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The Gold Digger and the Machine
Evidence on the Distributive Effect of the Artisanal and Industrial Gold Rushes in Burkina Faso *

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Abstract

This paper uses a quasi-natural experiment, the recent gold boom in Burkina Faso, to document the local impact of two alternative mining techniques: artisanal and industrial mines. Artisanal mines have a bad reputation. When these mines (managed in commons) compete for land with industrial mines (privatized), governments tend to favor industries. However, more than 100 million people depend on artisanal mines for their livelihoods. Our identification strategy exploits two sources of variation. The spatial variation comes from the exposure of households to different geological endowments, and the temporal variation comes from changes in the global gold price. We are the first to document the economic impact of artisanal mines. We show that a 1% increase in the gold price increases consumption by 0.15% for households neighboring artisanal mines. Opening an industrial mine, in contrast, has no impact on local consumption.

Keywords: artisanal mining, commons, extractive industries, gold, poverty, Burkina Faso
JEL Codes: D63, L72, O13, O55, Q32, Q33, R11

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1 Introduction

Karma, January 2015: 3 to 6 million euros in equipment on the construction site of True Gold vanish in flames after a local community protest (Capitant, 2017). Karma is located in Burkina Faso, a country where 43% of the population was living on less than 1.90 dollars per day in 2014 but which, thanks to heavy investments made by industrial mining companies such as the Canadian True Gold, became the 4th major gold exporter of Africa within a few years. Yet the population of Karma displayed extreme discontent against True Gold's investments, in particular the population linked to artisanal mining activities. The case of Karma is not exceptional: qualitative evidence abounds on local resistance to industrialization, notably from people engaged in traditional activities, be it in the mining sector or other sectors (Hilson and Andrew, 2003; World Bank, 2009; Stoop et al., 2018).

We shed light on one essential aspect of the tension between local populations and industries: the local economic consequences of traditional *versus* industrial activities. Artisanal mining is a traditional and labor-intensive activity that extracts natural resources under a regime of common property management.[1] The settlement of an industrial mine substantially increases productivity while privatizing the natural resources, since the production area is enclosed. Such a setting echoes various instances when a traditional activity (low in productivity, but accessible to all) is replaced by a modern activity, for example switching from traditional to modern agriculture, or replacing a communal forest with an oil field or any type of heavy industry.

The evolution of gold extraction in Burkina Faso since the late 1990s offers an ideal quasi-natural experiment. Artisanal and industrial mining targets overlapping areas in Burkina Faso, and the country has a long tradition of artisanal and small-scale gold mining (henceforth, ASM). The multiplication by four of the world gold price between 1998 and 2014 directly impacted on the benefit of both industrial and artisanal gold mining. As a result, in 2014, we estimate that 640,800 Burkinabes, representing nearly 4% of the total population of the country, were directly involved in ASM activities. Multiplying each artisanal miner by five dependents, the multiplier used by the UN report (2016), makes artisanal mining central to the livelihood of 3,200,000 people, which corresponds to 18% of the country's population at the time. Moreover, following both the price increase and the adoption of an investor-friendly mining code in 2003, eight major and three minor industrial mines opened between 2007 and 2014. All the gold deposits that are big enough to build industrial mines had been known for decades, but it suddenly

[1] Such that *"property rights are exercised (at least partly) collectively by members of a group. There must also be rivalry in consumption of the resource within the group"* (Seabright, 1993, p. 113)

became cost-effective to exploit them. The timing of the industrial gold boom is thus independent from local factors. At the national level, the settlement of industrial mines increased the gold production and exports: gold represented 2% of exports in 2007, and 55% in 2014. At the local level, this settlement cast aside artisanal miners, who lost access to the resource in areas privatized by the industrial mine owners (Côte and Korf, 2016).

To identify the impact of artisanal mines, we implement an analysis in which the treatment comes from variations in the global gold price and the distance to artisanal mines. Indeed, Burkina Faso is a price taker on the global gold market and the gold price induces a time variation in gains from mining. To define the location of artisanal mines, we exploit original data on all the registered artisanal mines and novel geological information. To identify the impact of industrial mines, we exploit the difference in their years of opening (which follow the global gold price), as well as the distance of households to these mines. We are able to isolate the effects of the gold boom by combining four waves (1998-2003-2009-2014) of household surveys collected by the national statistical agency of Burkina Faso, the INSD. These data have never before been exploited over such a long period, and we are the first to take advantage of the GPS coordinates of households to track changes at the local level. We use household consumption as the main indicator of household economic well-being (Deaton and Zaidi, 2002), and also investigate the effects on the two other aspects of human development (health and education).

Our results first document a strong positive impact of artisanal mining on consumption. A 1% change in the gold price leads to a 0.15% increase in nominal consumption for households located close to artisanal mines. This additional consumption is economically significant: the recent gold price boom translated into a 10% increase in households consumption (or 5 cents in euros each day for each person living next to an artisanal mine given the average consumption in the sample). We also document an amelioration in children health that is consistent with the income effect of artisanal mines taking over any pollution effect (at least in the short run) and a decrease in education attendance of people above 16.

We then proceed to show that industrial mines do not improve local economic conditions. Our estimates show that industrial mining never has an impact on neighboring household consumption because the point estimate, while reasonably precise, is close to zero. Thus, the efficiency gain (the strong increase in gold extraction) arising from the privatization of the gold resource by industrial mines does not translate into a gain for local labor.

Our results are unlikely to be driven by changes in migration or local prices. Most importantly, we show that artisanal mining activities in Burkina Faso are highly seasonal, and we document the positive consumption effect of artisanal mines outside the main mining season.[2] We also document that this effect is concentrated on the households who work in the agriculture, service, and trade sectors, all activities that allow households to benefit from the increase in the economic activity of the area. These households may either directly diversify their income source by mining, or indirectly benefit from the gold boom by providing gold diggers with goods and services (Moretti, 2010). We perform several other checks that are all inconsistent with a persistent surge in local prices.

We therefore make three significant contributions to the literature. We provide the first country-wide study on the local impact of artisanal mining, thereby reducing the knowledge-gap on ASM. ASM has a bad reputation and is often seen as a source of conflict and poverty. For example, the main international initiative focused on ASM, the Communities and Small-Scale Mining Initiative of the World Bank, stated that its aim was to transform artisanal mining *"from a source of conflict and poverty into a catalyst for economic growth and sustainable development"* World Bank (2007). Yet, more than a hundred million people globally, representing 1.5 to 4% of the world's population, depend either directly or indirectly on ASM for their livelihoods (considering both miners and their families, World Bank, 2009; artisanalmining.org, na). and these mines produce 20% of the minerals that we use (Buxton, 2013). Faced with such figures, we may be surprised that the existing quantitative literature has so far remained quasi-silent on ASM impacts.[3] This quasi silence comes from the technical challenge of pinning down artisanal mining activities. A few recent works aim to overcome this challenge by means of either extrapolation from the type of deposit, or first-hand data from specific regions. The only published work, by Lujala et al. (2005), shows that diamonds which can be mined artisanally –which happen to be lootable– induce more conflicts than other diamonds do. Rigterink (2018) exploits this heterogeneity by arguing that an important conflict determinant is the opportunity cost of time for fighters. Focusing on Eastern Congo, Stoop et al. (2018) document the tensions arising around the arrival of an industrial mine in sites of artisanal

[2]Mining takes place mainly in winter, when people have nothing to do in the fields. We exploit data collected between the months of May and July (or until September for one of the waves), that is during the plantation and growing period, when people are in the fields. This period also coincides with the rainy season during which ASM activities are illegal because the rainfall increases the danger of the mines collapsing.

[3]A World Bank report, aiming to summarizing the state of knowledge notes that *"An important caveat is that the focus of the study is on large-scale 'industrial' gold mining and not artisanal and small-scale gold mining that often takes place in proximity to large-scale mining. The data cannot be disaggregated to distinguish between these two classes of mining"*(World Bank, 2015, p. 11). Cust and Poelhekke (2015), in their literature review on the local impact of extractive activities, both call for more research on ASM, and summarize the overall negative perception of this activity: *"Finally, more research is warranted on a variety of fronts. The first is to look at an even finer spatial scale, such as artisanal mining, which in many rural areas may cause severe environmental and health risks, conflict and generally few economic benefits."* The only published work we know of that considers artisanal mines in a quantitative analysis, Zabsonré et al. (2018), actually merges their impact together with the impact of industrial mines. They find an overall positive impact on living standards. However, the fundamental differences between the two management modes, if only in terms of labor intensity, calls for further work that distinguishes their impacts. Such a distinction is all the more important in that the qualitative research on ASM offers a nuanced picture, and often outlines both the insurance effect of artisanal mining and its social costs (Hilson, 2006).

exploitation. Still in the conflict and institution vein, Sánchez de la Sierra (2017) shows that non-lootable coltan and lootable (artisanally exploited) gold lead to the development of different forms of stationary bandits in Eastern Congo. More recently, Guenther (2018) documents a positive correlation between artisanal mines, income, and deforestation in the Southern half of Ghana. Without underestimating the possible negative effects of ASM on conflicts and other dimensions of well-being, we exploit new and nationally representative data from Burkina Faso to provide causal evidence that ASM activities may have a significantly positive effect on local consumption.

Second, our results contribute in two important ways to the literature on the local impact of extractive industries. Our results make it possible to emphasize the different local impacts of opening *versus* extending a mine. Given the debate on the existence of a resource curse at the macroeconomic level (see van der Ploeg, 2011; Venables, 2016, literature reviews), researchers have investigated the consequences of extractive activities at the local level (see Cust and Poelhekke, 2015, for an overview). Aragón and Rud (2013) document that the increase in demand for local inputs of the largest Peruvian gold mine has generated positive economic spillovers for households living in the surroundings of the mine, while Aragón and Rud (2016) show a decline in agricultural productivity (and de facto consumption) with the extension of industrial gold mining in Ghana. We show here that the *opening* of new industrial mines in Burkina Faso has no local economic effect. Our results call for further attention to the distinct impact of opening a new mine *versus* expanding the production of an existing one. The characteristics of the local market for inputs is also likely to be an essential aspect of a policy betting on a local multiplier effect: the Peruvian production sector is more varied than that of Burkina Faso, such that the realization of the local linkages should be easier in Peru than in Burkina Faso or Ghana. Moreover, we show that whether or not we control for artisanal mines, the coefficient of industrial mines remains the same. Such an observation is reassuring for the credibility of the existing estimates in the literature. Although in many cases artisanal mines precede or co-exist with industrial mines (World Bank, 2009), virtually all the existing literature omits the distinctiveness of ASM, thus mixing together the impacts of the two mining techniques.[4]

Last but not least, our results bring empirical evidence to the mostly theoretical debate on the impact of private *versus* common property management of natural resources. Artisanal mines are not the ideal typical common, but these mines do display the core features of a common property management

[4]The most notable exception is the ongoing work of Stoop et al. (2018) on conflicts with overalpping artisanal and industrial mines. The literature on diamonds and conflicts reviewed in Rigterink (2018) takes a different perspective since artisanal and industrial diamond deposits do not overlap.

(absence of efficient production planning, and resource accessible to all), while industrial mines restrict access. A rich literature debates the distributive consequences of each mode of management (starting with the works by Weitzman, 1974; Pattanayak and Sills, 2001; Baland and Francois, 2005; Baland and Bjorvatn, 2013). In particular, Weitzman (1974) shows that, although efficient, privatization can be obtained at a distributional cost, making labor worse off. Indeed, under common property management, all gains go to the variable production factor (in our case, labor); while under private ownership the variable product gets only a share of the gains (the remainder goes to the owner of the fixed factor, here, the owner of the mine). Baland and Francois (2005) go further, showing that everyone may lose after privatization when markets are incomplete. Indeed, open access to the resource may be used as an asset of last resort for poor populations. However, it is challenging to find empirical evidence. To the best of our knowledge, our study offers the first large scale empirical evidence on the local impact of common *versus* private management of an extractive natural resource. Privatization in gold mining is a bundle treatment that, together with the nature of the property of the resource, changes the capital intensity of the extractive activity. We here provide a reduced form estimate of the impact of this bundle treatment.[5] We also note that the competition for land between different management modes translates into a trade-off between local labor consumption and State revenue. Indeed, while artisanal mines increase local consumption, their contribution to the State revenue is smaller than the contribution of industrial mines, in both relative and absolute terms. In 2014, artisanal mines contributed to the revenue of the State of Burkina Faso 5% of the value of their declared production, while industrial mines contributed 19% (ITIE, 2016).

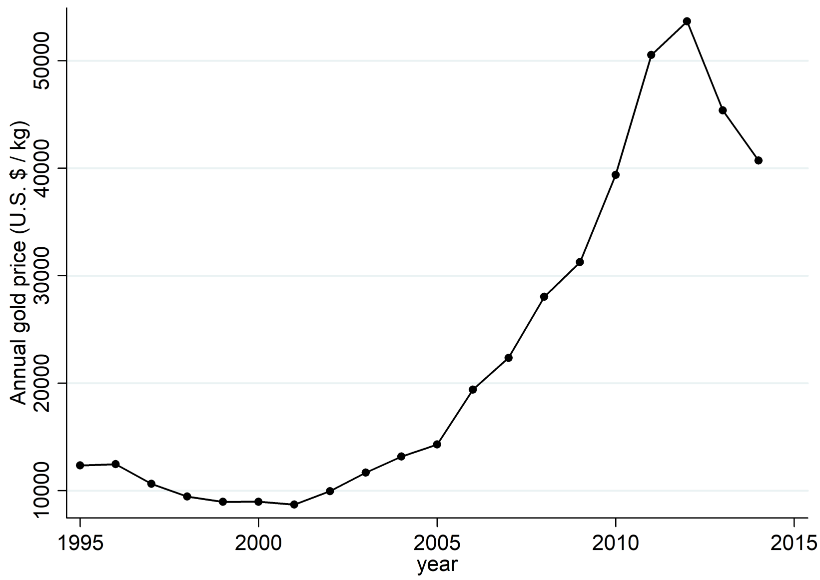
The paper is organized as follows. In the next section, we present gold mining in Burkina Faso. Section 3 focuses on the data and identification strategy. Section 4 provides the main results. Section 5 proposes a discussion of these results: we explore labor market effects and seasonality, and the potential effects of migration and prices. Section 6 concludes.

