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On the Origins of States: Stationary Bandits and Taxation in Eastern Congo

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Abstract: When do states arise? When do they fail to arise? This question has generated scholarship across all social sciences. A dominant view is that states first arise when violent actors impose a monopoly of violence in order to extract taxes (Carneiro, 1970, Tilly, 1985). One fundamental fact affects all existing studies: functioning states precede most statistics. There is therefore no statistical evidence on the causes of state formation. As a foundation for this study, I organized the collection of village-level panel data on violent actors, managing teams of surveyors, village elders, and households in 380 war-torn areas of DRC. I introduce optimal taxation theory to the decision of violent actors to establish local monopolies of violence. The value of such decision hinges on their ability to tax the local population. A sharp rise in the global demand for coltan, a bulky commodity used in the electronics industry, leads violent actors to impose monopolies of violence and taxation systems in coltan sites, which persist years after the demand collapses. A similar rise in the demand for gold, easier to conceal and more difficult to tax, does not. My findings support the view that the expected revenue from taxation, determined in particular by tax base elasticity, can explain the first stages of state formation.

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1 Introduction

In a stateless economy, economic agents can use coercion to expropriate goods and services. Since uncoordinated expropriation depresses incentives to invest, organizing coercion under a monopoly of violence can generate large welfare gains (Bates, Greif, and Singh, 2002, Grossman, 1999, Hirshleifer, 1995).

When do violent actors establish a monopoly of violence? In this paper, I answer this question to uncover the first stages of state formation. A dominant view across social sciences is that states emerged through coercion by violent actors who create a monopoly of violence (Carneiro, 1970, Olson, 1993, Tilly, 1985, Weber, 1946).[1] Social scientists identify state formation as part of the "Great Transformation" because of the prosperity it generated and the reduction of violence it induced (Bates, 2011, Polanyi, 1944).[2] As a result, a large number of scholars have attempted to provide an explanation for the origins of the state. One fundamental fact affects the scholarship on state formation, however: statistics are mostly absent prior to their creation by states (Scott, 1999).[3] There is therefore no formal statistical evidence on the process, let alone the causes of state formation.

As a foundation for this study, I managed a team of data collectors and village experts in areas of east Democratic Republic of Congo where the central state is historically virtually absent, in order to assemble a yearly panel data set of violent actors in 380 locations. The data allows me to identify types of violence (territorial conquests and pillage of assets), as well as village-level monopolies of violence and taxation by violent actors since 1995.

Using the data I assembled, I provide econometric evidence on the causes of monopolies of violence as a way to uncover the causes of the first stages of state formation. Drawing on the theory of optimal taxation, I develop an economic theory that can explain when violent actors

[1] There exists an unresolved debate about whether the legitimate use of violence by the state is a necessary element in the definition of the state. As defended by Tilly (1985), requiring violence to be legitimate by a monopoly of violence implies some redundancy, especially if legitimate violence requires other members to support the use of violence. I consider legitimacy elsewhere and find popular support for the monopolies of violence I study in this paper (Sanchez de la Sierra, 2014).

[2] In economics, Grossman (1994) argues: "Throughout history the responses of human societies to the problems of distributing property and of allocating resources between productive and appropriative activities probably have had greater consequences for welfare than have their responses to the problem of allocating resources among different productive activities taking property as given, which is the problem on which economic analysis traditionally has focused."

[3] While systematic data are inexistent prior to states, there exists data collected by churches and sparse archaeological evidence (Keeley, 1996, Kelly, 2000).

may choose to establish monopolies of violence. If violent actors formed states in order to tax, the choice to form a state in one location must depend on the expected ability to raise tax revenues in that location. The key insight of the model is that the value of output in a location increases the returns to form a monopoly of violence in that location, and more so if output is observable to the tax collector. A positive demand shock on coltan in the year 2000, a bulky mineral, leads violent actors in my data to conquer villages endowed with coltan, establish a monopoly of violence and develop stable taxation systems. A later demand shock on gold, easier to conceal and hence more difficult to tax, does not have this effect in villages endowed with gold.

Eastern Congo is a well-suited experimental ground of the initial stages of state formation. The Democratic Republic of Congo state is considered a "failed state" and is ranked the world's second weakest state. Violent actors have proliferated in the East and often use violence to rob populations. However, as in historical accounts of state formation, they often fight to establish territorial monopolies of violence, in which they develop elaborate taxation systems, provide protection and other public goods, and even obtain popular support.[4]

In the main result of the paper, I find that violent actors respond to an increase in the price of coltan by conquering coltan villages, in which they establish village-level monopolies of violence and create stable taxation systems mostly taxing coltan output, coltan labor, and households. In the year 2000, innovations in the video-games industry led the demand for columbite-tantalite (coltan) to skyrocket.[5] Due to the demand shock, US price of coltan rose abruptly from 90 US$ per kilogram to 590 US$ per kilogram at the start of the year, and collapsed at the end of the year. To establish a causal relationship, I exploit this positive demand shock for coltan and compare the change in behavior of violent actors in villages endowed with coltan to the change in behavior of violent actors in other mining and agricultural villages. I further find that this effect is concentrated in villages in the proximity of local airports, precisely where trade costs for coltan are not arbitrarily high.

However, tax revenues may not be the only mediator of the relationship between the coltan price and the behavior of violent actors. A rise in population density due to a migration response, for instance, could have increased the demand for order, leading to stationary bandits. To demonstrate that tax revenues are a central driver of monopolies of violence, I use a similar sharp positive

[4]See United Nations Security Council (2002), Nest, Grignon, and Kisangani (2011), Sanchez de la Sierra (2014) Stearns (2011) and Verweijen (2013). See also the RRMP program evaluation reports http://www.rrmp.org.

[5]See United Nations Security Council (2002), Nest (2011), Stearns (2011).

demand shock for gold, as profitable for miners, but whose output, easy to conceal, is impossible to tax. September 11^{th} and the resulting 2001-2002 global recession led investors to rush to safe investments such as gold, causing its price to rise sharply. Using this demand shock, I find that violent actors *do not* create monopolies of violence or taxation in response to the increase in the price of gold, whose output is impossible to tax. The contrast in these results suggests that tax revenues to violent actors are a major driver of state formation.

A large body of work in economics studies the decisions of government, in particular investments in state capacity (Acemoglu, Garcia-Jimeno, and Robinson, 2014, Acemoglu and Robinson, 2006, Acemoglu, Ticchi, and Vindigni, 2006, Besley and Persson, 2009, North and Weingast, 1989). However, research in economics usually takes the existence of the state as given and focuses on changes in state capacity as choices of existing states. Organizing a data collection project in a virtually stateless environment, I provide an explanation for the initial stages of state formation that precede the decisions usually considered in political economy.

This paper also contributes conceptually to unresolved debates about the causes of state formation which have implications for the conceptualization of states.[6] On the one hand, voluntaristic theories argue that states emerged as a result of a mutually beneficial social contract (Hobbes, 1651, Rousseau, 1762). On the other hand, conflict theories of state formation link the origin of states to the creation of monopolies of violence through coercion and conquest, and view states as successful organized crime (Bates, Greif, and Singh, 2002, Carneiro, 1970, Gennaioli and Voth, 2011, Grossman, 1997, Olson, 1993, Tilly, 1985). With rare exceptions, existing theories do not explain why states would have emerged in certain locations, but failed in other.[7] Drawing on the data I assembled, I provide support for conflict theories of state formation, but I go a step further. I use optimal taxation theory to explain *why* organizations of violence would form monopolies of violence in certain locations and not others as a result of a taxation problem. I then apply econometric analysis to show that, consistent with the role played by taxation, monopolies of violence are more likely to emerge, through territorial conquest, when potential tax revenues are expected to be high.

This paper contributes to the growing knowledge of civil war in economics in three ways, and complements the study of rebel governance in political science. First, I collected information on

[6]The literature on state formation is separated between early and modern state formation. The literature on early state formation is reviewed in Claessen and Van de Velde (1991) and Claessen and Skalnik (2011).

[7]See Carneiro (1970), Herbst (2011), Mayshar, Moav, and Neeman (2011), Vansina (1978, 2005) for some explanations.

armed groups' behavior in a large disaggregated data set, improving the empirical basis of the civil war literature. Blattman and Miguel (2010) indeed indicate that the study of civil war is limited by the absence of high quality disaggregated data. Second, I find that demand for labor-intensive commodities *increases* violence aimed at establishing monopolies of violence and taxation, while it leaves the rates of pillages and arbitrary expropriations unaffected. These findings contrast with Dube and Vargas (2013), who find that a rise in the price of a labor-intensive commodity *decreases* observed violence, which they interpret to be driven by a change in the opportunity cost of fighting. By adding taxation to the choices of armed groups previously considered, I thus complement existing explanations for the deployment of violent strategies (Dal Bó and Dal Bó, 2011). Third, by exploiting two exogenous sharp demand shocks, this paper also contributes to this field on the grounds of identification (Angrist and Kugler, 2008, Bazzi and Blattman, 2011, Besley and Persson, 2008, Dube and Naidu, forthcoming, Dube and Vargas, 2013, Nunn and Qian, 2012). In political science, this paper introduces high quality disaggregated data and causal identification to the growing field of rebel governance, which usually relies on qualitative evidence (Arjona, 2008, Mamphilly, 2011, Weinstein, 2007). Furthermore, I complement this field by linking the formation of monopolies of violence by violent actors to the first stages of state formation and grounding the conceptual analogy on systematic empirical evidence.

Having addressed limitations in both the civil war literature and the state formation literature, I link the two by providing an explanation of why actors that engage in violence may organize monopolies of violence. While political economy takes the monopoly of violence as given, the study of civil war in economics focuses on the individual choices to produce or predate, but largely ignores the possibility (or the relevance) to organize violence (Besley and Persson, 2009, Collier and Hoeffler, 2004, Dal Bó and Dal Bó, 2011, Humphreys and Weinstein, 2006, Weinstein, 2007).

Finally, this paper refines the literature on rentier states and the resource curse (Bannon and Collier, 2003, Bates and Lien, 1985). My findings challenge its most basic interpretation and they question the "conflict minerals" discourse. Advocates of this view suggest that when states have access to valuable resources, they will be less dependent on the population for taxes and hence will develop more predatory institutions and will be more prone to violence. This literature ignores that the population needs to be taxed when extraction of resources is labor intensive. I find that natural resources could facilitate the formation of institutions which rely on taxing the population, in a context where production is labor-intensive and rulers need to tax labor directly.

The remainder of the paper is organized as follows. Section 2 offers background and Section 3 presents the theory. Section 4 describes the data and Section 5 presents the empirical strategy. Section 6 presents the results. Section 8 concludes.

2 Background

As a result of the collapse of the central state, armed groups in the Democratic Republic of Congo have proliferated since the 1990's.[8] To finance their operations, they collect taxes on the mineral sector and other activities. Currently, there are 40 identified armed groups.[9]

2.1 The conflicts

This study covers two historical phases: the Second Congo War (1998-2003) and the "post-conflict" period (2003-2013).

The Second Congo War (1998-2003) involved a large number of armed groups, and is referred to as the "Great African War". In 1998, the Rassemblement Congolais pour la Démocratie (RCD) launched an offensive to overthrow the then DRC president in office, Laurent-Désiré Kabila.[10] The coup did not succeed, but a myriad of RCD units maintained control of the Eastern provinces, while the Congolese state defended the West. The RCD struggled to dominate the rural areas, where it faced resistance by the self-defense groups known as the Mayi-Mayi and by the Forces De Libération du Rwanda (FDLR). These groups formed unstable alliances, and the challenge to maintain structures of command led to discipline problems within their organizations. The war also involved the participation of nine foreign armies and thirty local militias, which fought mostly in the east of the country (Ngonzola-Ntalaja, 2002).

Despite support from the UN Peacekeeping force (MONUSCO), the Congolese state struggled to regain control over the Eastern Provinces in the "post-conflict" period (2003-2013). Following a peace agreement signed in Sun-City (South-Africa) in 2003, the Rassemblement Congolais pour la Démocratie (RCD) agreed to vacate the East of the Congo and integrate with the national government. Following the RCD departure, the Forces De Libération du Rwanda (FDLR) and

[8] The Democratic Republic of Congo was named Zaire until 1997.

[9] Source: United Nations Security Council ambassadors (http://www.reuters.com/article/2013/10/06/us-congo-democratic-un-idUSBRE9950IZ20131006)

[10] The First Congo War lasted from 1996 to 1997. It ended with the overthrow of President Mobutu.

local self defense groups increased their territorial control. Only in 2009 the Congolese army, together with the United Nations peacekeeping force and Rwanda, led a major operation against the FDLR. This operation, Kimia II, successfully weakened the link between the FLDR and its former tax base, although it failed to eradicate it. Armed groups continue to operate in the East, where they control up to 95% of the territory in some administrative divisions.[11] Between May 2012 and November 2013, a new armed group, the M23, established its own administration in a large territory, which included departments such as the Ministries of the Interior, of Foreign Affairs, of Agriculture.[12] These groups are motivated mostly by political goals, the organization of self-defense, and economic interests, among a myriad of motives.[13]

2.2 The mining sector

Despite their interests were originally political, armed groups discovered the economic value of violence at the start the Second Congo War, and these interests persisted during the post-conflict period. One of their major sources of revenues is the taxation of mineral trade.

Mineral extraction in Eastern Congo is both labor intensive and a major livelihood of the local population. The World Bank (2008) estimates there are between five hundred thousands and two million artisanal miners in DRC who are responsible for 90 % of DRC mineral production. Heavy minerals, with high real productivity of labor (coltan, cassiterite), coexist with light minerals (gold), which are harder to find and, thus, to produce. So-called artisanal mining requires minimal capital and skills. Miners hand over the extracted minerals in fifty kilogram bags to carriers who then walk to the closest support village, which can be up to various days away on foot. Local traders purchase the output and ship it by plane to Bukavu and Goma. Owing to the large volumes produced and a poor road infrastructure, traders ship heavy minerals to Bukavu and Goma by plane. Such trade is vulnerable to pillage, so armed groups protect businesses by providing security along the carrier's route, for which they collect taxes (Verweijen, 2013). Gold

[11]In Shabunda, an administrative division in Sud-Kivu part of this study, the Raia-Mutombokis control 95% of the territory. See for instance http://radiookapi.net/actualite/2013/02/28/shabunda-la-milice-raia-mutomboki-occupe-95-du-territoire-selon-son-administrateur/.

[12]See http://www.bbc.com/news/world-africa-19651888 , http://radiookapi.net/actualite/2012/08/07/nord-kivu-le-m23-installe-progressivement-son-administration-locale-rutshuru-2/

[13]For an overview of recent Congolese history, see the following historical accounts: Clark (2002), Nest (2011), Nest, Grignon, and Kisangani (2011), Ngonzola-Ntalaja (2002), Stearns (2011), Vlassenroot and Huggins (2005), Vlassenroot and Raeymaekers (2004), Van Reybrouck (2008), Autesserre (2006), Autesserre (2007), Autesserre (2008), Verweijen (2013).

output, in contrast, is easy to conceal. Because of its large value to weight ratio, gold miners conceal the gold output they are able to find. Miners and traders circumvent taxes by smuggling gold directly through Burundi, Bukavu, or Uvira, and Congolese border customs. According to World Bank (2008) estimates, the value of gold exports is US$125 million, most of which is smuggled. A central feature across minerals is that armed groups provide security and collect taxes at the mine as well as on other economic activity at the village.[14]

Property rights are generated in a pluralistic legal environment. Formal law and traditional law co-exist, often with contradictory property rights.[15] Many state or quasi-state agencies (including irregular groups), claim rights by taxing mining output. Despite the apparently chaotic distribution of rights, the production process is tightly organized in a well-defined hierarchy, where miners are partial residual claimants. Taxes are common knowledge, and armed groups often cooperate with the population by offering protection in exchange for taxes. Since production is labor intensive, armed groups rarely mine themselves, but tax output instead.

In the period for which I have data, the mining sector was affected by two price shocks. First, at the start of 2000, Sony announced the Christmas release of its new Playstation product, which is built with processed columbite-tantalite (named coltan in the DRC). At the time of the Playstation announcement, most columbite-tantalite was mined in Australia and its supply was inelastic because of large fixed costs in the production process. In response to the announcement, columbite-tantalite processing firms rushed for columbite-tantalite from other areas, leading the daily price of columbite-tantalite to skyrocket in 2000 from $90 per kilogram to $590 per kilogram. The DRC emerged as a major substitute of Australia's columbite-tantalite. Second, following 9/11 and the economic downturn, investors sought safe assets, which included gold. The price of gold rose in the aftermath of the 2002 crisis and continued to rise during the post-conflict period (2004-2013). Figures 1 and 2 show the world prices of gold and coltan.[16]

[14] The average world price per kilogram of gold in the period was US$17,404, compared with US$136 for coltan. Daily production per worker is approximately 20 kg in coltan, and between 1 and 10 grams in gold. See De Failly (2001), De Koening (2009), Nest (2011), Geenen (2013) and Vlassenroot and Raeymaekers (2004) for descriptions of the mineral sector and the role of armed groups.

[15] Traditional (customary) law is the legal system practiced by local Chiefs, which is justified on local customs. According to customary law, the village chief is the ultimate authority in the village and owner of the land.

[16] See Nest (2011), Stearns (2011), and United Nations Security Council (2002) for descriptions of the coltan shock.

3 A simple model of stationary bandits

In this section, I develop a model in which a violent actor (henceforth, the bandit) can acquire resources by taxing households' activities. The objective of the model is to show how global demand for output produced in a given location, and the physical properties of local production determine the value of holding a monopoly of violence in that location. The model produces three insights. First, an increase in global demand for minerals whose output can be taxed (coltan) increases the value of establishing a monopoly of violence over remaining in roving banditry. Second, an increase in the global demand for minerals increases the returns of monopoly of violence *especially* in areas where output can be traded. Third, an increase in the global demand for minerals whose output can be concealed, and hence impossible to tax, has a *weaker* effect on the value of holding a monopoly of violence. The model applies established results of optimal taxation to the decision to form monopolies of violence and has a similar setup to Besley and Persson (2013).[17]

Anecdotal observation dictates the following modeling choices. First, the model considers taxes on labor inputs and mining outputs. In reality violent actors levy taxes on mineral output, mining labor inputs, food sales, transit of persons, village mills, as well as poll taxes (Sanchez de la Sierra, 2014). I focus on labor taxes and output taxes for parsimony, because they capture the behavioral responses to the one tax when there are multiple dimensions of evasion. Second, the model considers a uncoordinated pillage or taxation (with commitment) in a monopoly of violence as two forms of expropriation. These extreme forms of expropriation reflect the anecdotal observation of the behavior of violent actors in Eastern Congo. Of 546 recorded violent events in the sample villages, 56% are pillage operations, aimed at capturing village assets. Another 38% are conquest attempts, aimed at gaining the monopoly of violence in a village. Monopolies of violence in the sample almost always collect taxes, and almost never pillage their own population.[18]

[17]Tax base elasticity in this model can capture mobility of factors of production, emphasized in Bates, Ndulu, O'Connell, Collier, and Soludo (2008), Herbst (2011), Scott (2009) and Bates and Lien (1985).

[18]Figure 11 provides empirical support to the distinction between conquests and pillages. The figure shows that conquests occur early in the morning, possibly to surprise the defense force, and pillage operations take place at sunset, consistent with a crime deterrence hypothesis (Becker, 1968).

3.1 A stateless economy

Consider one village economy and a mass of roving bandits. Roving bandits engage in uncoordinated expropriation of households' assets and output. A bandit who has superior force might choose to impose his monopoly of violence in the village, thereby turning into a stationary bandit. The stationary bandit announces his theft plan to households (a tax plan) in order to maximize his taxation revenue. The village is composed of k of identical households, $j = 1, 2, ..., k$. In what follows, I drop the household identifiers. Households are endowed with assets and choose the level of the following variables in N sectors $i = 1, 2, \ldots, n$: labor supply, the amount of labor to hide from the tax on labor, and the volumes of output to hide from the tax on output. The stationary bandit is a Stackelberg leader and households are uncoordinated followers.

At step 0, the strongest bandit chooses whether to compete for village assets by pillaging (roving bandit) or to impose his monopoly of violence (stationary bandit), at a fixed cost F. The fixed cost captures the costs incurred by attempting to conquer the village (waging troops, logistics, and expected losses for the group), maintaining control of the village, and potentially, the costs of administering the village. At step 1, the bandit expropriates. Roving bandits lack a long term relationship with households and create a common pool problem among themselves, so they cannot commit not to fully expropriate village assets and output. When there are only roving bandits, households anticipate that they will be expropriated in step 1 with probability one, and do not provide labor. Therefore, roving bandits can acquire only household assets. If, in step 0, the strong bandit chooses instead to acquire the monopoly of violence (becoming a stationary bandit), he has the option to develop a relationship with the households that allows him to commit to his promise of theft. When his monopoly of violence is uncontested, I assume he is able to do so.[19] The stationary bandit expropriates using taxes on output $\tau = (\tau_1, \tau_2, \ldots, \tau_n)$, taxes on labor inputs $t = (t_1, t_2, \ldots, t_n)$. He announces how much he plans to steal (tax) in order to maximize his revenue, internalizing the behavioral responses his tax generates. I first present the households' and stationary bandit's problems in step 1. I then derive comparative statics of the effect of price shocks on the bandit's choice to hold a monopoly of violence.

[19]A Folk theorem argument is sufficient to sustain this assumption, which is also supported by systematic evidence that stationary bandits in the villages establish a taxation plan and commit to it. Absent incentives from repeated interactions, the bandit would never commit and the households would never work. Such behavior can also be obtained by introducing a cost in the bandit's payoff from deviating from the taxation plan. For similar treatment of the future, see Dixit (2004)

3.2 Optimization problems of the households and the bandits

Labor real productivity, $\tilde{\alpha} \in R^n$, is stochastic, and has a known probability density function $f(\tilde{\alpha})$. Output in sector i, $\tilde{Y}_i$, is a linear function of real labor productivity in sector i, $\tilde{\alpha}_i$, and labor supply, e_i: $\tilde{Y}_i = \tilde{\alpha}_i e_i$. Households are partial residual claimants. They sell the output they produce in the world markets, where the prices of outputs, p_i, are exogenous. Households' Bernoulli utility is concave in the unique consumption good, and the dis-utility from labor, $c(e)$, is separable across sectors as well as convex in each sector labor supply, where $e = \sum_{i=1}^{n}$.

