro de Segurança Pública, 2022). It is also worth noting that the phenomena could not be explained by people leaving the cities since the region passes through a process of urbanization (Ferreira, et al., 2021).

To explain Amazon's violence trend in further detail, we analyze violence rates[16] between Amazon and the rest of Brazil, analyzing state and municipal homicide rates. According to (Soares, Pereira, & Pucci, 2021), the violence in the Amazonian states is remarkably higher than in other states in Brazil. Figures 3 and 4 depict the historical series of homicide rates and the difference between the homicide rates in Amazon states and the rest of Brazil between 1991 and 2019. As we can see, until the end of the 1990s, violence levels in the Amazon were relatively low compared to the rest of the country – the homicide rate in 1991 was approximately 17 per 100,000, which was approximately 70% of the rate observed in other regions.

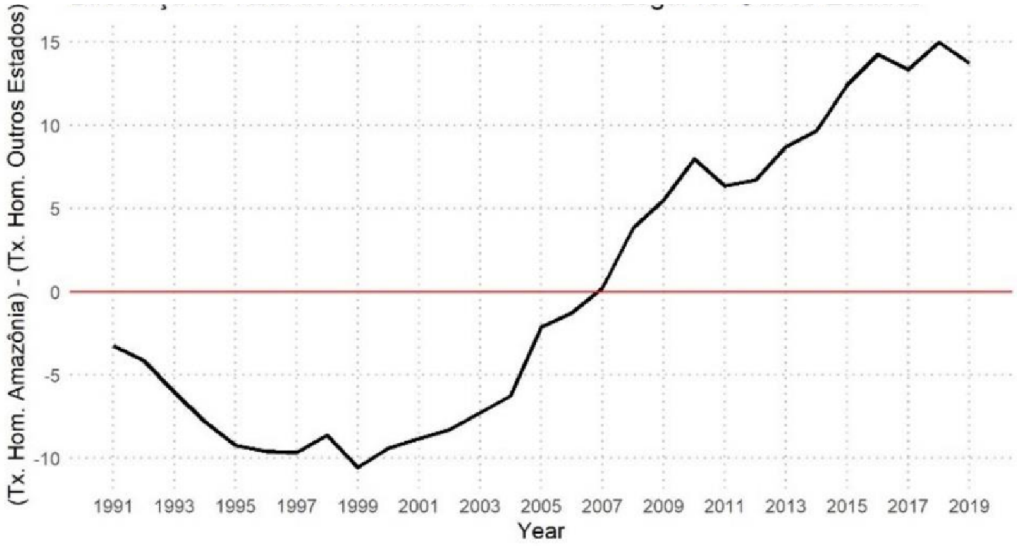
[16] The homicide data used comes from a source different than ours: the Brazilian Health System database (DATASUS)[16] and it is used according to the definition of assault mortality (Assault by means of physical violence; X93 – Assault by firing handgun, and Y03 – Assault by motorvehicle impact, among others) present in the International Classification of Disease (ICD-10), under the responsibility of the World Health Organization

Figure 3: Homicide rates Legal Amazon vs. Other states



Source: (Soares, Pereira, & Pucci, 2021)

Figure 4: The difference in the homicide rate – Legal Amazon vs. other states



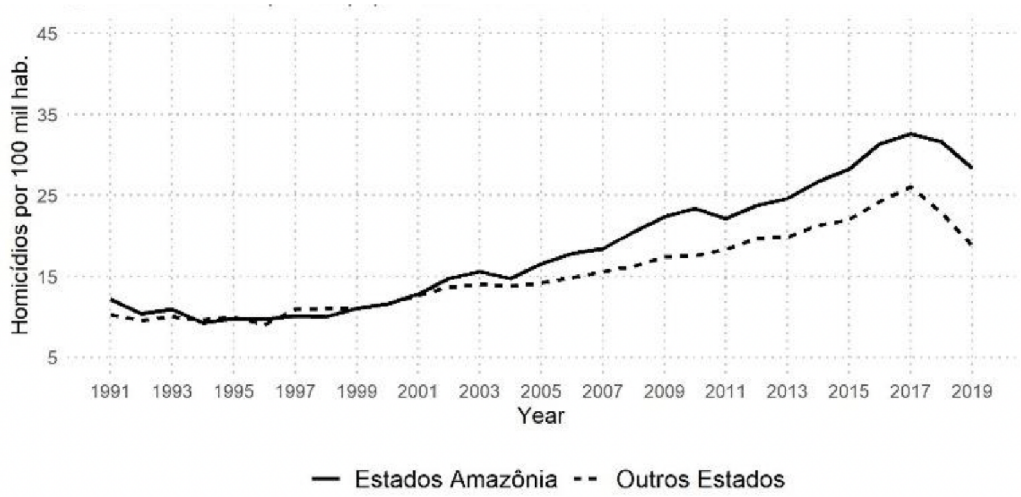
Source: (Soares, Pereira, & Pucci, 2021)

Beginning in 1999, however, the rate of violence in the Amazon accelerated significantly. In 2007, they reached parity with the rest of the country, and since then, they have followed an upward trend that has almost perpetually diverged from that of other regions. At the end of 2010, homicide rates in the Amazon were 70 percent higher than in other regions of Brazil (equivalent to approximately 15 additional homicides per 100,000 inhabitants). The difference in homicide rates between the Legal Amazon and other regions of the country shown in Figure 4 corresponds to a total of 12,160 deaths

between 1999 and 2019 (Soares, Pereira, & Pucci, 2021). This is the number of lives that would not have been lost if small municipalities in the region had maintained a trajectory similar to the rest of Brazil.

Figure 5 depicts the evolution of homicide rates in municipalities with fewer than 100,000 residents in Legal Amazon states and other states of the country[17]. During the early 1990s, the intensity and dynamics of violence in small municipalities in the Legal Amazon were remarkably similar to those observed in small municipalities in other regions of the country. From 1999 onwards, however, a trend reversal occurs, and the rate in the Legal Amazon begins to diverge from that observed in the rest of the country, reaching a level in 2019 that is roughly 50 percent higher than that observed in other regions (Soares, Pereira, & Pucci, 2021).

Figure 5: The difference in the homicide rate – Legal Amazon vs. other states in Municipalities with less than 100,000 inhabitants



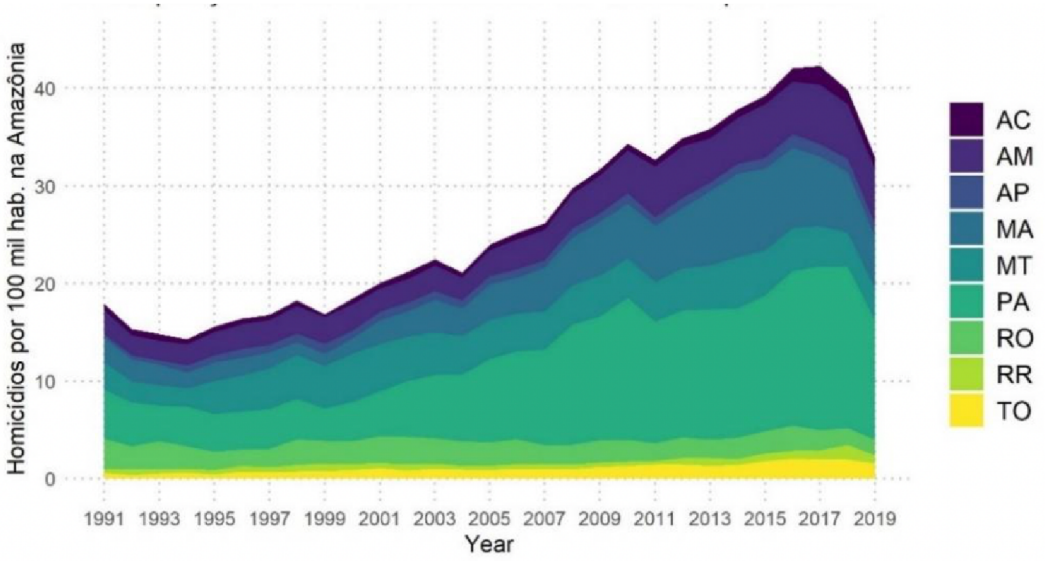
Source: (Soares, Pereira, & Pucci, 2021)

Analyzing the relative numbers, such as the difference between the two regions, reveals that this separation appears to occur in two cycles. The first phase occurs between 1999 and the end of the 2000s, when the homicide rate in the Legal Amazon begins to increase much more rapidly, before slowing down and approaching the levels observed in other regions. Then, beginning in 2013, there is a new acceleration and expansion of the detachment, which continues almost continuously until 2019.

[17] For more information on the differences between violence trends in small and large municipalities, the Appendix A displays the violence decomposed by Amazon states

Looking at violence between regions, Figure 6 demonstrates that the evolution of violence in the Amazonian states has not been uniform. While some states, such as Pará and Maranhão, appear to be responsible for an increasing proportion of the region's homicide rate, others, such as Rondônia and Mato Grosso, appear to maintain a constant or declining proportion. In this regard, Figure 6 provides an indication of the increasing role of the state of Pará, specifically in total homicides. The beginning of the marked increase in the relative participation of Pará coincides precisely with the year 1999, which corresponds to the inflection point shown in Figure 4 as the time when homicide rates in the Amazon began to increase significantly sustained and quicker than the national average.

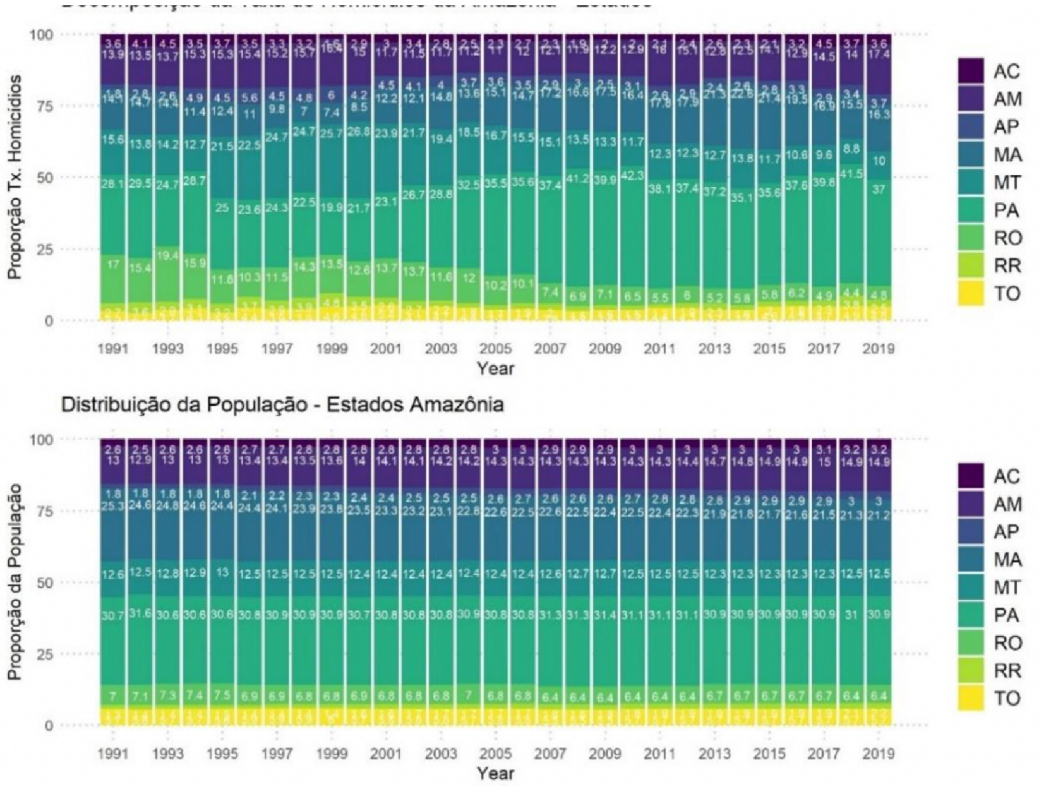
Figure 6: Regional homicide Rate, Legal Amazon States, 1991-2019



Source: (Soares, Pereira, & Pucci, 2021)

The increasing significance of Pará and other states in the region's violence could be attributable to both disproportionate increases in homicides and relative population growth, assuming that homicide rates remain constant. Nonetheless, Figure 7 - a state-by-state analysis of Amazon's total number of homicides and population – demonstrates that population changes between Amazonian states were comparatively minor and cannot account for the patterns in violence observed in Figure 6. Even though some states grew - Amazonas, where participation rose from 13% to 15%, and Amapá, where participation rose from 1.8% to 3%, for example - these changes in population composition pale in comparison to the relative changes in homicide rates.