2 Gold Mining in Burkina Faso

Several features of gold extraction in Burkina Faso make it the ideal candidate to assess the impact of artisanal *versus* industrial gold extraction. First, we detail that the two main drivers of the recent gold rush, namely the gold price and gold reserve locations, are exogenous to the action of local populations. Second, we describe the organization of artisanal gold mines. Third, we describe the setting in which the

[5]The mechanization of the exploitation of a communal land or the construction of an oil field instead of a communal fishery would similarly lead to changes in the capital intensity of the economic activity performed on a given area.

Figure 1: Evolution of the gold price, 1994-2014



Note: data sources are the gold price from London Gold Fixing.

industrial gold boom has taken place.

2.1 How Gold Affects Burkina Faso

While gold price fluctuations directly determine the benefit of gold extractive activities, Burkina Faso is a price taker on the international gold market. In 2012, its gold production of 28 tons made it the 22nd producing country in the world, far behind the 403 tons produced by Russia (indexmundi). Still, gold has become central for the economy of the country since the surge in the gold price in the 2000s (Figure 1), and gold is now the country's main export: it represented 55% of exports in 2014 (the last year in our study) against only 6% in 1998 (the first year in our study). We aim to assess how the artisanal and industrial gold rushes have affected the country's 17 million inhabitants, about half of whom live with less than $1.90 per day (from 80% in 1998, to 43% in 2014, 2011 PPP, World Bank).

The location of gold deposits all over the country is exogenously determined by the geological environment. Burkina Faso lies on top of the Birimian greenstone belts, a type of rock likely to host gold deposits within its core or at its frontiers (Béziat et al., 2008). Following this geological setting, Burkina Faso hosts hundreds of artisanal and small-scale mines, and hundreds of industrial exploration permits. Both types of mines compete for overlapping areas, as is clear from the repartition of artisanal mines and industrial research permits across the country, both overlapping with the Birimian belts (Appendix Figures 7 and 8). Importantly, if an exploration permit is successful and results in the construction of an industrial mine, artisanal miners lose access to that extraction site (Côte and Korf, 2016). Appendix

Figure 9 takes the example of the mine of Kalsaka: the industrial mine is enclosed by a fence, and within the fence lie some places where artisanal miners used to dig.

2.2 Artisanal Mines

Artisanal and small-scale gold mining (ASM) has been taking place all over Burkina Faso since the droughts in the 1980s, with recent variations in the profitability of the activity following the level of the gold price.[6] According to the 2003 mining code, traditional artisanal exploitations encompass any *"action that consists in extracting and concentrating mineral substances to retrieve commodities from them using traditional, manual methods and processes."*[7] Concretely, ASM sites look like a series of narrow shafts that may be several dozen meters deep. Gold diggers go down the shaft to bring the ore to ground level where further work allows to separate the gold from the useless dirt. In 2003, Jaques et al. (2003) already observed over 200 ASM sites in the country. In 2014, the number of ASM sites was estimated to be 700 to 1,000 (400 of which were registered, Zerbo and Ouedraogo, 2014; ITIE, 2016).

Artisanal and small-scale mines offer an original example of common property resource management (Rodríguez et al., 2018). ASM displays both aspects of a common property resource in the sense of Seabright (1993). First, the property rights of artisanal and small-scale mines *"are exercised (at least partly) collectively by members of a group"*. Indeed, as outlined below, several pivotal people have claims over a share of the resource, they are constantly re-negotiating, and newcomers will always be able to take part in the production process. Second, there is rivalry in consumption of the resource within the group. Indeed, one cannot mine what has been mined by one's neighbor. Last, ASM is prone to the investment externality: while small groups manage to organize to extract ore from their shaft with basic tools, there is a coordination failure when it comes to bigger investments that would make production more efficient, or strategic planning of the speed of extraction.

Life in the country's artisanal and small-scale mines has kept following some reasonably stable –informal– rules since the 1980s despite changes to the –formal– legal framework (Gueye, 2001; Jaques et al., 2003, 2005; Côte and Korf, 2016; Werthmann, 2017).[8] Unwritten rules organize the production and

[6] Local buyers pay gold diggers a fraction of the world gold price shown in Figure 1, that fraction is typically above 83%, Alvarez et al. (2016).

[7] The original French version reads: *"opération qui consiste à extraire et concentrer des substances minérales et à en récupérer les produits marchands pour en disposer en utilisant des méthodes et procédés traditionnels et manuels."*

[8] From a legal point of view, from 1986 onward, the CBMP, a state-owned trading post, was supposed to have monopsony power over the organization and buying of gold throughout the country. In 1997, the creation of private gold trading posts

ore repartition both within each shaft and between shafts. There are two key actors systematically entitled to a part of the ore: the gold diggers (by which we mean both the actual diggers and the other manual workers participating in the ore processing), and the shaft owner (who invested to open the shaft).[9] These unwritten rules are still subject to bargaining. For example, Côte and Korf (2016) report instances when local communities managed to leverage taxes from artisanal miners allowing them to finance a water pump, a mosque, or school classrooms. Newcomers are welcome on mining sites. A newcomer will either dig a new well or join an existing team (Balme and Lanzano, 2013). The main features of these rules appear in other ASM sites worldwide and as far as in Columbia (Rodríguez et al., 2018).

An exceptional feature of the ASM sector in Burkina Faso is that it is possible to know approximately where mining may take place from ongoing artisanal mining authorizations. Unfortunately, the authorization does not specify who is mining since when and how much. However, any authorization corresponds to a place where mining has been taking place at some point. ASM authorizations cover one square kilometer and were meant to empower gold diggers, but the bureaucratic knowledge necessary to get an authorization is such that, in practice, private trading posts have secured the authorizations. These trading posts then enforce a monopsony over the commercialization of the ore in their surroundings.[10] Artisanal mines remain managed as commons in so far as private gold posts do not act as strategic planners charging efficiency tolls for the use of their property (as is the case in the private ownership equilibrium in Weitzman, 1974). Moreover, while gold trading posts' attempts at enforcing a monopsony over the gold trade in some areas may limit the number of options gold diggers have to sell their gold, it does not limit access to the artisanal gold mining site (Balme and Lanzano, 2013).

Last but not least, ASM activities are likely to have local linkages and spillovers. Indeed, these

was authorized and the CBMP had such trouble competing with the private posts that it stopped working in 2005. In 2003, a new mining code changed the legislative framework for industrial mines with little effect on artisanal mines, save for a slight lowering of taxes. Another mining code was voted in 2015, that is after the last household survey that we use.

[9]Once prospectors identify a new spot, either one of them or the owner of the land invest to open a new shaft. Property rights for shafts are informal and follow a first-come, first-served basis. Up to several hundred shafts can be dug on a single site (as long as the site produces). The person who invests to dig the shaft will be the shaft owner (she needs to have some capital because she provides food to diggers while they dig the new shaft). The moment the shaft starts producing, the shaft owner and the diggers share the ore (usually with a 50:50 rule, and if the local land owner is not the shaft owner, she may collect a lump sum rent or a share of the ore). Hence, the gold diggers, the shaft owner, and the people processing the ore are paid according to 1) the amount and type of their input, and 2) chance, as 2a) the pay is a percentage of the ore, but actually gains are never known before the end of the transformation process, and 2b) the activity is risky for gold diggers and death is always a possibility (Mégret, 2008). A typical shaft is mined by 4 to 8 gold diggers. A last pivotal actor, present in all registered mines, is the trading post, which tries to secure a monopsony on buying the gold produced in the perimeter of the artisanal mining authorization.

[10]While this claim is illegal for places outside the authorization, and gold diggers may and do sell their gold to different gold trading posts or even smuggle it abroad, trading posts often manage to reach their goal. Post holders may enforce their monopsony in different ways, from lending money to gold diggers who need it to open new shafts (Balme and Lanzano, 2013; Hilson and Ackah-Baidoo, 2011), to the extreme case of physical violence (Werthmann, 2017).

activities are labor intensive and gold diggers' needs are likely to induce a high local labor multiplier (Moretti, 2010). Artisanal mining is a labor-intensive activity performed by local labor, from neighboring rural communities or floating populations from various regions (Werthmann, 2017). From the household survey we have, in 2014, approximately 640,800 people from Burkina Faso were active in mining. This local labor interacts with the local population for services, ranging from water supply to more or less elaborate forms of prostitution (Werthmann, 2017). Taking the 1 artisanal miner for 5 dependents multiplier used by the UN report (2016), artisanal mining was central to sustain the living of 3,200,000 people in 2014, which corresponds to 18% of the country's population that year. While the tendency of gold diggers to practice conspicuous consumption on items such as beer, electronic gadgets, or motorcycles, may create tensions with local traditions (Cros and Mégret, 2010), it also participates in the local redistribution of the money earned digging. Gold diggers also stimulate local trade for their inputs, be it batteries, kerosene, dynamite, hammers, pickaxes, shovels, wood ladders, ropes, buckets, calabashes, plastic bags, mortars, sluicing plates, and wood or metal sieves. All these inputs are traded by local shops and some of them may be produced locally, mechanically increasing the number of jobs created around each gold digger (Bohbot, 2017).

2.3 Industrial Mines

The country's mining potential has been known for decades such that the recent industrial gold boom is independent from local factors. Two key elements changed during the 2000s and attracted international investors in Burkina Faso: the promulgation of a new mining code in 2003, and the sharp increase in gold prices (Figure 1).[11] The 2003 mining code is the result of a move toward a liberalization of the mining sector encouraged by international organizations. It opened the sector to international investors and made the tax regime more company friendly. As a result, in 2014, Burkina Faso had 11 running industrial gold mines and three under construction. Appendix Table 8 presents each of these mines.[12]

Gold exploitation within industrial mines results from profit-maximizing decisions, in line with the logic of private ownership equilibrium in Weitzman (1974). The property rights over the fixed factor (here the ore) take the form of industrial exploitation permits owned by international companies.

[11] The only industrial gold mine in the country, the Poura gold mine, encountered great difficulties and had such a scarce production that it closed in 1999 when the gold price was low (Jaques et al., 2003).

[12] Two other major mining projects are under way in the country, one for zinc (production started in 2013) and the other for manganese (exploitation permit from 2012 but production still subject to a judiciary battle).

The recently flourishing mining industry is likely to have different local spillovers than artisanal mines. Industrial gold mines are capital-intensive, high-tech branches of international companies. The few employees of industrial gold mines have mostly formal contracts with a fixed pay and are highly skilled. To put things in perspective, next to the estimated 640,800 gold diggers active in the country in 2014, the industrial mining sector declared that it employed 6,464 people (ITIE, 2016). In addition to limited direct contacts between industrial mines employees and the local population (employees' dorms are enclosed within the fence of the industrial mines; see Appendix Figure 9 for the mine of Kalsaka), the inputs of industrial mines such as large-scale mills and generators or trucks need to be imported from abroad. Still, given the scale of the recent boom in industrial gold extraction throughout the continent (with some positive spillovers Benshaul-Tolonen, 2019), the competition for land between artisanal and industrial mines, and the observation that local content policies as encouraged by the World Bank may be successful in some contexts (see Aragón and Rud, 2013), it is important to assess the local impact of these mines.

3 Data and Identification

3.1 Data

We build a nationally representative dataset that is a repeated cross section comprising 35,000 households surveyed by the INSD (the National Institute of Statistics and Demography, based in Ouagadougou) in 1998, 2003, 2009, and 2014. The 1998, 2003, and 2014 surveys are registered in the World Bank Microdata Catalog, and the 2014 survey is additionally part of the Living Standards Measurement Study collection. We are the first to exploit the time dimension of these surveys over such a long period.[13] We are also the first to build and exploit their geocoding (with the geodesic center of each village, or city neighborhoods).

Each survey wave encompasses 8,300 to 10,030 households, who are spread out over 426 to 900 enumeration areas in 223 to 301 of the country's 351 municipalities. Our final sample omits Ouagadougou due to the specificity of year 2014 events in the city.[14] The drawing of enumeration areas for each survey is such that we have observations for at least two different points in time for 96% of the municipalities

[13] Grimm and Gunther (2007) and Zabsonré et al. (2018) use the 1998, 2003 or 2009 surveys. The 2014 survey has not yet, to the best of our knowledge, led to an academic publication.

[14] The city was at the core of the year-long protest of the "balais citoyen", requesting the departure of president Blaise Compaoré after his 27 years in power. According to ACLED, Ouagadougou hosted over 78% of the 51 protests that had taken place in the country by June 2014, the end collection date of our reference survey round for 2014. ACLED records a total of 139 events in the year 2014. To put this number in perspective, there is on average 22 ACLED events over the period 1997-2013 (with a minimum of one per year and a maximum of 63). Results are however robust to either including Ouagadougou, or to excluding entirely the data from 2014.

Table 1: Summary statistics

	Mean	se
head age	45	0.1
head is male (%)	89	0.002
rural household (%)	86	0.002
head can read (%)	23	0.003
household size	7	0.03
number of workers in the household	4	0.02
head works in agricultural sector (%)	84	0.002
head works in extractive sector (%)	0.01	0.0006
consumption per capita	119,481	823.03
Total number of households in the sample= 30,502		

Note: The mean and its clustered standard error are calculated using sample weights. Consumption is measured in CFA francs. Since January 1999, the CFA franc has had a fixed exchange rate with the euro (656 CFA Francs = 1 euro)

in our sample.