Prior to the realization of uncertainty, but knowing the distribution of real labor productivity and the vectors of taxes and prices, the households choose how much labor to supply to each sector $e_i,\ i = 1, 2, ...n$ and how much labor to hide from labor taxes $e_i^H,\ i = 1, 2, ...n$. Then, upon observing realized production, households choose the volume of output they conceal from taxes $H_i,\ i = 1, 2, ...n$, given the sector tax on output τ_i and the output price p_i. The value of output observable to the bandit is thus expressed as: $\tilde{y}_i = (\tilde{\alpha}_i e_i - H_i)\, p_i$ and observable labor is denoted $\tilde{e}_i$. The stationary bandit expropriates after households have allocated labor supply, hidden labor, and concealed output. Households choose labor supply and output concealing to maximize their expected utility. The household's problem is:

$$\begin{aligned}
\max_{e;H;e^H} \quad & \int_{\tilde{\alpha_1}} ... \int_{\tilde{\alpha_N}} u \left(\sum_{i=1}^{N} \left((1-\tau_i)\, p_i \tilde{\alpha}_i e_i + \tau_i p_i H_i - t_i \tilde{e}_i - G^i(H_i, p_i) - E^i\left(e_i^H, p_i\right) \right) \right) f(\tilde{\alpha}) \mathrm{d}\tilde{\alpha_1} ... \mathrm{d}\tilde{\alpha_N} - c(e) \\
\text{s.t.} \quad & H_i \leq \tilde{\alpha}_i e_i,\ i = 1, 2, \ldots, N \\
& e_i^H \leq e_i,\ i = 1, 2, \ldots, N
\end{aligned}$$

where $G^i(H_i, p_i)$ and $E^i\left(e_i^H, p_i\right)$ are respectively the costs of concealing output and hiding labor. Therefore, $\tau_i p_i H_i - G^i(H_i, p_i)$ and $t_i e_i^H - E^i\left(e_i^H, p_i\right)$ are respectively the profits from concealing output and hiding labor. The two cost functions are differentiable, monotonically increasing in both arguments, ($G_1^i > 0$, $E_1^i > 0$, $G_2^i > 0$, $E_2^i > 0$) and strictly convex ($E_{11}^i > 0$, $G_{11}^i > 0$). I focus on solutions where $e_i \geq 0,\ H_i \geq 0$. The problem is akin to a portfolio allocation problem, albeit here the household allocates its labor to sectors with uncertain real productivity $\tilde{\alpha}_i$; investment is costly (the dis-utility of labor supply); investment is taxed (the taxes on labor inputs); the returns to investment are taxed (the taxes on output); and the household can conceal part of the returns to investment (by concealing output). The household's F.O.C. for H_i imply that the household will conceal all output produced if and only if $\tau_i p_i > G_1^i(\tilde{\alpha}_i e_i, p_i)$. However, at interior solutions, the volume concealed is independent on the realization, i.e. $H_i^* = H_i(p_i, \tau_i)$. Thus, in the general case, the optimal volume concealed is the function $H_i^* = H_i(p_i, \tilde{\alpha}_i e_i, \tau_i)$. Figure 10 shows volume concealed as a function of realized output. The household's optimal choice is characterized by the straightforward solution to the F.O.C.'s, in the following functions: $e_i^*(p, F_\alpha, \tau, t)$, $e_i^{H*}(p_i, t_i)$, $H_i^*(p_i, \tilde{\alpha}_i e_i, \tau_i)$. In the absence of income effects, labor supply in sector i, e_i^*, is increasing in p_i and $E\alpha_i$. The stationary bandit chooses taxes to maximize his tax revenue:[20]

$$\max_{\tau,t} \quad E_\alpha \sum_{i=1}^{N} \left[p_i \tau_i \left(\tilde{\alpha}_i e_i^* \left(p, \tau, t \right) - H_i^* \left(p_i, \tilde{\alpha}_i e_i, \tau_i \right) \right) - t \tilde{e}_i^* \left(p, \tau, t \right) \right]$$

When input taxes are not available, the optimal tax satisfies the following relationship:

$$\frac{\tau_l^*}{1 - \tau_l^*} = E_\alpha \frac{1}{\tilde{\varepsilon}_l^{y_l} - \sum_{i \neq l}^{N} \frac{\tau_i \tilde{y}_i}{\tau_l \tilde{y}_l} \tilde{\varepsilon}_l^{y_i}} \tag{1}$$

where:

$$\tilde{\varepsilon}_l^{y_i} = \frac{\frac{\partial \tilde{y}_i}{\partial (1-\tau_l)}}{\tilde{y}_i} (1 - \tau_l)$$

is the elasticity of *observable* output in the sector.[21] Let:

$$s_i^e = E_\alpha \frac{\tilde{\alpha}_i e_i}{\tilde{\alpha}_i e_i - H_i}, \; s_i^H = E_\alpha \frac{H_i}{\tilde{\alpha}_i e_i - H_i} \; ,$$

The elasticity of observable output $\tilde{\varepsilon}_i^{y_i}$, can be rewritten as $s_i^e \tilde{\varepsilon}_i^{e_i} + s_i^H \tilde{\varepsilon}_i^{H_i}$. This formula captures that the optimal tax is proportional to the inverse of behavioral elasticities with respect to the tax rate (Ramsey, 1927).[22] The optimal tax is decreasing in the elasticity of the sector's taxable output.

[20] If the bandit would instead maximize a social welfare function, such as a Bergson-Samuelson functional, the optimal taxes would lie between the revenue maximizing taxes and zero. Revenue maximizing optimal taxes can be derived from the maximization of a social welfare function when the weighted average of the social marginal utilities is zero. For a review of the optimal taxation literature, see Salanie (2011) and Piketty and Saez (2012).

[21] While uniqueness is not relevant, existence is derived as in standard taxation problems in the literature. See Piketty and Saez (2012).

[22] In the absence of distributional concerns, the index of relative discouragement does not enter the optimal tax formula. The last term in the denominator captures complementarities in the optimal tax rates across sectors arising from the fiscal externalities in the presence of multiple dimensions of tax evasion. Increasing the tax rate in sector l might induce reallocation of labor to other sectors raising the optimal tax.

3.3 Gold

"Gold is immaterial: we never see it."[23] While a coltan miner might produce up to fifty kilograms of coltan per day, a typical day of work mining gold yields between a tenth and ten grams of gold output. In the absence of advanced monitoring technology, concealing gold is costless (Geenen, 2013).[24] The ability to observe gold output must therefore affect the violent actors' choice to become stationary bandit. In what follows $i = g$ denotes the gold sector.

Assumption G1: Let $\underline{H_i} \in R$ such that $\forall H_i < \underline{H_i}$, $G_1^i(H_i, p_i) = 0$. Let $\overline{\alpha}_g = sup\{A_g\}$, where A_g is the set of gold real labor productivity realizations: $\overline{\alpha_g} L \leq \underline{H_i}$.

Assumption G2: Let T_i be the fixed cost of taxing output in sector i: $\tau_g^* p_g \int (\tilde{\alpha}_{\mathrm{g}} \mathrm{e}_{\mathrm{g}} - \mathrm{H}_{\mathrm{g}}) \, \mathrm{dF}_{\mathrm{g}}(\tilde{\alpha}_{\mathrm{g}}) < T_g$.

Proposition 1. *Sufficient conditions for the tax on output to be exactly zero, $\tau_i^* = 0$ are either i) G1, in which case $\forall \tau_i > 0$, $H_i^* = \tilde{\alpha}_i e_i$ or ii) G2, in which case $\tau_i^* = 0$.*

Assumption G1 is consistent with anecdotal evidence, and guarantees that it is optimal to conceal any output realization in gold. Under assumption G1, a tax on gold output is irrelevant. Assumption G2 guarantees that it is not profitable to tax gold output. Each of assumptions G1 and G2 is a sufficient condition for $\tau_g^* = 0$.[25]

3.4 Prices and monopolies of violence

This section provides conditions under which the bandit b will choose to attempt to hold a monopoly of violence in the village, $s_b = 1$ or remain roving, $s_b = 0$. While the stationary bandit holds a monopoly of violence and can deter banditry and pillage by roving bandits, his "monopoly of taxation" could be contested by competing stationary bandits engaging in conquest.

[23] Source: interview with armed group member implemented in this project.

[24] Anecdotal evidence from gold mines located elsewhere shows that employers frequently use X-rays to monitor gold miners and prevent theft. See: http://factsanddetails.com/world.php?itemid=1235 & subcatid=324: "Workers at the end of their shift are ushered into a corridor surrounded by glass and monitored by video cameras. Security guards carefully pick through the workers clothes and give them random full body X-ray." The majority of villages in Eastern Congo lack electricity, and importing X-rays is unlikely to be realistic.

[25] From the first order conditions, it can be seen that e_g is increasing in $E\tilde{\alpha}_g$ in the absence of income effects, and H_g is independent on $\tilde{\alpha}_g$ at an interior solution. Finally, under the same assumptions, from equation 1, τ_g^* is increasing in $E\tilde{\alpha}_g$. Such a result is non-trivial without any of these assumptions: while lower average real labor productivity $E\tilde{\alpha}_i$ leads to lower output taxes, it does not necessarily lead to zero output tax. Concealing all output for any τ_i is only possible if $\forall \tau_i > 0$: $\tau_i p_i > G_1^i(\tilde{\alpha}_i e_i, p_i)$. However, under the assumption that $G_1^i > 0$, $\forall H_i$, there exists always some $\tau_i(\tilde{\alpha}_i e_i) > 0$, such that $\forall \tau_i < \tau_i(\tilde{\alpha}_i e_i)$, $H_i^* < \tilde{\alpha}_i e_i$.

Let $V_i,\ i = s, r$ be the expected present discounted value of taxation when the bandit chooses to be stationary. Let $\pi_s(s_b; s_{-b}) \in [0;1]$ be a contest success function for property over the monopoly of violence of bandit b, such that: $\pi_s(s_b; 0) = 1$, $\pi_s(0; s_{-b}) = 0$ and $\pi_s(1;1) = \pi_s$. I assume for simplicity that if the stationary bandit is overthrown, his payoffs terminate. Let F be the fixed cost of holding the village monopoly of violence and $\beta \in [0;1]$ is the time preference. Finally, let $\pi_r \in [0;1]$ be the probability that roving is successful in a given period. As an uncontested stationary bandit, he can collect V_s in taxes, against V_r as a roving bandit, representing his share of the total value of population assets with no output. The bandit b will choose to impose a monopoly of violence if and only if: $\frac{\pi_s(1;s_{-b})}{1-\pi_s(1;s_{-b})\beta}(V_s - F) > \frac{\pi_r V_r}{1-\beta}$.

3.4.1 One contender

If only one bandit can compete over the monopoly of violence, $\pi_s = 1$. Let $i = c$ denote the coltan sector, $i = g$ denote the gold sector. Assume a village is endowed only with one sector (either gold or coltan) and denote the output price of the only sector with p.

Proposition 2. *A rise in the price of the village mineral unambiguously increases the gains of the stationary bandit:* $\frac{\partial V_s}{\partial p} > 0$.

The magnitude of the effect of a price shock depends on the ability to tax the mineral. Proposition 3 establishes this result.

Proposition 3. *The effect of a price increase on the gains of the stationary bandit are larger when hiding output is costlier for the household,* $\frac{\partial^2 V}{\partial p \partial h}$. *The effect of a price increase on the gains of the stationary bandit are larger for coltan than for gold:* $\frac{\partial V_s}{\partial p_c} - \frac{\partial V_s}{\partial p_g} > 0$.

3.4.2 Multiple contenders

If multiple bandits can compete over the monopoly of violence, $\pi_s(s_b; s_{-b}) \in \{0; \pi\}$. In the case of two bandits, it is straightforward to see that the pure strategy Nash equilibria will depend on the output price. Proposition 4 characterizes the Nash equilibria in pure strategies as a function of the output price.

Proposition 4. $\exists\ p^S, p^W \in R,\ p^S < p^W$ *s.t.* $\forall p < p^S\ \{s_b = 0; s_{-b} = 0\}$ *is the unique Nash Equilibrium in pure strategies;* $\forall p^S < p < p^W\ \{s_b = 1; s_{-b} = 0\}$ *and* $\{s_b = 0; s_{-b} = 1\}$ *are the two*

Nash equilibria in pure strategies; $\forall p > p^W$ $\{s_b = 1; s_{-b} = 1\}$ *is the unique Nash Equilibrium in pure strategies.*

Proposition 4 shows that with symmetric contenders, when the price of output is sufficiently low, both bandits will prefer to remain roving bandits. If the output price increases, but not enough to induce both bandits to fight for the monopoly of violence, a stable "state" equilibrium exists, in which one bandit forms a monopoly of violence and remains uncontested. When the price is sufficiently high, a "war" equilibrium exists in which both bandits continuously attempt to hold the monopoly of violence. Proposition 3 and Proposition 4 have the following testable implications.

Testable implication 1: A rise in the price of coltan leads to new monopolies of violence, taxation, conquest attempts, and investments in deterrence in coltan villages.

Testable implication 2: A rise in the price of coltan leads to monopolies of violence, conquest attempts, and investments in deterrence in coltan villages *more so in coltan villages near airports*, where coltan can be exported to meet global demand.

Testable implication 3: A unitary rise in the price of coltan leads to monopolies of violence, conquest attempts, and investments in deterrence in coltan villages *more so than a unitary rise in the price of gold does in a gold village.*

4 The data

This section describes the data collection, defines the main variables used in this paper, and presents strategies used to minimize measurement error. I then present the summary statistics.

4.1 Data collection

I organized the collection of yearly historical data by eleven surveyors of 380 settlements of Eastern Congo, in order to map all (feasible) coltan sites and, within each administrative division (Territoire), a random sample of gold sites of the Province of Sud Kivu. The design of the data collection project reflects the structure of the mining sector. Each mining settlement (henceforth, mining site) is attached to a "support village", which is, in general, the closest village to the mining site. Each "support village" can have multiple mining sites, but each mining site is only attached to one "support village". The average distance between a mine and its support village in the sample is 10 walking hours, with a maximum of 180 hours. In response to changes in prices, the economic incentives of stationary bandits are most likely to be affected at the mining sites directly. Therefore, the survey collected data of every mining site, as well as of every "support village".[26] There are 380 sites, of which 113 "support villages", 20 matched pure agricultural villages in one administrative division, and 237 mining sites. The protocol contemplates multiple data collection activities in 7 days in each village to reduce measurement error and strategic mis-reporting of information.

First, the surveyors identify a group of "history specialists" on the first day in the support village. In practice, the history specialists are individuals who best master the relevant history and surveyors could identify them easily due to their involvement in the mining sector as well as to the tradition of oral history. These are often village chiefs, village elders, mining sector experts, including traders and miners. Surveyors then train the history specialists on how to collect historical data. In each subsequent day, the surveyors monitor how the history specialists collect data. In the last day in each village the surveyors hold a day-long meeting with the history specialists, where they confront the data gathered from the different sources. The data from this meeting is the main source of data used in this paper.

Second, in case of recall error by the history specialists, and in case the history specialists have a tendency to systematically misreport information, the surveyors implement 8 household surveys in private during the 7 days. In each household survey, they reconstruct the history of the village during a 4 hours discussion. In addition, the day-long interview with the history specialists at the end of the village visit contains multiple sources for key variables, which I use as cross-validation.

Third, the surveyors implement an exhaustive set of time cues to reduce measurement error associated with years (de Nicola and Gine, 2012). Surveyors use common knowledge regional events as a reference point to locate the events reported by the respondents in time. Anecdotal evidence suggests this strategy was very effective at identifying years with little uncertainty or none.

Fourth, survey questions focus on transitions and events easy to memorize.[27]

[26]Due to security and logistical challenges, the surveyors collected the data about each mining site during one week of work at the "support village", which was feasible because the entire population and authorities of "support villages" are involved in mining activities at the site, even if workers often live at the sites themselves. Sites vary in their degree of urbanization, thus I account for urbanization in the analysis using detailed data on economic activities at the mining site.

[27]For instance, there are two bags sizes for heavy minerals (50 kg and 75 kg). To measure output taxes, surveyors obtained the fee paid for each size of bag. I then compute the tax per kilogram based on these variables. To measure

Fifth, surveyors draft a qualitative report in each village, where they describe the history of the village, all groups that held a monopoly of violence, their activities and their motivations. To draft these reports, surveyors use the information acquired in the households and with the village experts, as well as additional in-depth interviews with combatants, ex-combatants, and other civilians.[28] By the end of the week, the surveyors were confident they had recovered the history of the village with certainty. I use the information in the 8 household surveys, the multiple (repetitive) modules in the village survey, the qualitative reports in order to cross-validate each observation.[29] Section 7.1 compares the data to other data sources, as well as well-known political events.

4.2 Measurement

This section describes the main variables I use in this paper.

I identified the villages endowed with minerals in existing datasets (International Peace Information Service, 2009) and complemented it with one week of exploratory work by the surveyors in each lower level administrative division in collaboration with the miners, authorities, and mineral traders. For all the analysis, the mineral endowment indicates whether a site has available mineral deposits of a given type at any time in the period. While this approach to measure mineral endowments can bias my estimates downwards, it allows me to circumvent the fact that mining output is endogenous. Figure 1 shows the US prices of gold and coltan. I define a stationary bandit as an armed actor who holds the monopoly of violence in a given site for at least 6 months (approximately). Stationary bandits are most frequently alone when they occupy a site.[30] Stationary bandits, which surveyors and villagers refer to as "organization of security" in the village, are a very common phenomenon in Eastern Congo. Villagers easily distinguish between stationary bandits and roving bandits. textitConquest attempts occur when a violent actor engages in violence with another armed group, with the aim of acquiring the monopoly of violence of the village.

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taxes on labor, surveyors recorded the daily fee miners paid at the entry of the mine for the right to work. These fees are relatively stable, which reduces measurement error. For this reason, certain variables had to be excluded from the mining site survey.

[28] In the reports, surveyors can note explanations for patterns in the data and provide in-depth description about how the bandits and civilians perceive their relationship. I use this information extensively in Sanchez de la Sierra (2014).

[29] I sampled gold villages within blocks defined by administrative division. Figure 5 maps the villages in the sample based on their endowment of minerals.

[30] In some cases, multiple stationary bandits collude (mostly the Mayi-Mayis and the FDLR), and in some, fewer cases, more than one stationary bandits may alternate in one location in a given year.

Pillages occur when a violent actor launches an attack on the village aimed *exclusively* at stealing assets. This definition reflects the observation that local populations are able to distinguish the purpose of the attacks unambiguously. There are also observable distinctions between *pillages* and *conquest attempts*. In a *pillage*, armed groups usually arrive at sunset - when they are harder to monitor - and flee with the village assets within a narrow period of time - to avoid sanctions by larger groups or the Congolese Army.[31] To measure taxes, I collected information on whether a tax was levied on a given activity and at what rate. There was always consensus on whether a given expropriation was taxation or simply pillage. Local populations are familiar with distinct types of expropriation by various actors. While taxation is always anticipated and reflects an implicit long-term contract between those who collect taxes and the population, other types of expropriation (*pillages*, or arbitrary expropriations, known as “tracasseries”) are not, and tend to be bargained on the spot, hence usually violent. In contrast, taxation tends to be at affordable rates. For instance, the data suggests that at the coltan spike, the ad valorem tax rate on output was on average 1% of the value of output on each miner, and the daily tax on labor was 2% of the expected value of output produced by the miner in one day.

With the geographic coordinates collected during the survey, I linked my dataset to geographical shapefiles I obtained from the Réferentiel Geographique Commun.[32] This source contains the map of the road network of the DRC, all airports (including small landing lanes), the location of forests, rivers, lakes, and the regional capitals. I compute the shortest distance of each village to the road, the lake, the forest, the regional capitals, Rwanda, and the closest airport. In the analysis, I use a dummy variable to indicate whether the distance to the closest airport is above the 50% percentile in the sample.[33] As prices, I use yearly US prices of minerals reported from United States Geological Survey (2010).

Table 1 reports the summary statistics for 1999. Figure 3 shows armed groups’ presence in the sample villages over the period. Figure 4 demonstrates that these stationary bandits do not acquire resources by repeatedly pillaging the population, instead provide protection and other public goods, and expropriate through comparatively low levels of taxation.[34]

[31] *Conquest attempts* take mostly place early in the morning and violence is targeted at the group controlling the village, with the aim to defeat them. Figure 11 shows the distribution of the hour of the attacks, by attack type, consistent with the conceptual distinction.

[32] See Référentiel Géographique Commun (2010).

[33] The results are unchanged when I use the continuous measure.

[34] The data suggests that the output tax during the year 2000 was approximately 1% of the value of output produced by the miner, compared to 100% expropriation during a pillage.

5 Empirical strategy

In this section, I present the econometric specification and discuss how I address potential threats to identification.

5.1 Econometric specification

Estimating the effect of mineral prices poses a few challenges. First, local prices are endogenous and might reflect changes in supply. For instance, by exercising local monopoly power or depressing supply, armed groups might inflate local prices. Second, local prices are retrospective, and despite efforts to increase the quality of data collection, they might contain large measurement error. Bias from measurement error may be correlated across minerals or periods. I address this challenge by using the world prices around the time of well-documented global demand shocks.[35] To estimate the effect of (exogenous) world price shocks I use as my baseline specification a linear probability model for simplicity of interpretation, where the dependent variable stationary bandit.[36] As main regressor I use the world price of coltan, interacted with a dummy indicating whether the site is endowed with coltan. All regressions include village and year fixed effects. Since the demand shock for coltan only occurs in the year 2000, including all years in the regression, increases statistical power at the cost of introducing bias if changes to the US price are not exogenous in the remainder of the period. For that reason, I present the results using the whole period, then focus most analysis on the years 1999 and 2000, and add 1998 when adding time trends. The results are identical across time periods. In Section 6, I describe alternative specifications.

While the fixed effects control for constant unobserved heterogeneity and common year effects, imbalance between coltan villages and gold villages could be associated with differential changes

[35]As a validity check on the relevance of the coltan shock, I collected economic data in the households surveys. The retrospective households' economic data reveals large economic effects of the mineral price shock. Figure 13 shows the results from the village survey for the annual number of marriages per village. Since marriage in the survey area requires the payment of a bride price, marriage is a normal good. The coltan shock drastically increased the number of celebrated marriages and led to large reallocation of labor to the mining sector. Second, nighttime satellite lights data confirm the evidence of the coltan shock. Figure 12 shows that a new bright town emerges in the year 2000 near Goma, the capital of the coltan province. This lighting is absent prior to 2000, and vanishes progressively in the following years. Henderson, Storeygard, and Weil (2011) introduced the nighttime data as a proxy for GDP. While not reported, this lighting is reflected in the provinces average stable lights. In addition, I computed zonal statistics of stable lights in each Province of the DRC and compared the change over time between coltan provinces and non-coltan provinces. The results show an increase in stable lights in 2000 in coltan Provinces, but remain constant in the remaining provinces. Finally, Figure 14 demonstrates that the survey identifies occupational transitions into mining in coltan villages as a response to the coltan shock.

[36]The results using conditional logit are analogous.

in armed actors' behavior that coincide with the timing of demand shocks for reasons other than demand shocks. Table 1 shows that this is unlikely, since coltan and gold villages are balanced on constant observable characteristics. Of 11 outcomes, only distance to a bridge in 2010, which is post-treatment, is significantly different across villages with different mineral endowments.[37] Equation 2 presents the baseline specification:

$$Y_{it} = \beta_t + \alpha_i + \gamma_c \, C_i \;\; p(C)_t^{US} + X_{it}' \, \beta + \varepsilon_{it} \tag{2}$$

where Y_{it} is a dummy indicating the presence of a stationary bandit, occurrence of an attack, or taxation by armed actors at site i in year t. The term α_i indicates site specific fixed effects, β_t indicates the year fixed effects, and when appropriate, I include X_{it}, a vector of site level time varying controls which I construct by interacting constant variables with year dummies. The variable C_i is a dummy for whether site i is endowed with coltan, and is constant over time, $p(C)_t^{US}$ is the logarithm of the price of coltan at year t in the US market, as recorded in United States Geological Survey (2010). The regressors p_{ct}^{world} and C_i are perfectly collinear with the year and village fixed effects and I can thus ignore them. In all regressions including more than two periods, I cluster the standard errors at the level of the cluster of sites attached to the same support village. [38]. Testable implication 1 implies $\gamma_c > 0$.

For each site, I obtain the shortest Euclidean distance of the support village to any airport. There are 45 airports in the sample. To test implication 2, I include a dummy indicating whether the village distance to the closest airport is above the sample median distance of support villages to airports and interact it with the main regressor, $C_i \;\; p(C)_t^{US}$.[39] Equation 3 presents the specification for testable implication 2:

$$Y_{it} = \tilde{\beta}_t + \tilde{\alpha}_i + \tilde{\gamma}_c C_i \, p(C)_t^{US} + \tilde{\gamma}_{ca} C_i \, p(C)_t^{US} D_i^a + \tilde{\gamma}_{pa} p(C)^{US} D_i^a + X_{it}' \tilde{\beta} + \tilde{\varepsilon}_{it} \tag{3}$$

[37] A probit of a dummy indicating coltan endowment on the geographic village characteristics in 1999 has a log-likelihood ratio of 29.96, which is above the 95% of the reference Chi-squared distribution. However, joint significance is driven by distance to bridges: when I exclude distance to bridges from the specification, the likelihood ratio drops to 11.85, and I cannot reject the null that all explanatory variables are joint not significant to predict mineral endowment.

[38] When I use only two periods, I do not need to account for serial correlation because the treatment is assigned only in one period. In that case, I cluster the standard errors at the level of the cluster of sites*year. The results are unchanged when I cluster at the cluster of sites. See Bertrand, Duflo, and Mullainathan (2004)

[39] The results are identical when I use the distance in kilometers.

where $\tilde{\alpha}_i$ are village fixed effects, and $\tilde{\beta}_t$ are the year fixed effects. The term D_i^a is a dummy indicating whether the shortest Euclidean distance to any airport is above the median of shortest distances to any airport for all villages in the sample. Testable implication 2 implies that $\tilde{\gamma}_c > 0$ and $\tilde{\gamma}_{ca} < 0$. Finally, let G_i indicate site i endowment in gold and $p(G)_t^{US}$ indicate the US price of gold at year t, and γ_g be the coefficient on $G_i \, p(G)_t^{US}$. Testable implication 3 implies rejecting $\gamma_c \leq \gamma_g$ against the alternative $\gamma_c > \gamma_g$.

5.2 Potential biases in the econometric specification and strategies to address them

I begin by discussing the threats to identification of the main effect, $\gamma_c > 0$, and the strategies I employ to address these threats.