Figure 7: Distribution of the Number of Homicides and Populations



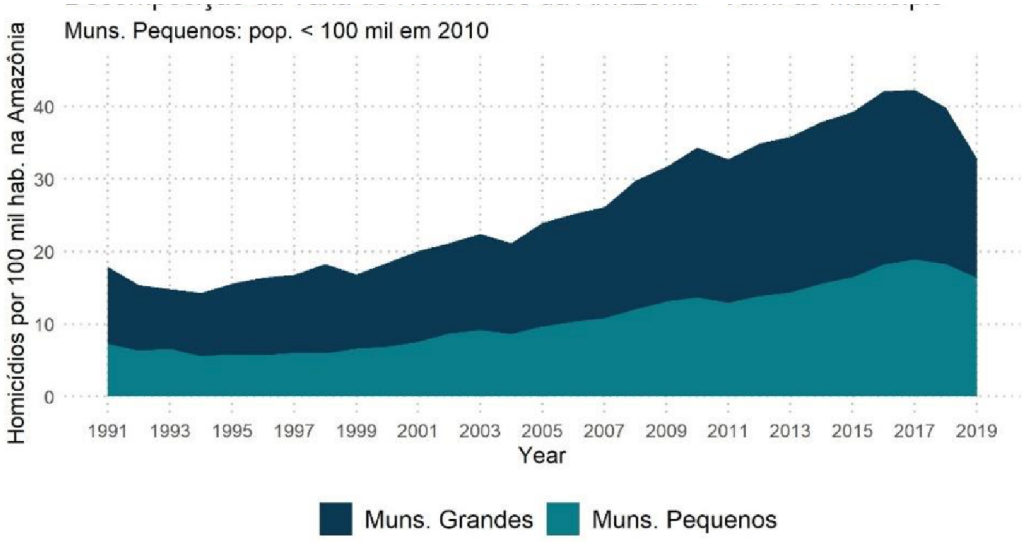
Source: (Soares, Pereira, & Pucci, 2021)

The lower panel of Figure 7 demonstrates that the state of Pará, which plays a prominent role in the region's population, maintains a largely constant population share throughout the period. This indicates that the changes observed in Figure 6 are a result of distinct dynamics of homicides across states and not a result of population composition changes. The panel of Figure 7 supports this conclusion. Despite its constant population, Pará's share of total homicides declines from 28% to 20% between 1991 and 1999 and then approaches 40% in the final years of the 2010s. Other states, such as Amazonas and Maranhão, also experience increases in their relative participation, but none is comparable to the rate observed in Pará, nor does it have such a large relative weight within the region. Therefore, figures 6 and 7 combined indicate that the narrative of the unbroken rise in violence in the Legal Amazon from the late 1990s onwards is, to a significant extent, the story of the rise in violence in Pará.

From the municipality-level perspective, the increase in violence was observed in both large and small municipalities, but it was more pronounced in small municipalities, as shown in Figure 8. In 1991, tiny municipalities were responsible for

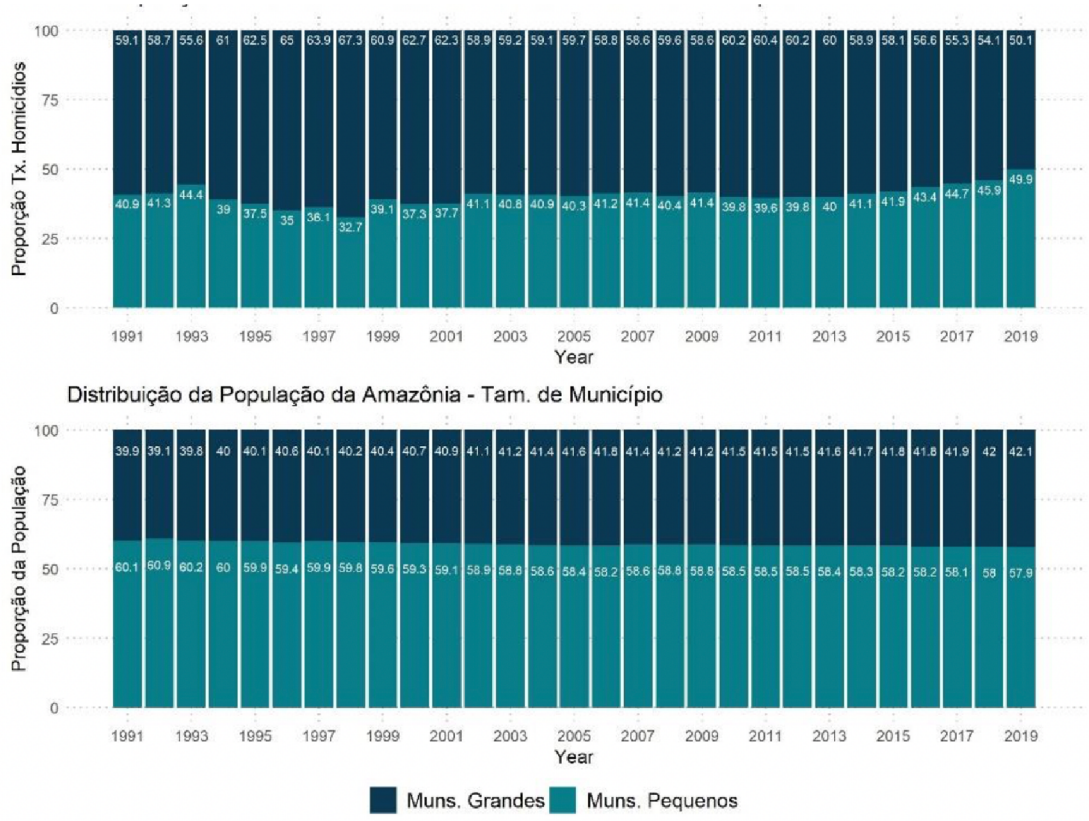
41% of homicides in the Legal Amazon; by the end of the 2010s, they were responsible for 50%. During the same time period, the percentage of Amazonian residents living in tiny municipalities decreased from 60% to 58%. During the period, a partial convergence of the average levels of violence in Amazonian minor municipalities and more urbanized regions was observed.

Figure 8: Homicide Rate Decomposition in Municipality Size (<100 thousand hab)



Source: (Soares, Pereira, & Pucci, 2021)

Figure 9: Homicide Rate Decomposition in Municipality Size in Amazonia



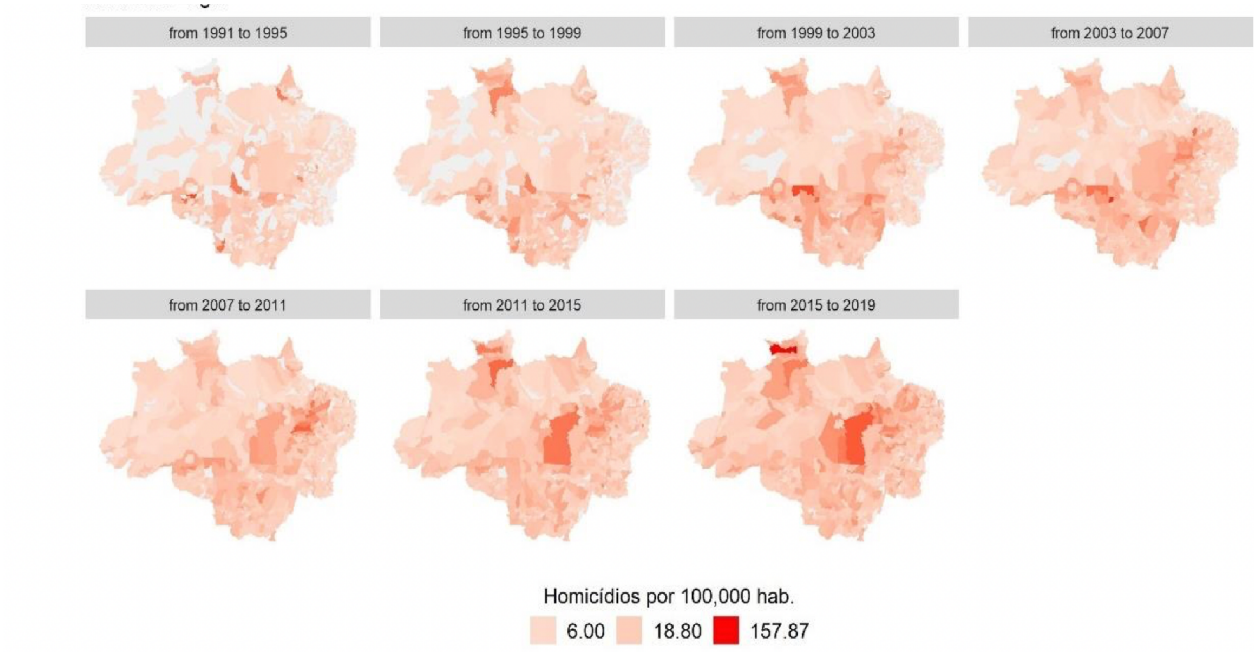
Source: (Soares, Pereira, & Pucci, 2021)

It is also noteworthy to observe that the process of increasing minor municipality participation in regional violence was not uniform. These municipalities tended to reduce their participation from 41% to 33% between 1991 and 1998 (Soares, Pereira, & Pucci, 2021). After 1999, however, they began an upward trend. As with the relative behavior of the Amazon in comparison to the rest of Brazil and the role of the state of Pará in the aggregate dynamics of violence in the region, the end of the 1990s also represents a unique moment in terms of the behavior of violence in small municipalities.

Figure 10 concludes the evidence presented in this section by examining the geographic dimension of recent changes in violence in the Legal Amazon states. The figure depicts diagrams illustrating the spatial distribution of the municipal homicide rate during seven subperiods from 1991 to 2019. The darker the color, the greater the homicide rate. The graph depicts the escalation of violence in the Amazon and its concentration, for the majority of the period, in southwest Pará. In particular, the region comprising the municipalities of Altamira, Itaituba, Jacareacanga, and Novo Progresso is experiencing an alarming rise in homicide rates. The findings are particularly pertinent to our study

since all of the municipalities have gold reserves. In addition, the map demonstrates a substantial increase in the level of violence in Roraima, which was not as evident in the previous diagrams due to the state's decreased population share in the region.

Figure 10: Geographic Evolution of the Homicide Rates, Municipalities, 1991-2019



Source: (Soares, Pereira, & Pucci, 2021)

This section concludes with a summary of the most important takeaways from the evidence presented. In this regard, it is important to emphasize the patterns that emerge in both the geographical and chronological dimensions. Geographically, a disproportionate share of the increase in violence observed in the Amazon over the past few decades is concentrated in relatively small municipalities (with fewer than one hundred thousand inhabitants), especially in the state of Pará. This finding demonstrates that, despite the recent dynamics of violence in the region's urban areas, environmental offenses appear to be potential explanations for the observed increase in historical homicide rates.

From a chronological standpoint, there appear to be three key moments: (I) the end of the 1990s, which marked the beginning of the Amazon region's separation from other regions of the country; (II) the middle of the 2000s, which marked the deceleration of violence, with partial convergence to the levels observed in other regions; and (III) the

beginning of the 2010s, which marked a new acceleration in the growth of homicide rates in the region.

2.2 Explanations for the Rise in Incidence of Violence in the Amazon Basin

The majority of the studies on land conflict and violence in the Brazilian Amazon attributed the phenomena to the conflictive nature of production and exchange relations (Foweraker, 1981) (Schmink & Wood, 1992) failure of Amazonian development (Cleary, 1993) (Hall, 1987) (Mahar, 1979) (Becker, 1990), weak tenure institutions (Mueller, Alston, Libecap, & Schneider, 1994) (Alston, Libecap, & Schneider, 1995) (Alston, Libecap, & Mueller, 1997) (Alston, Libecap, & Mueller, 1999) (Alston, Libecap, & Mueller, 2000) (Fetzer & Marden, 2017) (Mueller, 2022), and illegal activities (Chimeli & Soares, 2017) (Pereira & Pucci, 2021). Due to the scope of our research, we will primarily focus on the weak tenure institutions and illegal activities' reasons for causing violence in the Brazilian Amazon.

Firstly, land tenure, access to land, and the presence of natural resources are intertwined (Simmons, 2005) (Fetzer & Marden, 2017) (Alston, Libecap, & Mueller, 1999). According to the report of the Brazilian NGO (Comissão Pastoral da Terra – National Board, 2020), access and control over natural resources are crucial factors in land use conflicts in the southwestern Amazon. Despite recent cross-country findings indicating that resources are negatively associated with conflict in Latin America (Denly, Findley, Hall, Stravers, & Walsh, 2021), micro-level analyses suggest the opposite. By comparing twelve rural communities in Brazil and Bolivia, results indicate that uncertain property rights and the predominance of nuts in the economy generate a high level of harvest-time conflict in the Brazilian Amazon (Duchelle, Cronkleton, Kainer, & Guanacoma, 2012).