The core focus of INSD household surveys remained unchanged through time: assessing the standard of living and material well-being of households in Burkina Faso. Beside consumption, all surveys include standard questions such as household size and composition; the activity, education, and age of the members; the type and comfort of their house; etc. Table 1 presents an overview of the characteristics of the households in our sample. We estimate the means and standard errors using sample weights and clustering by primary sampling unit to account for the sampling design.

Our measure of consumption includes information on daily consumption (food, alcohol, tobacco, clothing, etc.), health, and education expenditures. We omit rents as estimated by households because 85% of households own their house. We follow Deaton and Zaidi (2002) and omit exceptional expenditures on ceremonies, durable items (such as electronic items, jewelry, or transportation modes) for which we cannot compute the rental equivalent.[15] This procedure gives us the nominal total consumption of

[15]Items listed in the questionnaires changed a bit from one survey to another. This is unfortunately often the case with household data. More precisely, the 1998 survey asks about 34 food-related items in the last two weeks and 31 other items in the last month, including health spending, while education spending are asked annually. The 2003 survey asks about 125 food-related items in the last two weeks and 40 other items in the last month, including health spending, while education spending are asked annually. The 2009 survey asks about 353 food-related items and 944 other items that households consumed in the last 12 days, including education and health, and then asks about the frequency of the consumption of these consumptions (from daily to yearly). The 2014 survey asks about the consumption of 64 food-related items in the last 7 days and the consumption of 129 other items in either the last 7 days or the last three months, including education and health. All the 1998 to 2014 surveys asks respondents to recall, for each item, the CFA equivalent of their consumption that they bought, obtained as a gift, or auto-consumed (for food related items). We apply a similar procedure to the raw data of each survey round. In particular, for each year and item and source of consumption, we replace extreme outliers – values that are beyond five standard deviations from the mean – by their median. For each survey round, less than 1% of the households have such outliers. We then make the data yearly for everyone. As long as any differences in the survey questionnaires are not correlated with our treatment (artisanal and industrial mine location), including year-specific effects is enough to account for each survey specificity. We further check the robustness of our estimates to excluding one year at a time.

each household.

The main challenge for us to answer our research question is obtaining the actual location of artisanal mines. We are able to provide a first answer to this challenge thanks to exceptional data from Burkina Faso. The Ministry of Mines gave us access to original data on the location of every registered artisanal gold mine. Obviously, due to the mobility of artisanal miners, this list does not include every artisanal mine. However, we do know that artisanal mining has taken place at some point in each of these registered locations. As a result, this list allows us to compute a first estimate of the impact of artisanal mining.

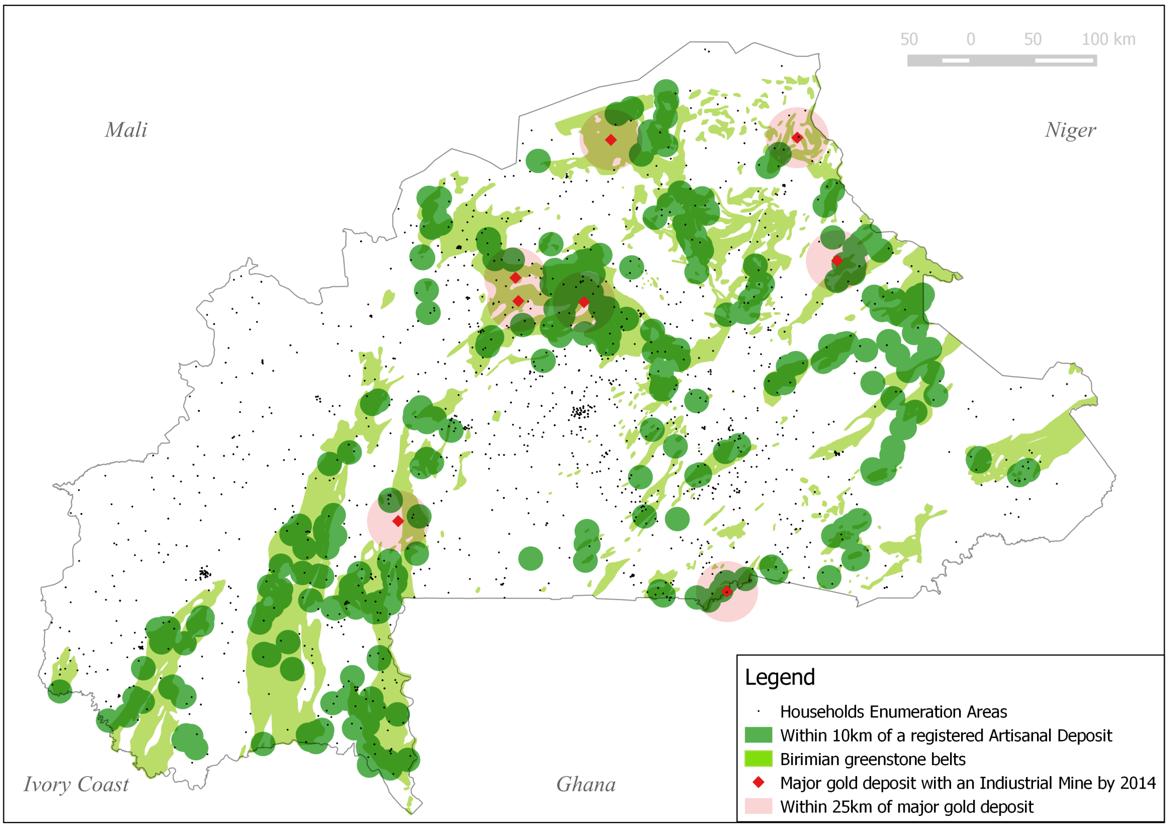
One may be concerned that specific places, for example that are closer to the capital, or more populated, are more likely to have registered artisanal mines. As an original check of the quality of the data on registered mines, we are able to overlay them with the location of the Birimian greenstone belts. Virtually all gold resources of Burkina Faso lie in Birimian belts (Béziat et al., 2008), mirroring what Fernihough and O'Rourke (2014) exploit for coal in the UK. Figure 2 shows the location of artisanal mines with a 10-kilometer buffer in dark green and the Birimian greenstone belt collected by geologists of the BRGM Orléans in light green. Registered artisanal mines clearly seem to follow the Birimian greenstone belt. We may however note that the two artisanal treatment definitions cover distinct household samples: they overlap for a maximum of 35% of the treated households.[16]

The ministry also gave us access to each industrial mine's localization, yearly production, and estimated reserves. Enumeration areas within a red zone of Figure 2 encompass households who live within 25 kilometers of a major industrial mine that was running by 2014.

The data does not tell the exact boundary (fences) of the industrial mines, making impossible to precisely test the effect from loosing access to artisanal mining fields. What the data allows is a comparison of the artisanal gold boom and the opening of industrial mines. Such opening acts as a bundle treatment, encompassing the creation of some formal jobs in the industrial mine, and the loss of access to some artisanal mining fields. Appendix Table 9 shows that each survey encompasses information on more than 1,300 households living next to an artisanal deposit, and more than 170 living next to an industrial mine.

[16]Treated meaning either living within 10 kilometer of a registered artisanal mine, that is in a dark green area, or living inside or within 5 kilometer of the Birimian greenstone belt, that is in a ligh green area or its close surroundings, accounting for the observation that many deposits lie on the edge of the belt. We can also use no buffer or a 10 kilometers buffer around the Birimian greenstone belt, it yield similar results, but it has an even lower correlation coefficient with the presence of registered artisanal mines.

Figure 2: Location of enumeration areas for household surveys and mines (both industrial and artisanal)



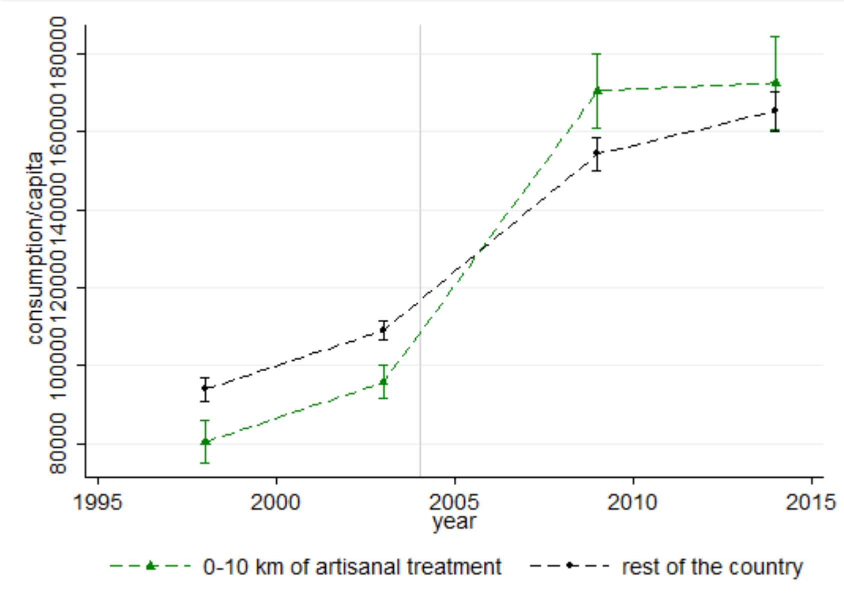
3.2 Identification Strategy

Our aim is to estimate the effect of different gold mining techniques on household living standards. We exploit two sources of variation: temporal (the global gold price boom) and spatial (household distance to gold deposits provides a source of heterogeneous exposure to potential mines). In this subsection, we successively explain how this allows us to identify the effect of artisanal and industrial mines.

We identify the locations of artisanal deposits by using the census of artisanal mines registered at the Ministry of Mines. In our baseline specification, we use a 10-kilometer buffer to distinguish treated and non-treated households, we also use the Birimian belt, a purely geological definition of the spatial treatment. We consider alternative distance definitions in robustness checks.

The boom in the gold price provides a time-varying treatment. We consider two different time treatments: the log of the gold price, and a dummy variable taking the value 1 after the gold price boom took place (in 2009 and 2014). The idea is that the gold price is the main driver of the benefit of (artisanal) mining activities since it directly determines the expected gains of the miners (Alvarez et al., 2016). When the gold price increases, it may become profitable for households to switch activities or to

Figure 3: The evolution of household consumption before and after the gold price boom



Note: Each point represents the mean level of consumption per capita for households in that group that year. The treated group encompasses households living within 10 kilometers of an artisanal deposit. The control group (rest of the country) excludes the treated areas. Bars around each point represent the 95% confidence intervals.

increase their labor supply in order to benefit from new earning opportunities. Moreover, even for a fixed work supply, the money gold diggers get for their gold will be a function of the gold price, meaning that they would be able to spend more and generate more local economic activity.

The validity of the empirical strategy relies on the assumption that the evolution of consumption in areas far from and close to these artisanal mines would have been similar in the absence of the increase in gold mining activities. Since the boom in the gold price started in 2004-2006, to be in the ideal setting for a double difference, similar trends should be observed between 1998 and 2003. The next survey wave (2009) already includes the effect of the gold boom. Figure 3 shows the yearly consumption of households located within 10 kilometers of a gold deposit that may be mined artisanally, and of those further away. Figure 3 supports the parallel trend assumption. The level of consumption is significantly lower in areas close to artisanal mining deposits in 1998 and 2003 but trends are parallel. The trends start to diverge only between 2003 and 2009, which is consistent with our hypothesis. The consumption level of households located around artisanal mines catches up with or even overtakes the consumption level of households in the rest of the country after the boom in the gold price.

To estimate the impact of artisanal mines on household consumption more formally, we propose equation 1:

$$C_{ivt} = \alpha(\text{price}_t \times \text{artisanal deposit}_v) + \beta\text{artisanal deposit}_v + \gamma' X_{it} + \delta_m + \eta_t + \epsilon_{ivt} \quad (1)$$

C_{ivt} is the log of the per capita consumption for household i living in village v of municipality m at time t. α is our coefficient of interest; it gives the estimated impact of the change in the gold price on the consumption level of households who live next to a gold mining site. Indeed, price_t is equal to the natural logarithm of the gold price (alternatively, we can use year dummies or a dummy equal to 1 in 2009 and 2014, the years when the gold price was high). Artisanal deposit_v is a dummy variable taking the value 1 if the household is exposed to an artisanal mine. In our baseline estimate, this dummy takes the value 1 if the household lives within 10 km of an artisanal gold deposit and 0 otherwise. X_{it} is a set of controls. It includes the age, sex, literacy, sector of occupation and nature of work of the household head, the number of household members and income earner members, a dummy for households in rural areas, and controls for electricity and water supply (following Aragón and Rud, 2013) We also include municipality fixed effects δ_m and year fixed effects η_t.[17] ϵ_{ivt} is the error term. Standard errors are clustered to take into account serial correlation at municipality level (Bertrand et al., 2004).

Our identification strategy may lead to two main biases. We acknowledge them both, but argue that they are likely to be, if they exist, attenuation biases.