Given the few number of years available to estimate the main effect, the main concern is that the *timing* of the coltan shock may coincide with events that occur systematically in coltan villages for reasons unrelated to the price. I next discuss how I address these concerns, although most of them are resolved by visual inspection of the figures for all years.

First, it is possible that the estimated coefficient picks up pre-existing differential time-trends in coltan villages instead of a causal effect of the coltan shock on armed actors' activity. I address the problem in two ways. I first show the pre-existing trends using figures, and then include the year 1998 to the main specification in order to estimate coltan specific linear trends that are not perfectly collinear with the main regressor by construction (with two periods a mineral specific linear trend is necessarily collinear with the treatment).

Second, since the coltan shock occurred during an episode of war, it is possible that the difference in armed actors' activity between coltan and gold sites is larger during the Second Congo War (1998-2004) than on average. This can be the case if geographic characteristics interact with coltan endowments and are related to the war but unrelated to the price shock. For instance, the Congolese Army is mostly present in period following 2004, and the Congolese Army might deter taxation of minerals in coltan villages particularly. The baseline specification focuses on the years 1999 and 2000 to avoid this potential source of bias.[40]

[40] In addition, in regressions on the whole period, I included controls in the specifications for the presence of the Congolese Army. To measure the presence of the Congolese Army, I use a dummy indicating whether to indicate if the army controls a given village in a given year. I also include the proportion of neighboring villages that are under the control of the Congolese Army in a given year. I operationalize "neighboring villages" by estimating the average

Third, since the villages not endowed with coltan are mostly endowed with gold, it is possible that the estimated coefficient is spurious, and a result of changes in the global demand for gold. To address this, I replicate the baseline specification including the US price of gold interacted with the endowments in gold. Between 1999 and 2000, the price of gold was stable, however.

Fourth, since the coltan shock occurred within an episode of war, the *sequence* of territorial conquest and armed groups' activity could reflect omitted variables that are correlated with mineral endowments. In particular, it is possible, that armed groups first conquered villages close to the road, and that coltan tends to be found in villages further from roads.[41] To account for omitted geographic variables, I control for distance to the road, time-invariant, interacted with year dummies, and replicate the exercise for distance to airports, bridges, parks, lakes, and main trading towns. I report only the results based on the interaction with distance to the road, results are unchanged when I use the other variables.[42]

Fifth, spatial clustering of coltan endowments and spatially correlated errors could give rise to the Moulton problem, and thus lead me to underestimate the relevant standard errors (Moulton, 1986). This is implausible, because, as seen in Figure 5, mineral endowments are not spatially clustered, and thus spatial clustering of errors needs not be accounted for. I account for this in three ways. First, I include region*year fixed effects to the baseline specification in order to account for the possibility that coltan sites may be concentrated within a few regions and that the armed groups actions change in the year 2000 in those regions for reasons unrelated to the coltan demand shock, but which affect all villages in the region, including non-coltan villages. Second, I cluster the standard errors in all specifications at the level of the cluster of sites*year (all sites attached to the same village) or bucked at a higher level (cluster of sites, to account also for autocorrelation of prices and errors over time). Third, I recompute the p-value using randomization inference to account for spatial correlation. [43] If there is any spatial or temporal

number of sample villages in the same administrative division that are under the control of the Congolese Army, replicating this procedure for all levels of the administration. Since the results are identical with all strategies, I include only the village-level variable.

[41]Another threat related to the sequence of conquest is that if a large number of gold villages are also endowed with coltan, the fact that the coltan shock precedes the gold shock may lead to conquest of gold villages - those endowed with coltan - and may thus lead to under-estimate the effect of the gold shock. This is not likely, since only 7 villages are endowed with both coltan and gold sites.

[42]However, as Table 1 shows, coltan and gold villages are not distinguishable by any observable geographic characteristics, except for the distance to bridges in the year 2010 (post-treatment). It is therefore unlikely that any constant observed village characteristic explains a different trajectory of stationary bandits independently of the demand shock.

[43]I construct a reference distribution of coefficients that does not hinge on assuming normally distributed errors or on assumptions about the structure of the variance-covariance matrix (Gerber and Green, 2012). I do so in two

correlation structure in the data that could lead OLS to underestimate the standard errors, the distribution of coefficients estimated through randomization inference will have thicker tails and the real coefficient will be hard to distinguish from coefficients estimated using fake assignments to treatments.

Sixth, the coltan price may be autocorrelated. To account for this, in addition to accounting for autocorrelation of standard errors using clustering of errors at the level of the cluster of sites, I also implement a falsification test by including in the regression the lead of the main regressor, as well as the lag of the main regressor. In addition, I cluster the standard errors and use randomization inference to account for serial correlation.[44]

Seventh, the specification choice may bias the results. First, the linear probability model with fixed effects will produced biased estimates in the presence of errors in variables in the dependent variable (Hausman, 2001). Second, fixed effects estimates are usually sensitive to measurement error (Angrist and Pischke, 2009). I thus check whether the results are robust to alternative specifications. I first replicate the baseline specification using conditional logistic regression instead (I only report the results of the logistic regressions in the online appendix), and also implement a regression with lagged dependent variable using Arellano-Bond dynamic panel GMM estimation, whereby I instrument for the first-differenced lagged dependent variable with its value the year before. I provide the results using additional specifications in the online appendix.

I next discuss threats to identification of $\gamma_c - \gamma_g$.

First, the coltan and gold price shocks seem to be of different magnitudes. Price shocks of different *magnitudes* might generate very different responses by armed actors, for instance, if the armed actors' territorial conquest cost functions are non-linear. For instance, if engaging in conquest has a fixed cost, a shorter, but more intense price shock might result in stronger outcomes. However, the gold price rise is much larger in absolute increase, it is thus unlikely that a positive difference is due to a weaker gold price rise. I use the logarithm of prices in the regressions in examine the effects of percentual changes in price levels.

Second, the *timing* of the shocks may be correlated with omitted variables. For instance,

ways, simulating 20,000 treatment assignments for each. In one set of simulations, I randomly re-assign US prices to years using the empirical vector of realized prices; in a second set of simulations, I randomly assign fake prices to years using a theoretical distribution. I use a uniform distribution with mean equal to the empirical mean of realized prices, but the result is not sensitive to the choice of the data generating process for prices.

[44] I do so by simulating 20,000 fake coltan endowments to the sample of villages and comparing the estimated coefficient using the real data to the distribution of estimated coefficients using the simulated endowments.

following the Second Congo War in 2003, the Congolese Army progressively regains control, which coincides with the rise in the price of gold. If the Congolese Army is a deterrent of armed actors' activity, $\hat{\gamma_c} - \hat{\gamma_g}$ will be biased upwards. To address this concern, I estimate the coefficient on the gold price for all possible year intervals in the sample, with and without controls for the nearby presence of the Congolese Army, and report the coefficients estimated with all periods. I do this by generating all possible of combinations of start and end dates such that the start date precedes the end date.

Finally, armed actors (and populations) in gold sites may be different than those in coltan villages. If different armed actors (or populations) self select into gold or coltan villages, the effects of price shocks could be different due to heterogeneity among populations. It is reassuring, however, that geographic characteristics (Figure 1), household level characteristics, as well as armed groups' identities are balanced across gold and coltan villages around the price shocks.

6 Results

This section presents the results.

6.1 Stationary bandits

I test the main implications from the model: the coltan shock leads armed actors to attempt to acquire the monopoly of violence at coltan sites; this effect must take place especially near airports, where trade costs are not prohibitive; the effect of the gold demand shock is lower than the effect of the coltan demand shock. Figures 6 to 8 show the main results graphically.

Figure 6 shows the average number of stationary bandits per site for all years, for sites endowed with coltan and sites not endowed with coltan, focusing on mining sites.[45] Four observations are relevant. First, the coltan shock in the year 2000 led to a drastic increase in the average number of stationary bandits in coltan sites, from .45 to .82, compared to a rise from .45 to .55 in sites not endowed with coltan. Second, the trends preceding the coltan shock are identical in coltan and

[45] I use the average stationary presents that have occupied a given site in a year, but if I use a dummy instead, the results are identical. Since a stationary bandit is defined as an armed actor (or actors) holding the monopoly of violence in the site for at least (approximately) 6 months in a given year, multiple stationary bandits occur when there is a succession of stationary bandits in a given year with lengths of approximately 6 months each, or when there is collusion between two armed actors.

non-coltan villages. The identical pre-existing trends justify the focus on the years 1999 and 2000 in the econometric specification, even if I also check for robustness to pre-existing trends. Third, the dynamics including all other years suggest that it is very unlikely that the differential increase in coltan in the year 2000 is due to intra-cluster correlation of shocks (shocks common to coltan sites) unrelated to the price shock. As is visible from Figure 6, the two time series are almost indistinguishable once the effect of the coltan shock is gone.[46] Finally, the dynamics of the series suggest that there is persistence in stationary bandits, and thus that a short-term demand shock in the year 2000 had a persistent effects on village institutions. I discuss persistence in Section 6.5.

I next turn to the econometric estimation of the effect of the coltan shock on stationary bandits. Table 2 shows the results from a linear probability model using site-year data, with as dependent variable a dummy indicating whether a site has a stationary bandit. Column (1) presents the results where I included observations of the whole period (1998-2008) and a control for the US price of gold interacted with gold endowments at the site level. The estimation suggests that the coltan shock, a seven fold increase in the price of coltan, drove the probability of having a stationary bandit in a coltan site up by 47 percent. In contrast, the effect of the price of gold is negative and insignificant, despite the fact that the price of gold was rising for the whole period and that Congo is considered a price taker in the global gold market. The table presents the results aimed to address the concerns I introduced in Section 5.2.

First, since the coltan shock only occurred in 2000, the price of coltan may not be exogenous when I use the whole period. Furthermore, using data from too many years around the coltan shock might understate the standard errors on the coefficient estimates (Bertrand, Duflo, and Mullainathan, 2004). To address this concern, Columns (2)-(5) restrict the sample to 1999-2000 thus implementing an estimation analogous to difference in differences with an exogenous shock to the price of coltan. Column (2), henceforth the baseline specification, replicates Column (1) using only 1999 and 2000 and excludes the gold interaction (the price of gold is stable between 1999 and 2000).[47] The main coefficient is unchanged.

Second, the sequence of conquest of coltan villages could reflect that coltan villages differ in

[46]This is important because it is theoretically possible that coltan villages are systematically subject to common year shocks. While a structure of common shocks among sites endowed with the same mineral endowments is implausible due to the absence of spatial clustering by mineral endowment, economic networks could link sites endowed with the same minerals, creating the conditions for an intra-cluster correlation - where clusters are defined by mineral endowment and not by their location - that is significant in magnitude.

[47]The result is identical when I include the gold interaction, which is to be expected since the price of gold is stable in 1999 and 2000.

constant characteristics, such as proximity to roads. For instance, armed groups may have first conquered sites close to the road in 1999, and then further villages in 2000. If coltan villages are systematically further from the road -which is implausible since coltan and gold villages are balanced by distance to the road - the main coefficient could be biased. To address this concern, Column (3) adds interactions with $D\ road_i$, a dummy indicating whether the site cluster of mining sites is far from a road (defined as distance to the road above the 50th percentile in the sample). When I include these controls, the main coefficient is even larger, despite the fact that the coefficient on $p(C)^{US}\ D_i^a$ is positive and significant. This suggests that the effect of the coltan shock is especially strong among villages in the proximity of roads.

Third I estimate the effect of the coltan shock among sites that are close to an airport and the marginal effect for villages that are far from an airport, Column (4) includes $D\ airport_i$, a dummy indicating whether the site cluster is far from a local airport (defined as distance to the road above the 50th percentile in the sample) and includes its interaction with the main regressor, $C_i\ \ p(C)^{US}$, as well as with $p(C)^{US}$. Consistent with testable implication 2, the main coefficient doubles, and the coefficient on $C_i\ p(C)^{US}\ D\ airport_i$ is negative and statistically significant. This suggests that the effect of the coltan shock is concentrated among sites which are in the proximity of an airport, and thus where coltan can be shipped to international markets.[48]

Fourth, spatial clustering of coltan endowments and spatially correlated errors could give rise to the Moulton problem, and thus to underestimate the relevant standard errors (Moulton, 1986). While I account for this by clustering the standard errors, Column (5) adds region Territoire*year fixed effects. The results are unchanged when I include these controls.

Columns (6)-(9) include in addition the year 1998 to allow additional robustness checks. Column (6) implements a falsification test by including the lead value of the main regressor, and the result is even stronger: the main coefficient rises to .20. Column (7) includes a lagged dependent variable and implements dynamic panel data GMM using Arellano-Bond. The results are identical to the results of the baseline specification.

To account for pre-existing differential time trends, Column (7) includes coltan-specific linear trends as regressors. The results are even stronger. Column (8) presents the baseline specification with all robustness checks and the results are unchanged.

[48]A possible concern is the airports may be constructed at a low cost. The qualitative fieldwork suggests that mining areas were often located in remote forests controlled by numerous adverse armed groups. This made building new landing lanes very difficult in the short-run. It is not implausible, however, that had the coltan shock lasted longer, the armed groups might have engaged in creating new airports.

Turning to testable implication 3, an increase in the price of coltan should have a larger effect than an equivalent increase in the price of gold. The point estimates provide support for this testable implication 3 across columns. The gold price is negatively related to presence of a stationary bandit in gold villages. I then run a t-test that the coefficient on coltan is smaller or equal to the coefficient on gold in the baseline specification rejects the null hypothesis with a p-value of 0.03. Since the rise in the price of gold is prolonged, the null estimate on the gold interaction can capture differential effects of changes in the political environment. In order to show that the gold effect is not a product of selecting a time interval in the baseline specification which yields convenient results, Figure 9 presents the estimated coefficient on gold for all combinations of start and end dates in the sample. In less than 2% of regressions, the coefficient on gold is positive and statistically significant, consistent with testable implication 3.[49] In sum, the estimated behavioral response on stationary bandit emergence are consistent with the testable implications 1,2,3.[50]

6.2 Expropriation strategy: from pillage to regular taxation

Figure 7 shows the proportion of sites in which an armed actor collects regular taxes for all years, for sites endowed with coltan and sites not endowed with coltan, focusing on mining sites. While the proportion rises from .3 to .65 among coltan sites, it remains constant in sites not endowed with coltan. Again, the figure makes clear that the trends preceding the shock are identical in coltan sites and in sites not endowed with coltan, demonstrating that the differential increase in taxation is not picking up pre-existing differential time trends. Second, following the shock, taxation exhibits persistence in coltan sites, before becoming identical to the rates of taxation in sites not endowed with coltan. This is consistent with a view in which establishing a taxation system entails fixed costs (for instance, by waging a conquest operation to gain the control of the monopoly of violence). Table 3 presents the econometric results and follows a structure identical to Table 2. Across all columns, the main coefficient is positive and statistically significant, suggesting

[49] Some coefficients are negative and statistically significant. The rise in the gold price, however, coincides with the rise in power of the Congolese army, which could act as a deterrent on stationary bandits in gold villages. When I control for gold specific time trends, the negative coefficients of gold are no longer significantly different from zero.

[50] However, while the discrepancy in coefficients is consistent with the theoretical results, it alone is no evidence that the underlying mechanism the inability to tax gold output is the underlying mechanism leading to this result. This relationship would also be predicted on the basis of the lower real productivity of labor in gold. I re-scaled the estimated coefficients obtained from the baseline specification as derived in Appendix A, and reject the null at conventional levels of statistical significance. Thus, the magnitude of the difference in the coefficients is consistent with the interpretation that the ability tax mineral output is driving the main result.

that the demand shock for coltan led to the emergence of taxation in coltan sites.

Table 4 shows the results from a linear probability model with six different types of taxes as well as occurrence of pillages as dependent variables. Columns (1) through (7) use as dependent variables dummies indicating respectively the presence of the following types of expropriation: mineral output taxation, taxation of mining labor, poll taxes in the attached village, taxes on food sales in the corresponding market of the attached village, taxes on population transit in and out of the attached village, taxes on daily activity of a mill in the attached village, and pillaging in the attached village. Columns (1) through (3) demonstrate that the coltan shock led to the emergence of mineral output taxation, mining labor taxation, and poll taxes, and left the other forms of expropriation unaffected. The results are consistent with the standard evasion problem developed in the theoretical framework: the desirability of raising poll taxes increases as the value of output increases, part of which is not being captured due to tax evasion. Armed actors increase the collection of poll taxes in order to capture the rise in household income.

6.3 Organized attacks

Figure 8 shows the the average number of attacks per site, for coltan sites as well as for sites not endowed with coltan. It also shows the average tax that armed groups obtain per kilogram of coltan output, as a proxy for the value of controlling a coltan site. While the average number of external attacks rises from .3 to 1.2 in coltan sites, they remain around .4 for sites not endowed with coltan. The output tax rate per kilogram rises in exactly the same proportion as the US price of coltan. Table 5 presents the econometric results. The main coefficient is statistically significant across columns, and is of the same magnitude as the coefficient for stationary bandits in Table 2.

While I do not observe conquest operations in mining sites, I observe it for their attached support village. Thus, I can map the average number of attempted conquests on support villages of coltan sites. The distance to the neighboring village should translate into a smaller increase in the temptation to hold a monopoly of violence in the attached village. The estimated coefficient, thus, will likely be an under-estimate of the actual effect in mining sites. Figure 15 in the online appendix plots the average territorial conquests attempted on the attached villages, for villages that are the support for coltan sites, and villages that are the support for other sites which are not endowed with coltan. While the average number of conquest operations increases from .10 to .40 in villages linked to a coltan site, it remains constant at .25 in villages linked to no coltan site, and this change is not the continuation of a pre-existing trend. The figure restricts the sample to villages in which a stationary bandit was already present in 1999, since as predicted by the theory, conquest operations should occur in villages where a stationary bandit is present already (otherwise, the armed actors can just walk in the village).

6.4 Spillovers effects on neighboring villages

In order to estimate spillovers, I first define the cluster within which I expect spillovers can be positive. Each support village is attached to a site or multiple sites. The sites tend to be very remote, and the support village is in general the closest village to the sites. I focus on spillover effects of the sites on the attached village.[51] Table 6 presents the results on the linear probability model for village level outcomes in order to estimate spillovers on the village attached to the mining sites. The main regressor, $Coltan_i\ Pc_t$ is computed coding as 1 all villages where at least one site attached to it is endowed with coltan, and interacting this dummy with the logarithm of the US price of coltan. The columns use as outcome variables the following dummies: whether a stationary bandit is settled at the village; whether an armed actor regularly collects poll taxes at the village; whether armed men organized external attacks on the village; whether armed men organized external attacks on the village which where specifically aimed at attempting conquest and obtaining the village monopoly of violence; whether armed actors organized external attacks on the village which were specifically aimed at pillaging (acquiring resources quickly and violently); whether a stationary bandit settled in the village in a given year increased his stock of guns (usually AK47). Standard errors are clustered at the level of the village*year. The table shows

[51]The effect of the coltan shock on coltan sites may spillover on the attached village for various reasons. First, there can be direct economic and institutional spillovers stemming from changes in the profitability output at the mine. For instance, if populations working in the site live and consume in the neighboring attached village, the profitability of holding the monopoly of violence in the attached village will increase whenever the value of output at the site increases. In addition, if stationary bandits derive disutility from settling at the site, a rise in the profitability of holding a monopoly of violence at the site may induce stationary bandits to settle at the attached village. Second, there can be economic and institutional spillovers stemming from strategic interactions between potential stationary bandits at the attached village and the site, who take into account the direct spillovers on each other and adjust their decision whether to settle in response to each others' strategy. For instance, the decision of whether to settle in a support village by one armed actor and the decision of whether to settle in a mining site by another may be complements if there are positive migration effects, or if they benefit from sharing fixed costs of investments in state capacity. They may be substitutes if settling in the proximity of each other also decreases their costs of attacking each other. I ignore the distinction between direct spillovers and strategic response by attached villages, and instead estimate the total spillovers using a reduced form approach. Acemoglu, Garcia-Jimeno, and Robinson (2014) estimate state capacity spillovers in Colombia and find evidence for strategic complementarities across villages.

that, independently of the distance to the village, there are positive spillovers arising from the mining sites on the attached villages. An increase in the price of coltan leads to the emergence of stationary bandits in attached support villages, the emergence of poll taxes, the presence of external attacks, the presence of conquest operations, as well as the accumulation of guns (AK47) by stationary bandits.

6.5 Persistence of stationary bandits' fiscal capacity

Historical accounts of the formation of European states suggest that rulers created state capacity, and in particular fiscal capacity, as a result of a temporary need for public revenue to finance wars, and that fiscal capacity persisted in the aftermath of the wars (Besley and Persson, 2008, Salanie, 2011, Tilly, 1990). Using the fact that the coltan shock was temporary, I can estimate the persistence of stationary bandits' fiscal capacity.

Figures 6 and 7 plot stationary bandits and taxation in coltan and other sites between 1995 and 2012. Stationary bandits and taxation emerged in response to the coltan demand shock and persisted for various years despite the return of coltan prices to levels preceding the coltan shock. Table 7 presents the analysis of persistence of stationary bandits in a regression framework [52]. The online appendix provides results for persistence of spillover effects in the neighboring agricultural villages (Table 11).

Table 7 shows the estimates from a linear probability model regressing the presence of a stationary bandit on the lagged values of the $C_i \quad p(C)_t^{US}$. Columns (1)-(4) replicate the baseline specification, but include the lags. The coefficient on the first lag of $C_i \quad p(C)_t^{US}$ suggests that the coltan demand shock led to the emergence of stationary bandits which persisted for two years after the shock, despite the sudden and permanent reversal of coltan demand in 2001.

However, the results in Columns (1)-(4) may not be due to persistence (autocorrelation in the dependent variable), but simply to the coexistence of a contemporaneous and a delayed effect of the coltan shock. To capture the role of autocorrelation in the dependent variable, Column (5) includes the lagged dependent variable as a regressor and implements Arellano-Bond GMM estimation - I choose Arellano-Bond GMM estimation instead of standard OLS with fixed effects due to the potential biases that arise in the presence of lagged dependent with fixed effects. Inclusion of the lagged dependent variable renders the lags of the coltan shock statistically insignificant and

[52] the analysis of persistence of taxation is even stronger, and unreported here but available upon request

close to zero, while the lag of stationary bandit is significant at the 1% level with magnitude of .74. This suggests that the coltan shock led to stationary bandits, and stationary bandits are strongly persistent. Column (6) adds the second lag of stationary bandit and the results are unchanged.

A remaining alternative explanation, however, is that stationary bandits persisted despite the sudden decrease in global prices, simply because the local price remained high in the years following the coltan demand shock, which allowed them to continue generate revenues from taxation (Figure 2). Anecdotal evidence and survey data on expectations suggests that local coltan traders continued to demand coltan after the sudden price decrease of the start of 2001, because they expected that the world price of coltan would rise again. To rule out that continued local demand for coltan is accounting for the persistence of stationary bandits, Column (7) includes the average price of coltan paid by traders at the site level, collected in the survey.[53] When I include the log of the local price of coltan, interacted with coltan mineral endowments as a control in Column (7), its coefficient is positive and statistically significant. However, the lag of stationary bandit remains of similar magnitude and statistically significant at the 1% level. This suggests that the local price of coltan alone cannot explain the persistence of stationary bandits.

Finally, Column (8) implements a 2SLS panel regression of stationary bandit on its lag, where I instrument the first lag of stationary bandit with the first lag of $C_i \;\; p(C)_t^{US}$ in order to circumvent endogenous location of stationary bandits. The results are unchanged, and the estimated impact of lagged stationary bandit on stationary bandit is close to 1.

Overall, this analysis suggests that proto-state structures and fiscal capacity emerge endogenously where potential tax revenues rise, and persist in the aftermath, consistent with the presence of a fixed cost of developing fiscal capacity (Besley and Persson (2009), Tilly (1990)). Temporary commodity shocks can create persistent proto-state structures.

7 Discussion

In this section, I provide evidence that provides additional confidence in the quality of the data using external sources of data. I then discuss the whether the stationary bandits are good, and their relevance to the process of state formation.

[53] To minimize the risk that measurement error drives the results, I averaged the yearly values of the price of coltan for all villages in the sample.

7.1 Measurement error

First, the data on stationary bandits benchmark very well with well-known historical junctures, which provides support to the quality of the data. Figure 3 plotted the survey-based measures of armed groups' occupation of villages in the sample on years. Stationary bandits emerge in 1996, as expected, coinciding with the AFDL rebellion. Stationary bandits re-emerge at the time of the RCD rebellion and Mayi-Mayi resurgence in 1998. They progressively disappear in 2003/2004 coinciding with the last years of the Second Congo War, when the RCD was known to gradually disengage, and the partial re-integration of Mayi-Mayi factions into the Congolese Army.