The divergence across studies can be attributed to the fact that not all resources might be associated with conflicts. According to the World Bank's compendium of papers, civil conflicts are primarily associated with narcotics, oil, coltan, diamonds, gold, and other hard-rock minerals (Bannon & Collier, 2003). World Bank's study corroborates our primary hypothesis about the existence of an association between gold and violence in the Amazon. Moreover, as a significant part of the gold in the Amazon region is

lootable, it is also in accordance with the assessment that specific natural resources might be associated with the onset of conflict depending on their lootability[18].

To Simmons (2005), the combination of natural endowments and unequal distribution of land that exacerbates resource competition between landless farmers and large landowners is one of the main drivers of conflict in the Amazon. On the frontier, land value is low, property rights are inadequately defined, and investments are minimal; however, as settlement advances, land occupation increases, thereby bolstering land demand and property values. Consequently, increased demand for land and decreased availability result in conflict,[19] highlighting the need to define property rights. In the face of rapidly increasing land rents, the government's failure to provide tenure leads to violent outcomes. The phenomena were evident in the late 1970s when mineral wealth was discovered in Amazonia and brought up to 100,000 miners and an escalation of violence in the region (Simmons, 2005).

Alston, Libecap, & Mueller (1999) provide additional empirical evidence that violence in the Brazilian Amazon is associated with land disputes. Moreover, they demonstrate that land disputes are intrinsically linked to the absence of well-established property rights in the communities. Using a framework to measure the incentives for squatters and landowners to invade or evict each other's property, they discovered highly statistically significant results for the correlation between land conflict and weak institutions. Specifically, land disputes in Brazil are correlated with the presence of colonizers and a government agency that facilitates settlers' title claims. According to the authors, federal agencies - IBAMA (Brazilian Institute of Environment and Renewable Natural Resources)[20] and INCRA (the National Institute for Colonization and Agrarian Reform)[21] - offer different incentives to proprietors, and the insecurity regarding their property results in violence.

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[18] The lootability factor can also be applied to other minerals according to Lujala, Gleditsh & Gilmore (2005). According to them, lootable and non-lootable diamonds have opposing effects on the occurrence of conflict. Lootable diamonds are on the surface and are more readily seized, whereas non-lootable diamonds are buried and are more difficult to access. And only the former is associated with the onset of conflicts (Lujala, Gleditsch, & Gilmore, 2005)

[19] Land conflict emerges as a class struggle between individuals with different material affluence and political power mobilization capacities (Schmink & Wood, 1992)

[20] IBAMA is a federal environmental agency responsible for implementing national environmental policies, regarding environmental licensing, environmental quality control, authorization for the use of natural resources, and inspection in accordance with the Ministry of the Environment's guidelines. To read more about: < http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2007/lei/l11516.htm> Accessed on May 20, 2023

[21] INCRA is a federal agency that processes title applications for state-owned properties. INCRA is tasked with surveying, documenting, and ultimately titling squatter claims to government lands. (Alston et al.,

IBAMA administers a law requiring Amazonian properties to retain 80% of their land area as forest[22], whereas INCRA considers such a property to be unproductive and therefore subject to expropriation. Formally, the resolution requires landowners to register the forested portion of their property with IBAMA as a natural reserve, exempting it from punitive taxes and expropriation. In practice, however, this action is costly and bureaucratic, requiring the employment of a certified agronomist to develop a forest management plan (Alston, Libecap, & Mueller, 1999).

In addition, once the reserve is registered, the landowner loses the ability to clear that area in the future, whereas an unregistered forest can be cleared with a lower likelihood of IBAMA detection. Consequently, very few proprietors opt to register with IBAMA. Inadvertently, this process of land reform resulted in increased violence, the opposite of what was intended. According to Alston, Libecap, & Mueller (1999), an additional INCRA settlement initiative between 1987 and 1990 would result in 1.33 more land disputes.

Alston, Libecap, & Mueller's (1999) results are in accordance with Froese et al's (2022) findings that show land conflict is associated with legal uncertainty caused by overlapping responsibilities of government institutions. This legal ambiguity implies that individuals who have been granted access to land are prevented from doing so (Froese, et al., 2022). Fetzer & Marden (2017) supplement empirically the findings of Alston, Libecap, & Mueller (1999)[23] by demonstrating that violence decreases with the expansion of protected areas[24]. Once land is protected, it fulfills the productive use requirement and is thus no longer contestable. The estimated effects are large and generally consistent with local conflict being completely driven by the availability of contestable land. Additionally, a more permissive land regulation can also stimulate illegal land grabbing in the Brazilian Amazon (Brito, Barreto, Jr, Baima, & Gomes, 2019).

Other than disputes over land, illegal activities are also associated with violence in the Amazon municipalities. According to a recent report by Human Rights Watch, a significant proportion of homicides in the Amazon region are linked to illicit

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2000). Between 1988 and 2017, the agency settled over a million households on over than 75 million hectares of land (Fetzer, Marden, 2017).

[22] In theory, environmental policies and social policies for the Amazon do not have to be mutually exclusive. However, in practice, policies that reconcile these two objectives in Brazil are rare (Alston et al., 2000)

[23] The results from both authors are also supported by the cross-country research results of Fearon and Laitin (2003) who analyze 127 conflicts in six continents and conclude that weak institutions and ineffective states provide the necessary conditions for conflict

[24] Specifically, ecological and indigenous protected areas

deforestation[25]. This anecdotal evidence is corroborated by the findings of Chimeli & Soares (2017), who demonstrated that increases in violence in the Brazilian Amazon after the prohibition of mahogany harvesting were at least partially attributable to illegal mahogany exploration. Using a difference-in-difference strategy, they obtained relative increases in homicide rates after prohibition in areas with the natural occurrence of mahogany. Even incapable of identifying specifically through which mechanism the illegal activity affects the incidence of violence, the authors' hypotheses are competition among loggers, resolution of labor disputes within illegal firms, renegotiation of contracts, or conflict with local communities over environmental protection, among other possibilities.

Chimeli & Soares's (2017) results are reinforced by Pereira & Pucci's (2021) findings regarding illegal resource exploration and violence. As the previous authors, Pereira & Pucci (2021) use a differences-in-differences approach to investigate the relationship between a regulatory change in the gold market and the rate of homicides in regions with greater exposure to gold. Comparing municipalities with legal and illegal gold deposits before and after the regulatory change, they discovered an increase of more than 8 extra homicides per 100,000 (more than 20 percent). They argued that the new regulation boosted illegal gold exploration, and consequently violence, by exempting first-time purchasers of gold from legal liability in the event that the precious metal originated from illicit sources[26]. The purchasers were permitted to acquire unrefined gold, assuming that all documents provided by miners were authentic, which permitted sellers to use existing extraction permits to close the deal (more than 20 percent) (Pereira & Pucci, 2021).

In conclusion, based on specialized academic publications, violence in Amazonian municipalities is mainly driven by land disputes and illegal activities related to local resource extraction, being subjected to different factors than the urbanized areas across the country. Among the micro-oriented empirical studies that present explanations

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[25] As stated in the report, conflicts over resources and disputes over land have resulted in the death of more than three hundred people over the past decade, with illicit loggers playing a significant role. Available at <https://www.hrw.org/report/2019/09/17/rainforest-mafias/how-violence- and-impunity-fuel-deforestation-brazils-amazon)>. Accessed on May 5, 2023.

[26] According to the new regulation implemented by Law n 12.844: " the legality of the gold purchased and the good faith of the acquiring legal entity are presumed when the information mentioned in this article, provided by the seller, is duly filed at the headquarters of the institution legally authorized to carry out the purchase of gold" (Law n 12.88, article 4, p.2). To read further about the regulation: < https://www.gov.br/mme/pt-br/acesso-a-informacao/legislacao/leis/lei-n-12-844-2013.pdf/view>. Accessed on May 20, 2023

for the violent conflicts in the area (Alston, Libecap, & Mueller, 1999) (Fetzer & Marden, 2017) (Chimeli & Soares, 2017) (Pereira & Pucci, 2021) the findings of Pereira & Pucci (2021) are particularly relevant for our study since the researchers proved empirically with robust results the correlation between illegal gold exploration and violence. In this context, we will try to complement this study by analyzing the illegal gold market prices and homicides in the Amazon municipalities in the face of international price shocks of gold, a similar approach adopted by Idrobo, Mejía, & Tribin (2014), who compared the rise in the international price of gold and homicides in Colombia.

Since the incentives of the international commodity prices in incentivizing illegal activities and violence is an essential part of our study, it is essential to consider the role of the value of the prize in the micro-oriented empirical conflict literature (Miguel, Satyanath, & Sergenti, 2004) (Hidalgo, Naidu, Nichter, & Richardson, 2010) (Eynde, 2016) (Harari & Ferrara, 2018) (Dube & Vargas, 2013) (Berman, Couttenier, & Thoenig, 2017) (Miguel, Satyanath, & Sergenti, 2004). Because of that, we will analyze the association between price shocks and conflict in the next subsection. In our case, the prize will be the incentive in joining the dangerous venture of illegal gold exploration.

2.3 Violence and natural resources

Multiple mechanisms allow price fluctuations in commodities such as gold to influence violent crime. Specifically, the theory implies that income disruptions can have two major impacts on armed conflict: the opportunity cost effect and the rapacity effect. The opportunity effect refers to the cost of committing violence or joining a rebellion in comparison with the expected benefits of illegal activity in case of success. In this case, higher (lower) wages might reduce (increase) conflict by decreasing (increasing) incentives to appropriation. In contrast, a rise in contestable income may increase violence because it increases gains from appropriation (Dube & Vargas, 2013). The existence of two opposing influences suggests that, depending on the relative intensity of the two effects, some income disruptions may mitigate conflicts, while others may exacerbate them.

From the perspective of opportunity cost, an increase in income may reduce conflict by decreasing the amount of labor supplied to illicit or conflict activity (Becker, 1968). In Becker's model, a criminal act is preferred and chosen if the expected benefits of committing a crime outweigh the expected costs, including the costs of any deferred legal alternatives. In other words, employees will choose the option that yields the highest

returns, whether that be legal employment or illicit activity. Consequently, the wage represents the opportunity cost of battle. The theory conforms to Collier and Hoeffler's (1998) ground-breaking civil war model. (Collier & Hoeffler, 1998) assert that revolutionaries are influenced by rational expectancies regarding the potential gains and costs of civil conflict. In other words, dissidents are rational predators or, to use terms with a less negative connotation, entrepreneurs seeking a profitable opportunity (Collier & Hoeffler, 2004).

According to the rapacity effect, a greater income implies there are more goods to dispute. As a result, an increase in income may exacerbate conflict by increasing the return on predation and encouraging rapacity over these resources. It is believed that this form of predation explains why exporters of oil and other natural resources are more likely to experience civil war (Fearon & Laitin, 2003). Other authors contend that, given the capital-intensive nature of natural resource production, a resource price rise will increase capital-intensive production and reduce labor-intensive sectors, thereby freeing up inexpensive labor for insurrection (Berman, Couttenier, & Thoenig, 2017)

The nature of resource production, according to Dube and Vargas (2013), determines whether the opportunity cost or rapacity effect will prevail. A price increase may increase rentals to battle over as a result of the rapacity effect, but it may also increase wages, thereby increasing the opportunity cost of fighting. Price increases for labor-intensive products reduce conflict, whereas price increases for non-labor-intensive goods increase conflict. They support this theoretical perspective by analyzing the impact of various types of commodity disruptions on the outcomes of the civil war in 978 Colombian municipalities over a period of 18 years. According to their findings, a decline in coffee prices increased violence in regions that cultivate coffee more intensively, and they discovered similar patterns with other labor-intensive agricultural commodities, such as sugar, plantain, tobacco, and palm. In contrast, the price increase of natural resources, such as oil, coal, and gold, intensifies assaults in regions that produce more of these commodities.

As Dube and Vargas (2023), there is extensive empirical research that supports the notion that a decline (increase) in commodity prices may lead to more (less) conflict. Additionally in Colombia, steep declines in coffee prices reduced worker wages and increased their propensity to join armed groups. (Dube & Vargas, 2006) The abrupt decline in coffee prices considerably increased both the frequency and severity of the conflict. Similarly, Hidalgo, Naidu, Nichter, and Richardson (2010) find evidence that

rural productivity disruptions, such as droughts, reduce the returns to agricultural labor, thereby increasing conflict in Brazil. Harari and Ferrara (2018) found statistically significant correlations between agriculture-related disruptions and local conflict. According to them, since agriculture is a labor-intensive industry, negative economic disruptions reduce the returns from labor market participation in comparison to battling. In other words, a price decline has a substantial impact on the income of agricultural producers, making their participation in a rebellion more attractive. In his study of the Ugandan civil conflict, Deininger (2003) observes a positive correlation between expropriated agricultural assets (coffee plantations) and violence. And maize price fluctuations contributed to Mexico's burgeoning drug trade and indicate the violent consequences of a growing drug industry (Dube, Garca-Ponce, & Vargas, 2013).