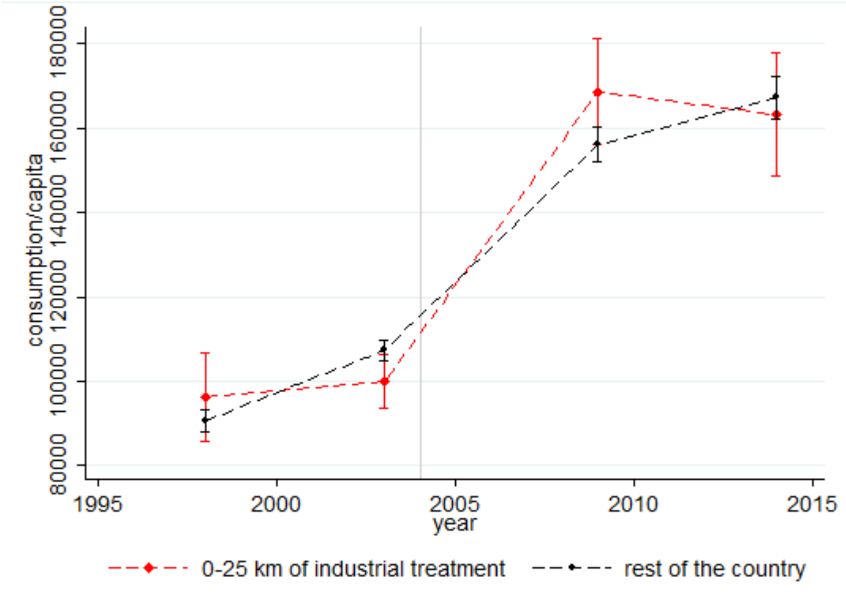
First, a bias may come from the under-declaration of artisanal mining when using the census of registered artisanal mines. Importantly, if any contamination of the treatment by the control –or of the control by the treatment– occurs because of an inappropriate definition of the deposit areas, this mechanically implies an attenuation bias of our results. We can also consider alternative buffers, and check the overlay of registered artisanal mines and the Birimian greenstone belts.

Second, our definition of the time treatment is coarse, and we may consider some places as treated by the gold price, or in 2009 and 2014 (when our gold boom dummy is equal to one), whereas there actually was not any mining in these places at this moment. This possible contamination of the treatment by the control due to our blunt definition of the time treatment would again mechanically lead to an attenuation bias.

Concerning industrial mines, we also exploit time and spatial variations. Similarly to artisanal mines,

[17]The municipality is the smallest geographic entity for which we can include fixed effects. These fixed effects are fine grained: the country comprises 351 municipalities. Since one municipality encompasses several enumeration areas, we account for the specificity intrinsic to the enumeration areas surrounding artisanal mines through the dummy $deposit_v$.

Figure 4: The evolution of household consumption before and after the opening of industrial mines



Note: Each point represents the mean level of consumption per capita for households in that group that year. The treated group encompasses households living within 25 kilometers of a deposit that would host an industrial gold mine by 2014. The control group (rest of the country) excludes the treated areas. Bars around each point represent the 95% confidence intervals.

the spatial source of variation is the household distance to a gold deposit, as a source of heterogeneous exposure to a potential mine. Here, we use a 25-kilometer buffer to define treated households.[18]

The time variation comes from the years of the opening of the industrial mines. As can be seen in Appendix Table 8, industrial mines opened in a staggered manner, the first one opening in 2007 and the last one in 2013. More precisely, four mines opened between the 2003 and 2009 surveys and seven other mines opened between the 2009 and 2014 surveys. In the empirical analysis, we also take into account the possible spillovers coming from the construction of these mines, because exploration and construction taking place in particular two years before actual production starts are intensive in unskilled labor.[19]

Our identification again relies on the assumption that the effect of a mine declines with distance and that the evolution of consumption in areas far from and close to an industrial mine would have been similar in the absence of the mine. Figure 4 shows consumption trends. There never is a statistically significant difference in samples averages within each year: the levels of consumption of households

[18]There is no consensus in the literature on this threshold. For instance, Aragón and Rud (2013) use a 20-km buffer in Ghana, while Aragón and Rud (2016) use a 100-km buffer in Peru. We chose this threshold, taking into account the poor quality of roads and the scarcity of public transportation, but we chose a larger buffer than for artisanal mining as the demand shock is likely to be less localized. We later provide estimates using different thresholds.

[19]This choice of two years is based on qualitative interviews with mining company engineers and experts from the BRGM. It typically takes about two years to open a mine. It is also consistent with Benshaul-Tolonen (2019).

located within 25 kilometers of an industrial mine or elsewhere in the country are statistically impossible to distinguish during each of the four survey waves. Importantly, we need to keep in mind that for the years 2009 and 2014, consumption in treated areas of Figure 4 reflects the consequences of two changes. First, the artisanal gold rush taking place also targeted major gold deposits (artisanal and industrial mines target overlapping areas in Figure **??**). And second, the opening of industrial mines took place in a staggered manner after 2007, most opening actually taking place between 2009 and 2014 (these openings also meaning the reduction of land available for artisanal mines). Figure 4 gives a rough overview which mixes both of the treatments, the regression analysis allows us to disentangle them.

To formally estimate the effect of the opening of an industrial mine, we propose the following equation:

$$\text{C}_{ivt} = \chi(\text{industrial mine}_t \times \text{major deposit}_v) + \lambda \text{major deposit}_v + \gamma' X_{it} + \delta_m + \eta_t + \epsilon_{ivt} \quad (2)$$

Where industrial mine_t is a dummy variable taking the value 1 when a mine is open or in construction, 0 otherwise. χ gives the effect of opening a new mine, and we can compare it to λ that controls for areas with major known gold deposits (major deposit_v) such that $\chi + \lambda$ gives the estimated *net* impact of a new mine on household consumption. In our baseline estimates, major deposit_v is a dummy variable taking the value 1 if the household lives within 25 km of the deposit, 0 otherwise. Other variables are similar to those included in equation 1 and again we cluster standard errors at the municipality level. The year fixed effects partial out any spillovers that industrial mines would have that are averaged at the national level, for example, through taxes that allow the state to improve the population's general level of well-being.[20]

4 Results

4.1 The Effects of Artisanal Mining

Table 2 documents the positive impact of artisanal mining on household consumption. We consider households living close to registered artisanal mines (columns 1 to 3). Looking at household consumption for each survey wave, we show that households living close to artisanal mines are poorer than the rest of the country in 1998 and 2003, and richer in 2009 and 2014 (column 1). The negative sign for

[20]While industrial mines do contribute to the state revenue, we focus here on the direct impact that industrial mines may have on populations surrounding them. Resource-induced taxes do not always affect the living standard of the population, even when local authorities report spending in this direction (Caselli and Michaels, 2013), and the state-level consequences of natural resources are the subject of a specific debate (van der Ploeg, 2011; Venables, 2016).

the artisanal deposit variable in column 2 shows that these areas are poorer on average, consistent with our observations in Figure 1. We reject the hypothesis that the sum of the artisanal mine and gold boom coefficients is equal to zero, which means that the net effect of living close to an artisanal gold deposit is positive during the gold boom. The net effect of the gold price boom is about 10 percentage points increase in consumption (column 2).[21] Alternatively, using the gold price as a continuous definition of the time treatment, a 1% increase in the gold price increases these households' consumption by 0.14% (column 3).

The concern is that registered artisanal mines do not provide an accurate picture of artisanal gold mining since not every mine is registered and there may be endogeneity in the selection of mines that are registered. The fluid nature of artisanal activity makes it hard to alleviate this concern. We pursue three different approaches to answer to this concern. First, we take advantage of the geological features of Burkina Faso. The Birimian belts are the main gold provider in Burkina Faso and households living close to the Birimian belts are exposed to both declared and undeclared gold mines. We code all households living on the Birimian greenstone belt as if they were living close to a gold mine. Since not all of the Birimian belt hosts mining, such coding provides a lower-bound estimate of the impact of artisanal mines. Results in columns (4) to (6) are qualitatively similar for all three coding of the time treatments as the results we observed for registered artisanal mines (columns 1 to 3 of Table 2).

In columns (7) and (8), we include both definitions of the treatment –registered deposits and the Birimian greenstone belts– simultaneously. Note that the area of Birimian belts is larger than that of artisanal deposits, but the latter are almost always located on Birimian belts. Coefficients magnitudes slightly shrink down and the effect of Birimian greenstone belts becomes insignificant (although all p-values remain below 0.15). Following the results in columns (7) and (8), the main effect of any illegal mines seems to occur mainly within the 10-kilometer footprint of registered mines. Thus, we keep declared mines as our baseline definition of artisanal mines in the rest of the paper. For time variation we favor the exogenous world gold price.

The second strategy we pursue to acknowledge the imprecise registration of artisanal mines is to vary the size of the mine footprint. Figure 5 shows that the positive impact of artisanal mines on household consumption decreases with distance to the mine, which is consistent with our identification strategy. The figure displays the coefficient estimates of the impact of a 1% variation of the gold price on the consumption of households close to an artisanal deposit, according to the distance between the house-

[21]We favor the specification with the boom-specific dummies as in column (1) the treated places in 2003 do not differ significantly from the baseline, while the treated places do differ from the baseline in both 2009 and 2014 (the years of the gold price boom), and the two latter coefficients are statistically impossible to distinguish.

Table 2: The effects of artisanal mines on household consumption: baseline estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep. Var.: ln pc Cons.								
Artisanal deposit	0.0329							
× year 2003	(0.0526)							
Artisanal deposit	0.214**							
× year 2009	(0.0922)							
Artisanal deposit	0.186***							
× year 2014	(0.0638)							
Artisanal deposit		0.179***					0.132**	
× gold price boom		(0.0566)					(0.0568)	
Artisanal deposit			0.139***					0.0999**
× ln(gold price)			(0.0420)					(0.0409)
Artisanal deposit	-0.116**	-0.898***	-0.0956**				-0.0692	-0.641**
	(0.0578)	(0.276)	(0.0448)				(0.0433)	(0.265)
Birimian belt				0.0398				
× year 2003				(0.0413)				
Birimian belt				0.158*				
× year 2009				(0.0832)				
Birimian belt				0.159**				
× year 2014				(0.0641)				
Birimian belt					0.134**		0.0877	
× gold price boom					(0.0569)		(0.0594)	
Birimian belt						0.109**		0.0735
× ln(gold price)						(0.0437)		(0.0451)
Birimian belt				-0.0898*	-0.0656	-0.697**	-0.0397	-0.468
				(0.0528)	(0.0400)	(0.283)	(0.0394)	(0.289)
Observations	30,502	30,502	30,502	30,502	30,502	30,502	30,502	30,502
R-squared	0.418	0.417	0.418	0.417	0.417	0.417	0.418	0.418

Note: All columns include municipality fixed effects, year fixed effects, and household level controls (age, sex, ability to read, the sector of occupation and nature of work of the household's head, the number of household members and adult members, the electricity connection and main source of drinking water of the household), and a control for urban areas. Robust standard errors are clustered at the municipality level. *** p<0.01, ** p<0.05, *p<0.1.

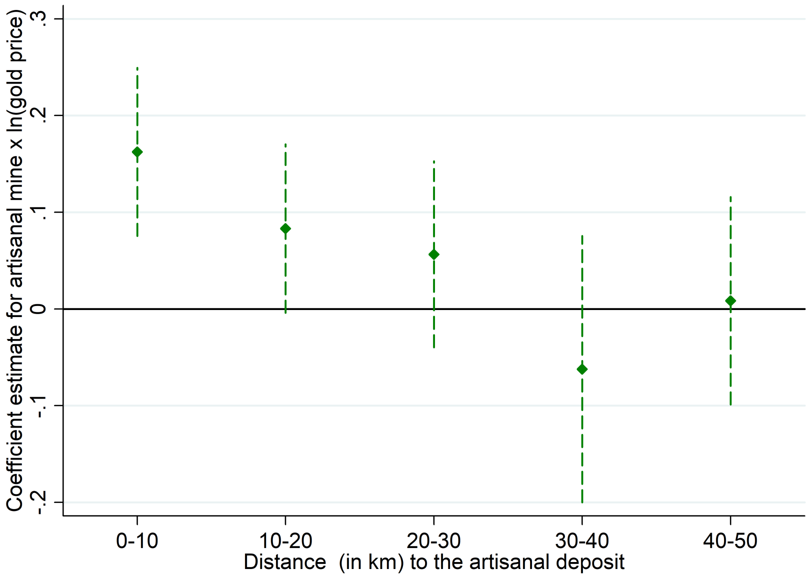
hold and the mine. The coefficient remains positive and is borderline insignificant (p-value at 0.12) for households living within more than 10 but less than 20 kilometers of an artisanal mine. It may be the case that either unregistered mines are concentrated around registered mines, or that the footprint of each registered mine extends beyond 10 kilometers.

The last strategy we pursue is to define the treatment at the municipality level, considering that an entire municipality is treated as soon as it hosts at least one artisanal mine. In this case the main effect of the artisanal deposit is absorbed in the municipality fixed effects. Results remain unchanged (Appendix Table 10).

4.2 The Effects of Industrial Mining

We now turn to the effect of opening an industrial gold mine. All industrial mines active in 2014 opened in the 2000s-2010s. Before that, many of the areas where industrial mines settled were exploited by

Figure 5: Impact of artisanal mines on consumption by distance to the deposit



Note: Each point represents the coefficient estimate for artisanal mine x ln(gold price) for households living at a given distance from the mine. We estimate all the coefficients in one single equation. We allow heterogeneity in the effect according to the distance to the mine by using location-specific dummies for households living 0 to 10 kilometers from a mine, or 10 to 20 kilometers from a mine, etc. Bars around each point represent the 90% confidence intervals.

artisanal miners who extracted gold in artisanal and small-scale mines, without limitation to entry for gold diggers (Côte and Korf, 2016). Industrial mines thus offer an original case of a privatization of a common. Any industrial mine opening corresponds to a bundle treatment, with both the opening of the industrial mine, and the closing of any artisanal mine that was operating within its fences.