Second, the data on attacks also fit the known historical evidence on major episodes of the Congo Wars. Figure 16 plots the survey-based measures of armed groups' attacks on villages in the sample on years. The recorded attacks map precisely to the known phases of the war: the spike in 1996 by the AFDL corresponds to the well known timing of the AFDL combats in 1996. The resurgence in attacks between 1998 and 2003 corresponds to the RCD rebellion and its resistence by the Mayi-Mayi.[54] Furthermore, the data captures the drastic rise in attacks by the FDLR in 2009, 2010, 2011, as a result of the Kimia II operation led by the Congolese Army, which undermined their access to stable finances (Sanchez de la Sierra, 2014). Finally, attacks recorded by the survey also capture the contemporaneous rise of the Raia Mutombokis since 2011.

Third, local prices benchmark the world prices, adjusted. Figure 2 shows that the survey-based recall prices closely track the international world price. It further captures the well-known fact that local traders expected the price to rise back to its peak, once the world price fell. [55] Overall, the data on prices, armed groups, and attacks correlates well with known historical events.

Despite its precision, the data could have systematic under-reporting biases due to the sensitive nature of the information collected. To assess under-reporting, I assigned violent events geo-coded by an external dataset (ACLED) to circles around the surveyed villages. The ACLED dataset contains 3,500 violence events since 1997, coded by perpetrator and type of event. Unlike the data collected in this study, the ACLED data is based on news reports. I compare this data to my source that contains the number of attacks on villages.[56] When an event falls in circles

[54]There is a also a sharp spike exactly in 2004, corresponding to the well documented timing of the CNDP rebellion. I do not report it for clarity of the Figure.

[55]see Online Appendix D and United Nations Security Council (2002)

[56]The survey module I used here contains larger numbers of violent events than the survey module used to discriminate pillages and conquests, because villagers could not remember the details of some attacks.

assigned to more than one village, I allocated the event to all village circles in which it fell. Figure 17, based on the survey module which asks respondents to report the number of violent attacks (as opposed to the details of each attach that they remember), shows that the ACLED dataset systematically reports less violence around the selected villages than the current survey. The gap between ACLED and the survey is especially strong during the Second Congo War and in particular the coltan shock. While it is possible that this difference between the survey and the ACLED data is due to the unobserved fact that villagers over-report violent events in the survey, under-reporting due to memory loss and fear of retaliation is more likely given the nature of the data.[57] The patterns in Figures thus suggest that the survey improves upon the ACLED dataset for the locations for which I have data. I then correlate the data to ACLED's data in an OLS framework. Regression estimates for the variable conquest attacks in the neighborhood of the village are positive and significant (Table 8). In addition, attacks reported by my survey are less likely to be reported in ACLED when the villages were under RCD occupation (suggesting that the source of under-reporting in ACLED could be obstruction of information),which is especially plausible for attacks that are smaller in scale (pillages).[58]

7.2 Are stationary bandits good?

I can use my data to examine whether these stationary bandits have positive welfare effects by estimating production and growth differentials between stationary bandits' sites and sites in which a stationary bandit is absent. If stationary bandits' protection allows to increase production, production should increase *more* in villages in which there is a stationary bandit. Figure 22 shows the median volume produced by the average miner in coltan sites over the years, for sites in which a stationary bandit is present in 2000 and sites in which there is not.[59] In response to the coltan shock, most production increases in coltan villages occurs where a stationary bandit is present.

However, this relationship may be the result that stationary bandits self-selected into the most profitable coltan villages. Since the distance to a local airport proxies for trade costs and thus

[57]It would be very unlikely that villagers report fake attacks, and so proportionally to the incidence of real conflict, since they may fear retaliation.

[58]This result applies even stronger with RCD perpetrated violent events, consistent with reporting bias.

[59]I used median production because of the presence of large production outliers in stationary bandits controlled coltan sites. Thus, while the results are similar using the mean instead, using the median biases the results against the finding that stationary bandits have a positive effect on production. Figure 23 shows the results with mean production instead.

inversely relates to the value of holding a monopoly of violence, I regress production on year effects and control for year effects interacted with distance to the closest airport. Figure 24 plots the residuals, and shows that the results remain: coltan sites in which a stationary bandit was present, even after controlling on observable characteristics which predict the profitability of the village, benefit most from the coltan shock. Obviously, this result relies on the assumption that stationary bandits select coltan sites only on the basis of observable distance to the closest airport. Nevertheless, it is consistent with the interpretation that the welfare gains from the protection provided by stationary bandits dominate the welfare losses from the distortions their taxation generates on effort and investment. It is also consistent with the results in Sanchez de la Sierra (2014), where a later shock to the presence of stationary bandits in targeted villages to estimate their impact on production.

7.3 Where do we go from here: bandits or states?

Some scholars, especially in international relations (Mamphilly, 2011), recognize states mostly through their legal status in the international system. As a result of the choice of definition, this scholarship struggles to recognize the conceptual analogy between armed groups and the process of state formation that precedes its recognition by the international community (Carneiro, 1970, Tilly, 1985). This reasoning reduces the process of state formation to international politics, and ignores the underlying social process leading to its success or failure, which is the focus of this paper.

A larger number of scholars emphasize the necessity of legitimacy to distinguish states from coercive territorial control by armed groups. This constraint would apply, in their view, to discriminate between monopolies of violence that may turn into states and those that will not. The stationary bandits I observe in this study would thus be of little interest for the study of state formation. First, the belief that the states as we know them today emerged from attempts to establish control by a legitimate authority runs against historical evidence (Carneiro, 1970, Tilly, 1985). Through war and coercive taxation, the first stages of state formation are likely to have been associated with coercion, violence, and even systematic enslavement. Second, the behavior of the stationary bandits provides additional support to this analogy. They indeed expropriate through stable taxation, but they also frequently provide protection and administer justice, and enjoy surprising popular support from the population they control. As a matter of fact, the population in many areas they control very often does not even recognize the Congolese state as a legitimate ruling organization (Sanchez de la Sierra, 2014). Third, the view that are states only those monopolies of violence whose authority is legitimate, however, seems to hinge on a misinterpretation of Weber (1946)'s famous definition of the state as a "monopoly of legitimate violence". While distinct from legitimate authority, which as suggested cannot be a necessary condition for the process of state formation, the legitimacy of violence follows from holding the monopoly of violence. Indeed, if the monopolist of violence can decide on violence by the mere fact of having the monopoly of violence, he has by implication the monopoly of violence that he declares legitimate using his monopoly of violence to coordinate sanctions on the violence that he declares illegitimate. A monopoly of violence implies legitimate violence, but not vice-versa. Thus, while the stationary bandits I observe enjoy some legitimacy and provide some public goods, legitimacy lacks empirical and predictive content, even to understand the behavior of today's states. Many of which lack legitimate authority or even legitimate violence.[60]

A limitation of the current study is the focus on rulers whose technology of violence allows them to own the monopoly of violence in the small territory they control and design property rights. Individuals holding a monopoly of violence, however, are rare in larger units. This setting, thus, reduces the room for mutual dependencies with administrators which characterize large parts of the state formation process at a larger scale. As states grow, the control exerted by individual rulers over their territory diminishes, and the monopoly of violence held by the state depends the ability to coordinate coercion and other policies by administrators (Greif, 2008).

Overall, pessimistic views on what stationary bandits actually do, as well as conceptualizations of the state by current scholars likely influenced by the recent anomalous development of the welfare state and which ignore a long coercive and extractive history of the state, underpin the failure to recognize the relevance of stationary bandits in the process of state origins and their relevance to the study of state behavior.[61]

[60]The coercive definition of the state stripped of its legitimacy content, predates Weber (1946). Trotsky (1905) wrote in 1905: "in any normally functioning state, whatever its form, the monopoly of brute force and repression belongs to the state power. That is its inalienable right, and of this right it takes the most zealous care, ever watchful lest any private body encroach upon its monopoly of violence. In this way the state organization fights for its existence."

[61]Economists also recognized the criminal origins of states and the relevance of economics of crime: "The study of the economics of crime promises to offer profound insights into the origins and workings of governments, not as most of us know them, but like those that have ruled the bulk of humanity in the past, and continue their sway in many countries today." (Baumol, 1995).

8 Conclusion

This paper provides an empirical basis to study the first stages of state formation in economics, but also contributes conceptually to unresolved debates about the nature and origins of the state in other disciplines. The findings mostly provide support for conflict theories of state formation, where state structures emerge through coercion in order to increase expropriation, although they do not discredit a contractarian view of the origins of the state as a possibility. They suggest that economic analysis can go a long way to explain empirical patterns of state formation.

The results have implications for policy. Armed groups are a topic of growing interest among governments. This study provides econometric evidence of the relationship between violence and mineral endowments in the DRC. I find that mineral price shocks lead to violence between armed groups in order to acquire the territory that is mineral rich. I also demonstrate that fluctuations in global demand for electronic products can have profound long-lasting consequences for violence and institutions in villages supplying required minerals. Stationary bandits emerge in villages endowed with that mineral, design elaborate taxation plans, and they remain in place in the aftermath of the shock.

My findings suggest a similarity between violent organizations and states. Like states, actors who can organize violence can exert coercion in order to expropriate, but also to maintain a monopoly of violence and provide protection. Their strategies might turn in favor of the population when the population can be a profitable tax base, leading potentially to the first stages of state-like structures. Future research in the political economy of state formation should examine the conditions under which rulers successfully coordinate their administrators (Greif, 2008).

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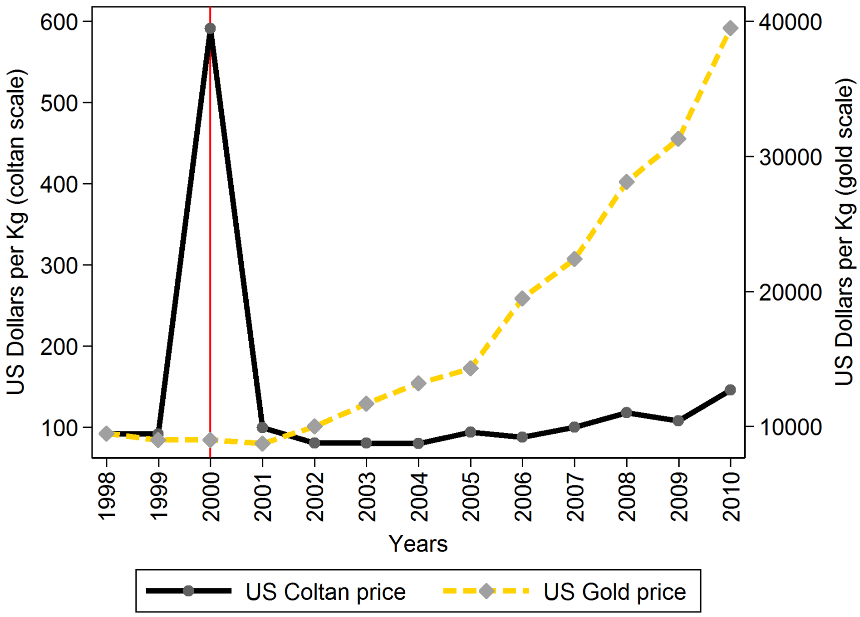
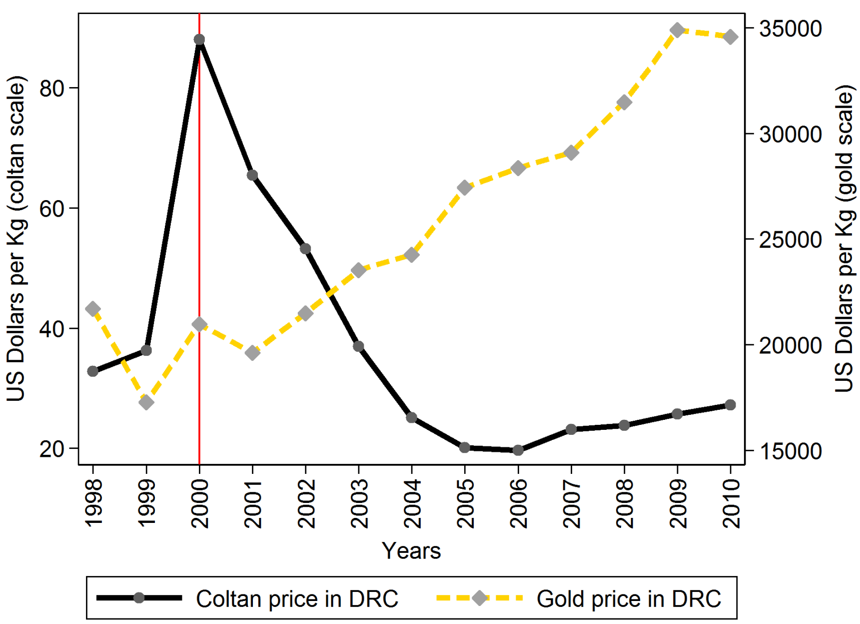
Figures and Tables

Figure 1: World prices of coltan and gold



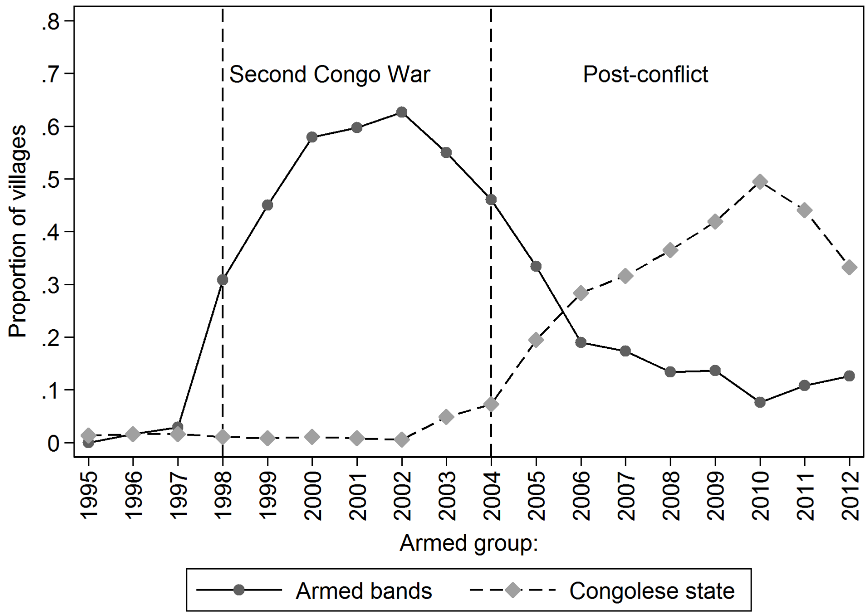
Notes: This figure plots the yearly average price of gold and coltan in the US market, in USD per kilogram. The price of coltan is scaled on the left vertical axis and the price of gold in the right axis. Source: United States Geological Survey (2010).

Figure 2: Local prices of coltan and gold



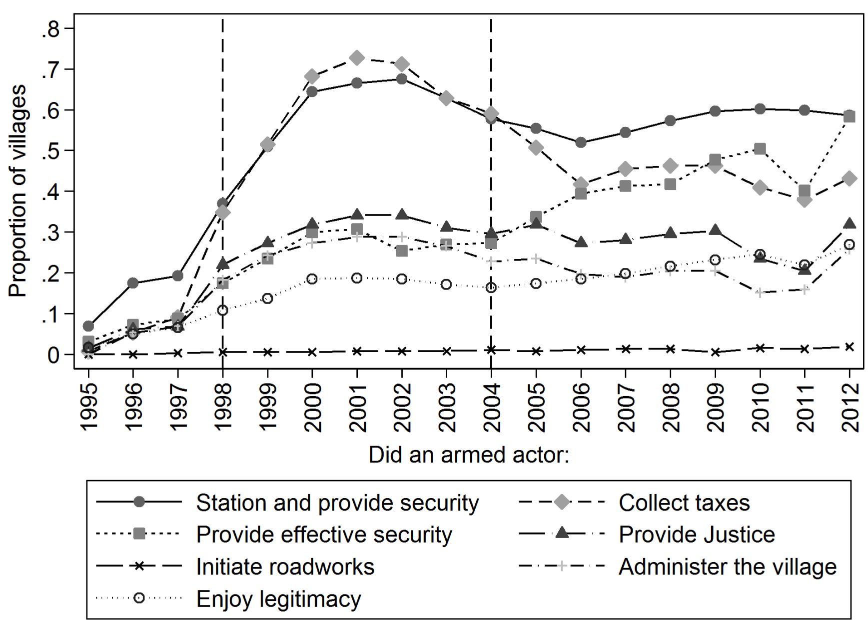
Notes: This figure plots the yearly average price of gold and coltan in Sud Kivu, in USD per kilogram, as measured in the survey. The price of coltan is scaled on the left vertical axis and the price of gold in the right axis. Source: United States Geological Survey (2010).

Figure 3: Stationary bandit's organizations



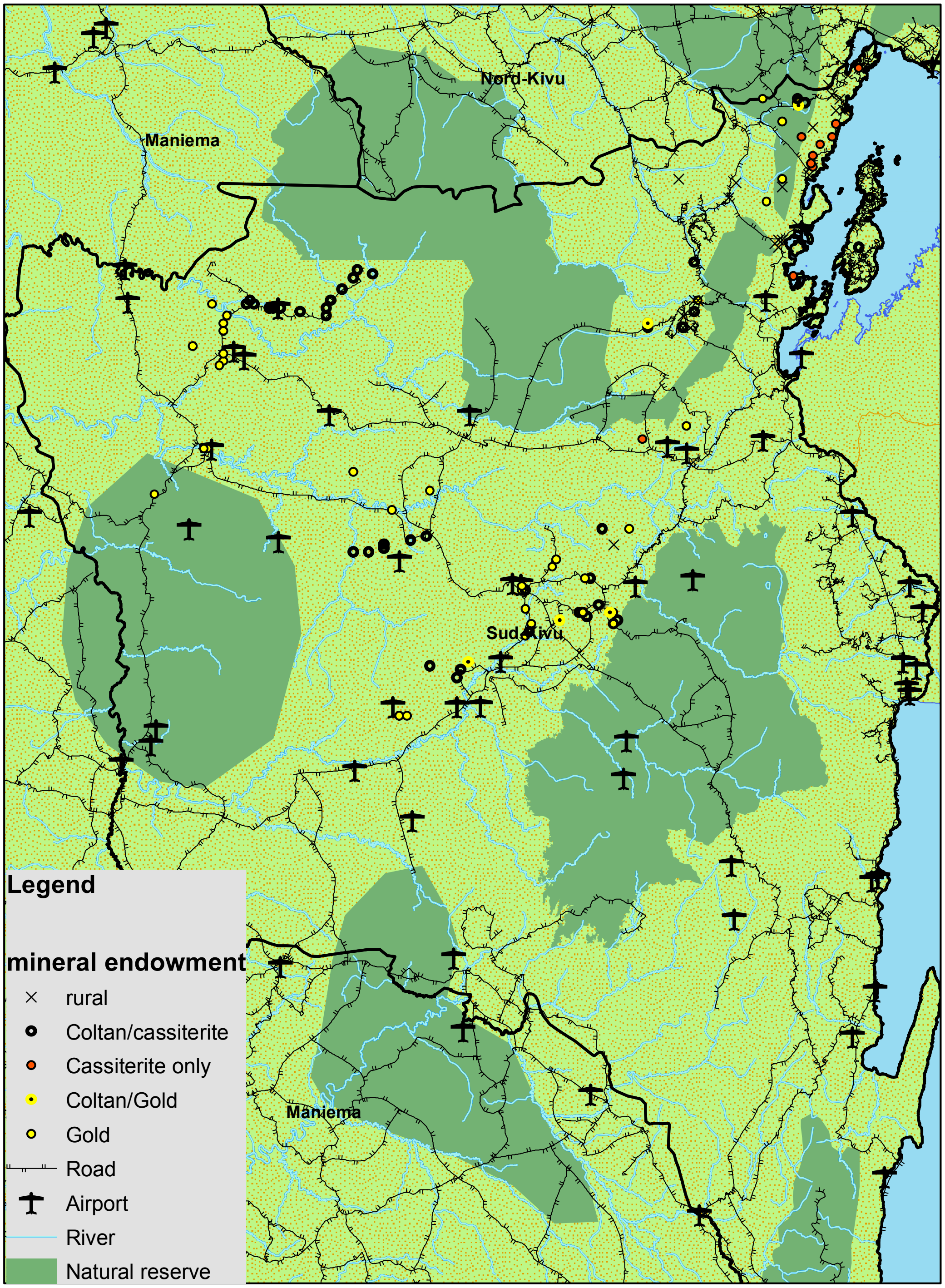
Notes: This figure graphs the proportion of villages in the sample under the control of armed actors on year. The solid line indicates the proportion of villages which are controlled by armed bands who are not the Congolese Army. The dashed line indicates the proportion of which are controlled by the Congolese Army. The data fits the historical phases of the conflict and post-conflict periods. The dashed vertical lines indicate the start and end of the Second Congo War. The Congolese Army progressively replaces irregular armed groups after 2004, the end of the second Congo War. However, local armed groups were integrated into the national army after 2003, without successfully changing their structures of command, blurring the distinction between the Congolese Army and irregular armed bands.

Figure 4: Stationary bandits' activities



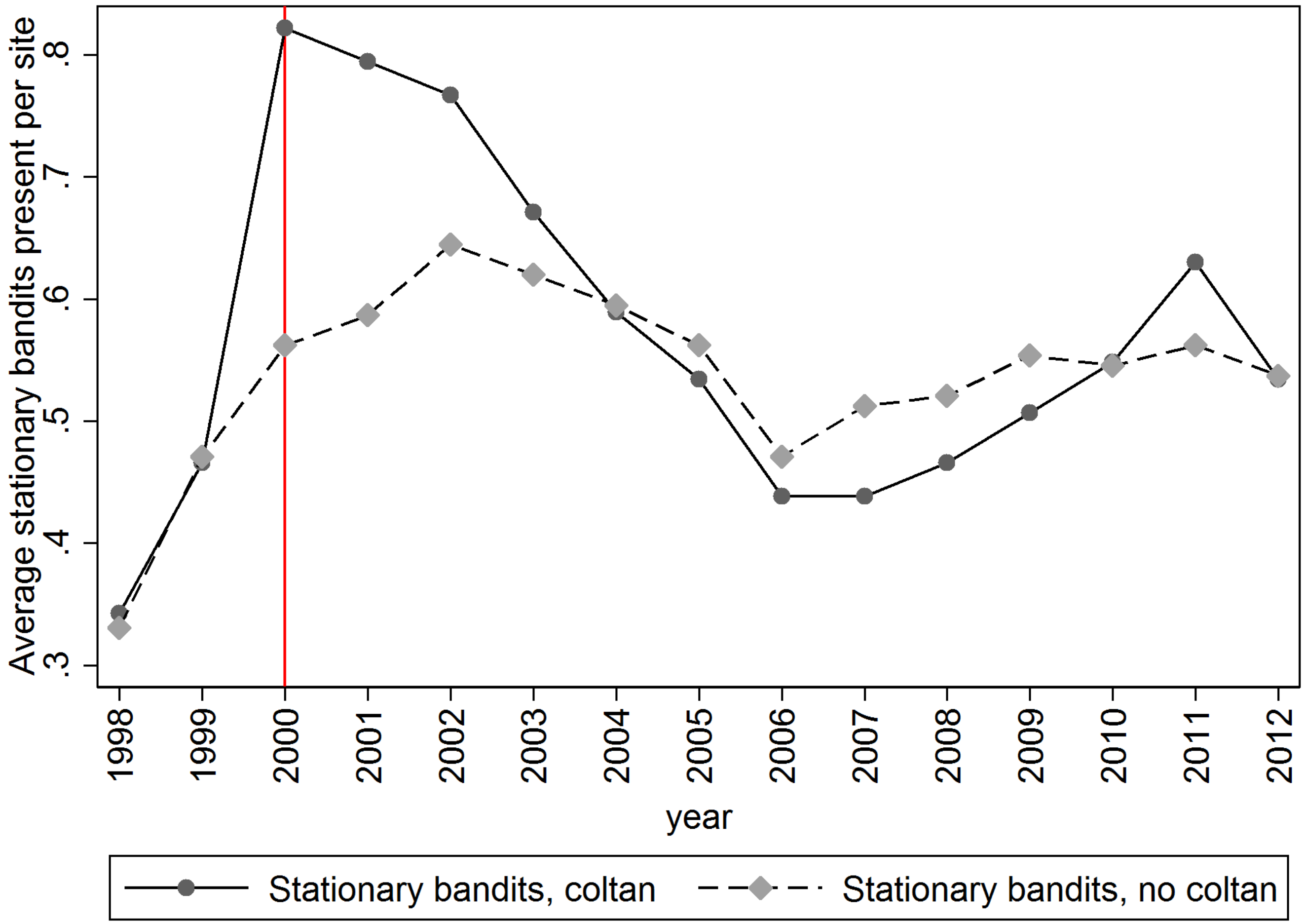
Notes: This figure graphs the proportion of villages in the sample where armed actors do one of the following activities, on year: station and provide security, collect taxes, provide effective security as reported by villagers, provide justice, initiate roadworks, administer the village, developed legitimacy (measured by self-reported popular support by villagers).