Nonetheless, Bazzi and Blattman (2014) obtained contradictory results compared to their predecessors. Using new data on export commodity price shocks, they tested three theories linking income to conflict and found no effect on new conflict, even when the price shocks occurred in high-risk nations. According to them, rising prices had the opposite effect of what was predicted by the theory that rising state revenues encourage state capture, resulting in shorter, less lethal conflicts. Their evidence suggests that rising revenues enhance counterinsurgency capabilities and decrease individual incentives to combat extant conflicts (Bazzi & Blattman, 2014). According to Berman, Couttenier, and Thoenig (2017), a plausible explanation for this contradictory result might be the excessive level of aggregation of their country-level level, given that most conflicts are concentrated in specific regions. Eynde (2016) adds to the argument by showing that the effects of income disruptions on conflicts are contingent on the type of targets and the revenue sources of the insurgents. More specifically, a dissident group's combat capacity appears to benefit more from negative income disruptions if its tax base is sufficiently independent of the agricultural economy.

Regarding the increase in the cost of non-labor-intensive products. Angrist and Kugler (2008) provide evidence of the economic factors that increase the revenues associated with armed conflict in Colombia. They discovered that increases in coca prices operate as a form of "resource curse" that attracts more people into the illicit drug trade, resulting in an increase in violence (Angrist & Kugler, 2008). Bellows and Miguel (2009) show that the mining of diamonds in Sierra Leone during the civil war exacerbated violence. Berman, Couttenier, and Thoenig (2017) demonstrated that price increases for multiple minerals, including gold, lead to an increase in violence and conflict between

rebel groups in the exact locations of mineral deposits in Africa. Quantitatively, their estimates suggest that the historical increase in mineral prices could account for as much as one-fourth of the average level of violence in African nations from 1997 to 2010. After analyzing geolocalized data on conflict events and mining exploitation of 14 minerals in all African nations during the period, the authors reached this conclusion. Similarly, the conflict in Colombia was affected by the increase in gold prices. According to Idrobo, Meja, and Tribin (2017), when the price of minerals increases, drug cartels escalate conflicts over gold deposits. As the value of minerals rises, armed groups are more likely to fight for them despite their inherent dangers.

The majority of this literature, however, makes generalized assumptions about individual liberty and the ability to choose whether or not to commit an offense. In addition, informal institutions and social networks are disregarded. In numerous states with inadequate property rights and institutions, non-state actors, such as organized criminal groups, can exert varying degrees of influence over local economies, thereby determining how to price disruptions impact different communities (Roett, 2020). Even if they affect labor-intensive products, certain disruptions that benefit illicit organizations can exacerbate violence and increase the likelihood of conflict. Due to the extremely concentrated character of criminal activity in Brazil, we must pay particular attention to organized crime.

The convergence of environmental crime, like illegal mining, with traditional illicit markets is well documented (Van Uhm, 2018) (South & Wyatt, 2011), including in the case of Brazil (Waisbich, Risso, Husek, & Brasil., 2022). According to Waisbich, Risso, Husek, and Brasil (2022), illegal mining in Brazil has extensive connections to criminal organizations and other environmental crimes. They analyzed the criminal network involving illicit mining by accumulating Federal Police operations against environmental crime in Amazonian states from 2016 to 2021. The information gathered revealed that the illegal mining landscape in the Brazilian Amazon has strong ties to drug trafficking, a high rate of violent crimes (against individuals or illegal possession of firearms, ammunition, or explosives), and the involvement of criminal organizations.

However, the relationship between criminal activities and the international price for minerals suggests different results than conflict. Taking into account price fluctuations in 15 internationally traded minerals to examine the effect of mineral wealth on local crime rates in South Africa over a 10-year period, Axbard, Benshaul-Tolonen, & Poulsen, (2021) discovered that an increase in mineral wealth leads to a reduction in crime. In

total, the number of local offenses decreased by approximately 0.7% for every 10% increase in the value of mining production (Axbard, Benshaul-Tolonen, & Poulsen, 2021). According to them, the examination of mechanisms suggested that the influence is caused by the mining industry's creation of new employment opportunities. Consequently, their findings suggest that low international mineral prices can lead to an increase in criminal activity in contrast with the main findings of the "natural resource curse" regarding conflict measures.

3 Data and Descriptive Statistics

Our primary hypothesis, derived from the preceding sections, is that an increase in the international price of gold might stimulate illicit gold extraction and violence. To analyze the violence incidence and gold extraction, we had to create an entirely new dataset by combining multiple datasets containing information on gold deposits, Indigenous Territories and Conservation Areas, and four measures of violence. In the following subsections, we elaborate on each of these databases.

3.1 International Price for Gold

The international gold price is quoted using 24K gold and troy ounces (Heider & Nery, 2022)[27]. As Berman et. al (2014), we use the Real Annual World Bank Commodities prices dataset from 2000 to 2019, measured in constant 2010 dollars.

3.2 Gold Deposits Mining status

To determine the presence of gold deposits in Brazil, we employed the following technique: first, we determined the Amazonian municipalities that contributed to the tax called CEFEM (Financial Compensation for Mineral Resources Exploration) at least once between 2000 and 2019. According to Law No. 01/1991, all miners in Brazil, regardless of their form of extraction permit, must pay this specific financial compensation to exploit natural resources. Therefore, the accumulation of compensation is a significant indication that gold deposits exist in the municipalities. In addition, the payment must be made within the same calendar year as the extraction. We can therefore rely on the fact that all gold deposits considered in the analysis are recent and were mined in at least 2000. For

[27] Since Brazil represents less than 2% of the gold exports globally[27] (OEC - The Observatory of Economic Complexity, 2023), that would be no apparent reverse causality between Brazil's gold production and the international gold price in case of regression.

the study period, 347 municipalities out of 786 municipalities have registered at least one gold exploration in the past 20 years.

It is more challenging to characterize unlawful mining due to the fact that limited state regulations prevent us from pinpointing its precise location. However, gold exploration is strictly prohibited in Indigenous Territories (IT) and Conservation Areas (CA) in Brazil, rendering illegal any mining activity that takes place within these territories. The first case is protected by the Federal Constitution of Brazil in 1988, which prohibits mining in Indigenous Territories until Congress passes a law regulating this practice. Since 1988, this has never occurred, so all miners operating in these regions are doing so illegally. The second case is protected by Law 9.985/2000, which establishes and regulates Natural Conservation Areas (Unidades de Conservação, or UCs) (Pereira; Pucci, 2021). Despite this, clandestine mining occurs in several UCs across the country, just as it does in IT[28]. The data for IT was retrieved from FUNAI[29] –Justice's National Foundation for Indigenous Affairs – and the data for CA is retrieved from the Brazilian Ministry of Environment and Climate Change[30].

To circumvent the paucity of data on illicit mining in Brazil, we employ the same strategy as Pereira & Pucci (2021): we cross the presence of gold deposits with municipally protected areas to determine municipalities likely exposed to illegal mining. Consequently, we classify municipalities into three categories: I) illegal mining – when a municipality has the risk of illegal mining on its territory due to the presence of gold deposits and is located in a protected zone; II) legal mining – when a municipality has registered gold deposits but is located outside of a protected zone; and III) no mining – when a municipality has no gold deposits regardless of whether it is located in a protected zone or not. In our sample, there are a total of 117 municipalities with a likelihood of illicit mining, 236 municipalities with a likelihood of legal mining, and 439 municipalities with no likelihood of mining activity.

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[28] According to MapBiomas data, the area occupied by mining in ILs increased by 495% between 2010 and 2020, while the increase in UCs was 301%. In 2020, TIs (9.3%) and CUs (40%) comprised fifty percent of the national mining area.

[29] The data is available at: http://sii.funai.gov.br/funai_sii/informacoes_indigenas/visao/visao_terras_indigenas_lista.wsp?tmp.uf_codigo=3&tmp.terrai_codigo=&tmp.etnia_codigo=&tmp.coord_codigo=&tmp.mun_codigo=&tmp.fase_codigo=

[30] The data is available at: https://dados.mma.gov.br/dataset/44b6dc8a-dc82-4a84-8d95-1b0da7c85dac/resource/3562d093-14ed-434b-9fa3-411b664d6836/download/unidade-de-conservacao.csv

3.3 Deforestation

We combine the deforestation variable to our dataset in order to support the hypothesis of the existence of mining activity in protected areas. In this context, we refine the strategy adopted by Pereira & Pucci (2021) that crossed protected areas with gold deposits. We chose deforestation as the ideal indicator for identifying illegal mining activity because it has been extensively documented the positive correlation between mining and deforestation. Using the data on deforestation at municipality-year from the Brazilian National Institute for Space Research, a research unit of the Brazilian Ministry of Science, Technology, and Innovation[31], we found a positive correlation between deforestation and revenues generated from mining activities within a 10% Confidence Interval.

Pairwise correlations

Variables	(1)	(2)
(1) Deforestation (km)	1.000	
(2) Mining revenues (R$)	0.366*	1.000

*** p<0.01, ** p<0.05, * p<0.1

Therefore, the level of deforestation can also point to the existence of illegal mining activity in Indigenous Territories (IT) and Conservation Areas (CA) that have gold deposits.

3.4 Violence

3.4.1 IPEADATA – Total annual number of homicides

As our main dependent variable, we use the municipality-year homicide rate per 1000,000 habitats. The source of data for the homicide rate is IPEADATA[32] which provides information on the total number of homicides per municipality. We calculate the homicide rate for each mining category (illegal, legal, and no mining) by dividing the total number of homicides by the total population at the municipality level. The data on population is retrieved from the Brazilian Institute of Geography and Statistics - IBGE[33].

[31] The data is available at: http://www.dpi.inpe.br/prodesdigital/prodesmunicipal.php
[32] The data is available at: https://www.ipea.gov.br/atlasviolencia/dados-series/20
[33] The data is available at: https://www.ibge.gov.br/estatisticas/sociais/populacao/9103-estimativas-de-populacao.html?edicao=17283&t=downloads

The annual total number of homicides and total population at the municipality level are used from 2000 through 2019.

3.4.2 IPEADATA – Total annual causalities caused by firearm

In order to check the intensity of violence, we supplement the homicide rate data with the violent causalities caused by firearms rate. The municipality-year data is also retrieved from IPEADTA[34] from 2000 to 2019. As firearm is normally the weapon used in illegal markets confronts, we expect to verify a higher rate of firearm causalities in illegal mining areas. We divide the total annual causalities by the total population retrieved from IBGE for each mining category.

3.4.3 IPEADATA – Total annual violent causalities

An additional method to measure the intensity of violence is using the dataset of violent causalities compiled by IPEADATA[35]. The dataset counts the total fatalities involving aggressions and injuries with an unclear intention to kill. The dataset is annual between 2000 and 2019 at a municipal level. We divide the total annual violent causalities caused by unknown reasons by the total population retrieved from IBGE for each mining category.

3.4.4 Brazilian Ministry of Justice and Public Security (MJSP) – Total annual intentional homicides

To track illegal criminal activity, we use the data retrieved from the highest public security authority in Brazil. The data is retrieved from the Brazilian Ministry of Justice and Public Security- MJSP[36]- and refers to causalities that have signs of aggression and violence - taking aside femicides -, intentionally caused traffic deaths and deaths with indices of crime or external aggression qualified as a homicide. The data is collected monthly but for analysis purposes, we have aggregated annually. Even though the data only covers 2018 and 2019, we can use it to compare both the level of criminality and the

[34] https://www.ipea.gov.br/atlasviolencia/filtros-series/2/juventude-perdida
[35] https://www.ipea.gov.br/atlasviolencia/filtros-series
[36] The data is available at: https://www.gov.br/mj/pt-br/acesso-a-informacao/dados-abertos

intensity of violence among the regions. We divide the total annual intentional homicides by the total population retrieved from IBGE for each mining category.