Table 3 shows the (absence of) effect of industrial mines on consumption. Throughout the table, we control for any specificity of the areas around major gold deposits (prone to the installation of industrial mines) through a dummy variable equal to 1 for households living within 25 kilometers of an industrial gold deposit. The absence of effect of industrial mines on household consumption holds independently of the way in which we account for industrial mines. In column (1) of Table 3, we account for industrial mines through a dummy variable equal to 1 from the year that the industrial mine started producing onward. In columns (2) and (3), the absence of effect is independent of the size of the industrial mine. We either use the interaction term between mines size of reserves and activity (column 2), or distinguish major industrial mines from smaller industrial mines (using a cutoff on mine reserves, column 3).[22] In column (4), accounting for mine construction (two years before production, which requires a lot

[22]Indeed, the major mines listed in Table 8 have estimated reserves above 20 tons of gold, the other industrial gold mines have estimated reserves largely below 10 tons.

Table 3: The effects of industrial mines on household consumption

	(1)	(2)	(3)	(4)
Dep. Var.: ln pc Cons.				
Industrial deposit	-0.0621			-0.0608
× active mine	(0.0700)			(0.0699)
Industrial deposit		0.0155		
× active mine × ln(gold reserves)		(0.0172)		
Industrial deposit		-0.0265		
× ln(gold reserves)		(0.0220)		
Industrial major deposit			-0.0863	
× active mine			(0.0746)	
Industrial minor deposit			0.0560	
× active mine			(0.110)	
Industrial deposit				0.0106
× construction mine				(0.0677)
Industrial deposit	0.132**		0.137**	0.131**
	(0.0629)		(0.0632)	(0.0638)
Observations	30,502	20,699	30,502	30,502
R-squared	0.416	0.419	0.417	0.416

Note: All columns include municipality fixed effects, year fixed effects, and household-level controls (age, sex, ability to read, the sector of occupation and nature of work of the household's head, the number of household members and adult members, the electricity connection and main source of drinking water of the household), and a control for urban areas. Robust standard errors are clustered at the municipality level. *** p<0.01, ** p<0.05, *p<0.1.

of unskilled workforce), has no local impact on household consumption. We also consider interactions between the industrial mine activity and the gold price since a high gold price translates into more profit for mines, the effect of industrial mines does not change (Table not included).

Last, we investigate the effect of the threshold used to define the proximity of households to a deposit. In Appendix Figure 10, we show the estimated coefficients for different distance intervals. The coefficient is never significantly different from zero. We note that for households within 10 kilometers of an industrial deposit the effect, if any, would be negative (p-value at 0.12, however the sample size makes us cautious about interpreting this effect).

Overall, we can reasonably conclude that, as of 2014, the opening of industrial mines has not had a significant impact on household consumption at the local level. The zero effects in Table 3 allows to underline the importance of the link to the local economy. Focusing on the extension of existing mines, Aragón and Rud (2013, 2016) document positive effects through local linkages on income in Perou and negative effects through pollution on agricultural productivity in Ghana. In a country with little production of intermediary goods (unlike Perou) and before the mine extension lead to major use of chemicals (unlike Ghana) the effect of a mine opening appears to be zero. Our results also align with the insights of the literature which points at commons as beneficial for local labor, or even for the whole local population, despite their lower productivity. Privatization is presented as efficiency enhancing. Nevertheless, this efficiency may come at a distributional cost such that the net gain is not granted, in particular for local labor (Weitzman, 1974; Baland and Francois, 2005). Industrial mines may have other benefits, which may appear in the longer run, or at a more macro level (such an impact is the subject of a wide literature and debates reviewed in van der Ploeg, 2011; Venables, 2016). In particular, industrial mines do contribute much more to the state budget than artisanal mines do. Our results however shed light on a potential reason why the arrival of a new industrial mine may locally trigger discontent.

4.3 The Effects of Artisanal and Industrial Mining

In this section, we estimate jointly the effect of artisanal and industrial mines. The data does not tell the exact boundary (fences) of the industrial mines, making impossible to precisely test the effect from loosing access to artisanal mining fields (as shown in appendix Figure 9 for the mine of Kalsaka). What the data allows is a comparison of the artisanal gold boom and the opening of industrial mines. We keep our preferred specification to account for artisanal and industrial mining activities, considering registered artisanal deposits multiplied by the gold price and active industrial mines.

Table 4 column (1) shows that coefficients magnitude and precision remain stable when we consider artisanal and industrial mines jointly. Importantly for the existing literature on the local impact of opening an industrial mine, the coefficient of industrial mines remains perfectly stable, independently of whether we control or not for artisanal mines (comparison of the coefficient between columns 1 of Tables 3 and 4). The difference of buffer size for artisanal and industrial mine, given the size of each activity, may be subject to debate. Table 4 shows that results remain consistent if we consider similar buffers for all activities, be it 10 or 15 kilometer buffers (columns 2 and 3). Consistent with Appendix Figure 10, the effect of industrial mines turns negative for households living within 10 kilometers of these mines. However, the number of households treated by industrial mines in this specification is then limited (101 households in 2009 and 376 in 2014).

The results are robust and remain remarkably stable under different checks. We focused so far on variations in the definition of the treatment (Tables 2 to 4). We may however be concerned that the impact of mining is fundamentally different between rural and urban areas. Appendix Table 11 shows that effects of artisanal mines are qualitatively similar in both areas, although slightly bigger in urban areas (columns 1 and 2). Urban areas are, if anything, loosing with the opening of industrial mines, but few households live in an urban area that is within 25 kilometer of an industrial mine (we only observe 90

Table 4: The effects of artisanal and industrial mines, varying to distance to the mine

	(1)	(2)	(3)
Dep. Var.: ln pc Cons.			
Artisanal deposit : 10 km	0.139***	0.141***	
× ln(gold price)	(0.0417)	(0.0423)	
Artisanal deposit : 10 km	-0.897***	-0.908***	
	(0.274)	(0.278)	
Artisanal deposit : 25 km			0.148***
× ln(gold price)			(0.0438)
Artisanal deposit : 25 km			-0.974***
			(0.283)
Industrial deposit : 25 km	-0.0647		-0.0789
× active mine	(0.0713)		(0.0647)
Industrial deposit : 25 km	0.128*		0.134**
	(0.0669)		(0.0620)
Industrial deposit : 10 km		-0.145*	
× active mine		(0.0853)	
Industrial deposit : 10 km		0.216***	
		(0.0758)	
Observations	30,502	30,502	30,502
R-squared	0.418	0.418	0.419

Note: All columns include municipality fixed effects, year fixed effects, and household-level controls (age, sex, ability to read, the sector of occupation and nature of work of the household's head, the number of household members and adult members, the electricity connection and main source of drinking water of the household), and a control for urban areas. Robust standard errors are clustered at the municipality level. *** p<0.01, ** p<0.05, *p<0.1.

such treated households in 2014). We may also wonder if the control group we used is appropriate. We check that the results hold independently of sample variations aiming at making the treatment and control samples more comparable such as reducing the sample to either households living within 50 kilometers of an artisanal mine, or households not living within 25 kilometers of an industrial mine, or including the capital city of Ouagadougou (Appendix Table 11 columns 3 to 5). Since the survey questionnaire slightly changed over years, we also check that no particular survey drives the results (Appendix Table 11, columns 6 to 9). Lastly, since Burkina Faso has different type of climate in different parts of the country, we check that results are robust to omitting each of the 13 regions one by one (Appendix Table 12). Alternatively, we check that results hold when including region specific trends or region-year fixed effects (appendix Table 11, columns 10 and 11).

4.4 Extension: Effects on Health and Education

While the main focus of this article is on consumption patterns, it may be interesting to investigate the impact of artisanal and industrial mines on the two other main dimensions of human development, namely health and education. Artisanal mining has a bad reputation in both dimensions, while scholars have documented ambiguous effects of industrial mines (Ahlerup et al., 2017; Aragón and Rud, 2016; Corno and de Walque, 2012; Hilson, 2006; Benshaul-Tolonen, 2019). We are not perfectly equipped to investigate these aspects which would each deserve a dedicated study, but we can present some basic results.

The expected health effect of extractive activities is ambiguous. If the artisanal gold boom has positive effects on income, it should increase the ability of households to take care of their health. However, artisanal mines also have notoriously bad working conditions and use polluting substances such as mercury, which have a negative effect on health. In parallel, industrial gold mines may provide health infrastructures as part of their corporate social responsibility investments, and thus improve the health of households in their surroundings without increasing households' health spending (Benshaul-Tolonen, 2019). These mines however may also pollute in larger amounts (with consequences on local health, Aragón and Rud, 2016).

In Appendix Table 13, we investigate the evolution of the probability of being sick for households living next to artisanal and industrial gold mines.[23] Overall, we document a significant improvement in the health of 6-to-16-year-old children during the artisanal gold boom (columns 3 and 4). Such an improvement is consistent with the income effect dominating the pollution effect (at least in the short run period we observe). Industrial gold mines do not appear to significantly affect the health outcome of populations in their surroundings.

Finally, we investigate the possible effects on education. Once again, expected results are ambiguous. The increase in job opportunities would reduce the incentive to attend school around artisanal mines and increase it around industrial mines (Ahlerup et al., 2017; Ebeke et al., 2015). The income effect would increase school enrollment around artisanal mines.

In Appendix Table 14, we document the effect of mining activities on the probability of being at school for different age samples. We observe no effect of the artisanal boom for 0 to 16 years old children. We observe a drop in school enrollment for individuals above 16 during the artisanal gold rush: a one percent increase in the gold price reduces their probability of being at school by 0.007% in areas close to artisanal mines. We do not find any effect of opening an industrial mine. While corporate responsibility investment may increase health or educational amenities, such improvement had not yet impacted households significantly as of 2014.

[23] One health proxy is consistently recorded throughout our survey data through the question "Have you been sick or injured in the last 15 days?".

5 Discussion

After having shown that artisanal mining has a positive effect on consumption while industrial mines do not, it would be interesting to understand where this effect comes from. In the literature on the local multiplier, the additional income coming from extractive activities would lead to a local demand shock which will benefit other groups (here for example groups providing inputs or services to gold diggers, Moretti, 2010; Werthmann, 2017). In the literature on the commons, the main effect comes from direct access to the resource. Households who allocate time to gold extraction might increase their income, which will have an effect on the local economic conditions.

In this section, we document the likelihood of different channels through which the effect of artisanal mines may be transmitted on the labor market and through migration. We also investigate whether extractive activities appear to have persistent effects on local prices.

5.1 Labor Market Effects and Seasonality

Gold extraction offers local workers new earning opportunities, which could trigger either an increase in employment, or a reallocation of the labor force in favor of working in the extractive sector or providing inputs for this sector (Aragón and Rud, 2013; Kotsadam and Tolonen, 2016; Aragón et al., 2018). However, Table 5 contradicts both intuitions. Column (1) shows that the probability of having a work is independent from both mining activities. In column (2), we estimate the probability of having permanent work, and still find no effect. Finally, we document no effect of artisanal mining activities on the probability of working in one or another sector.[24] Thus, the effect of mining on consumption is not likely to come from a direct massive increase in job opportunities in artisanal mines. On the other hand, the opening of an industrial mine seems to lead to a small reallocation of workers from the service to the health and education sector (columns 5 and 8). [25] The absence of a labor re-allocation in favor of the extractive sector may seem puzzling in a country hosting gold and during a period where the gold price was multiplied by four.

[24]We have a consistent record of a 1 digit level definition of sectors of activities. MOst sector titles are self explanatory. The extractive sector encompass people working i nboth the artisanal and the industrial mines. The service sector encompass activities related to finance, cleaning, fabrication or transportation of water or electricity, or construction. The trade sector encompass activities related explicitly to trade as well as housing market.

[25]Column (8) results are consistent with significant corporate social responsibility programs implemented by the industrial mines. Column (8) results could also be consistent with part of the taxes levied on industrial mines benefiting their home localities, however the latter interpretation isn't consistent with the absence of increase in the number of civil servants in the locality, column 7). Replicating the same exercise on female alone to investigate the gender-specific effects that Kotsadam and Tolonen (2016) point at, we do not observe a significant impact of artisanal mining on female labor force participation. The opening of an industrial mine on the other hand decreases female labor force participation by 6% and their probability to work in the extractive sector by 2% (results not included).