Figure 5: Villages in sample



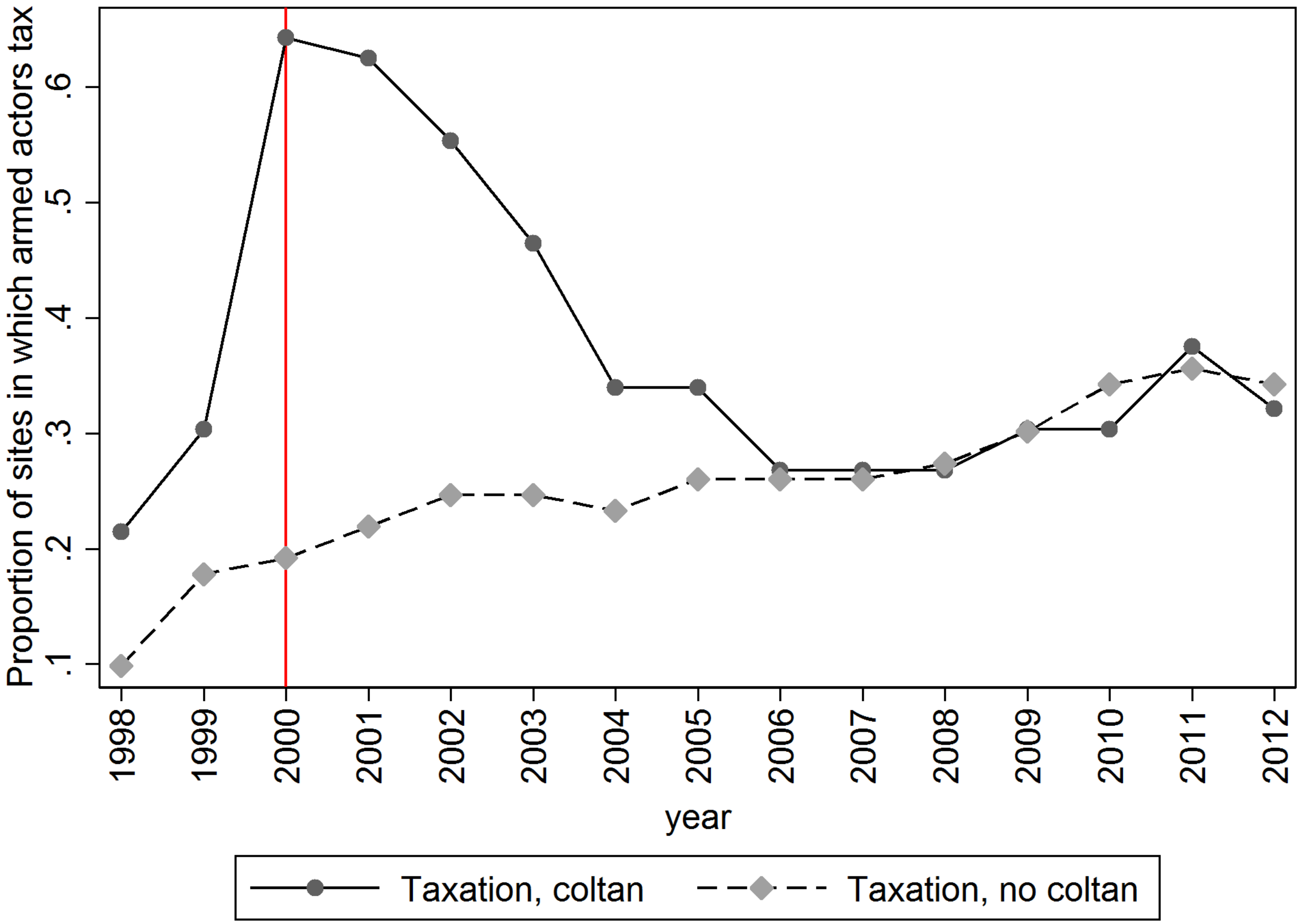
Notes: This map presents the location of the survey villages across Sud Kivu. The villages endowed with coltan only are indicated in black circles. The villages endowed with coltan and gold are indicated as black dots in golden circles. Villages endowed with cassiterite only are indicated in orange. Purely agricultural villages are indicated as crosses. In each Territoire (Shabunda, Mwenga, Walungu, Kabare, Kalehe) the data collection team assembled the data in all coltan villages that were accessible to the survey teams. In addition, it also collected data in a sample of gold villages randomly selected within each administrative division (Territoire). In the Territoire of Kalehe, I also collected data in a agricultural villages, which I sampled by matching to the mining villages in Kalehe prior to the survey using pre-survey geographic characteristics.

Figure 6: Demand shock for coltan and presence of stationary bandits



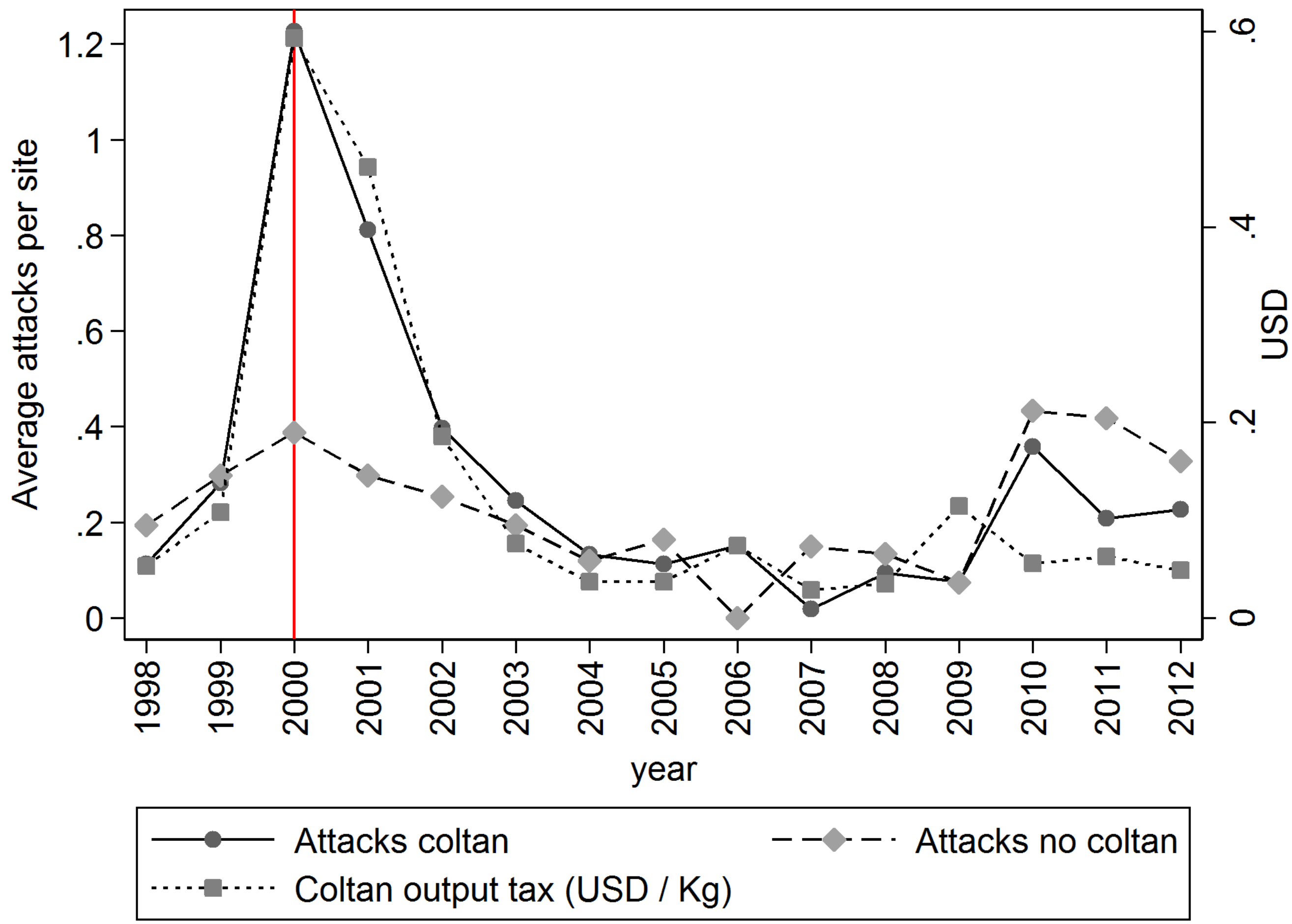
Notes: This figure plots the average number of stationary bandits on year. I take the variable stationary bandit from the site survey, in which the specialists are asked to list past "organizations of security" in the site. A stationary bandit ("organization of security" in the survey) is defined as an armed actor who holds the monopoly of violence in a given site for at least 6 months (approximately). Stationary bandits most frequently are alone when they occupy a site. In some cases, multiple stationary bandits collude (this is mostly only for the Mayi-Mayis and the FDLR in some cases), and in some, fewer cases, more than one stationary bandit may alternate in one location in a given year. The solid line graphs the average number of stationary bandits per year for sites that are endowed with available coltan deposits, and the dashed line reports the same quantity for sites that are not endowed with coltan deposits.

Figure 7: Demand shock for coltan and presence of taxation



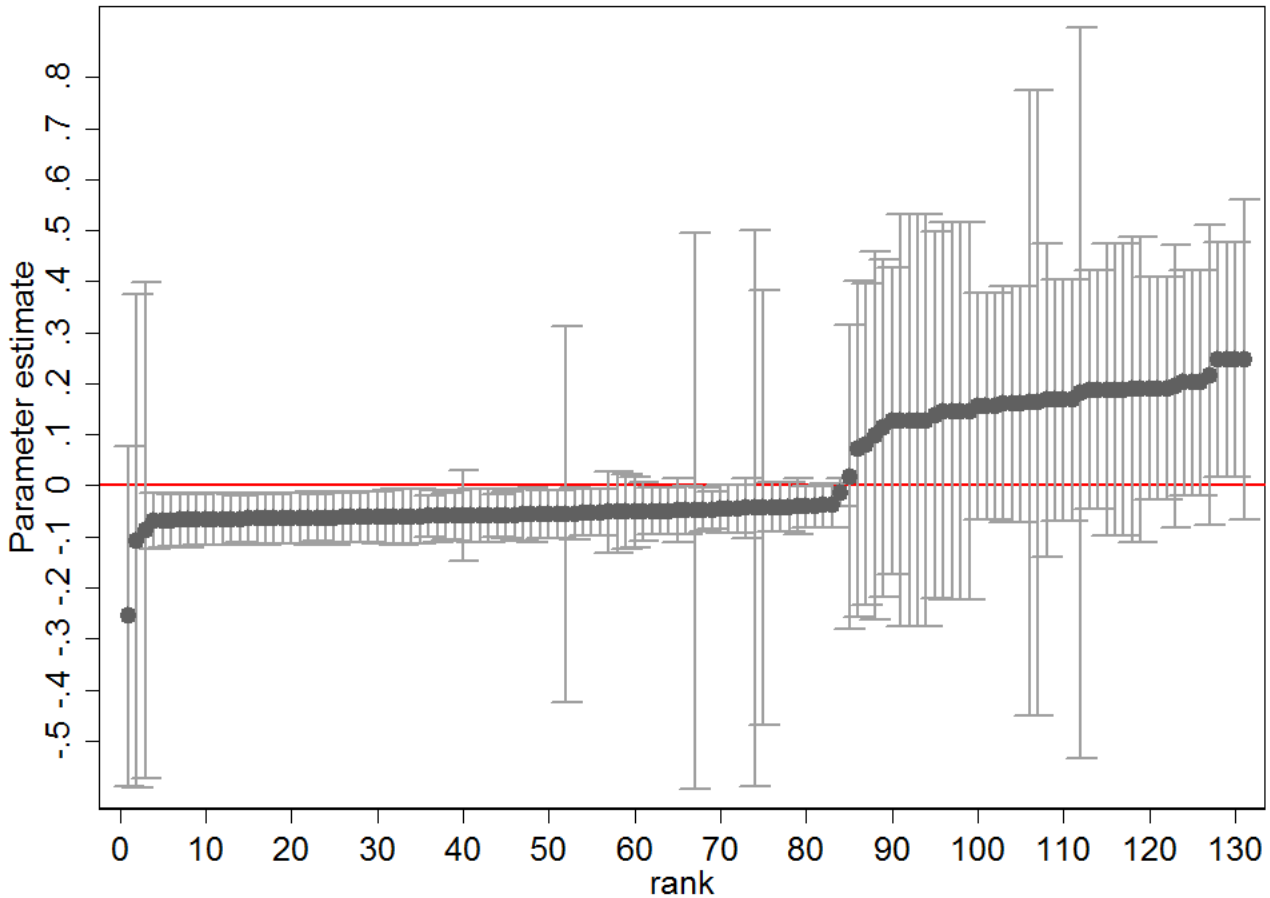
Notes: This figure plots the average number of sites where an armed actor collects taxes regularly on years. I take this variable from the site survey, in which the specialists are asked to list past taxes in the site. Taxes by an armed actor are defined in the survey as a mandatory payment on mining activity which is regular (sporadic expropriation is excluded), stable (rates of expropriation are stable) and anticipated (villages make investment decisions with knowledge of these expropriation rates and that these will be respected). The solid line graphs the average number of sites where an armed actor collects regular taxes for sites that are endowed with available coltan deposits, and the dashed line reports the same quantity for sites that are not endowed with coltan deposits.

Figure 8: Demand shock for coltan, output tax, and external attacks on site



Notes: This figure plots the average number of sites with an external attack, as well as the value of taxes to be paid per kilogram of coltan produced. An external attack is defined as a violent operation in which an armed band from outside the site travels to the site and uses explicit violence - whatever its purpose. Most external attacks are conquest attempts, whereby armed bands attempt to overthrow the existing stationary bandit in order to hold the monopoly of violence at the site. The solid line graphs the average number of sites where armed actors who are not the stationary bandit implement an external attack for sites that are endowed with available coltan deposits, the dotted line reports the same quantity for sites that are not endowed with coltan deposits. The dashed line reports the average tax to pay for the armed man holding the monopoly of violence per kilogram produced.

Figure 9: Effect of the gold price on stationary bandits, all time intervals



Notes: This figure plots the estimated coefficients on Gold endowment, interacted with the world price of gold, from the baseline specification using all possible time intervals.

Table 1: Summary statistics, year 1999

	Sample size	Gold	Coltan	Difference	p-value	Source
Mining settlements						
Stationary bandit	128	0.58	0.46	0.12	0.19	Survey
Mining labor tax by armed actors	126	0.15	0.11	0.04	0.50	Survey
Mining ouptut tax by armed actors	125	0.00	0.24	-0.24	0.00 ***	Survey
External attacks	117	0.30	0.20	0.11	0.48	Survey
Villages attached to mining settlements						
Stationary bandit	112	0.68	0.55	0.13	0.18	Survey
Poll tax by armed actors	111	0.55	0.56	-0.01	0.92	Survey
Cassava sales tax by armed actors	113	0.18	0.11	0.07	0.30	Survey
Transit tax by armed actors	113	0.19	0.16	0.03	0.66	Survey
Mill tax by armed actors	113	0.09	0.11	-0.02	0.73	Survey
Effective security provision	112	0.25	0.21	0.04	0.53	Survey
Justice provision	112	0.36	0.18	0.18	0.04**	Survey
Administration provision	112	0.30	0.18	0.13	0.12	Survey
Rely on chief for household taxation (Indirect rule)	112	0.45	0.32	0.13	0.18	Survey
External attacks	112	0.34	0.16	0.18	0.03**	Survey
Conquest attacks	113	0.19	0.11	0.09	0.37	Survey
Assets' expropriation attacks (pillages)	113	0.11	0.09	0.02	0.78	Survey
Distance to the closest natural reserve	102	15.46	14.97	0.49	0.83	Survey and RGC
Distance to the closest lake	102	80.97	92.60	-11.64	0.30	Survey and RGC
Distance to Bukavu	102	93.97	96.03	-2.07	0.81	Survey and RGC
Distance to Rwanda	102	86.72	93.82	-7.10	0.49	Survey and RGC
Distance to the closest river	102	5.07	5.39	-0.32	0.76	Survey and RGC
Distance to the closest bridge	102	6.35	13.42	-7.07	0.00***	Survey and RGC
Distance to the closest airport	102	14.39	16.29	-1.90	0.34	Survey and RGC
Accessible by car	92	0.21	0.16	0.05	0.51	Survey
Accessible by motorbike	92	0.33	0.34	-0.01	0.95	Survey
Phone network	92	0.05	0.06	-0.01	0.80	Survey

Notes: *** p<0.01, ** p<0.05, * p<0.1. This table presents the summary statistics of the main variables in the year 1999, by type of mineral endowment at the site. Every mining settlement (site) is attached to only one village, which is in general the closest village and may have multiple mines attached to it. I collected most of the data organizing a data collection project with 10 surveyors, but I use the village GPS location I collected and data from Référentiel Géographique Commun (2010) in order to compute Euclidean distances between the village and the closest geographic feature of interest.

Table 2: Effects of price shocks, presence of stationary bandit

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Coltan(i) X pc(t)	0.07**	0.10***	0.17***	0.21***	0.11***	0.20***	0.12***	0.13**	0.28***
	(0.03)	(0.03)	(0.04)	(0.05)	(0.03)	(0.03)	(0.02)	(0.05)	(0.08)
Coltan(i) X pc(t) X D road(i)			-0.08						-0.07
			(0.07)						(0.07)
pc(t) X D road(i)			0.03						0.03
			(0.03)						(0.04)
Gold(i) X pg(t)	-0.03								
	(0.03)								
Coltan(i) X pc(t) X D airport(i)				-0.13**					-0.10
				(0.06)					(0.06)
pc(t) X D airport(i)				0.01					0.00
				(0.02)					(0.04)
Coltan(i) X pc(t+1)						0.06**			
						(0.03)			
Constant	0.27**	0.29***	0.17*	0.20***	0.27***	-0.03	0.00	41.97	91.16*
	(0.11)	(0.06)	(0.09)	(0.07)	(0.06)	(0.10)	(0.00)	(46.28)	(49.25)
Observations	2,134	388	360	360	388	582	388	582	540
R-squared	0.68	0.87	0.87	0.88	0.88	0.76		0.79	0.82
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Village FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Region*Year FE	NO	NO	NO	NO	YES	YES	NO	NO	YES
Arellano-Bond	NO	NO	NO	NO	NO	NO	YES	NO	NO
Coltan time trends	NO	NO	NO	NO	NO	NO	NO	YES	YES
Sample	98-08	99-00	99-00	99-00	99-00	98-00	98-00	98-00	98-00
Number of groupreshape_id							194		

Notes: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. This table presents the results on the linear probability model for *stationary bandits*. A stationary bandit is defined as an armed actor who holds the monopoly of violence in a given site for at least 6 months (approximately). The baseline specification is $Y_{it} = \beta_t + \alpha_i + \gamma_c Coltan_i pc_t + \varepsilon_{it}$ where $Coltan_i$ is a dummy indicating whether site i is endowed with available coltan, which is constant over time, pc_t is the logarithm of the US price of coltan, and β_t and α_i are year and site fixed effects. Column (1) presents the results of the baseline specification for the whole period, 1998-2008 and includes a control for the US price of gold interacted with gold endowments at the site level. Columns (2)-(6) restrict the sample to 1999-2000. Column (2) replicates Column (1) using only 1999 and 2000, Column (3) adds interactions with $Droad_i$, a dummy indicating whether the site cluster is far from a road (defined as distance to the road above the 50th percentile in the sample), Column (4) does the same with $D\ airport_i$, a dummy indicating whether the site cluster is far from a local airport (defined as distance to the road above the 50th percentile in the sample). Column (5) adds region (Territoire)*year fixed effects. Columns (6)-(9) include in addition the year 1998 to allow additional robustness checks. Column (6) implements a falsification test by including leads and lags of the main regressor. Column (7) includes a lagged dependent variable and implements Arellano-Bond. Column (8) includes coltan specific linear trends as a regressor. Column (9) replicates the baseline specification with all robustness checks.

Table 3: Effects of price shocks, presence of taxation

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Coltan(i) X pc(t)	0.15***	0.17***	0.19***	0.29***	0.18***	0.23***	0.07***	0.16***	0.29***
	(0.03)	(0.04)	(0.05)	(0.06)	(0.04)	(0.03)	(0.01)	(0.06)	(0.08)
Coltan(i) X pc(t) X D road(i)			-0.01						0.01
			(0.08)						(0.07)
pc(t) X D road(i)			0.01						-0.02
			(0.02)						(0.03)
Gold(i) X pg(t)	0.01								
	(0.03)								
Coltan(i) X pc(t) X D airport(i)				-0.17**					-0.22***
				(0.08)					(0.06)
pc(t) X D airport(i)				-0.00					0.07
				(0.03)					(0.05)
Coltan(i) X pc(t+1)						0.05			
						(0.03)			
Constant	-0.16	-0.11	-0.17	-0.14	-0.13	-0.36***	0.00	-28.71	-11.57
	(0.11)	(0.09)	(0.10)	(0.09)	(0.08)	(0.12)	(0.00)	(54.65)	(57.61)
Observations	1,417	258	240	240	258	385	256	385	358
R-squared	0.71	0.84	0.85	0.86	0.86	0.77		0.77	0.82
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Village FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Region*Year FE	NO	NO	NO	NO	YES	YES	NO	NO	YES
Arellano-Bond	NO	NO	NO	NO	NO	NO	YES	NO	NO
Coltan time trends	NO	NO	NO	NO	NO	NO	NO	YES	YES
Sample	98-08	99-00	99-00	99-00	99-00	98-00	98-00	98-00	98-00
Number of groupreshape_id							129		

Notes: *** p<0.01, ** p<0.05, * p<0.1. This table presents the results on the linear probability model for *taxation* by armed actors. Regular taxes by an armed actor are defined as a mandatory payment on mining activity such that the payment is required on a regular basis, the rate is stable and can be anticipated by the population before they make investments and allocate labor. The baseline specification is $Y_{it} = \beta_t + \alpha_i + \gamma_c Coltan_i pc_t + \varepsilon_{it}$ where $Coltan_i$ is a dummy indicating whether site i is endowed with available coltan, which is constant over time, pc_t is the logarithm of the US price of coltan, and β_t and α_i are year and site fixed effects. Column (1) presents the results of the baseline specification for the whole period, 1998-2008 and includes a control for the US price of gold interacted with gold endowments at the site level. Columns (2)-(6) restrict the sample to 1999-2000. Column (2) replicates Column (1) using only 1999 and 2000, Column (3) adds interactions with $Droad_i$, a dummy indicating whether the site cluster is far from a road (defined as distance to the road above the 50th percentile in the sample), Column (4) does the same with $D\ airport_i$, a dummy indicating whether the site cluster is far from a local airport (defined as distance to the road above the 50th percentile in the sample). Column (5) adds region (Territoire)*year fixed effects. Columns (6)-(9) include in addition the year 1998 to allow additional robustness checks. Column (6) implements a falsification test by including leads and lags of the main regressor. Column (7) includes a lagged dependent variable and implements Arellano-Bond. Column (8) includes coltan specific linear trends as a regressor. Column (9) replicates the baseline specification with all robustness checks.