3.4.5 Comissão Pastoral da Terra (CPT) – Violence Aggregated

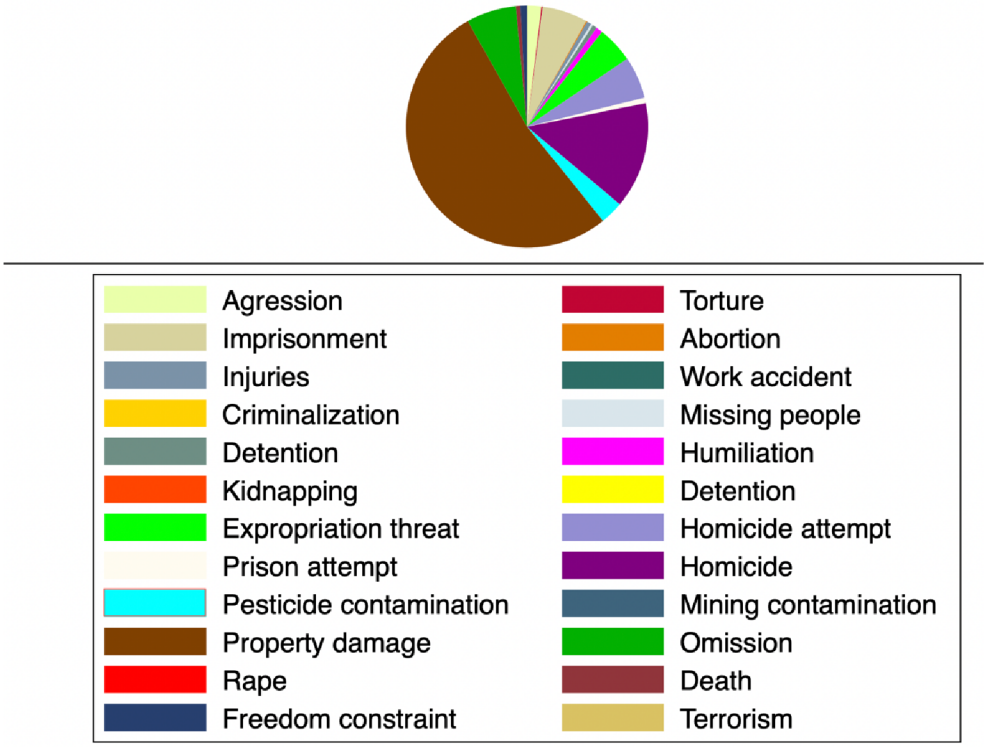
We combine three datasets with registered multiple incidences of violence at the municipality level from 2012 to 2020 provided by the Brazilian non-profit Comissão Pastoral da Terra (CPT)[37]. After combining the three datasets, we created a dummy variable to measure the likelihood of the municipality being inflicted by a case of violence in a determined year.

CPT, a Brazil church-based NGO active since 1976, collects data from various sources[38], and registers instances ranging from intimidation to actual murders. We augment IPEADATA's dataset with CPT's dataset in order to track the intensity of violence, including in the form that typically receives little attention from the authorities. As a result, we are able to capture the illegal armed organization's actions and forms of violence in a more comprehensive manner. Moreover, land disputes are associated not only with homicides but also with instances of violence against persons (intimidation, threats, injury, and murder of laborers and rural leaders), property damage (houses, agricultural fields, etc.), and displacement and expulsion of families (Celentano, 2007), and all of them are recorded by CPT. As we can see in Figure 14, there is a prevalence of property damage (60.67%) and homicide (17.90%) in the indicator. Finally, to enhance the statistical significance of the data, which was geographically and temporally dispersed, we compiled all reported incidents of violence into a singular indicator at the municipal level.

[37]The data is available at: https://www.cptnacional.org.br

[38] The CPT compiles information on violence from a variety of data sources, including local, national, and international news articles; state and federal government reports; reports from various organizations such as churches, rural unions, political parties, and non-governmental organizations; reports by regional CPT offices; and citizen depositions (CPT, 2004).

Figure 11: CPT violence indicator decomposed



Source: Author's compilation using CPT data

3.5 Descriptive Statistics

Our final sample covers 786 municipalities distributed in 347 municipalities with gold deposits and 439 municipalities with no indices of gold over 9 years. In total, we have 1572 observations. Out of the 347 municipalities with gold, 117 are located in prohibited mining areas, such as the Indigenous Territories (IT) and Conservation Areas (CA), and therefore exposed to illegal mining. The dataset had to be cleaned, incongruencies between municipalities' names had to be resolved for matching, and new variables were created.

Table 1 depicts some descriptive statistics. Some features are worth mentioning. First, on average, municipalities exposed to illegal mining have 13.8% more incidences of homicide rate than municipalities exposed to legal mining and 63% more than municipalities not exposed to mining. Moreover, municipalities exposed to illegal mining also have a 39.15% higher incidence of violence measured by CPT than legal mining-exposed municipalities, and 55.42% more than no-mining municipalities. Illegal mining municipalities also have 54.61% more violent deaths than municipalities exposed to legal mining, and 122.84% more than municipalities with no mining activities exposure.

Municipalities with illegal mining exposure also have an 85.07% more firearms deaths rate than legal mining-exposed municipalities, and 439% more than municipalities with no exposure to mining activities. Based on the data, we can conclude municipalities located in illegal mining zones in the Brazilian Amazon present higher rates of violence than other municipalities considering three different measures for violence. It is worth noting that (I) the difference between illegal mining exposed municipalities and non-mining municipalities is always higher than the difference between illegal mining exposed municipalities and legal mining exposed municipalities; (II) the higher the intensity of the violence rate, the higher is the difference between the violence rate between illegal mining exposed municipalities and others.

Second, the indicator of employment at the municipality level measured by the Federation of Industries of the State of Rio de Janeiro - FIRJAN[39] is 2.9% higher for municipalities exposed to illegal mining in comparison with municipalities exposed to legal mining and 17.42% higher in comparison with municipalities not exposed to mining. Therefore, municipalities with exposure to illegal mining have, on average, higher employment rate in comparison with other municipalities. The total deforestation is 21.90% higher for illegal mining-exposed municipalities in comparison with legal mining-exposed municipalities and 57.08% higher when compared to municipalities not exposed to mining. The municipalities exposed to illegal mining are also richer than the other municipalities – with a 28.05% higher municipal revenue[40] than legal mining-exposed municipalities and a 45.69% higher municipal revenue than municipalities not exposed to mining. In terms of population, the illegal mining-exposed municipalities are more populous than other municipalities with 27.76% more inhabitants than municipalities exposed to legal mining and 42.56% than municipalities not exposed to mining.

[39] It was established in 2008 and is based solely on official public statistics provided by the Ministries of Labor, Education, and Health; Nine indicators extracted from two Ministry of Labor and Employment (MTE) databases: the Annual Social Information List (Rais) and the General Register of Employed and Unemployed People (Caged). It can range from 0 to 1 based on 2010 results and fixed cut-off scores (minimum and maximum) for each component indicator. Since the index ranges from 0 (minimum) to 1 (maximum), which means low employment from 0 to 0,4, from 0,4 to 0,6 (regular), from 0,6 to 0,8 (moderate) and 0,8 to 1 (high). Available at: https://www.firjan.com.br/ifdm/

[40] Data retrieved from IPEADATA. Available at: http://www.ipeadata.gov.br/Default.aspx

Table 1: Summary statistics: N mean by (Mining status)

Mining status: Illegal

	N	Mean
Annual homicide rate	2281	25.718
Annual aggregated violence (dummy)	2281	.166
Annual total property damage	243	.35
Annual violent death rate	162	9.549
Annual firearm death rate	2281	.124
Employment Index	789	.384
Revenues (R$)	1934	68945029
Deforestation (km)	1457	1498.783
Population (hab)	2281	28077.646

Mining status: Legal

	N	Mean
Annual homicide rate	4479	22.598
Annual aggregated violence (dummy)	4479	.101
Annual total property damage	294	.299
Annual violent homicides rate	397	6.176
Annual firearm death rate	4479	.067
Employment Index	1567	.373
Revenues (R$)	3795	49600495
Deforestation (km)	2795	1170.447
Population (hab)	4479	20280.54

Mining status: No mining

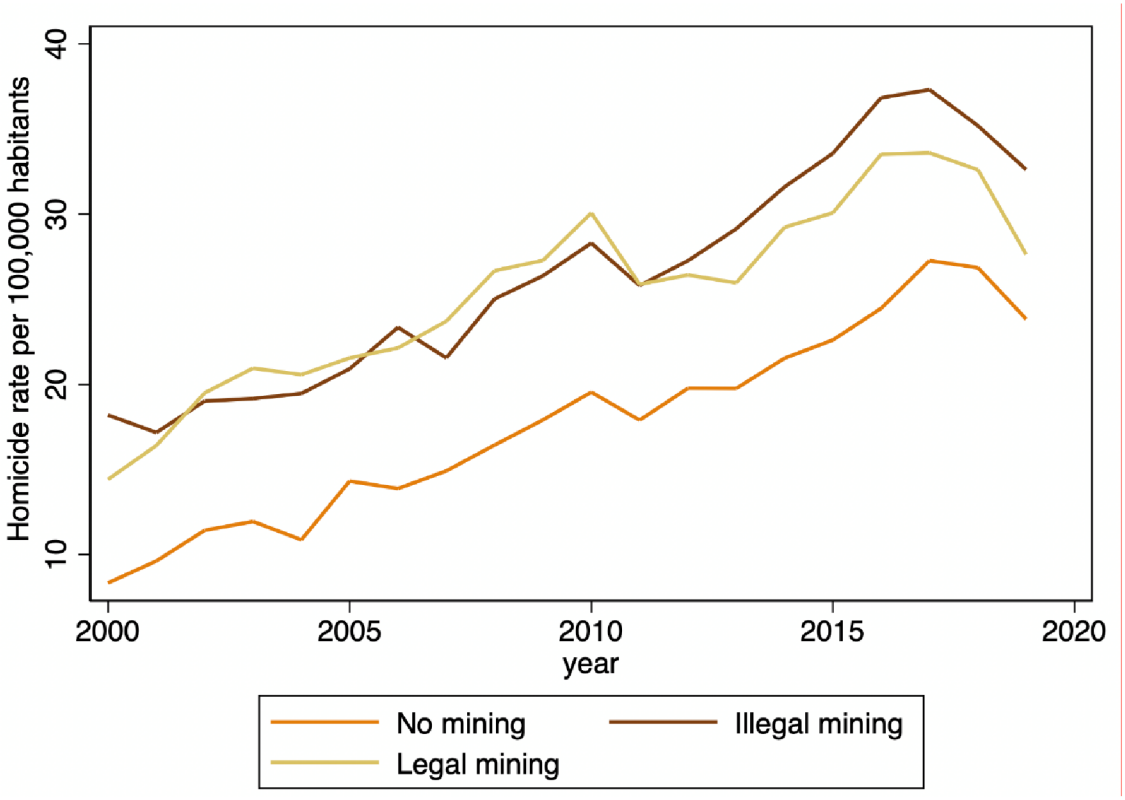
	N	Mean
Annual homicide rate	8612	15.765
Annual aggregated violence (dummy)	8612	.074
Annual total property damage	372	.379
Annual violent homicides rate	685	4.285
Annual firearm death rate	8612	.023
Employment Index	2796	.308

Revenues (R$)	7315	37440325
Deforestation (km)	5268	643.275
Population (hab)	8612	16127.308

4 Stylized Facts for Illegal Gold Mining and Price Shocks in Brazil

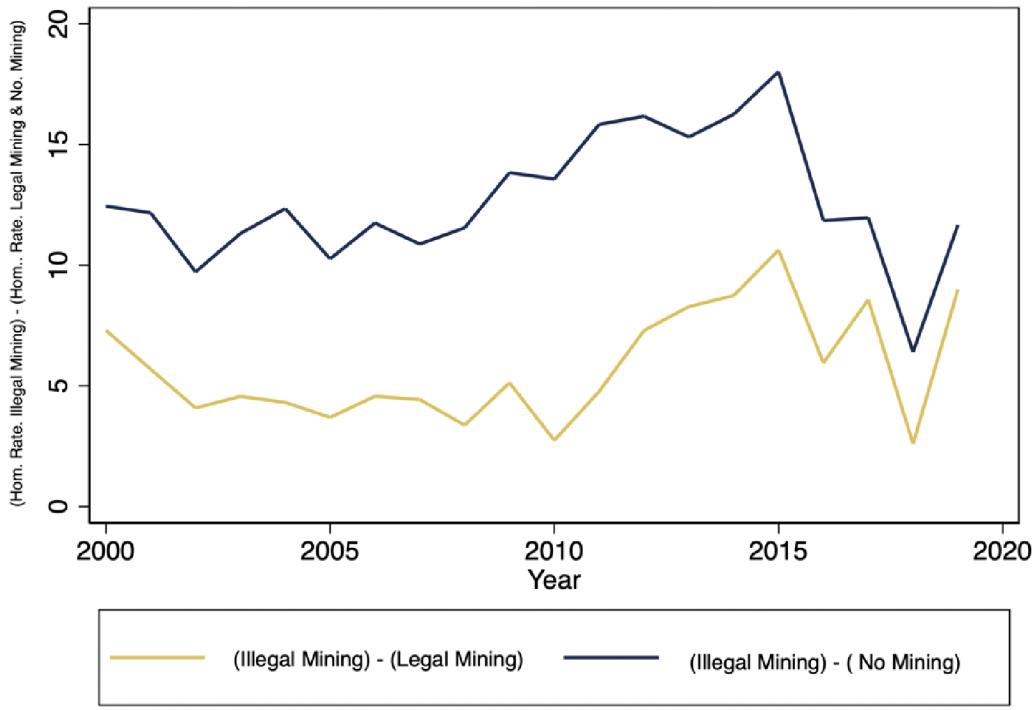
4.1 Violence in the Brazilian Amazon at the municipality level