Table 5: Labor market effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep. Var.:			Probability that the head works in					
	any work	permanent position	agriculture	extractive	services	trade	public servant	health education
Artisanal deposit	0.00583	0.0176	-0.00740	0.00588	0.00251	0.00536	0.000624	-0.00628
× ln(gold price)	(0.00754)	(0.0396)	(0.0179)	(0.00543)	(0.00546)	(0.00782)	(0.00397)	(0.00503)
Artisanal deposit	-0.0195	-0.141	0.0687	-0.0426	-0.0175	-0.0468	-0.00347	0.0447
	(0.0493)	(0.250)	(0.121)	(0.0361)	(0.0364)	(0.0544)	(0.0268)	(0.0348)
Industrial deposit	0.0145	-0.0388	0.0607	-0.0173	-0.0145**	-0.0158	-0.00111	0.0109*
× active mines	(0.0165)	(0.0648)	(0.0546)	(0.0301)	(0.00718)	(0.0112)	(0.00290)	(0.00565)
Industrial deposit	0.0140	0.0306	-0.0709	0.0509	0.0122	0.0206	0.00166	-0.00547
	(0.0140)	(0.0470)	(0.0850)	(0.0514)	(0.0108)	(0.0152)	(0.00329)	(0.00401)
Observations	30,653	21,838	30,727	30,727	30,727	30,727	30,727	30,727
R-squared	0.125	0.427	0.341	0.081	0.119	0.135	0.070	0.085
Mean Dep. Var.	0.922	0.451	0.738	0.006	0.052	0.063	0.055	0.027

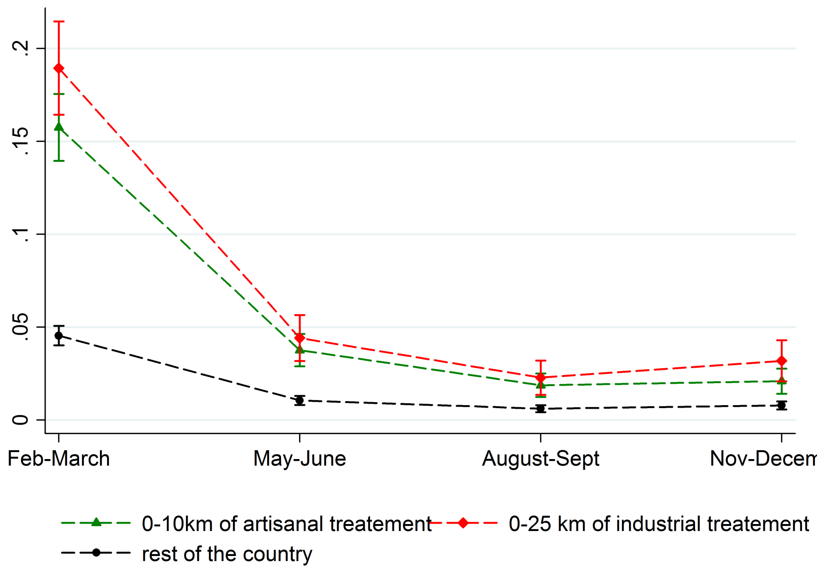
Note: All columns include municipality fixed effects, year fixed effects, and household level controls (age, sex, ability to read, the number of household members and adult members, the electricity connection and main source of drinking water of the household), and a control for urban areas. Robust standard errors are clustered at the municipality level. *** p<0.01, ** p<0.05, *p<0.1.

The exceptional features of the 2014 survey allow us to show that the apparently puzzling –absence of– results in Table 5 is actually a matter of survey timing. The 2014 survey is exceptional in that it is quarterly: we are thus able to check whether people work in the extractive sector at different times of the year. Figure 6 shows that the share of workers in the extractive sector is highly seasonal. Extractive activities are defined to encompass all forms of extraction, be it industrial or artisanal. Given than artisanal and industrial activities overlap, and given the formal nature of employment in industrial mines, we interpret the seasonality of extractive activities within 25 kilometers of industrial deposits as driven by the timing of artisanal mining. Figure 6 also shows that the seasonality of extractive activities affects households everywhere in the country. Extractive activities are concentrated in the first and to a lesser extent the second quarter of the year. Since in the 1998 to 2009 surveys, households were surveyed during the second or third quarters, when most people had left the extractive sector to go back to their usual activities, it is easy to understand why we observe no impact of the gold rush on the labor market in Table 5.[26]

The seasonality of extractive activities – and any accompanying activities – has at least two causes. First, artisanal mining takes place when there is nothing to do in the fields (Jaques et al., 2005). The rainy

[26]The 1998 and 2003 surveys took place around the second quarter, while the 2009 survey took place around the third quarter. For consistency, all the results presented for the years 1998-2014 in this article rely on data for the second quarter of 2014. The results are robust to using the third quarter of 2014 (not included). We do not know where gold diggers practice their activity, but it seems clear that they strongly cluster around gold deposits. Yearlong gold diggers are much less numerous, and may either bypass the government ban by staying in Burkina Faso or migrate to neighboring countries. To have an idea of the magnitude of the phenomenon, according to the 2014 survey, extractive activities were the main source of activity for 640,800 individuals in February-March; 159,300 individuals in May-June, and 37,200 individuals in August-September. These numbers are important given that the total population of Burkina Faso was 17.6 million in 2014, 3.3 million of whom lived within 10 kilometers of an artisanal deposit.

Figure 6: Share of workers in the extractive sector during the different quarters of 2014



Each point represents the share of active household heads who are involved in the extractive sector for each period and location. The extractive sector encompasses all forms of extraction, be they artisanal or industrial. The treated groups are defined spatially and encompass households living either within 10 kilometers of an artisanal deposit, or within 25 kilometers of a deposit that would host an industrial gold mine by 2014. The control group (rest of the country) excludes the treated areas. Bars around each point represent the 95% confidence intervals.

season, marking the beginning of the seeding period, starts in May for most of the country.[27] Second, because the peak of the rainy season puts artisanal mines at danger of collapsing, the government forbids artisanal activities between June and October (there is evidence that the ban is not always followed, but it clearly decreases the extent of the activity, Compaoré, 2011). In either case, one important implication of Figure 6 is that mining does not appear to lead many individuals to abandon other activities such as agriculture permanently. Rather, mining appears to be a seasonal complement to pre-existing activities. Moreover, mining is mainly practiced by households who live close to artisanal mines: Appendix Figure 12 shows that the probability of working in the extractive sector decreases quickly with the distance to a mine, even when we focus on answers to the February-March survey of 2014 (at the peak of the extractive activity).

Since we document the economic spillovers of artisanal mining outside the mining season, we implicitly assume that households are able to somehow smooth consumption within the year. While life-cycle smoothing may be difficult in the context of Burkina Faso, the assumption of within year smoothing

[27]Out of the 65 locations for which records are available throughout the 13 regions of the country, 22% have 40mm of rain or more in April, 66% in May, and 22% in June (https://fr.climate-data.org/country/14/). In particular, the entire Sahel region is the one where the rainy season starts only in June. However, this inter-region variation during the rainy season does not seem to drive our results: omitting each region in a row leaves our results unchanged as shown in Appendix Table 12.

is consistent with the literature on savings in developing countries. While Deaton (1989) suggests that savings take the form of small assets, in Dupas et al. (2018) an extreme 97% of households surveyed in Uganda report to store money either at home or in a "secret place".

Finally, we document how the artisanal and industrial gold boom affects the consumption of households in certain sectors of activity while leaving others unaffected. Table 6 displays the results for subsamples defined by whether the household head works in the following sectors: agriculture, extractive industries, services, trade, public servant or health and education.

Households affected the most by the artisanal gold boom are those able to either diversify their income by practicing gold digging part time, or to answer the demand shock created by the gold boom (answering gold diggers' demand in goods and services). These households are those where the head works in agriculture, trade, or services (columns 1, 3, and 4 of Table 6).[28] The magnitude of the effect is particularly strong for households in trade and services (columns 3 and 4). Public servants offer the perfect counter-factual (Table 6, column 5). They have full-time formal jobs with better pay than the average, hence neither the time nor the need to go gold digging. Moreover, their pay is fixed by the state. Hence, it makes sense that their consumption level should not change with the gold price, no matter how close they live to an artisanal or industrial mine. People employed in health and education are a mix of public servants and people employed in a variety of institutions that may be private (column 6).

Households related to the extractive sector do not benefit from the artisanal mining boom, they only benefit from the industrial mining boom (column 2). Given the surveys timing, these are households whose head practice an extractive activity outside the main period of artisanal mining. Thus column (2) covers two groups. First, the sample covers the employees of industrial mines, who are in the same situation as public servants: they have full-time formal jobs and a pay unrelated to the artisanal boom. Second, the sample covers some year-long gold diggers, in which case it means that gold diggers do not receive a significant share of the increase in benefits induced by the artisanal gold boom, (which rather go to intermediaries and local traders, consistent with the results in columns (3) and (4), and qualitative observations in Côte and Korf, 2016). The positive impact of industrial mines opening in column (2) is consistent with the fact that the likelihood of the first explanation increases with the opening of an industrial mines and workers in industrial mines get on average better pays than gold diggers.

Households whose head is active in the service and trade sectors are both the main beneficiaries of

[28]Note that households in active in agriculture are the only ones who are initially poorer around artisanal gold deposits. Indeed, if we define the time treatment with the gold boom dummy, the artisanal deposit dummy is insignificant for other households (table not included). Note also that we obtain overall similar effects if we split the sample according to households having at least one member working in one or another sector (meaning that some households then appear in several columns). The only difference in the later case is that industrial mines stop having any effect on anyone (table not included).

Table 6: Heterogeneous effect according to the sector of occupation

	(1)	(2)	(3)	(4)	(5)	(6)
Sample: hh head works in					public	health
	agriculture	extractive	services	trade	servant	education
Dep. Var.: ln pc Cons.						
Artisanal deposit	0.110***	-0.608	0.368***	0.253*	-0.0796	0.0606
× ln(gold price)	(0.0375)	(0.432)	(0.115)	(0.140)	(0.0897)	(0.130)
Artisanal deposit	-0.702***	4.930	-2.069**	-1.730*	1.183*	-0.173
	(0.249)	(3.021)	(0.795)	(0.946)	(0.635)	(0.830)
Industrial deposit	-0.0737	0.776**	-0.488***	-0.297*	-0.0171	-0.106
× active mine	(0.0808)	(0.298)	(0.157)	(0.176)	(0.211)	(0.107)
Industrial deposit	0.131*	1.158***	-0.109	0.277*	0.634**	0.327
	(0.0705)	(0.406)	(0.180)	(0.146)	(0.309)	(0.295)
Observations	22,406	198	1,611	1,963	522	831
R-squared	0.360	0.789	0.506	0.476	0.667	0.654
Mean Dep. Var.	11.32	12.02	11.97	11.93	12.32	12.36

Note: All columns include municipality fixed effects, year fixed effects, and household-level controls (age, sex, ability to read, the sector of occupation and nature of work of the household's head, the number of household members and adult members, the electricity connection and main source of drinking water of the household), and a control for urban areas. Robust standard errors are clustered at the municipality level. *** p<0.01, ** p<0.05, *p<0.1.

the artisanal mining boom and the main looser of the opening of an industrial mine (columns 3 and 4). These results would be consistent with a decrease in the artisanal activity following the privatization of the area by the settlement of an industrial mine, translating into a decrease of the benefits for artisanal miners' providers. However, our sample does not allow us to formally test this interpretation.

5.2 Are the Effects Driven by Migration?

One possible explanation of our results is that the gold boom induced migration (Fafchamps et al., 2017). If migrants are positively selected, the increase in average consumption around artisanal mines would not be the result of an income increase as such, but the effect of a population change. A population change may be good news, but corresponds to a different channel than an actual increase in economic activity. The data does not allow a direct study of migration patterns. However, several observations are inconsistent with a positive selection of migrants being the main driver of the consumption results.

First, migrating to settle in agriculture is unlikely, and households working in agriculture do benefit of a local mining boom (Table 6).

Second, it is important to keep in mind that artisanal mining is a seasonal activity (as seen in Figure 6). Although some artisanal gold mines may attract hundreds to thousands of gold diggers, migrant gold diggers will not be surveyed as households belonging to the area of the artisanal mine. Indeed, a person is considered a resident of an area if that person spent at least six months in that place. This means that all gold diggers who are seasonal migrants will be counted as members of their families of origin.

Any money these seasonal migrants send to their family will increase that family's consumption, creating another source of attenuation bias of our estimates (since some families that we consider as untreated may actually benefit from the gold boom thanks to the remittances of the seasonal migrants from Appendix Figure 12). In other words, we show a positive impact on consumption on resident households, and this consumption effect is persistent after short-term migrants' return.

Third, the evolution of the number of permanent resident households appears to have been similar around artisanal and industrial mines and in the rest of the country. Indeed, since our dataset is a repeated cross section, the statistical agency drew a new sample of households for each survey round, and it provides weights that should ensure that the sample is representative nationally. Appendix Figure 11 shows that the artisanal gold rush does not induce any significant inflow of population.

Last, we can go further and show that not only the absolute number of resident households, but also the characteristics of these households, were not affected by the artisanal gold boom. In Appendix Table 15, we check whether migration within the extended family has increased. The gold boom does not affect the size of households, their sex or age composition, or level of education (columns 1 to 7). Overall, the persistence of household characteristics in front of the mining boom is inconsistent with a self-selection of rich individuals into migration to mining places.

5.3 Changes in the Price Structure

Another challenge is assessing whether the mining boom affects local prices. Indeed, all consumption estimates rest on nominal consumption figures. Importantly, all consumption figures come from outside the mining season, thus we document the positive consumption effect of artisanal mines outside the main mining season. One may still be concerned that the local demand shock induced by the gold boom may affect local prices persistently, leading to a persistent increase in nominal consumption that may not reflect the real consumption level. We are unfortunately not able to compute price indexes throughout the the surveys. However, several observations are consistent with a real impact of the artisanal gold boom on consumption rather than a pure nominal impact.

First, three sets of existing results are consistent with an increase in households consumption in real terms. We indeed control for any region-specific inflation when we include fixed effects at the region $\times$ year level and the result remains stable (Appendix Table 11 column 12).

We also document an amelioration in self-reported health during the artisanal gold boom which is consistent with a positive (real) income effect (Appendix Table 13).

Table 7: Effects of mines on proxies of price levels

	(1)	(2)	(3)	(4)
Dep. Var. :	share food	ln(minimum income)	ln(rent)	food issue
Artisanal deposit	0.00913	-0.0155	0.0813	0.0392
× ln(gold price)	(0.0100)	(0.0686)	(0.0898)	(0.0287)
Artisanal deposit	-0.0668	0.160	-0.555	-0.277
	(0.0654)	(0.462)	(0.596)	(0.192)
Industrial deposit	-0.0114	-0.126	0.294***	-0.0336
× active mines	(0.0165)	(0.116)	(0.0890)	(0.0372)
Industrial deposit	0.0349***	0.0472	-0.0591	-0.0495
	(0.0114)	(0.0745)	(0.0832)	(0.0414)
Observations	30,726	23,725	30,198	38,066
R-squared	0.340	0.306	0.897	0.194

Note: share food tells the share of consumption spending dedicated to food. Ln(minimum income) is the log of the answer to the question "What is the minimum income level you would need to fulfill your basic needs?" asked in the 2005, 2007 and 2014 surveys. ln(rent) is the log of the estimation by households of the renting value of their living place as recorded in the 1998, 2003, 2009, and 2014 surveys. Food issue is a dummy taking the value 1 if the household answered yes to the question "Did you face difficulties to fulfill food household needs during the last year" and recorded in the 2003, 2005, 2007, 2009, and 2014 surveys. All columns include municipality fixed effects, year fixed effects, and household level controls (age, sex, ability to read, the number of household members and adult members, the electricity connection and main source of drinking water of the household), and a control for urban areas. Column 1 controls of the log of total consumption per capita. Robust standard errors are clustered at the municipality level. *** p<0.01, ** p<0.05, *p<0.1.