Table 4: Effects of price shocks, taxation instruments

VARIABLES	(1) Output Tax	(2) Labor Tax	(3) Poll Tax	(4) Food Tax	(5) Transit Tax	(6) Mill Tax	(7) Pillage
Coltan(i) X pc(t)	0.12***	0.07***	0.10***	-0.01	0.01	0.02	-0.04
	(0.03)	(0.02)	(0.03)	(0.02)	(0.03)	(0.02)	(0.04)
Constant	-0.20***	-0.06	0.28***	0.11**	0.13**	0.01	0.24***
	(0.06)	(0.06)	(0.07)	(0.05)	(0.06)	(0.03)	(0.09)
Observations	1,521	1,599	1,690	1,463	1,729	1,729	1,729
R-squared	0.60	0.72	0.56	0.61	0.59	0.72	0.12
Year FE	YES	YES	YES	YES	YES	YES	YES
Village FE	YES	YES	YES	YES	YES	YES	YES
Location	MINE	MINE	VILLAGE	MARKET	VILLAGE	VILLAGE	VILLAGE
Sample	99-00	99-00	99-00	99-00	99-00	99-00	99-00

Notes: *** p<0.01, ** p<0.05, * p<0.1. This table presents the results on the baseline linear probability model for dummies indicating whether a taxation instrument is used, as dependent variable. For village level taxes, the main regressor, $Coltan_i X pc_t$ is computed coding as 1 all villages where at least one site attached to it is endowed with coltan, and interacting this dummy with the logarithm of the US price of coltan. Standard errors are clustered at the level of the site*year. All village level regressions, thus, also include the regressor computed using distance weights. Columns (1) and (2) show the results on dummies indicating mining taxes, respectively output tax (in US dollars paid per kilogram produced, to be paid at the exit of the mining site), and labor tax (paid in US Dollars in order to get the right to work at the mine). Columns (3) to (6) examine taxes paid by the population of the village attached to the mining site. Column (3) regresses a dummy indicating whether an armed actor collects poll taxes in the attached village, Column (4) regresses a dummy indicating whether an armed actor collects taxes on the market used by the village population (as indicator I use the tax per day to be paid by households selling cassava flour, a basic consumption good), Column (5) regresses a dummy indicating whether an armed actor collects taxes on population transit to enter and/or to exit the village. Column (6) regresses a dummy indicating whether an armed actor taxes the village mill. Column (7) regresses a dummy indicating whether a village was pillaged as an additional form of expropriation. Standard errors are clustered at the village level.

Table 5: Effects of price shocks, organized attacks on site

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Coltan(i) X pc(t)	0.12***	0.14***	0.13**	0.15**	0.13***	0.16***	0.05***	0.12	0.17
	(0.04)	(0.04)	(0.05)	(0.07)	(0.05)	(0.04)	(0.01)	(0.08)	(0.11)
Coltan(i) X pc(t) X D road(i)			0.03						-0.03
			(0.09)						(0.10)
pc(t) X D road(i)			-0.03						0.02
			(0.03)						(0.06)
Gold(i) X pg(t)	0.03								
	(0.03)								
Coltan(i) X pc(t) X D airport(i)				-0.01					-0.06
				(0.09)					(0.09)
pc(t) X D airport(i)				-0.02					0.05
				(0.04)					(0.07)
Coltan(i) X pc(t+1)						0.02			
						(0.03)			
Constant	-0.19*	-0.15	-0.11	-0.14	-0.15	-0.25*	0.00	-34.28	-23.94
	(0.11)	(0.10)	(0.12)	(0.11)	(0.10)	(0.14)	(0.00)	(81.72)	(91.29)
Observations	1,287	234	214	214	234	351	234	351	321
R-squared	0.24	0.71	0.69	0.69	0.71	0.42		0.42	0.46
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Village FE	YES	YES	YES	YES	YES	YES	Y	YES	YES
Region*Year FE	NO	NO	NO	NO	YES	YES	NO	NO	YES
Arellano-Bond	NO	NO	NO	NO	NO	NO	YES	NO	NO
Coltan time trends	NO	NO	NO	NO	NO	NO	NO	YES	YES
Sample	98-08	99-00	99-00	99-00	99-00	98-00	98-00	98-00	98-00
Number of grouprshape_id							117		

Notes: *** p<0.01, ** p<0.05, * p<0.1. This table presents the results on the linear probability model for *external attacks* by armed actors. An external attack is defined as a violent operation in which an armed band from outside the site travels to the site in order to produce violence. Most external attacks are conquest attempts, whereby armed bands attempt to overthrow the existing stationary bandit in order to hold the monopoly of violence at the site. The baseline specification is $Y_{it} = \beta_t + \alpha_i + \gamma_c Coltan_i pc_t + \varepsilon_{it}$ where $Coltan_i$ is a dummy indicating whether site i is endowed with available coltan, which is constant over time, pc_t is the logarithm of the US price of coltan, and β_t and α_i are year and site fixed effects. Column (1) presents the results of the baseline specification for the whole period, 1998-2008 and includes a control for the US price of gold interacted with gold endowments at the site level. Columns (2)-(6) restrict the sample to 1999-2000. Column (2) replicates Column (1) using only 1999 and 2000, Column (3) adds interactions with $Droad_i$, a dummy indicating whether the site cluster is far from a road (defined as distance to the road above the 50th percentile in the sample), Column (4) does the same with $D\ airport_i$, a dummy indicating whether the site cluster is far from a local airport (defined as distance to the road above the 50th percentile in the sample). Column (5) adds region (Territoire)*year fixed effects. Columns (6)-(9) include in addition the year 1998 to allow additional robustness checks. Column (6) implements a falsification test by including leads and lags of the main regressor. Column (7) includes a lagged dependent variable and implements Arellano-Bond. Column (8) includes coltan specific linear trends as a regressor. Column (9) replicates the baseline specification with all robustness checks.

Table 6: Effects of price shocks, spillovers on attached village

VARIABLES	(1) Stationary Bandit	(2) Village Poll Tax	(3) Attacks External	(4) Attacks Conquest	(5) Attacks Expropriation	(6) Guns Accumulation
Coltan(i) X pc(t)	0.07*	0.07**	0.09*	0.09**	-0.02	0.06**
	(0.04)	(0.04)	(0.05)	(0.03)	(0.05)	(0.03)
Constant	0.47***	0.39***	0.09	-0.06	0.15	-0.07
	(0.09)	(0.07)	(0.10)	(0.07)	(0.10)	(0.05)
Observations	264	260	262	266	266	264
R-squared	0.83	0.86	0.70	0.72	0.59	0.63
Year FE	YES	YES	YES	YES	YES	YES
Village FE	YES	YES	YES	YES	YES	YES
Sample	99-00	99-00	99-00	99-00	99-00	99-00

Notes: *** p<0.01, ** p<0.05, * p<0.1. This table presents the results on the linear probability model for non-mine specific, village level outcomes in order to estimate spillovers on the village attached to the mining sites. The main regressor, $Coltan_i X pc_t$ is computed coding as 1 all villages where at least one site attached to it is endowed with coltan, and interacting this dummy with the logarithm of the US price of coltan. All columns include the baseline specification at the attached village level, with village and year fixed effects. Columns (1) to (6) respectively use as outcome variables the following dummies: whether a stationary bandit is settled at the village; whether an armed actor regularly collects poll taxes at the village; whether armed men organized external attacks on the village; whether armed men organized external attacks on the village which where specifically aimed at attempting conquest and obtaining the village monopoly of violence; whether armed actors organized external attacks on the village which were specifically aimed at pillaging (acquiring resources quickly and violently); whether a stationary bandit settled in the village in a given year increased his stock of fire arms. Standard errors are clustered at the level of the village*year.

Table 7: Persistent effects of price shocks, persistence of stationary bandits

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES								
stationary bandit(t-1)					0.74***	0.74***	0.74***	1.04***
					(0.03)	(0.03)	(0.03)	(0.30)
stationary bandit(t-2)						-0.05**	-0.05**	
						(0.02)	(0.02)	
Coltan(i) pc^{local}(t)							0.05**	
							(0.03)	
Coltan(i) X pc(t)	0.07**	0.07**	0.07**	0.08**	0.08***	0.06***	0.06***	0.10***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)
Coltan(i) X pc(t-1)		0.07**	0.07**	0.07**	0.01	-0.00	0.00	
		(0.03)	(0.03)	(0.03)	(0.01)	(0.01)	(0.01)	
Coltan(i) X pc(t-2)			0.04	0.04	-0.02	-0.02	-0.01	
			(0.03)	(0.03)	(0.02)	(0.02)	(0.02)	
Coltan(i) X pc(t-3)				0.02	-0.03	-0.02	-0.00	
				(0.03)	(0.02)	(0.02)	(0.02)	
Constant	0.21***	0.10	0.03	-0.01	0.11**	0.18***	0.20***	-0.20
	(0.06)	(0.08)	(0.10)	(0.11)	(0.05)	(0.05)	(0.05)	(0.17)
Observations	2,951	2,951	2,951	2,951	2,724	2,497	2,497	2,724
R-squared	0.67	0.68	0.68	0.68				
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Village FE	YES	YES	YES	YES	YES	YES	YES	YES
Sample	98-12	98-12	98-12	98-12	98-12	98-12	98-12	98-12
Number of sites					227	227	227	227

Notes: *** p<0.01, ** p<0.05, * p<0.1. Table 7 shows the estimates from a linear probability model regressing the presence of a stationary bandit on the lagged values of the $C_i \ \ p(C)_t^{US}$. Columns (1)-(4) replicate the baseline specification, but include the lags. The coefficient on the first lag of $C_i \ \ p(C)_t^{US}$ suggests that the coltan demand shock led to the emergence of stationary bandits which persisted for two years after the shock, despite the sudden and permanent reversal of coltan demand in 2001. Column (5) includes the lagged dependent variable as a regressor and implements Arellano-Bond GMM estimation. Column (6) adds the second lag of stationary bandit and the results are unchanged. To rule out that continued local demand for coltan is accounting for the persistence of stationary bandits, Column (7) includes the average price of coltan paid by traders at the site level, collected in the survey. Finally, Column (8) implements a 2SLS panel regression of stationary bandit on its lag, where I instrument the first lag of stationary bandit with the first lag of $C_i \ \ p(C)_t^{US}$ in order to circumvent endogenous location of stationary bandits. The results are unchanged, and the estimated impact of lagged stationary bandit on stationary bandit is close to 1.

A Online Appendix: Model

A.1 Households first order conditions

There are N First order conditions for e_i, N First order conditions for e_i^H, N first order conditions for H_i conditioned on $\tilde{\alpha}_i e_i$ plus the $N+1$ first order conditions from the constraints. The Kuhn-Tucker conditions with respect to H_i, $i = 1, \ldots, N$ give:

$$\forall\ \tilde{\alpha}_i,\ u'[\tau_i p_i - G'(H_i, p_i)]\mu_i = 0,\ i = 1, \ldots, N$$

and

$$\tau_i p_i - G_1(H_i, p_i) \geq 0\ i = 1, \ldots, N$$

An interior solution is therefore given by $H_i < \tilde{\alpha}_i e_i$ and $H_i > 0$, hence $\mu_i = 0$ and:

$$\tau_i p_i = G_1(H_i, p_i)$$

Similarly, an interior solution for $e_i^H$is given by $e_i^H < e_i$ and $e_i^H > 0$:

$$t_i = E_1(e^H, p_i)$$

The FOC with respect to e_i, $i = 1, \ldots, N$ give:

$$\int (\mathrm{u}'[(1-\tau_\mathrm{i})\mathrm{p}_\mathrm{i}\tilde{\alpha}_\mathrm{i} - \mathrm{t}_\mathrm{i}] + \mu_\mathrm{i})dF(\alpha) - \lambda - c'(e_i) = 0,\ i = 1, \ldots, N$$

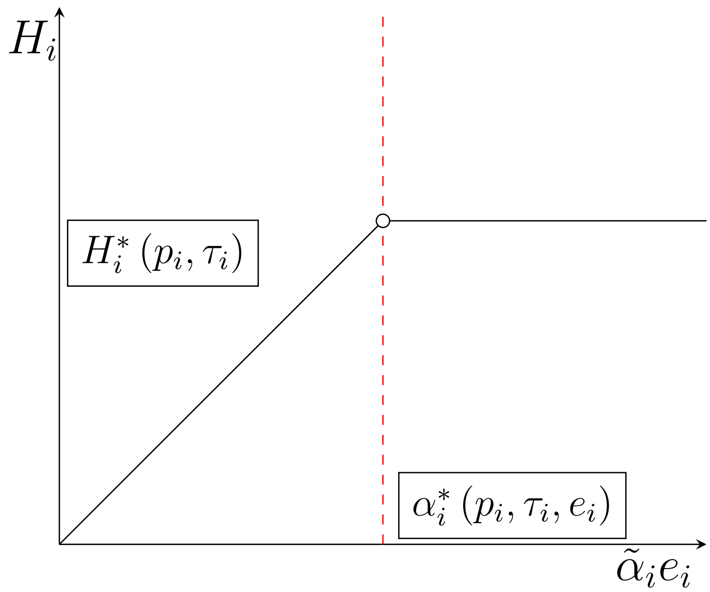
for sectors where the hiding constraint is binding, and:

$$\int (\mathrm{u}'[(1-\tau_\mathrm{i})\mathrm{p}_\mathrm{i}\tilde{\alpha}_\mathrm{i} - \mathrm{t}_\mathrm{i}])dF(\alpha) - \lambda - c'(e_i) = 0,\ i = 1, \ldots, N$$

for sectors where it is not.

A.2 First order conditions on hidden volume

Figure 10: Labor real productivity and volume hidden by households



Notes: This figure represents the relationship between the volume of output hidden in sector i, H_i, and the realized output in sector i, $\tilde{\alpha}_i e_i$ derived from the household's first order conditions. If the realized labor real productivity is below a certain threshold, the household is at a corner solution and hides all output. If the realized labor real productivity is above the threshold, the volume hidden is an interior solution. Any additions to the realized production do not increase the volume hidden by the household.

A.3 Proof of proposition 1

Suppose there is only one sector, so I drop the sector identifiers i. Let $G(H, p) = k\frac{H^2}{2}$. The parameter k captures the cost of hiding output. Let $c(e) = \frac{e^2}{2}$ and the utility function be linear in consumption. Labor supply in this form is isoelastic, and the optimal tax is:

$$\tau^* = \frac{1}{2} \frac{1}{\alpha^2 + \frac{1}{\alpha^2 k}}$$

The optimal tax is larger the higher is the cost to conceal an additional unit of output. At the limit, if output cannot be concealed, and $k = +\infty$, $\tau^* = \frac{1}{2}$. This is because labor supply is isoelastic and always equal to 1, which can be seen from the inverse elasticities rule. If $k \in R^+$, $0 < \tau^* < \frac{1}{2}$. When α is large τ^* approaches its upper bound, and when α is small, τ^* tends to 0. Since $\overline{\alpha}_g \approx 0$, the optimal tax in a village where the only sector is gold will be low. Furthermore, if

$\overline{\alpha}_g$ is sufficiently low so that $\overline{\alpha}_g L < \underline{H}$ (assumption G1), the choice of tax is irrelevant and always raises no revenues, since output is always hidden. Turning to assumption G2, the tax revenue can be written as:

$$
\begin{aligned}
R &= \frac{1}{2}\frac{\alpha^2 p^2}{\alpha^2 + \frac{1}{k}}\left(\alpha^2 (1-\tau) - \frac{\tau}{k}\right) \\
&= \frac{1}{4}\frac{\alpha^4 p^2}{\alpha^2 + \frac{1}{k}}
\end{aligned}
$$

which is strictly increasing in α. Therefore, $\exists \underline{\alpha}$ s.t. $\forall \alpha < \underline{\alpha}$,

$$R(\alpha) \leq F_g, \; \tau^* = 0$$

and $\forall \alpha > \underline{\alpha}$,

$$R(\alpha) > F_g, \; \tau^* > 0$$

where F_g was defined as the fixed cost of levying an output tax in the gold sector.

A.4 Proof of propositions 2 and 3

Let $\tilde{e} = e_i - e_i^H$ the observable labor input,

$$\frac{\partial E_\alpha V}{\partial p_c} = \tau_c E \alpha_c \left(e_c + p_c \frac{\partial \tilde{e}_c}{\partial p_c}\right) + \frac{\partial \tilde{e}_c}{\partial p_c} t_c > 0,$$

and

$$\frac{\partial E_\alpha V}{\partial p_g} = \frac{\partial \tilde{e}_g}{\partial p_g} t_g > 0$$

A rise in the output price in one location increases the value of choosing stationary bandit in that location through three channels: it raises the value of each unit of output output taxed; it increases the units of output taxed (if the income effect on labor supply is smaller than the substitution effect); and it increases the amount of labor taxed. In gold villages, only the third channel affects the value of holding a monopoly of violence.

Let $c(e) = \frac{1}{2}e^2$, $E(e_H) = \frac{c}{2}e_H^2$ $G(H,p) = \frac{ph}{2}H^2$ for simplicity. The household's and the bandit's programs are now, respectively:

$$\max_{e,e_H,H} \quad (1-\tau)\,p\alpha e + \tau p H - t\,(e-e_H) - \tfrac{1}{2}e^2 - \tfrac{c}{2}e_H^2 - \tfrac{ph}{2}H^2$$

$$\max_{t,\tau} \quad \tau p\,(\alpha e - H) + t\,(e-e_H)$$

The optimal taxes are $\tau^* = \frac{1}{2}\frac{1}{1+s}$ and $t^* = \frac{\alpha p}{2}\frac{c}{1+c}\frac{s}{1+s}$, where $s = \frac{1+c}{p\alpha^2 h}$. Applying the Envelope theorem to the bandit's objective function, it follows that:

$$\frac{\partial V}{\partial p} = \frac{\alpha^2 p}{(1+s)^2}\left(\frac{1}{2} + s\frac{3+4c}{1+c} + \frac{s^2}{2}\frac{c}{1+c}\right) > 0$$

This establishes proposition 2.

It is then straightforward to show that an increase in the cost of hiding output impacts the tax revenue of the bandit positively:

$$\frac{\partial^2 V}{\partial p \partial h} = \frac{\partial^2 V}{\partial p \partial s}\frac{\partial s}{\partial h} = \frac{(1+c)^2}{4h^2}\frac{1+\frac{3}{4}s}{(1+s)^3} > 0$$

This establishes proposition 3 when $\alpha_g = \alpha_c$ and $p_g = p_c$.

Let us now allow $\alpha_g \neq \alpha_c$ and $p_g \neq p_c$. For gold, there is no tax on output, therefore:

$$\frac{\partial V}{\partial p_g} = \frac{\alpha^2 p}{2}\frac{c}{1+c}$$

We then have:

$$\begin{aligned}\frac{\partial V}{\partial p_c} - \frac{\partial V}{\partial p_g} &= \frac{\alpha_c^2 p_c}{(1+s)^2}\left(\frac{1}{2} + s + \frac{s^2}{2}\frac{c}{1+c}\right) - \frac{\alpha_g p}{2}\frac{c}{1+c} \\ &= \frac{1}{2}\frac{\alpha_c^2 p_c}{(1+s)^2}\,(1+2s)\left(1 - \frac{c}{1+c}\frac{\alpha_g^2 p_g}{\alpha_c^2 p_c}\right)\end{aligned}$$

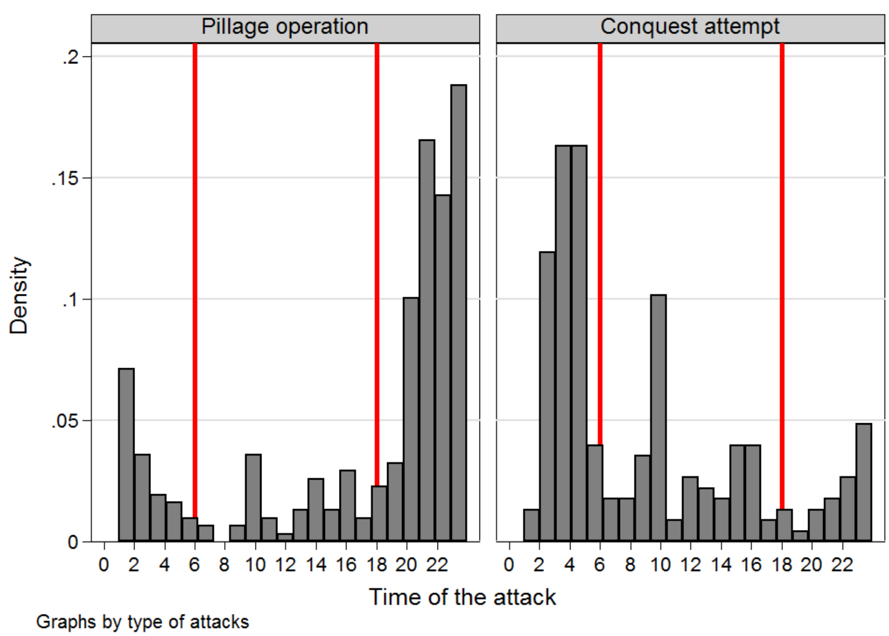
As already established, this is positive if $\alpha_g = \alpha_c$ and $p_g = p_c$. When $\alpha_g \neq \alpha_c$ and $p_g \neq p_c$:

$$\begin{aligned} \frac{\partial V}{\partial p_c} - \frac{\partial V}{\partial p_g} &> 0 \\ &\equiv \\ c &> \frac{1}{r-1} \end{aligned}$$

where $r = \frac{\alpha_g^2 p_g}{\alpha_c^2 p_c}$. Parametrizing the labor productivity and prices of coltan in units of grams (per day) and dollars per gram produced with the values of 1999, we have $r = .000004$, thus this condition holds for all values of c. I can go a step furtehr and rescale the partial derivates, dividing them $\alpha_g^2 p_g$ and $\alpha_c^2 p_c$. It is straightforward to show that $\frac{\frac{\partial V}{\partial p_c}}{\alpha_c^2 p_c} - \frac{\frac{\partial V}{\partial p_g}}{\alpha_g^2 p_g}$. In an extension, I use this property to re-scale the estimated partial effects and my results remain. This analysis assumed a cost of hiding function that increases linearly in prices. This assumption is not a necessary condition and was chosen for simplicity of exhibition.

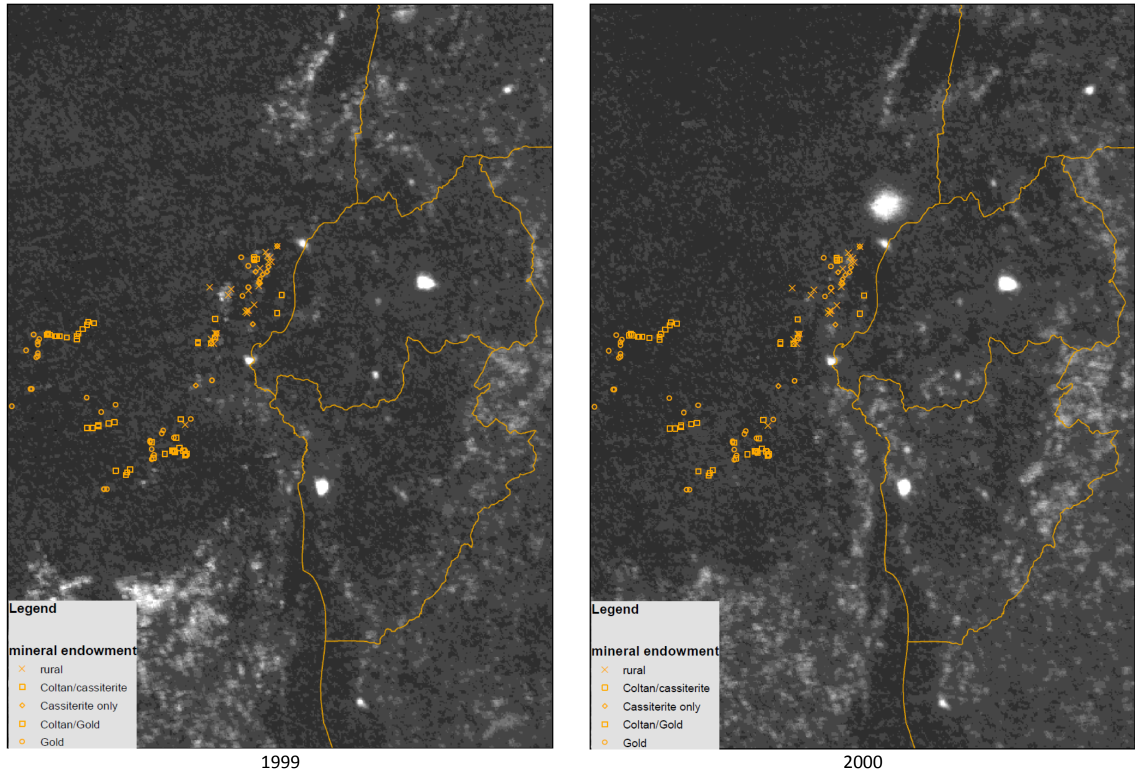
B Online Appendix: Validation of the data

Figure 11: The coltan demand shock and the demand for marriage



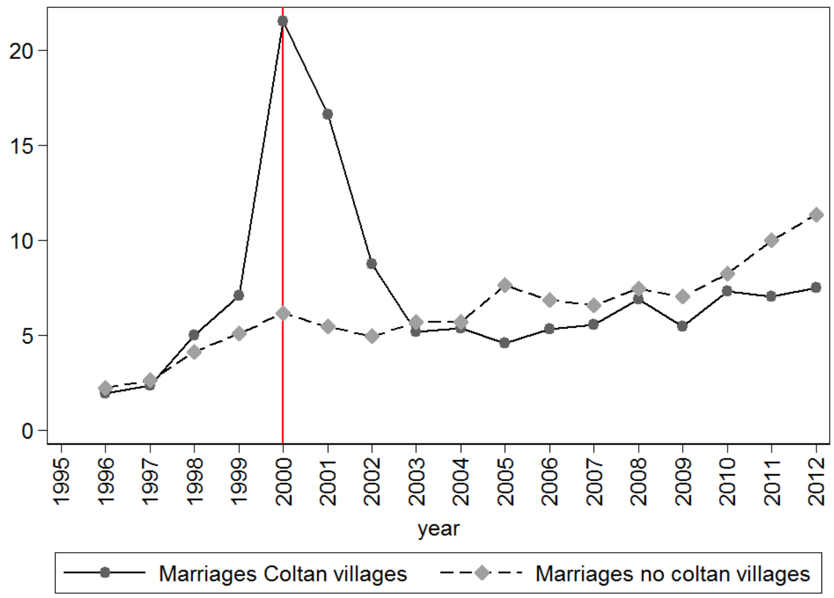
Notes: This figure shows the distribution of the hours at which the attacks take place in the sample. Pillages take place mostly when monitoring is lower, after sunset.