Figure 12: Comparison of the homicide rate (per 100,000 habitants) for legal, illegal, and no-mining municipalities



Source: Author's computation using IPEADATA

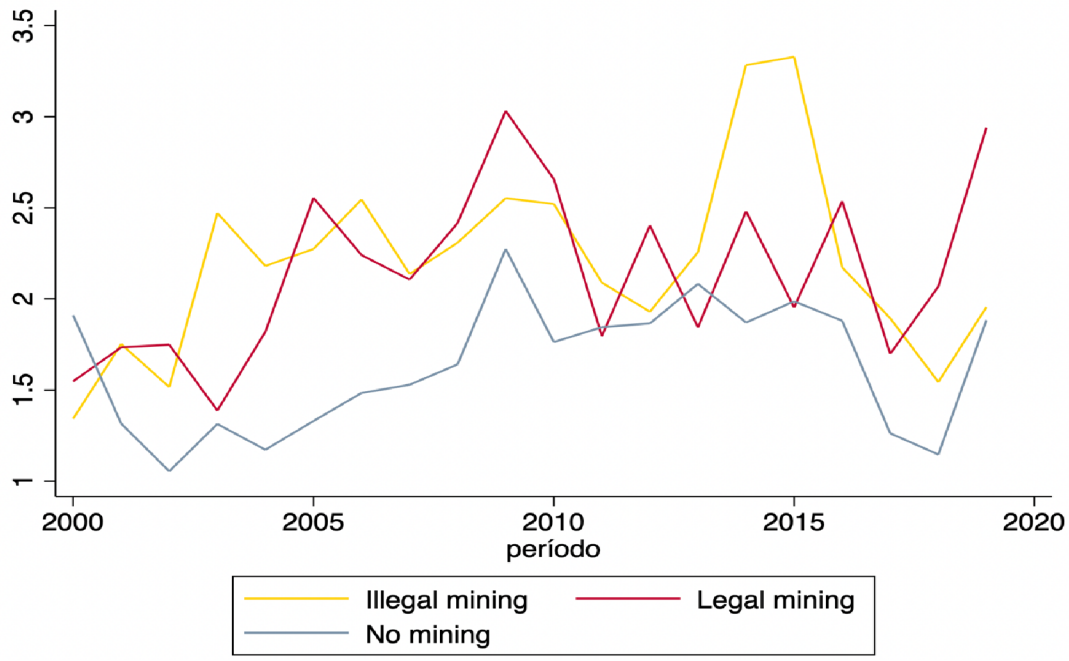
Figure 13: The Difference in the Homicide Rate



Source: Author's compilation using IPEADATA

Figure 12 depicts the historical progression of homicide rates in legal, illegal, and non-mining municipalities between 2000 and 2020. The same information is presented in a different format in Figure 13: the difference between the homicide rates in illegal mining municipalities and legal and non-mining municipalities. Both graphs depict an upward trend in the homicide rate for all municipalities in the Legal Amazon throughout the time period, but their peaks occur in different years. Between 2000 and 2010, the homicide rate in municipalities with gold deposits and no protected areas within their municipal boundaries increased significantly, reaching a peak of 30 per 100,000 inhabitants in 2010. This trend has reversed since 2011, with a 36% increase between 2011 and 2017, the year with the highest apex of 37.31 homicides per 100,000 residents in illicit mining areas.

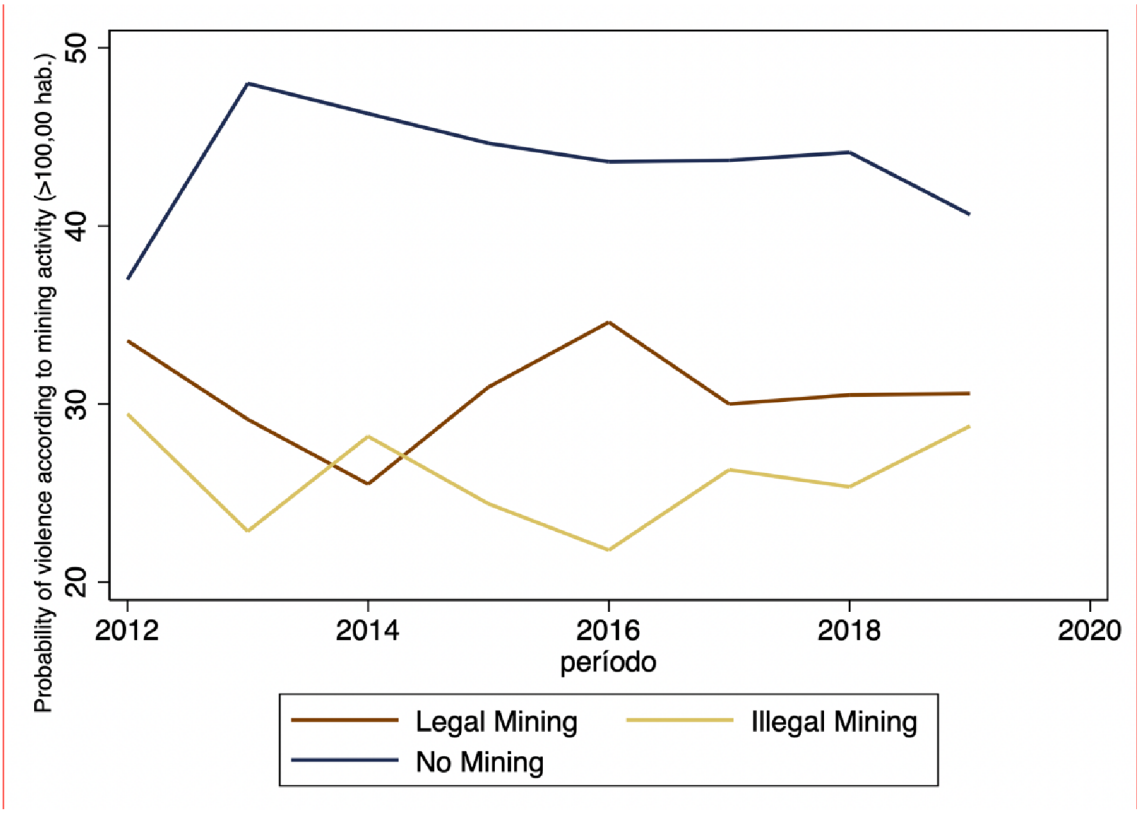
Figure 14: Violent death rate according to mining exposure



Source: Author's compilation using IPEADATA

Figure 14 depicts the historical series of violent death rates at the municipality level aggregated by mining exposure from 2000 to 2020. On average, the violent death rate for municipalities exposed to illegal mining is 54.61% higher than for municipalities exposed to legal mining and 122.84% higher compared with non-mining exposed municipalities within the period. As seen in Figure 14, the fluctuations of violent death rates are higher than homicide rates. In comparison with illegal mining-exposed municipalities, legal mining-exposed municipalities presented 12.33% higher incidences of violent death rates in 2005, 18.75% in 2009, 16.58% in 2016, and 50% in 2019. Despite violent deaths in municipalities with mining activities not located in Indigenous Territories or Conservation Areas being higher than in other municipalities in most of the years, the municipalities exposed to illegal mining presented a 78.98% higher incidence of violent deaths in 2003 and 70.25% in 2015. Municipalities not exposed to mining presented a higher incidence of violent causalities rate in 2000 but after the decrease in the rate, it remained more stable and lower than the violent death rates for municipalities in mining zones. It was worth noting that the rate for non-mining municipalities, in general, follows a similar pattern for the violent death rates for those exposed to illegal mining.

Figure 15: Aggregated violence in mining



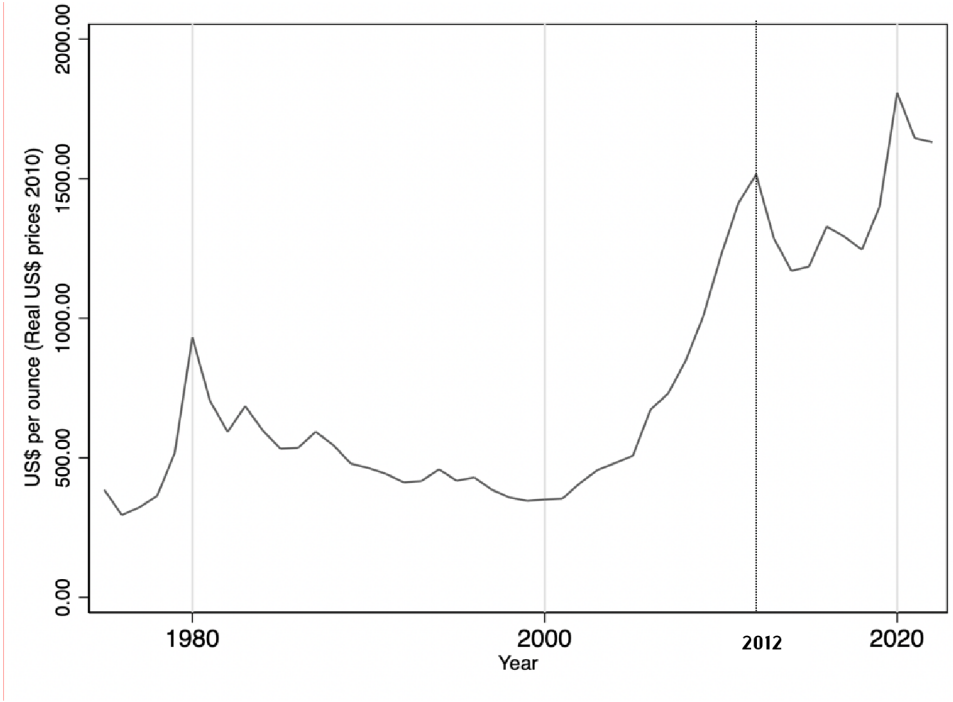
Source: Author's computation using CPT dataset

Figure 15 depicts the likelihood of the municipality presenting at least one case of violence from 2012 to 2020. In contrast with the other measures of violence, the majority of municipalities afflicted by violence using the dataset provided by the non-profit CPT were municipalities not exposed to mining activities. On average, the municipalities not exposed to mining have a 45% chance of having at least one case of violence each year, while municipalities exposed to legal mining have 30% and municipalities exposed to illegal mining have 25%. Since property damage represents 60% of the cases of violence, it might suggest that municipalities that are not subjected to gold extraction, have more conflicts over property. The expansion of the agricultural frontier in the Legal Amazon, especially the enlargement of cattle ranching, in many municipalities that do not have gold deposits, might be associated with this trend of violence in non-mining municipalities since become a prominent source of conflict within states with low gold deposits (Domingues & Sauer, 2022).

4.2 International Price of Gold Dynamics

First, figure 16 illustrates the gold price trajectory between 1975 and 2020. The most pertinent information we can glean from the long-term trend is how high the price of gold got in the 2000s in comparison with the past 30 years. Even with the political turmoil in the late 1970s and early 1980s – Two oil crises, among other destabilizing factors - from 1975 to 2005, with the exception of 1979-1980 (when it reached $820), the price fluctuated but always returned to a mean average of approximately $400 per ounce. In contrast with the 2000s when the price grows from $350/troy ores in 2000 to $1808/ troy ores in 2020, representing an increase of 19,35% (Beretta & Peluso, 2022).

Figure 16: Real annual prices for gold ($/troy oz), real 2010 US dollars, 1975-2020



Source: Author's compilation using World Bank dataset

Our research seeks to describe the increase in the international price of gold during the 2000s and violence in the Brazilian Amazon, and to that end, we examine the years 2000-2019. To describe correlations between price and violence indicators in this segment, it is essential to comprehend the international gold price trend from 2000 to 2019. This period includes three of the most notable price trends: I) a substantial increase from 2005 to 2012; II) a moderate decline from 2011 to 2018; and III) a modest increase.