Moreover, the heterogeneity of the impact of the artisanal gold boom according to households' activities is inconsistent with the idea that local price inflation is driving our results. If the impact of the artisanal gold boom were circulating through local prices rather than through a change in real consumption, we would observe a similar impact on everyone, from the public servants to the service providers, since everyone faces similar prices. Instead, the artisanal gold boom affects consumption only for households who are able to either directly or indirectly participate in gold digging activities (Table 6), consistent with an increase in the real consumption of these households.

Second, we can show that the share of food spending in total consumption is unrelated to artisanal extractive activities. The share of total consumption spent on food is a good indicator of price levels (used to compute both cross-country and within-country price deflators, Almås, 2012; Almås et al., 2018). The share of food spending is likely to be particularly sensitive to prices when the population is closer to subsistence consumption. In Burkina Faso, according to the World Bank, 44% of the population lived with less than 1.90 dollars per day in 2014 (2011 PPP). With such a poverty rate, if prices were increasing, many households would need to re-allocate their spending to ensure a minimum food intake.

Table 7 column (1) shows that the spending shares on food of households living around artisanal mines and in the rest of the country are statistically impossible to distinguish be it during the artisanal gold rush or outside the rush. Such an observation is inconsistent with a surge in local prices around artisanal mines.

Last, Table 7 shows additional evidence inconsistent with a surge in local prices during the artisanal boom. In column (2), we report how much income households think they would need to fulfill their basic needs. If there had been a boom in local prices following the gold boom, households should report that they need a higher income. It is not the case. In the thrid column, we calculate the impact on rents.[29] We find a positive impact of the opening of new industrial mines, consistent with local inflation around industrial mines.[30] This effect is not significant for artisanal mining. In the last column, we investigate whether households faced difficulties to fulfill their needs in terms of food during the gold boom. The result is not significant. We should note that the share of households stating that they had difficulties dropped sharply between 2003 - 2009 (when more than 60% of households said they had difficulties) and 2014 (when there were 30%). Overall none of the results of this section are consistent with a surge of prices during the artisanal mining boom.

6 Conclusion

More than a hundred million people globally depend on artisanal mines for their livelihoods (World Bank, 2009; artisanalmining.org, na). The competition for land between artisanal and industrial mines leads to local conflicts. This paper provides the first country-wide analysis of the impact of artisanal *versus* industrial extraction of a natural ressource on local living standards.

Overall, we estimate that the 2009-2014 boom in the gold price increased consumption by about 10% for people living around artisanal mines. This additional consumption is economically significant. In comparison, despite the amount of money transiting through private industrial gold mines, the opening of these mines does not affect households' consumption. These results are robust to a battery of checks, including changes in the definition of the treatment or the size of the treatment and control groups.

Our results add novel evidence to the literature on the local impact of extractive activities in three dimensions. This is the first paper to empirically assess the impact of artisanal mining on households' living standards with nationally representative data, thereby reducing the knowledge-gap on artisanal mines, and qualifying the general perception that artisanal mines are a plague. Second, we show that

[29] We interprete colmn 3 results keeping in mind that 85% households own their house, but still include it here since homes that are the least tradable good.

[30] Meaning that the zero effect of opening an industrial mine that we estimate might suffer from an upward bias and the true effect would be either closer to zero or negative.

the local spillover effects of industrial mines are not granted. Third, we document that omitting artisanal mines from the picture (as virtually all economists do when assessing the local impact of industrial mines) does not affect our estimates for industrial mines: in our sample, independently of the specification, opening an industrial gold mine does not affect local consumption.

Moreover, our results provide empirical evidence aligned with the theoretical prediction that although efficient, privatization may be obtained at a distributional cost, making local labor worse off (Weitzman, 1974; Baland and Francois, 2005). We however also note that industrial mines contribute more to the state revenues than artisanal mines do (15% and 5% of the value of their respective production in 2014). Thus, the competition for land here translates into a trade-off between consumption of local workers *versus* tax revenues for the State.

The distinctive features and benefits of artisanal and industrial mines match cases of the worldwide competition for land, for example between traditional and modern agriculture or forests and oil fields. The reflection that there may be a trade-off between local labor consumption and state revenues may help to understand or prevent violent protests by local communities when they see the land around them move into different hands. Such understanding may help to avoid serious waste of resources, such as the millions of euros that vanished in flames in the construction site of the industrial mine of Karma.

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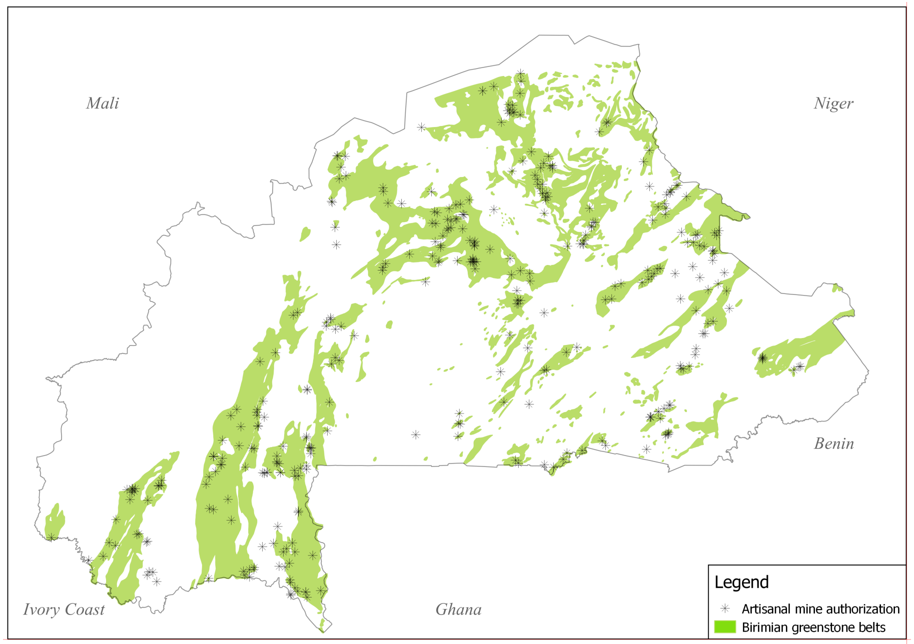
7 ONLINE APPENDIX, NOT FOR PUBLICATION

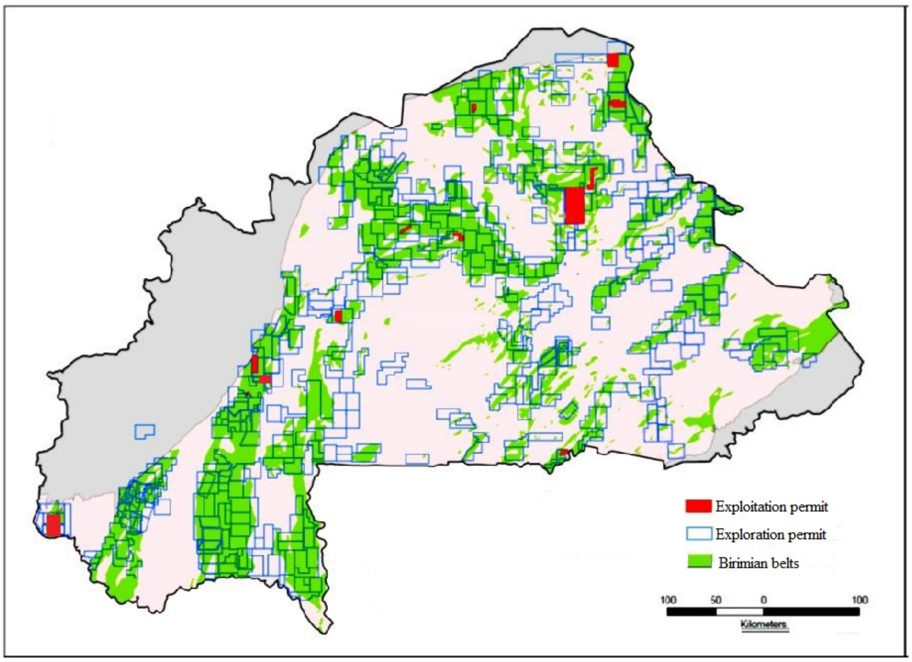
7.1 Appendix Figures

Figure 7: The overlap of Birimian greenstone belts and artisanal exploitation permits



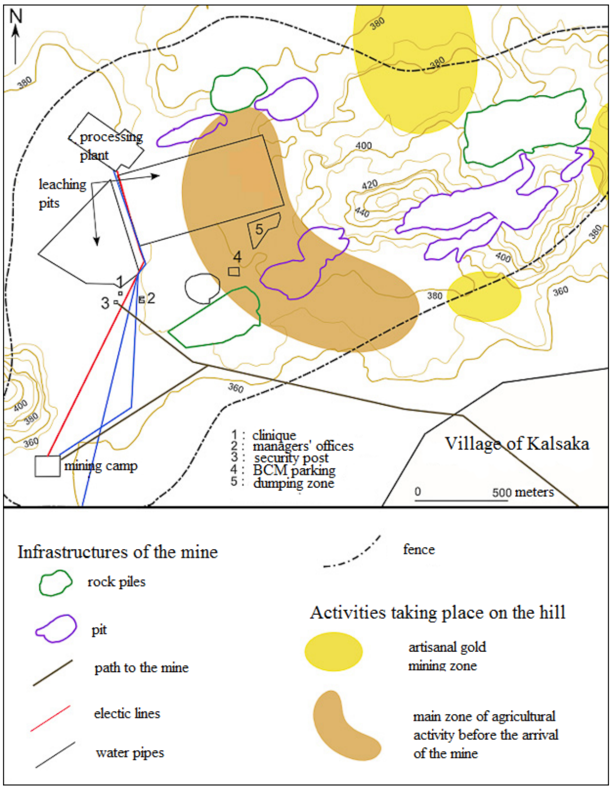
Note: authors' calculations

Figure 8: The overlap of Birimian greenstone belts and industrial exploration permits



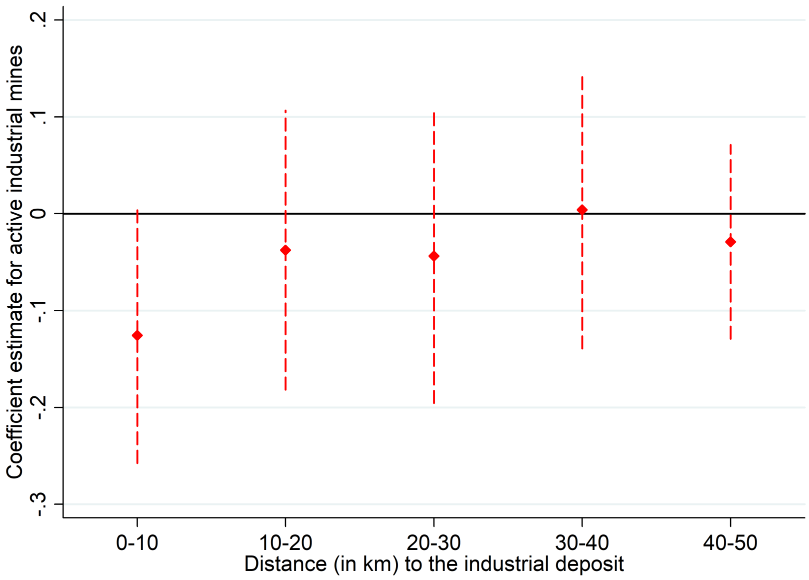
Note: source: http:www.burkina-emine.com, translation is ours

Figure 9: Organization of space within and around an industrial mine, the example of Kalsaka



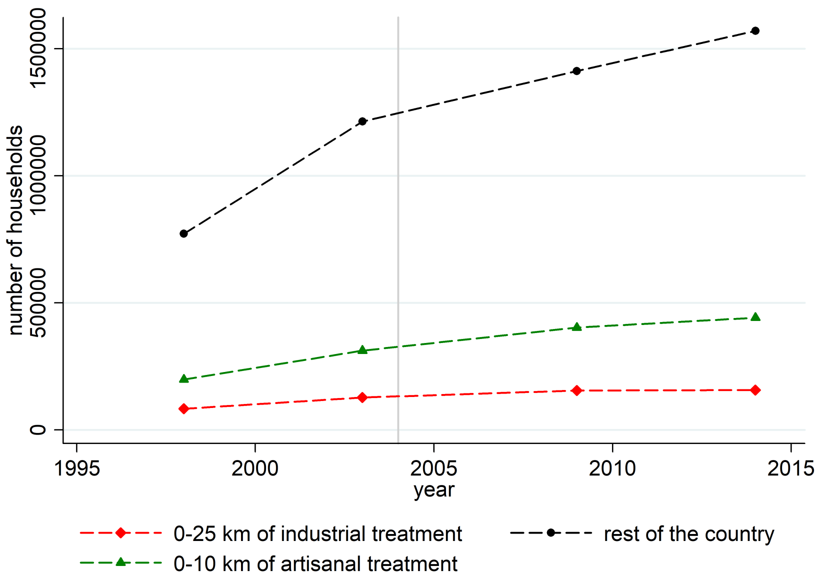
Note: Figure from Thune (2011), translation is ours.