Figure 12: The coltan price shock from satellite



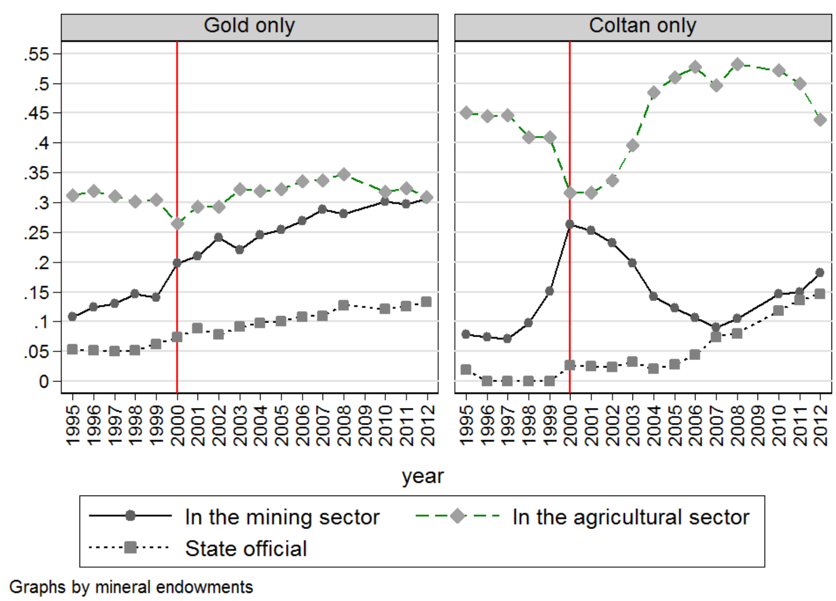
Notes: This figure presents satellite imagery of the survey area at night. The left image shows the average cloud free lights captured by NASA-NOAA satellites from the survey area in 1999. The right image does so for 2000. International borders are drawn as orange lines. The Democratic Republic of Congo is on the left of the vertical line, and from North to South are Uganda, Rwanda, Burundi, Tanzania on the right of the line. The mineral endowments of the villages are as indicated in the figure legend. In the year 2000, town lighting increases in the northern part of the picture, bordering Rwanda, which is the area around Goma, the trading hub for coltan trade. As the price of coltan boomed, economic activity increased around Goma.

Figure 13: The coltan demand shock and the demand for marriage



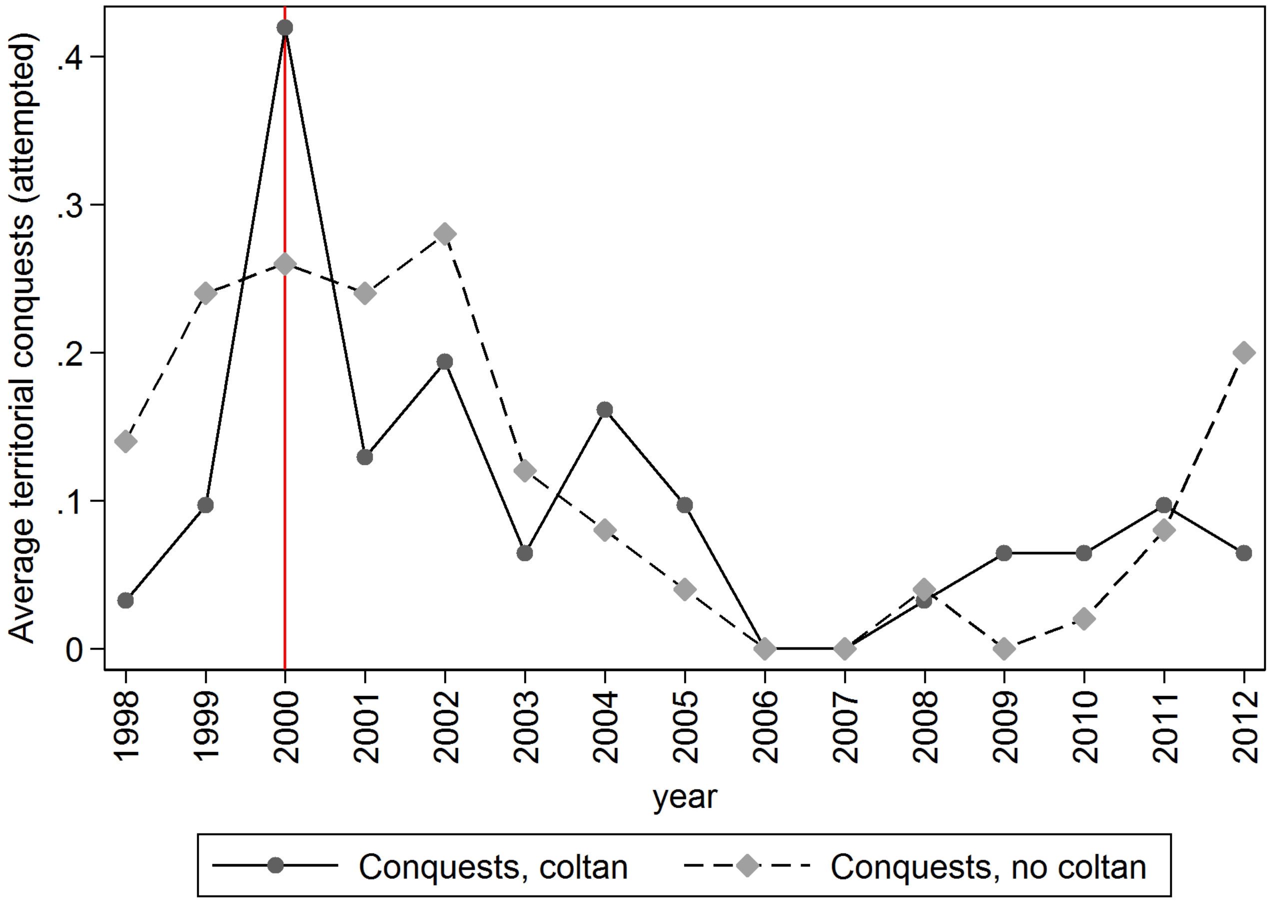
Notes: This figure plots the average number of recorded marriages in the survey villages by year. The solid line indicates the average number of marriages in coltan villages, by year. The dashed line indicates the average number of marriages in villages not endowed with coltan, by year.

Figure 14: The coltan demand shock and labor supply



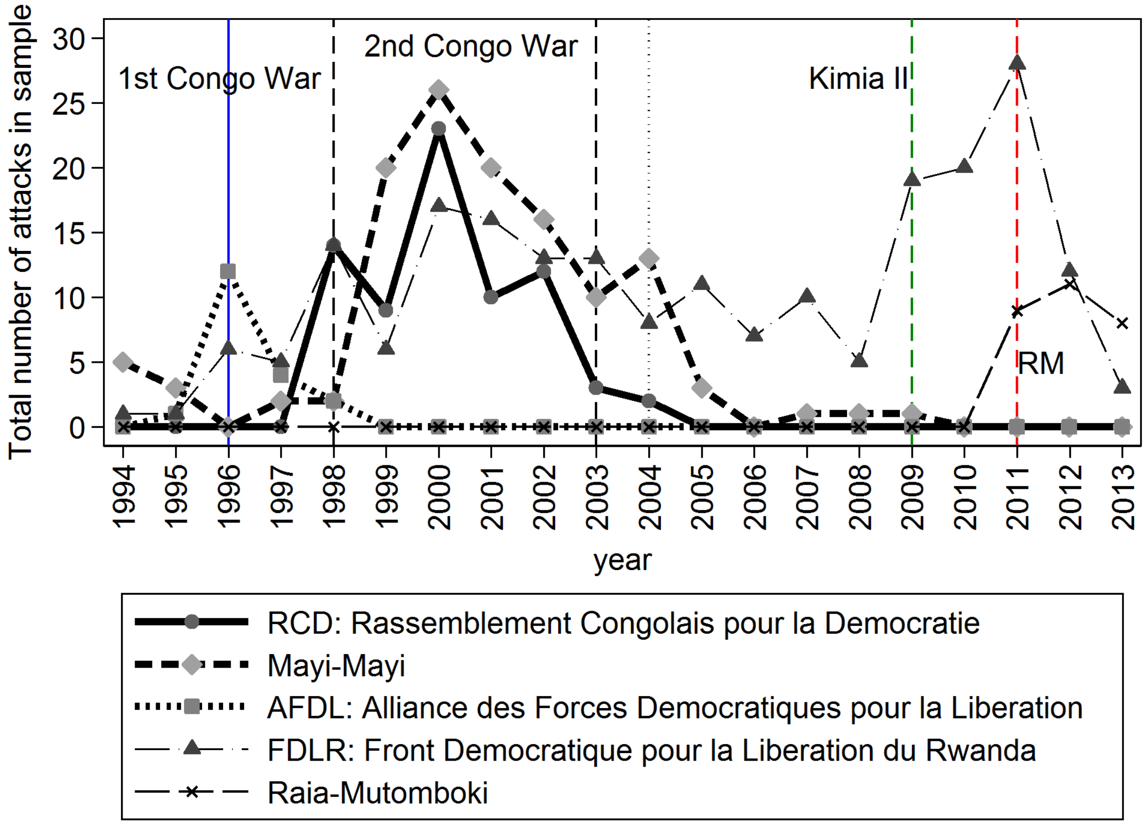
Notes: This figure plots the proportion of respondents of the household survey who work in a given sector, by year. The solid line indicates the proportion of respondents who work in the mining sector, the dashed line indicates the proportion of respondents who work in agriculture, and the dotted line represents the proportion of respondents who work as state officials.

Figure 15: Coltan demand shock and conquest attacks on attached village



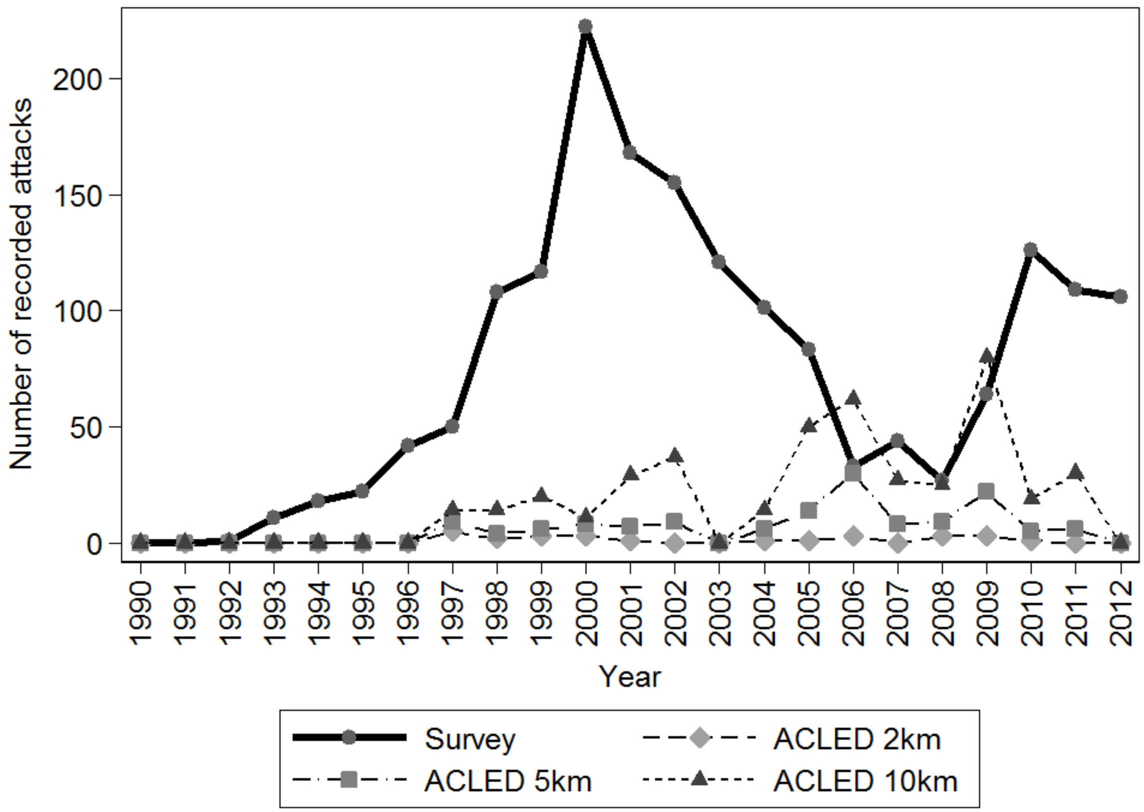
Notes: This figure plots the average number of conquest attempts on villages attached to a mining site. A conquest attempt is defined as an operation in which armed bands attempt to overthrow the existing stationary bandit in order to hold the monopoly of violence at the site, by fighting. The solid line graphs the average number of conquest attempts for villages attached to sites that are endowed with available coltan deposits, the dotted line reports the same quantity for villages that are attached to sites not endowed with coltan deposits.

Figure 16: Recorded violent Events and known historical rebellions



Notes: This figure plots the number of attacks on the sample villages by different armed organization identified in the survey for each year and uses well known dates for known historical rebellions as a benchmark. The left axis indicates the number of attacks recorded in the sample by armed actors of a given armed organization, and the horizontal axis indicates the year. The dates of the attacks recorded from the survey coincide exactly with well known historical rebellions, which are marked by the vertical lines. The thin dotted line indicates attacks by the AFDL, the thick solid black line indicates attacks by the RCD, the black thick dashed line indicates the number of attacks by the Mayi-Mayi's, the thin dahed line with triangles indicates the number of attacks by the FDLR and the think dashed line with crosses indicates the number of attacks by the Raia Mutomboki. Correspondingly, the vertical blue line at 1996 marks the period of the AFDL rebellion as known from history; the black vertical dotted lines at 1998 and 2003 bound the Second Congo War; the vertical dotted line indicates the date of the CNDP offensive, the green vertical dashed line at 2009 marks the Kimia II military intervention, which resulted in massive pillage operations by the FDLR to acquire resources as their financial base was being disrupted, and the red vertical dashed line at 2011 indicates the known year of the emergence of the Raia Mutomboki. While the number of recorded attacks is larger in the data, the source used in this figure is the attacks module, which focuses on the details of the major attacks on the village.

Figure 17: Recorded violent Events and ACLED violent events



Notes: This figure plots the number of attacks on the sample villages I recorded in the survey, as well as the number of attacks recorded by ACLED which are located in the neighborhood of the survey villages. I represent the total number of attacks recorded in the survey the solid line, and the number of attacks recorded from ACLED in the neighborhood of my survey villages with the dashed lines, for different perimeters around the villages.To assign battles recorded by ACLED to the survey villages, I computed the number of geo-located ACLED battles that were located within a given perimeter of the survey village. The dashed lines report the results using the number of events of ACLED near the village using circles of radius 10km, 5 km, and 2 km. The solid line corresponds well-known phases of the Congo Conflict. The number of attacks rises in 1998 drastically, with the beginning of the Second Congo War, and in 2000 during the coltan shock. It then decreases with the post-conflict period, and rises again in 2009, 2010. This last rise is the rise in attacks by the FDLR armed organization in response to the Kimia II (see Sanchez de la Sierra (2014)). In contrast to the survey data, the geo-referenced ACLED dataset does not capture these trends, which is especially problematic for the earlier attacks (the Second Congo War for instance). This provides additional confidence in the attacks data from the survey.

Table 8: Survey and ACLED battles

VARIABLES	(1) 1 km	(2) 2 km	(3) 5 km	(4) 10 km	(5) 15 km	(6) 20 km	(7) 25 km	(8) 50 km
Conquest attempts, survey	0.0132***	0.0281***	0.0534***	0.0652***	0.0970***	0.0976***	0.133***	0.117***
	(0.00381)	(0.00650)	(0.0103)	(0.0161)	(0.0224)	(0.0258)	(0.0280)	(0.0347)
Constant	0.00712*	0.0292***	0.0510***	0.0807***	0.125***	0.200***	0.244***	0.606***
	(0.00368)	(0.00628)	(0.00996)	(0.0156)	(0.0217)	(0.0249)	(0.0271)	(0.0335)
Observations	2,128	2,128	2,128	2,128	2,128	2,128	2,128	2,128
R-squared	0.107	0.132	0.145	0.172	0.232	0.272	0.283	0.398

Notes: *** p<0.01, ** p<0.05, * p<0.1. This table presents the results on the OLS regression of battles recored by ACLED on battles recorded in the survey. To assign battles recorded by ACLED to the survey villages, I computed the number of geo-located ACLED battles that were located within a given perimeter of the survey village. From left to right, columns (1) to (8) report the results using the number of events of ACLED near the village using circles of radius 1km (column 1), 2km (column 2), 5km (column 3), 10km (column 4), 15km (column 5), 20km (column 6), 25km (column 7), 50km (column 8). Standard errors are clustered at the village*year level.

C Online Appendix: Robustness

I implement five strategies to increase confidence in the main OLS estimates.

First, I replicate the baseline specification for all variables using conditional logistic regressions instead, since in the presence of errors in variables, linear probability models could be biased (Hausman, 2001). Table 9 reports the results in columns (1), (2), (3) for the three main outcome variables (stationary bandit, conquest, taxation). The results are unchanged.

Second, I account for the observation that conquest attempts are rare events. In that case, OLS estimation could lead to biases in the estimated probabilities and standard errors (King and Zeng, 2001). I therefore run a logistic version of the baseline specification which corrects for a small sample and rare events in order to generate approximately unbiased and lower-variance estimates, as introduced in King and Zeng (2001). Table 9 reports the results in columns (4), (5), (6). The results are unchanged.

Third, I account for the fact that while some sites may be sufficiently "urbanized" and thus have the amenities for stationary bandits, other sites may not. It is thus logical to expect stationary bandits to be less likely to respond to the price shocks in mining sites that are not urbanized. To measure urbanization, I collect information on each site on whether villagers of the support village are involved in the following activities: beer retail, hotel industry, prostitution, mineral trading, or other business (water, for instance, is a profitable business in urbanized mining sites). Table 10 replicates the baseline specification separating sites which are urban from sites which are not. Consistently across outcome measures, most of the armed actors' response to the price shocks is concentrated in sites which are urban.

Fourth, I account for the problem of spatially correlated distances and errors which may lead to bias in the estimation of the standard errors if not correctly accounted for. Distance to the closest airport is similar for neighboring villages, which are also likely to share common economic and social shocks due to their proximity to airports. Villages that are close to airports, *even if they are close to different airports*, may experience similar shocks if they are better integrated in the regional and world economy. I use randomization inference, which allows me to avoid making assumptions about the distribution of the error term. I tackle different problems with different assignment processes in turn.

To tackle spatial correlation, I randomly re-assign mineral endowments to sites. To derive a reference distribution, I generated 20,000 random assignments to coltan endowment (0 or 1 for each village) following properties of the empirical distribution (the proportion of villages that have coltan). For each simulated assignment, I re-estimated the main coefficient, $Coltan_i \ Pc_t$ and stored it. The figure presents the distribution of coefficients estimated using the simulated coltan endowments. To obtain a p-value using the new reference distribution, I compute the relative mass of coefficients derived using the simulated endowments whose value is larger than the value estimated using the real endowments. Figure 20 shows the resulting distribution. As expected, the distribution of estimated coefficients is centered at zero - since the treatments are fictitious- and the estimated p-value is 0.0002.

I then tackle the problem of common shocks that may simultaneously affect all coltan villages alike, which could lead me to underestimate the true standard errors. To derive a reference distribution, I generated 20,000 random assignments of the empirical coltan prices to years. For each simulated assignment, I re-estimated the main coefficient, $Coltan_i \ pc_t$ and stored it. The figure presents the distribution of coefficients estimated using the simulated coltan endowments. To obtain a p-value using the new reference distribution, I compute the mass of coefficients derived from the simulated endowments whose value is larger than the value estimated using the real endowments. Figure 20 shows that the resulting distribution is bi-modal and centered below zero. This is expected, since treated villages are used in the simulation and because one of 12 prices is an outlier (the price that really occurred in 2000) and thus for simulations in which the price is assigned to another year than the year 2000, the majority, the estimated coefficient is negative. The estimated p-value, anyways, is 0.0001. I finally proceed by using a theoretical data generating process for the prices. To derive a reference distribution, I generated 20,000 random vectors of prices on years randomly drawn from a uniform distribution with mean equal to the empirical mean. Figure 20 shows the resulting reference distribution and the corresponding p-value, and the results are analogous.

Fifth, I implement conditional differences-in-differences matching, introduced by Heckman, Ichimura, and Todd (1998), and the results remain.[62]

[62] This method is similar in spirit to case control methods, presented in Goldstone, Bates, Epstein, Gurr, Lustik, Marshall, Ulfelder, and Woodward (2010), where I select observations based on whether I observe coltan endowment and then select matches. As matching variables, I use distance to airports and to roads, as well as upper level administrative divisions (Territoire). Finally, to control for constant unobserved heterogeneity across regions (Territoires), I also match on Territoire. This procedure is thus equivalent to conditional differences-in-differences within calipers defined by administrative divisions (Cochran and Rubin, 1973). I do not report this result here but it is available upon request.

Table 9: Replication of the main result with conditional logit and Rare Events Logistic Regression (King and Zeng, 2001)

VARIABLES	(1) Stationary Bandit	(2) Attacks Conquest	(3) Taxation Any type	(4) Stationary Bandit	(5) Attacks Conquest	(6) Taxation Any type
Coltan(i) X pc(t)	0.35*	0.70**	0.76**	0.36***	0.71***	0.79**
	(0.21)	(0.31)	(0.38)	(0.14)	(0.20)	(0.31)
Constant	-0.11	-1.52***	-1.83***	-0.11	-1.55***	-1.88***
	(0.17)	(0.30)	(0.35)	(0.27)	(0.37)	(0.38)
Observations	454	260	242	454	260	242
Year FE	YES	YES	YES	YES	YES	YES
Village FE	YES	YES	YES	YES	YES	YES
Model	LOGIT	LOGIT	LOGIT	RELR	RELR	RELR
Sample	99-00	99-00	99-00	99-00	99-00	99-00

Notes: *** p<0.01, ** p<0.05, * p<0.1. This table uses alternative specifications to replicate the results of the linear probability model for the outcomes *stationary bandits*, *attempted conquests*, *taxation*. A stationary bandit is defined as an armed actor who holds the monopoly of violence in a given site for at least 6 months (approximately). The baseline linear probability model was $Y_{it} = \beta_t + \alpha_i + \gamma_c Coltan_i pc_t + \varepsilon_{it}$ where $Coltan_i$ is a dummy indicating whether site i is endowed with available coltan, which is constant over time, pc_t is the logarithm of the US price of coltan, and β_t and α_i are year and site fixed effects. Columns (1) to (3) present the results using a conditional logit regression with village and year fixed effects instead. Columns (4) to (6) present the results using rare events logistic regression, as developed by (King and Zeng, 2001), in order to account for the possibility that small number of successes among the dependent variables leads to a rare event bias (this is may only the case for conquest attacks).