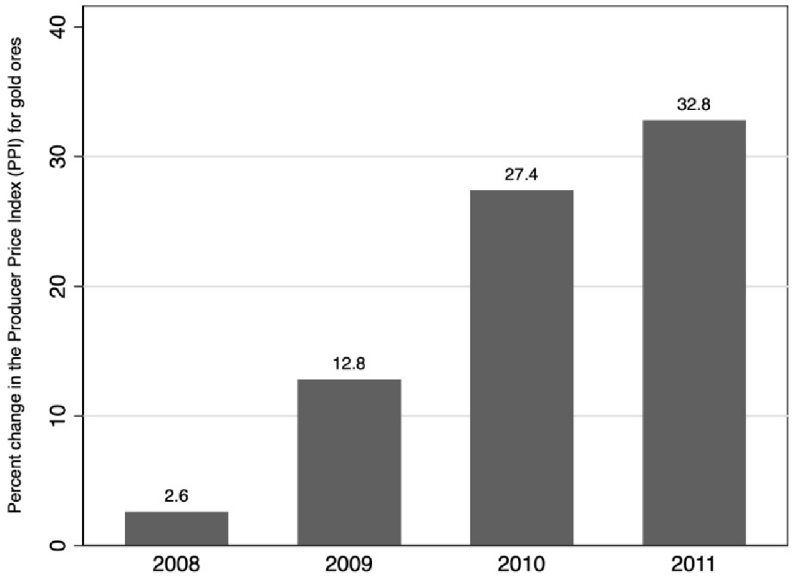
The price of gold increased significantly in the international market between February 2005 and August 2011, with the exception of the second half of 2008, during the global financial crisis. This period encompasses the so-called peak years of 2005 to 2008 when commodity prices rose across the board, part of the third economic expansion since the 1950s. Possible explanations include an influx of investor capital into commodity indexes and an increase in demand from emergent economies such as China and India and investor sentiment over the economy (Beretta & Peluso, 2022).

The increases in the international price of gold reflect the global uncertainty over the economy, holding the metal as a hedge against the global financial crisis (Jones & Sackley, 2014) (Bhanja & Dar, 2015) (Beckmann, Berger, & Czudaj, 2015). During periods of market instability, such as exchange rate fluctuations, economic crises, and stock market calamities, investor sentiment is affected (Lutz, 2015) (Ding, Liu, Zhang, & Long, 2017)(Lutz, 2015; Ding et al., 2017). As a result, they are inclined to invest in secure assets, which drives up the price of gold on the international market (Balcilar et al., 2017). When developed economies slow down, international investors shift their focus from speculative and riskier investments to fundamental commodities. In countries where these minerals are prevalent, as in the case of Brazil, the increase in the international price of fundamental commodities increases the incentives for exploitation (Hergt, 2013).

The high increases in prices are also captured by the data from the US Department of Labor: Bureau of Labor Statistics[41]. Between 2008 and 2011, the Producer Price Index (PPI) for gold ores rose by 101.1%, a sharp increase in the price of gold on the international market. In contrast with the commodity data, the PPI measures specifically the average change over time in the selling prices received by domestic producers for their output. This indicator is important since we can capture the direct financial incentives for gold miners across time. Notably, the percent change in the PPI for gold ores has been increasing each year, especially from 2010 to 2011, when the percent change achieved 32.8% (U.S. Bureau of Labor Statistics, 2023).

[41] Available at <https://www.bls.gov/data/>

Figure 17: Percent change in the Producer Price Index (PPI) for gold ores



Source: Author's computation from the US Department of Labor: Bureau of Labor Statistics

From its apex in August 2011 to mid-September 2018, however, the prices fell from $1,870 to $1,050. For some, this did not come as a surprise because the preceding period's upswing was a bubble. In 2016, gold began to monitor a mean price of approximately $1,200, where it remained until September 2018. There is a brief decrease in prices from 2012 to 2016 as a result of the recovery of the world economy after the recovery from the global recession in 2008, but the decrease did not sustain for long (Beretta & Peluso, 2022).

From 2020 onwards, gold has since increased again. The increase since the start of 2020 is part of a lengthier upward trend. That is, it cannot be attributed solely to the COVID-19 pandemic. Currently, the price remains above the 2020 average of approximately $1,620, but below its August 2011 all-time high of $1,888. While it may continue to rise, historical evidence indicates that periods of decline are not unprecedented (Beretta & Peluso, 2022).

To illustrate how gold prices and national mining are intertwined, we use the Commodities price dataset from the World Bank[42] and the mining permits issued by the Brazilian National Mining Agency (ANM) for small artisan miners, called Permissão de Lavra Garimpeira (PLG)[43]. Since the ANM requires a much more simplified process for

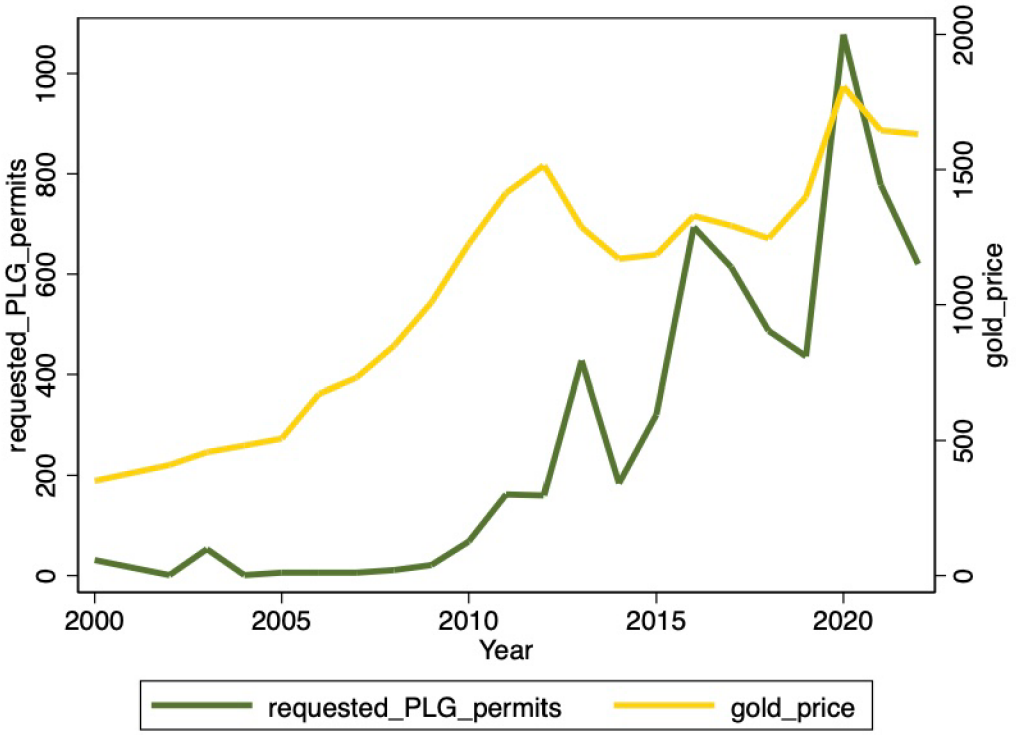
[42] Available at < https://databank.worldbank.org/databases/commodity-price-data>
[43] Available at < https://www.gov.br/anm/pt-br/acesso-a-informacao/acoes-e-programas/dados-abertos>

granting the PLG than other permits,[44] the PLG can capture the immediate effect of the increase in international gold prices on mining. Finally, we use the data from the private research group CEIC on gold production in Brazil[45] to compare with international gold prices. Figure 1 depicts the trajectory of the international gold price and the number of gold mining licenses in Brazil from 2000 to 2020. And Figure 2 depicts the concurrent evolution of the international price of gold and the official records of reported average gold production in Brazil during the same period.

According to the two diagrams, gold prices, licenses, and production follow a similar trend over time. In other words, the official data on gold mining responded to the market opportunities presented by the rise in global gold prices.

4.3 Gold Mining in Brazil x International price of Gold

Figure 18: Number of requested PLG permits vs international price of gold

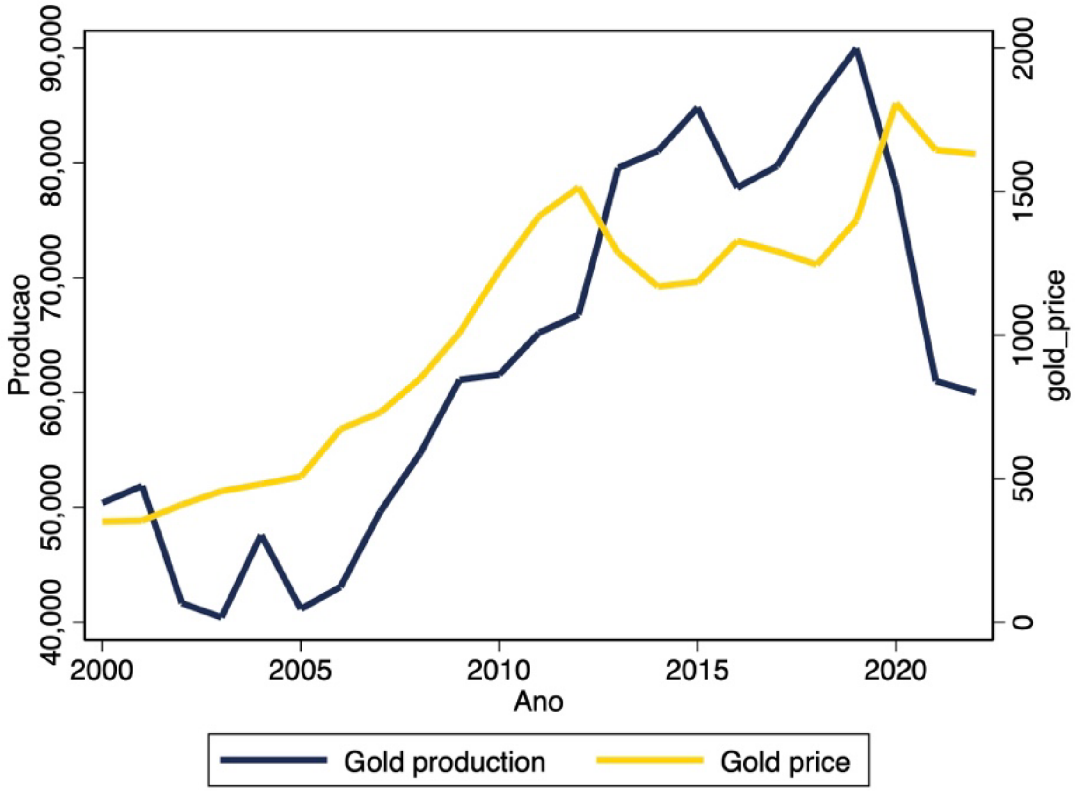


[44] The PLG does not require a Mineral Prospection Report prior to application and the process to acquire an environmental license is much more simplified than for others mining permits (Pereira & Pucci, 2021). The other modalities of permits as the entire institutional framework for the mining industry will be covered in the third chapter.

[45] Available at < https://www.ceicdata.com/en>

Source: Source: Author's computation from World Bank Commodities prices dataset and ANM's dataset.

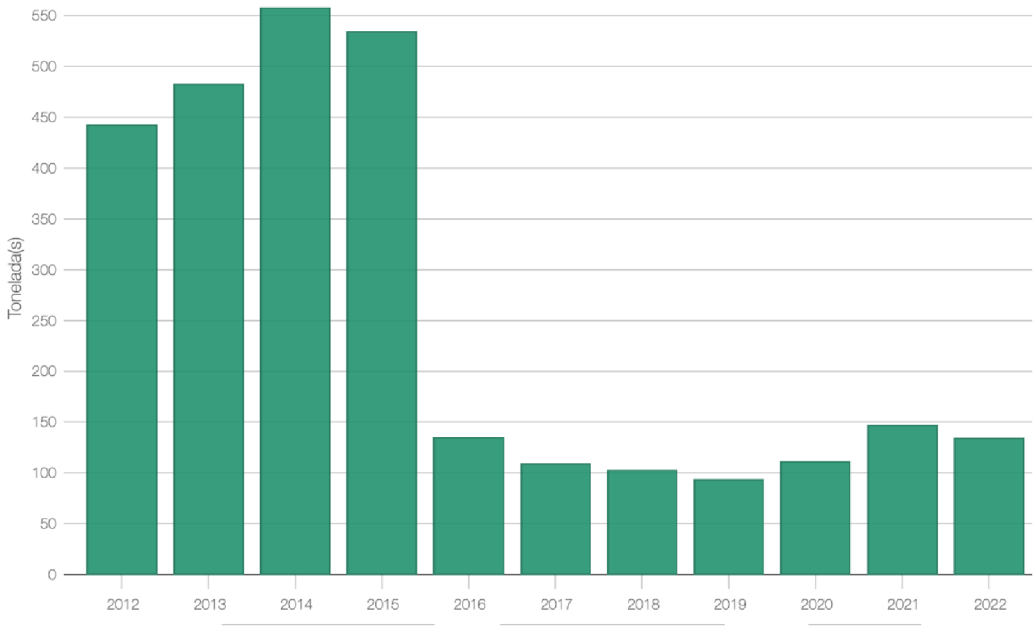
Figure 19: Gold production measured by 1000kg vs international price of gold



Source: Author's computation from World Bank Commodities prices dataset and CEIC Dataset.