Figure 10: Impact of industrial mines on consumption by distance to the mine



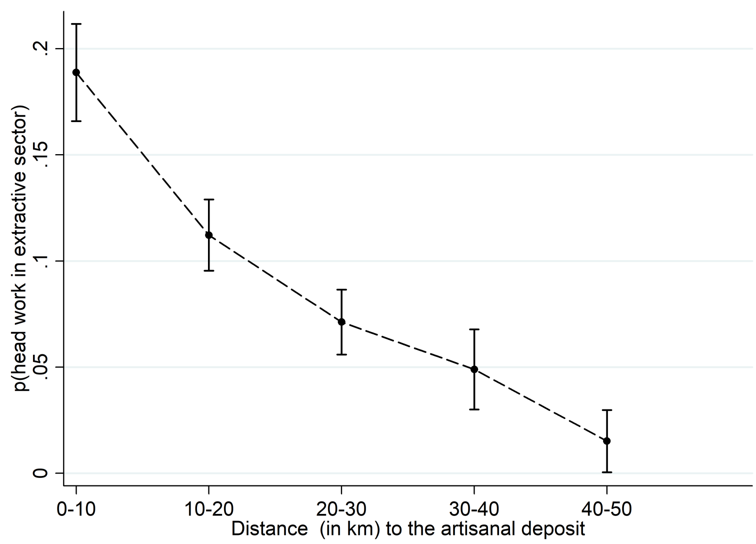
Note: Each point represents the coefficient estimate of active industrial mines for households living at a given distance from the mine. We estimate all the coefficients in one single equation. We allow for heterogeneity in the effect according to the distance to the mine by using location-specific dummies for households living 0 to 10 kilometers from a mine, or 10 to 20 kilometers from a mine, etc. Bars around each point represent the 90% confidence intervals.

Figure 11: Evolution of the population of Burkina Faso



Note: Each point represents the total population in this area. The treated groups encompass households living either within 10 kilometers of an artisanal deposit or households living within 25 kilometers of a deposit that would host an industrial gold mine by 2014. The control group (rest of the country) excludes the treated areas.

Figure 12: The probability to work in the extractive sector decreases with the distance to artisanal mines



Note: Each point represents the share of household heads who are involved in the extractive sector in the 1st survey period in 2014 (February-March), according to the distance of the household to an artisanal mine. The extractive sector encompasses all forms of extraction, be they artisanal or industrial. Bars around each point represent the 95% confidence intervals.

7.2 Appendix Tables

Table 8: Industrial and mechanized gold mines in Burkina Faso, producing and about to produce in 2014

Name	Cumulated production in 2014 in tons	Estimated gold reserves in tons[a]	Year production started	Country of main controlling company
Taparko	23.1	35	2007	Russia
Kalsaka	10.2	20	2008	UK
Mana	36	35	2008	Canada
Youga	16.1	25	2008	Canada
Essakane	46.9	100	2010	Canada
Inata	20.0	22.5	2010	UK
Pinsapo	0.33	NA	2012	Switzerland
Seguenega	1.7	5	2013	Australia
Bissa	15.7	34	2013	Russia
Guiro	0.24	1.6	2014	Canada
Sotexmi	0.01	NA	2014	Burkina
Karma	0	29	2016[b]	Canada
Niorka	0	20	2016[b]	Australia
Poura	0	7	2017[b,c]	Australia

Note: data from the Ministere des Mines et de l'Energie of Burkina Faso completed by the authors for the smallest mines. All gold mines in Burkina Faso are open-pit. [a] estimation from time of feasibility studies. [b] 2014 plan of year of production start. [c] That mine had a marginal production in 1998 before closing in 1999.

Table 9: Number of households in each survey round, by place of residence.

	1998	2003	2009	2014
Households that live within:[a]				
- Artisanal deposit	1,404	1,398	1,530	1,925
- Birimian belt	3,351	3,356	3,272	4,504
- Industrial deposit	776	770	829	1,126
- Industrial mine	0	0	178	465
Total households in the survey	6,796	6,804	7,388	9,514

Note: data from the INSD. [a] Treated samples overlap with each other

Table 10: Robustness to the definition of the artisanal mines treatment at municipality level.

	(1)	(2)
Dep. Var.: ln pc Cons.		
Municipality hosting registered artisanal minning	0.156***	
× gold price boom	(0.0500)	
Municipality hosting registered artisanal minning		0.128***
× ln(gold price)		(0.0399)
Observations	30,502	30,502
R-squared	0.418	0.418

Note: All columns include municipality fixed effects, year fixed effects, and household level controls (age, sex, ability to read, the number of household members and adult members, the electricity connection and main source of drinking water of the household), and a control for urban areas. Robust standard errors are clustered at the municipality level. *** p<0.01, ** p<0.05, *p<0.1.

Table 11: Robustness to the sample definition and specification.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	only	only	within 50km of	without areas	including	omiting one survey round at a time				without	controlling for	
Sample:	rural	urban	arti. deposit	next indu. mines	Ouaga.	- 1998	- 2003	- 2009	- 2014	HH controls	region×trends	region×year
Artisanal deposit	0.112***	0.209***	0.133***	0.156***	0.161***	0.112***	0.135***	0.139***	0.0990***	0.129***	0.133***	0.131***
× ln(gold price)	(0.0397)	(0.0680)	(0.0453)	(0.0486)	(0.0426)	(0.0397)	(0.0427)	(0.0439)	(0.0373)	(0.0447)	(0.0331)	(0.0302)
Artisanal deposit	-0.727***	-1.308***	-0.860***	-0.993***	-1.042***	-0.727***	-0.882***	-0.899***	-0.632**	-0.832***	-0.859***	-0.856***
	(0.261)	(0.486)	(0.298)	(0.321)	(0.280)	(0.261)	(0.287)	(0.295)	(0.245)	(0.297)	(0.213)	(0.195)
Industrial deposit	-0.0711	-0.301***	-0.0662	NA	0.0624	-0.0711	-0.108	-0.0723	-0.0730	-0.107	-0.0828	-0.0717
× active mines	(0.0728)	(0.0545)	(0.0714)	NA	(0.070)	(0.0728)	(0.0927)	(0.0880)	(0.0637)	(0.0926)	(0.0767)	(0.0748)
Industrial deposit	0.107	NA	0.132*	NA	0.134**	0.107	0.119	0.146	0.0531	0.154**	0.124*	0.119*
	(0.0681)	NA	(0.0682)	NA	(0.0682)	(0.0681)	(0.0878)	(0.0922)	(0.0407)	(0.0679)	(0.0682)	(0.0703)
Observations	22,541	7,961	27,351	27,001	34308	23,706	23,698	23,114	20,988	30,597	30,502	30,502
R-squared	0.384	0.473	0.424	0.419	0.462	0.381	0.406	0.510	0.414	0.234	0.426	0.430

Note: All columns include municipality fixed effects, year fixed effects, and a control for urban areas. All columns except column 10 include household level controls (age, sex, ability to read, the number of household members and adult members, the electricity connection and main source of drinking water of the household). Robust standard errors are clustered at the municipality level. *** p<0.01, ** p<0.05, *p<0.1.

Table 12: Excluding each of the 13 regions one by one

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Dep. Var: ln. pc. Cons.													
Artisanal deposit	0.139***	0.134***	0.175***	0.118***	0.131***	0.144***	0.140***	0.143***	0.118***	0.151***	0.134***	0.133***	0.144***
× ln(gold price)	(0.0452)	(0.0429)	(0.0414)	(0.0390)	(0.0445)	(0.0438)	(0.0420)	(0.0453)	(0.0371)	(0.0457)	(0.0444)	(0.0439)	(0.0451)
Artisanal deposit	-0.889***	-0.864***	-1.149***	-0.782***	-0.853***	-0.926***	-0.904***	-0.914***	-0.784***	-0.973***	-0.854***	-0.839***	-0.932***
	(0.298)	(0.280)	(0.271)	(0.259)	(0.294)	(0.288)	(0.276)	(0.299)	(0.240)	(0.302)	(0.292)	(0.290)	(0.296)
Industrial deposit	-0.0810	-0.0627	-0.0495	-0.0179	-0.0935	-0.0601	-0.0621	-0.0635	-0.0828	-0.132	-0.0650	-0.0110	-0.0617
× active mines	(0.0808)	(0.0717)	(0.0753)	(0.0792)	(0.0810)	(0.0723)	(0.0717)	(0.0719)	(0.0694)	(0.0800)	(0.0713)	(0.0669)	(0.0724)
Industrial deposit	0.138**	0.127*	0.138**	0.153**	0.133*	0.127*	0.126*	0.126*	0.133**	0.146*	0.127*	0.0511	0.124*
	(0.0688)	(0.0692)	(0.0693)	(0.0741)	(0.0776)	(0.0677)	(0.0670)	(0.0677)	(0.0639)	(0.0795)	(0.0674)	(0.0482)	(0.0725)
Observations	27,370	28,943	27,641	28,186	27,777	28,616	29,848	28,002	26,808	27,815	28,516	28,131	28,371
R-squared	0.421	0.416	0.414	0.416	0.421	0.421	0.416	0.420	0.416	0.418	0.420	0.421	0.416

Note: All columns include municipality fixed effects, year fixed effects, and household level controls (age, sex, ability to read, the number of household members and adult members, the electricity connection and main source of drinking water of the household), and a control for urban areas. Robust standard errors are clustered at the municipality level. *** p<0.01, ** p<0.05, *p<0.1.

Table 13: Health effects: the probability of being sick

	(1)	(2)	(3)	(4)	(5)
Sample:	household head	above 16 years old	11 to 16	6 to 10	0 to 5
Dep. Var.: has been sick or injured					
Artisanal deposit	0.00708	0.00679	-0.0159**	-0.0147*	0.00914
× ln(gold price)	(0.0114)	(0.00783)	(0.00691)	(0.00820)	(0.0109)
Artisanal deposit	-0.0500	-0.0412	0.101**	0.0890	-0.0603
	(0.0737)	(0.0506)	(0.0459)	(0.0556)	(0.0723)
Industrial deposit	0.0315	0.0227	0.00657	-0.00616	0.0162
× active mines	(0.0296)	(0.0169)	(0.0163)	(0.0209)	(0.0198)
Industrial deposit	-0.00233	0.0116	0.00488	0.00236	0.00711
	(0.0169)	(0.0106)	(0.0108)	(0.0158)	(0.0136)
Observations	30,137	105,728	32,235	37,455	45,677
R-squared	0.050	0.032	0.034	0.040	0.052

Note: All columns include municipality fixed effects, year fixed effects, and a control for urban areas. Robust standard errors are clustered at the municipality level. *** p<0.01, ** p<0.05, *p<0.1.

Table 14: Education effects: the probability of being at school

	(1)	(2)	(3)	(4)	(5)
Sample	household head	above 16 years old	11 to 16	6 to 10	0 to 5
Dep. Var: education ongoing					
Artisanal deposit	0.00273	-0.00751**	0.00458	0.0144	-0.0166
× ln(gold price)	(0.00269)	(0.00382)	(0.0247)	(0.0215)	(0.0156)
Artisanal deposit	-0.0172	0.0501**	-0.0415	-0.0817	0.0773
	(0.0176)	(0.0250)	(0.163)	(0.143)	(0.102)
Industrial deposit	0.00319	0.00322	0.0362	0.0578	-0.0207
× active mines	(0.00603)	(0.00959)	(0.0456)	(0.0373)	(0.0303)
Industrial deposit	-0.00504	-0.00920	-0.0139	-0.00124	0.00601
	(0.00373)	(0.00642)	(0.0318)	(0.0253)	(0.0209)
Observations	30,714	106,259	33,026	37,597	6,979
R-squared	0.039	0.056	0.174	0.164	0.154

Note: All columns include municipality fixed effects, year fixed effects, and a control for urban areas. Robust standard errors are clustered at the municipality level. *** p<0.01, ** p<0.05, *p<0.1.

Table 15: Effects on household characteristics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	number of	head characteristics			members characteristics		
Dep. Var. :	household members	sex	age	can read	sex	adult	can read
Artisanal deposit	-0.179	-0.00569	-0.0137	-0.00606	0.00574	-0.00241	-0.00255
× ln(gold price)	(0.193)	(0.0149)	(0.582)	(0.0197)	(0.00465)	(0.00591)	(0.0166)
Artisanal deposit	1.197	0.0466	-0.377	0.0399	-0.0427	0.00976	0.00426
	(1.275)	(0.0991)	(3.965)	(0.129)	(0.0309)	(0.0399)	(0.109)
Industrial deposit	0.178	-0.0176	1.457	-0.00178	-0.000604	0.0107	0.00446
× active mines	(0.489)	(0.0326)	(1.336)	(0.0283)	(0.00931)	(0.0113)	(0.0261)
Industrial deposit	-0.155	-0.00168	0.0548	-0.0205	-0.00176	0.00719	-0.0205
	(0.384)	(0.0206)	(1.396)	(0.0248)	(0.00712)	(0.0122)	(0.0220)
Observations	30,823	30,823	30,793	30,753	226,929	228,652	154,595
R-squared	0.094	0.064	0.050	0.117	0.003	0.008	0.117
P(deposit=mine)	0.961	0.584	0.278	0.471	0.787	0.137	0.609

Note: All columns include municipality fixed effects, year fixed effects, and a control for urban areas. Robust standard errors are clustered at the municipality level. *** p<0.01, ** p<0.05, *p<0.1.