Table 10: Replication of the main result, separating urban mining settlements from non-urban

VARIABLES	(1) Stationary Bandit	(2) Turnover	(3) Mine Taxes	(4) External Attacks	(5) Stationary Bandit	(6) Turnover	(7) Mine Taxes	(8) External Attacks
Coltan(i) X pc(t)	0.09**	0.15***	0.19***	0.13**	0.05	0.06	0.13**	0.13**
	(0.04)	(0.05)	(0.05)	(0.06)	(0.06)	(0.07)	(0.06)	(0.06)
Constant	0.45***	-0.09	-0.09	-0.08	0.13	0.00	-0.16	-0.28*
	(0.07)	(0.09)	(0.11)	(0.12)	(0.11)	(0.11)	(0.15)	(0.16)
Observations	308	308	182	174	166	166	78	68
R-squared	0.87	0.46	0.85	0.72	0.84	0.44	0.80	0.60
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Village FE	YES	YES	YES	YES	YES	YES	YES	YES
URBAN	YES	YES	YES	YES	NO	NO	NO	NO
Sample	99-00	99-00	99-00	99-00	99-00	99-00	99-00	99-00

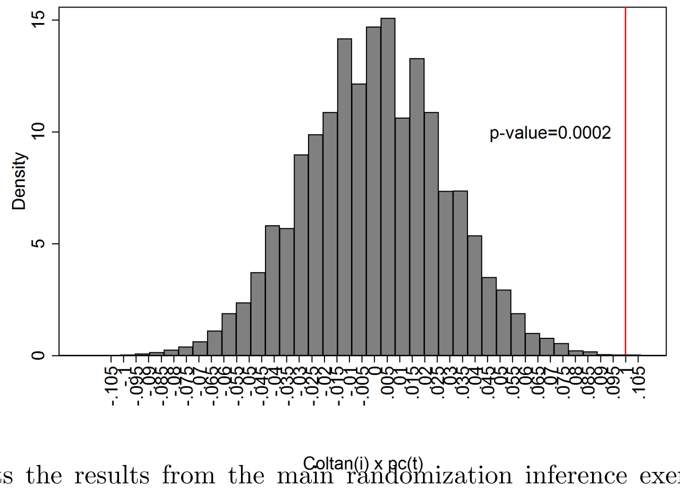
Notes: *** p<0.01, ** p<0.05, * p<0.1. This table uses alternative specifications to replicate the results of the linear probability model for the outcome *stationary bandits*. A stationary bandit is defined as an armed actor who holds the monopoly of violence in a given site for at least 6 months (approximately). The baseline linear probability model was $Y_{it} = \beta_t + \alpha_i + \gamma_c Coltan_i pc_t + \varepsilon_{it}$ where $Coltan_i$ is a dummy indicating whether site i is endowed with available coltan, which is constant over time, pc_t is the logarithm of the US price of coltan, and β_t and α_i are year and site fixed effects. Columns (1) to (3) present the results conditioning the sample on mining sites that are urban. Columns (4) to (6) present the results conditioning the sample to non-urban mining sites. While the effects seem to be concentrated among urban mining sites, the sample size for non-urban sites is very small.

Table 11: Persistence of spillover effects on neighboring village stationary bandits

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
stationary bandit(t-1)					0.63***	0.63***	0.63***	0.98
					(0.04)	(0.05)	(0.05)	(1.06)
stationary bandit(t-2)						-0.04	-0.06**	
						(0.03)	(0.03)	
Coltan(i) pc^{local}(t)							0.02	
							(0.04)	
Coltan(i) X pc(t)	0.03	0.03	0.03	0.04	0.05*	0.03	0.04	0.07
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.06)
Coltan(i) X pc(t-1)		0.03	0.03	0.04	-0.00	-0.01	-0.01	
		(0.03)	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)	
Coltan(i) X pc(t-2)			0.03	0.03	-0.00	-0.01	-0.00	
			(0.03)	(0.03)	(0.02)	(0.02)	(0.02)	
Coltan(i) X pc(t-3)				0.03	-0.02	-0.01	-0.00	
				(0.03)	(0.04)	(0.03)	(0.04)	
Constant	0.41***	0.35***	0.28**	0.21	0.26**	0.37***	0.31**	-0.14
	(0.07)	(0.09)	(0.12)	(0.14)	(0.10)	(0.13)	(0.13)	(0.93)
Observations	1,716	1,716	1,716	1,716	1,584	1,452	1,353	1,584
R-squared	0.54	0.55	0.55	0.55				
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Village FE	YES	YES	YES	YES	YES	YES	YES	YES
Sample	98-12	98-12	98-12	98-12	98-12	98-12	98-12	98-12
Number of groupreshape_id					132	132	123	132

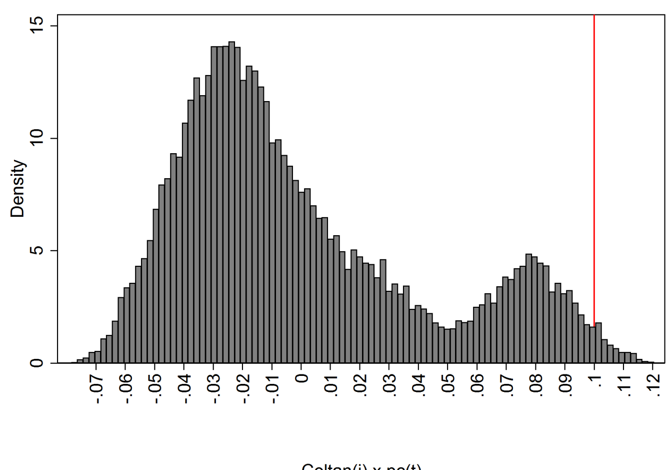
Notes: *** p<0.01, ** p<0.05, * p<0.1.

Figure 18: Randomization inference, results from 20,000 simulated assignment to coltan endowment



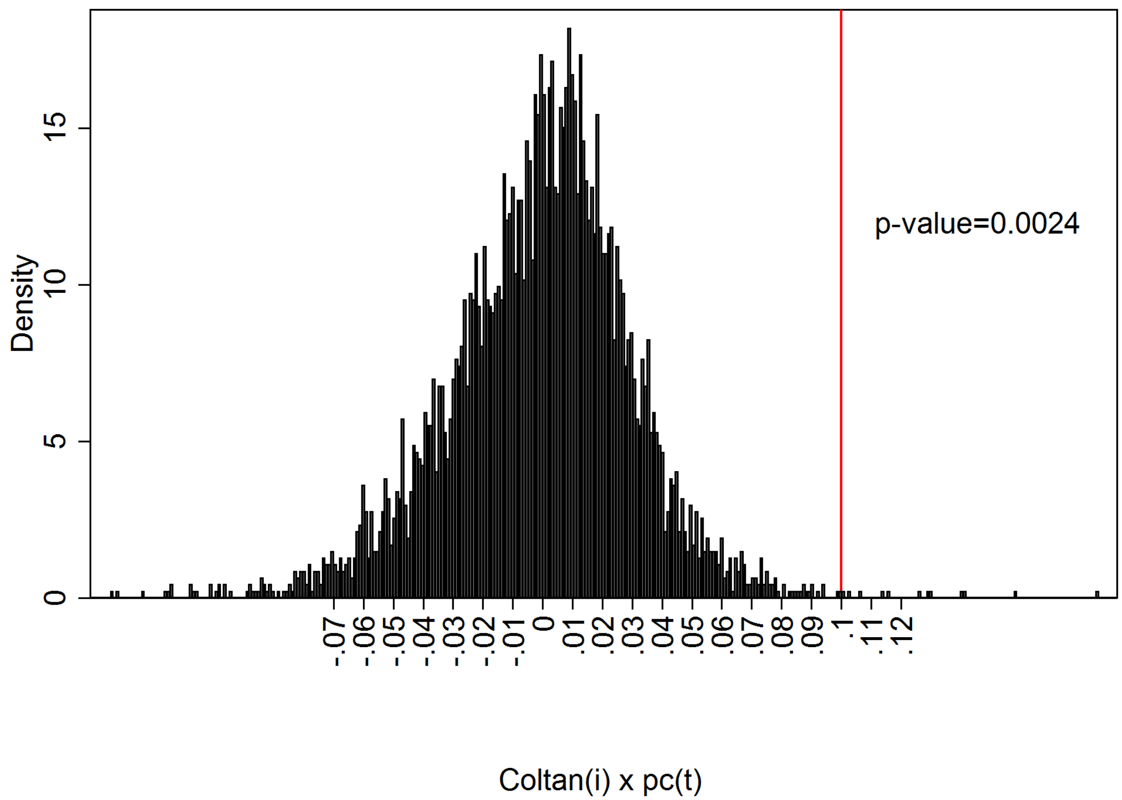
Notes: This figure presents the results from the main randomization inference exercise. To derive a reference distribution, I generated 20,000 random assignments to coltan endowment (0 or 1 for each village) following properties of the empirical distribution (the proportion of villages that have coltan). For each simulated assignment, I re-estimated the main coefficient, $Coltan_i\ pc_t$ and stored it. The figure presents the distribution of coefficients estimated using the simulated coltan endowments. To obtain a p-value using the new reference distribution, I compute the mass of coefficients derived from the simulated endowments whose value is larger than the value estimated using the real endowments. The resulting distribution is centered at zero, as expected since the prices are simulated.

Figure 19: Randomization inference, results from 20,000 simulated re-assigment of observed coltan prices to years



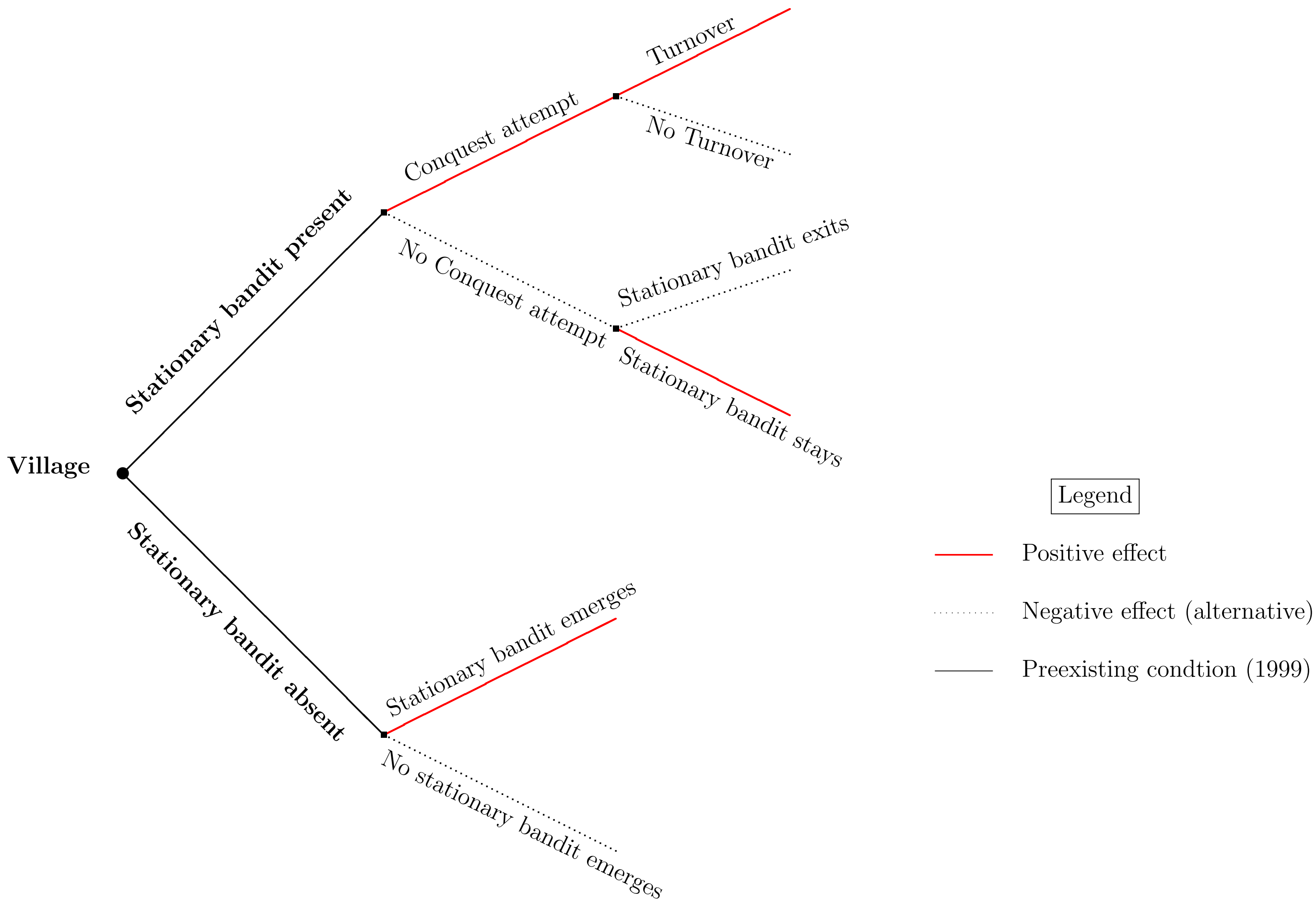
Notes: This figure presents the results from the main randomization inference exercise. To derive a reference distribution, I generated 20,000 random assignments of the empirical coltan prices to years. For each simulated assignment, I re-estimated the main coefficient, $Coltan_i\ pc_t$ and stored it. The figure presents the distribution of coefficients estimated using the simulated coltan endowments. To obtain a p-value using the new reference distribution, I compute the mass of coefficients derived from the simulated endowments whose value is larger than the value estimated using the real endowments. The resulting distribution is bi-modal and centered below zero because one of 12 prices is an outliers (the price that really occurred in 2000) and thus for simulations in which the price is assigned to another year than the year 2000, the majority, the estimated coefficient is negative.

Figure 20: Randomization inference, results from 20,000 simulated random assigment of coltan prices to years



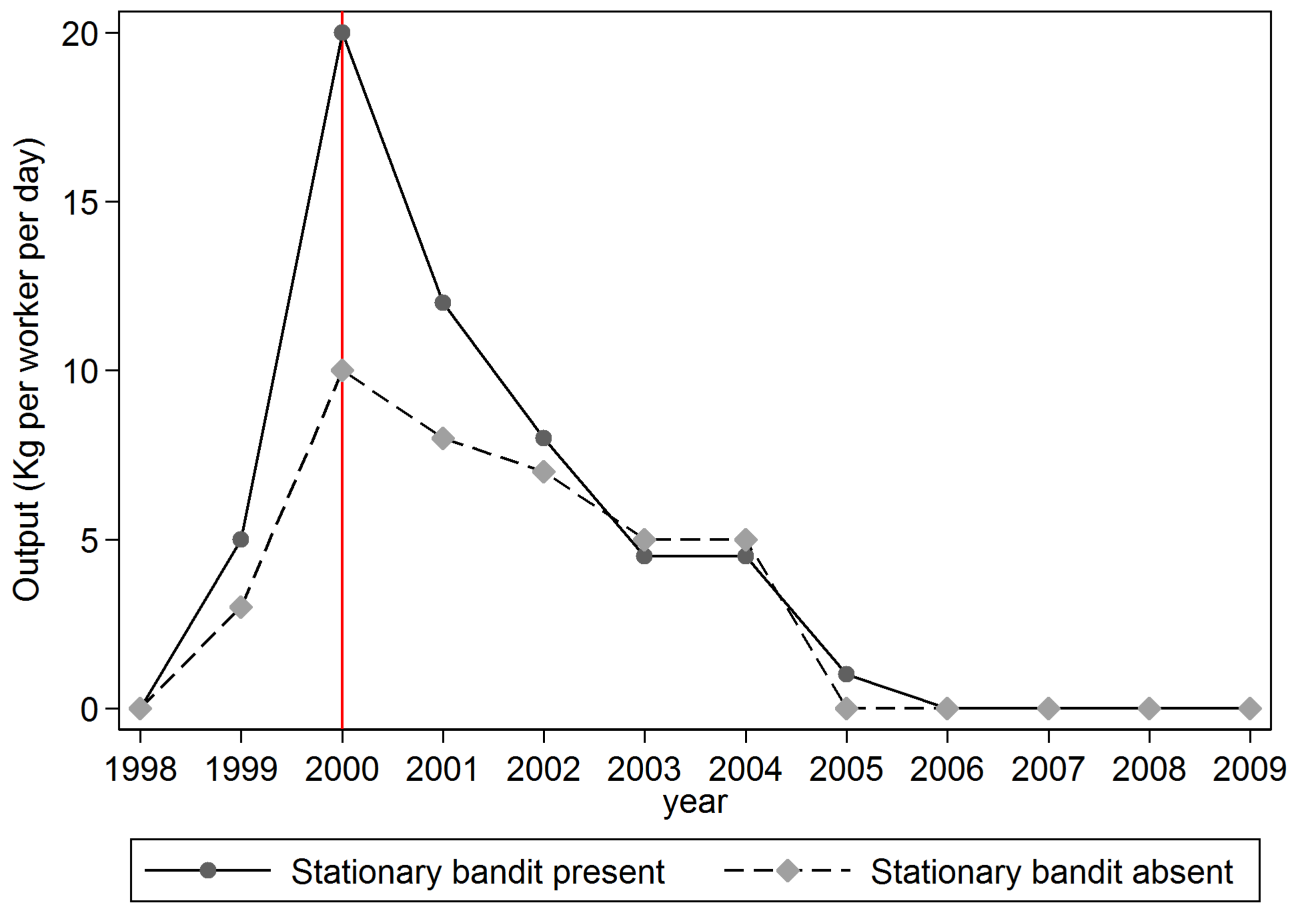
Notes: This figure presents the results from the main randomization inference exercise. To derive a reference distribution, I generated 20,000 random vectors of prices on years from a theoretical distribution. For each simulated assignment, I re-estimated the main coefficient, $Coltan_i \; pc_t$ and stored it. The figure presents the distribution of coefficients estimated using the simulated coltan endowments. To obtain a p-value using the new reference distribution, I compute the mass of coefficients derived from the simulated endowments whose value is larger than the value estimated using the real endowments. The resulting distribution is centered at zero, as expected since the prices are simulated.

Figure 21: Summary of the main result, coltan shock



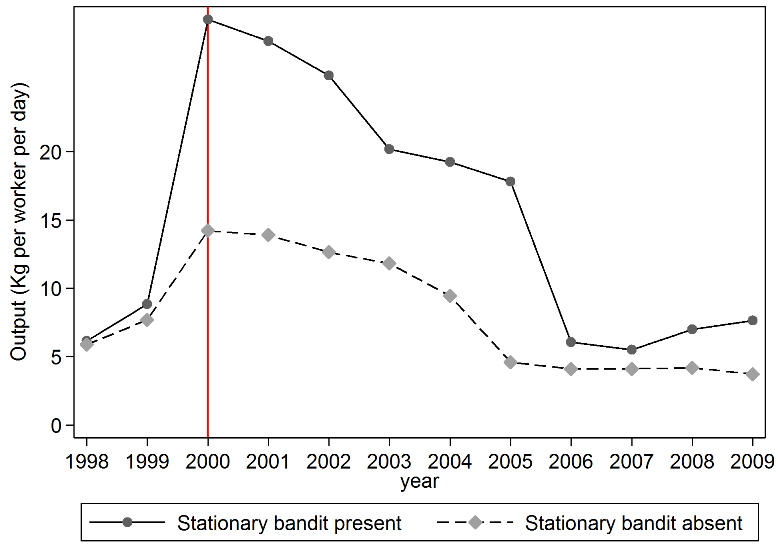
Notes: This graph summarizes the results on the coltan price shock (testable implication 1). At the time of the coltan shock, villages were either occupied by an armed group (stationary bandit present) or not (Stationary bandit absent). For an occupied village, armed groups may attempt a conquest (”Conquest attempt”) or not (”No conquest attempt”). The attempt may be successful, in which case the armed group emerges as the new stationary bandit or it may fail. If there is no conquest attempt, the stationary bandit present at the village may also decide to leave or remain as stationary bandit. If no stationary bandit is present, an armed group may emerge as the village stationary bandit or the village may remain unoccupied.

Figure 22: Coltan demand shock, stationary bandits and median production



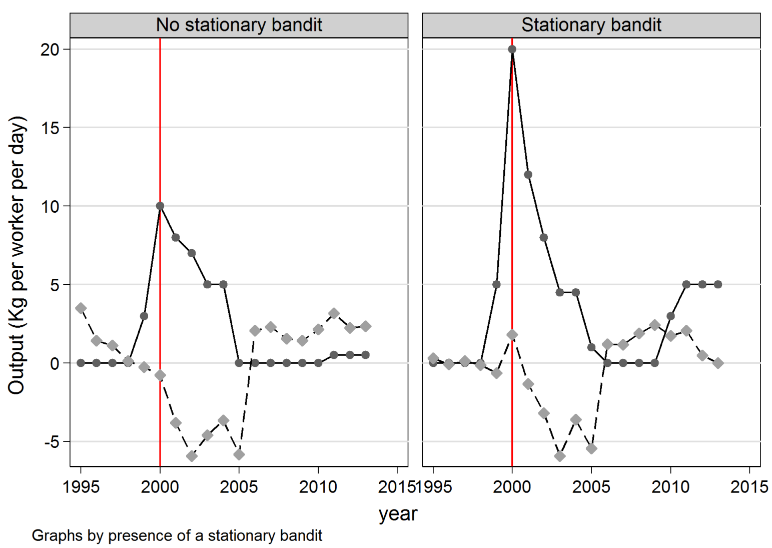
Notes: This figure plots the median coltan production on year, for mining sites in which a stationary bandit was present in 2000, and for mining sites in which a stationary bandit was not present in 2000. A stationary bandit is defined as an armed actor who holds the monopoly of violence in a given site for at least 6 months (approximately). The solid line graphs the median output (in Kilograms per worker per day) in coltan sites where a stationary bandit is present, the dotted line for sites where a stationary bandit is not present. I report the median production instead of the mean production because outliers inflate the effect in my favor when I use mean production. In the online Appendix, I also report the mean production.

Figure 23: Coltan demand shock, stationary bandits and mean production



Notes: This table replicates Figure 22 using mean production instead of median production. In the main text, I used median production to prevent outliers from driving the result, given the presence of outliers. The figure shows that average production is much more affected by the coltan shock in villages where a stationary bandit was present, suggesting that there are complementarities between the presence of a stationary bandit and production, consistent with the value of the protection they provide.

Figure 24: Coltan demand shock, stationary bandits and median production controlling for geography



Notes: This table replicates Figure 22 and also reports the residuals from regressing production on year dummies interacted with an indicator for whether the village is located far from a local airport. I control for airport distance year dummies since stationary bandits may have just chosen to locate in the best coltan villages, near airports where the coltan can be shipped cheaply, thus generating a selection effect. Even after controlling for the airport distance year dummies, which proxy for the profitability of the coltan village, the effect of the coltan demand shock on production is concentrated in villages where a stationary bandit is present, suggesting that there are complementarities between the presence of a stationary bandit and production, consistent with the value of protection they provide..

D Online Appendix: Expectations

First, if villagers anticipated the coltan shock, estimates of the coltan shock may reflect a lower bound of the real effect. For instance, groups could have fought for monopolies of violence in coltan villages in 1999 knowing that the price would rise in the future. Second, following the price increase, if local populations anticipated that the shock was going to be short-lived then the estimates of the effect of the shock underestimate the real effects of permanent price shocks, especially if groups' cost functions have non-convexities. Third, following the sudden price drop in international markets, the persistence of the effects of the coltan shock is overestimated if populations expected the price would rise back to the level it reached during the year 2000 spike.

There is significant anecdotal evidence on expectations about the coltan price level - most people in the Kivus remembered very well the coltan shock. This anecdotal evidence has three implications. First, unanticipated innovations in the electronics markets led to the rush to coltan. Second, this demand for coltan vanished when Playstation II performed poorly for unexpected reasons in the year 2000 Christmas market. It is therefore very unlikely that local populations expected a sudden drop in demand for this mineral. Third, following the sudden price drop in 2001, local traders hoarded minerals because they expected the world demand to rise back to its peak level of 2000.[63] In addition, I collected retrospective measures of expectations held by the villagers in this survey. Villagers expected neither the increase nor the decrease in prices.

[63] United Nations Security Council (2002).