According to Figure 1, when the gold prices rise more people become interested in exploring the land as a gold miner, and new requests for mining exploration permits are made. The relationship is also verified in terms of production according to Figure 2. In other words, when the gold price goes higher, not only it attracts new entrants to the gold industry but also intensifies the exploration of the ones who already have the permit. All this is from a legal perspective but there are pieces of evidence that the illegal market for gold follows the same (Wagner & Hunter, 2020). Moreover, we can also attest to the correlation between international gold prices and national gold production by looking at gold exports. The increase stimulated the Brazilian mining industry, as evidenced by historical data on gold exports and national production estimations.

Figure 20: Brazilian Gold Exports in Annual Tons

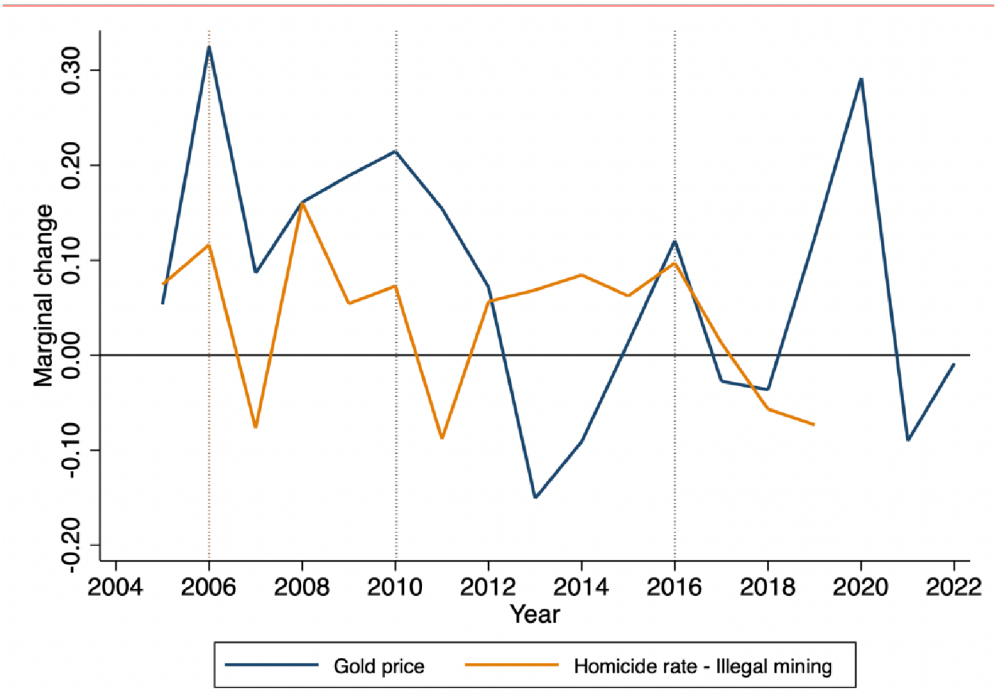


Source (Ministry of Development, Industry and Foreign Trade of Brazil, 2023)

Nonetheless, nearly half of the country's produced and exported ore is of questionable origin. The study of the non-profit Instituto Escolhas crossed gold production permits, trade registrations, areas with indices of extraction, and the exportation of companies involved in the operations, and found 229 tons of gold with evidence of illegality between 2015 and 2020. The analysis is based on over 40,000 records of extraction and commercialization from the National Mining Agency (ANM), as well as spatial images that can identify mining locations. (Instituto Escolhas, 2022). Now we describe the trend of gold prices and different measures of violence across legal, illegal, and no-mining zones.

4.4 Marginal changes in gold price x Violence

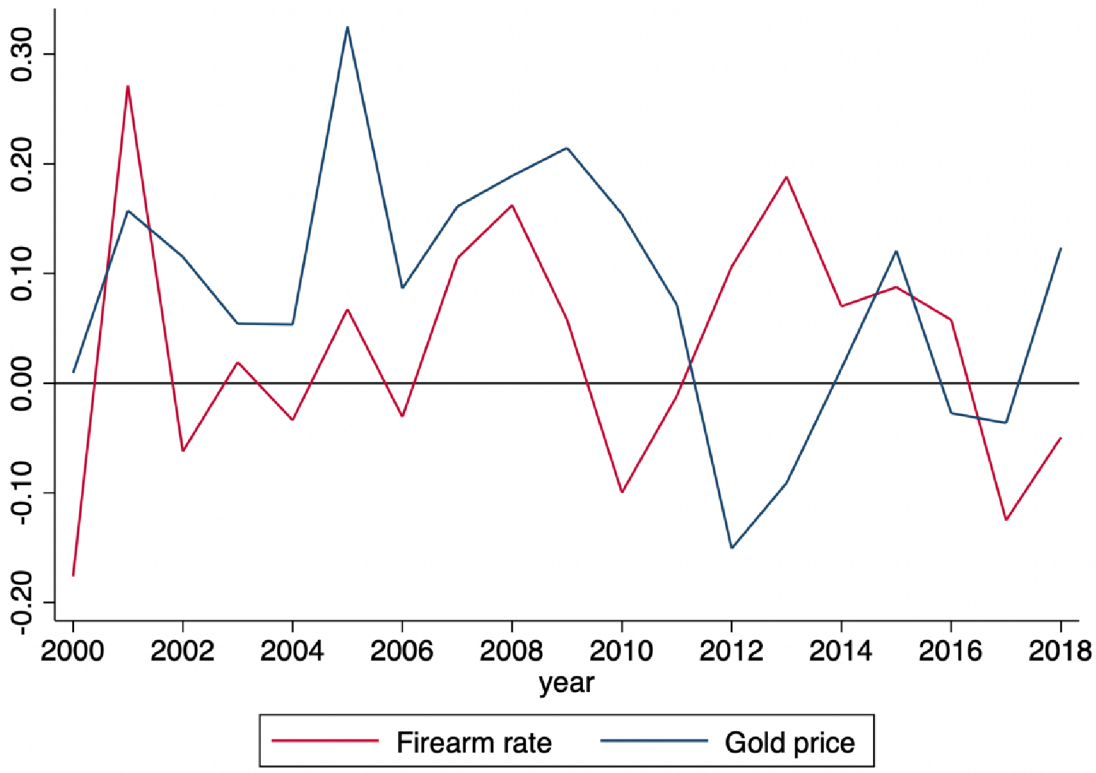
Figure 10: Marginal changes in gold price vs. Homicide rate in illegal mining Municipalities



Source: Author's computation using World Bank Commodities price and IPEADATA

Figure 22 depicts the marginal changes in gold prices in comparison with the changes in homicide rates for illegal mining municipalities. According to the data, the gold prices and homicide rate have followed a similar pattern especially from 2006 through 2010, when there was a rise in international gold prices in 2006, followed by a minor decline and subsequent recovery. From 2011 to 2015, however, the variation in the international price of gold and the homicide rate rise followed opposite directions. The international price for gold started a descent trend in 2010 and reached its peak in 2013, while the homicide rate started an ascending trend from 2011 to 2016. Therefore, the variables seemed to be correlated until 2011 but then started to move in opposite directions.

Figure 11: Marginal changes in gold price vs. Firearm deaths rate in illegal mining exposed municipalities



Source: Author's compilation using IPEADATA

Figure 23 depicts the marginal changes in gold prices in comparison with the changes in firearm death rates for illegal mining municipalities. From 2000 to 2010, the gold prices and firearm death rates followed similar trends, including significant increases in 2001, 2005, and between 2008 and 2009. From 2010 to 2012, while the price of gold kept decreasing at marginal rates, the firearm death rate started to increase significantly at marginal rates. The same trend was previously exposed in Figure 22 when comparing the marginal changes in homicide rates and gold prices. In both cases, the measures of violence went up while the price of gold went down. From 2012 to 2014, however, it occurred the contrary: while the firearm death rate slightly decreased, the international price of gold increased substantially. Overall, in the case of the firearm death rates except between 2002 and 2004 when the firearm death rates changed and the gold price remained relatively constant, and from 2012 to 2014 when the marginal changes followed opposite directions, the marginal changes in gold price and marginal changes in firearm deaths rate followed the same pattern during the period from 2000 to 2018.

Figure 12: Marginal changes in gold price vs. Violent death rate in illegal mining exposed municipalities

Source: Author's compilation using IPEADATA

Figure 24 depicts the marginal changes in gold prices in comparison with the changes in violent death rates for illegal mining municipalities. The pattern followed by violent deaths in municipalities exposed to illegal mining is slightly different from firearm deaths and homicides. The violent death rate changes have higher peaks of violence and abrupt changes. Between 2001 and 2002, the increase in violent deaths was over 0.6, practically double the other variables. Regarding the relationship with the international price of gold, the variable follows the same pattern as others, positively correlated to the gold fluctuations with the exception of the period between 2010 and 2015.

5 Conclusions

Despite traditional explanations for rising violence in Brazilian Amazon municipalities, we sought to provide an explanatory analysis of a largely unexplored link between illegal gold mining and violence indicators. Based on the extensive microeconomic literature review and analysis of violence in the Legal Amazon, we came to some conclusions.

First, on average, municipalities exposed to illegal mining present higher death rates, violent death rates, and firearm death rates when compared to municipalities exposed to legal mining or not exposed to mining at all. For death rates, they have 13.8% more incidences of homicide rate than municipalities exposed to legal mining and 63% more than municipalities not exposed to mining. For violent death rates, illegal mining municipalities have 54.61% more violent deaths than municipalities exposed to legal mining, and 122.84% more than municipalities with no mining activities exposure. For firearm death rates, municipalities with illegal mining exposure also have an 85.07% more firearms deaths rate than legal mining-exposed municipalities, and 439% more than municipalities with no exposure to mining activities. Even though we cannot describe exactly the exact mechanism through which municipalities more exposed to illegal mining have higher homicide rates, firearms deaths rate, and violent deaths rates, it could possibly be competition among miners, resolution of labor disputes within illegal firms, renegotiation of contracts, conflict with local communities over environmental protection, or criminal organizations actions, among other possibilities.

Second, it is worth noting that (I) the difference between illegal mining-exposed municipalities and non-mining municipalities is always higher than the difference between illegal mining-exposed municipalities and legal mining-exposed municipalities; (II) the higher the intensity of the violence rate, the higher is the difference between the violence rate between illegal mining exposed municipalities and others.

The only measure of violence in which municipalities exposed to illegal mining presented less violence was the aggregated violence measure built from three different datasets provided by the Brazilian non-profit CPT. We believe one of the main reasons the aggregated violence measure was higher for non-mining exposure municipalities is related to the agricultural frontier in non-mining zones across the Legal Amazon.

Third, we saw that the international price of gold followed the same pattern of increase as the newly required mining permits, which suggests that rising prices are an incentive for new entrants to the Brazilian gold market, both legally and illegally. Fourth, the marginal change in the gold price and violence indicators in municipalities exposed to illegal mining has followed the same trend which suggests a positive correlation between positive price shocks of capital-intensive commodities such as gold in the instances of violence in municipalities subject to the illicit market of gold. The reverse trend between 2011 and 2015 could be possibly explained by the introduction of the Brazilian regulatory change, which, as previously mentioned, exempted gold buyers from the liability of buying illegal gold, expanded money laundering, and increased more than 8 extra homicides per 100,000 in illegal mining zones (Pereira & Pucci, 2021).

As an explanatory analysis, we believe we provided: (I) the current landscape of violence at the regional and municipal level in the Brazilian Amazon; (II) an extensive literature review discussing the main debates of the natural resource curse, including the effects of price shocks on violence for civil conflict and crime; (III) an entirely new dataset with over 15 thousand observations; (IV) data visualization of several violence measures aggregated by mining exposure; (V) comparison between the marginal changes in the international price of gold and changes in the violence measures for municipalities exposed to illegal mining.

On the basis of the information presented, we hope to contribute to future research on the subject, particularly research that intends to test the causality between gold price shocks and violence at the municipal level in order to analyze the recent escalation of violence in the Legal Amazon. If there is causality, our research can support the direction of a number of policy implications, such as (I) price stabilization schemes that place a floor on the price of gold and can help mitigate violence in the wake of price shocks; (II) improved monitoring and control over gold revenue to prevent from rapacity effect and fueling conflicts; and (III) improvement of the fiscal structure at the local government level since funds from gold extraction can leak through looting.

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