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

Traditional 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, dozens of millions of people depend on artisanal mines for their livelihood. We document the local economic impact of the two alternative mining techniques. Our identification strategy exploits two sources of variation: geological endowments in gold in Burkina Faso and changes in the global gold price. We are the first to show that artisanal mines may have a positive local economic impact. Opening an industrial mine, in contrast, has no impact.

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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 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, and 43% of the population of the country was still living on less than 1.90 dollars per day in 2014. The case of Karma is not exceptional: qualitative evidence abounds on local resistance to industrialization, notably from people engaged in traditional activities (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 a natural resource, 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 industrial mines opened between 2007 and 2014. The eight gold deposits, big enough to build industrial mines, had been known for decades, but it suddenly became cost-effective to exploit them. The timing of the industrial gold boom is thus independent from local factors. At the national

[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)

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, the time variation in gains from artisanal mines directly follows the gold price and Burkina Faso is a price taker on the gold market. To define the location of artisanal mines, we exploit novel geological information to complement the information on all the registered artisanal mines. To identify the impact of industrial mines, we exploit the difference in the opening years of industrial mines (which follows 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).

Our results first document a strong positive impact of artisanal mining. A 1% change in the gold price leads to a 0.15% increase in consumption for households located close to artisanal mines. A back-of-the-envelope calculation suggests that a high gold price translates into 5 additional cents (in euros) of consumption each day for each person living near an artisanal mine. This additional consumption is economically significant, given that on an average day the average household member in our sample consumes 50 cents in euros.

Our results are unlikely to be driven by changes in migration or local prices. Indeed, 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 of those who work in the agriculture, service, and trade sectors, all activities that allow households to either directly diversify their income source by mining, or to indirectly benefit from the gold boom by providing gold diggers with goods and services (Moretti, 2010).

We then proceed to show that industrial mines do not improve local economic conditions. Our esti-

[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.

mates 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.

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.[3] 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). 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.[4] 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 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 strongly 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

[3]For example, the main international initiative focused on ASM, the Communities and Small-Scale Mining Initiative of the World Bank, states that its aim is to transforming artisanal mining *"from a source of conflict and poverty into a catalyst for economic growth and sustainable development"*.

[4]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 ton 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).

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. We crucially 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.[5] Moreover, 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. We show here, however, that the *opening* of new industrial mines 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, and to the characteristics of the local market for inputs (for example, the fact that the Peruvian production sector is more varied than that of Burkina Faso such that the realization of the local linkages is harder).

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. 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. 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 systematic empirical evidence on the local impact of common *versus* private management of an extractive natural

[5]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 the impacts of the two modes together. 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 since artisanal and industrial diamond deposits do not overlap.

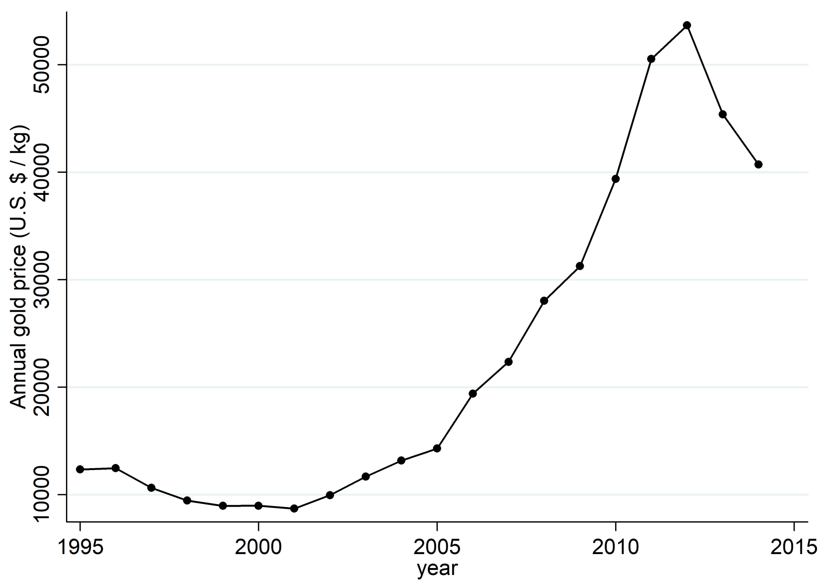
resource. In Burkina Faso, the competition for land between different management modes translates into a trade-off between local labor consumption and State revenue. Indeed, while artisanal mines increase local consumption, their contribution to the State revenue is smaller than the contribution of industrial mines, in both relative and absolute terms. In 2014, artisanal mines contributed to the State revenue 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, as well as the effects on education and health. 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 industrial gold boom has taken place.

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



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

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 10 and 11). 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 12 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 (Figure 1). 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."*[6] 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).

[6]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."*

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).[7] Unwritten rules organize the production and 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 and other workers, and the shaft owner (who invested to open the shaft).[8] 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).

[7] 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 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.

[8] 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.

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. 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). 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.

Last but not least, ASM activities are likely to have local linkages and spillovers. Indeed, these 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, p. 2). 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.

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).[9] 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 eight running industrial gold mines and three under construction, all open-pit. Appendix Table 10 presents each of these mines.[10]

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.

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 12 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, 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.

[9] 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).

[10] 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).

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. 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.[11] 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 in our sample.

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.[12] We are also the first to build and exploit their geocoding (with the geodesic center of each village, or city neighborhoods).

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.), rents as estimated by households, health, and education expenditures. 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.[13]

[11] 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).

[12] 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.

[13] Items listed in the questionnaires changed a bit from one survey to another. This is unfortunately often the case with household data. However, we apply a similar procedure to the raw data of each survey round to compute comparable estimates. Moreover, as long as any difference in the survey questionnaire is not correlated with our treatment (artisanal and industrial

Table 1: Summary statistics

	Mean	sd
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		

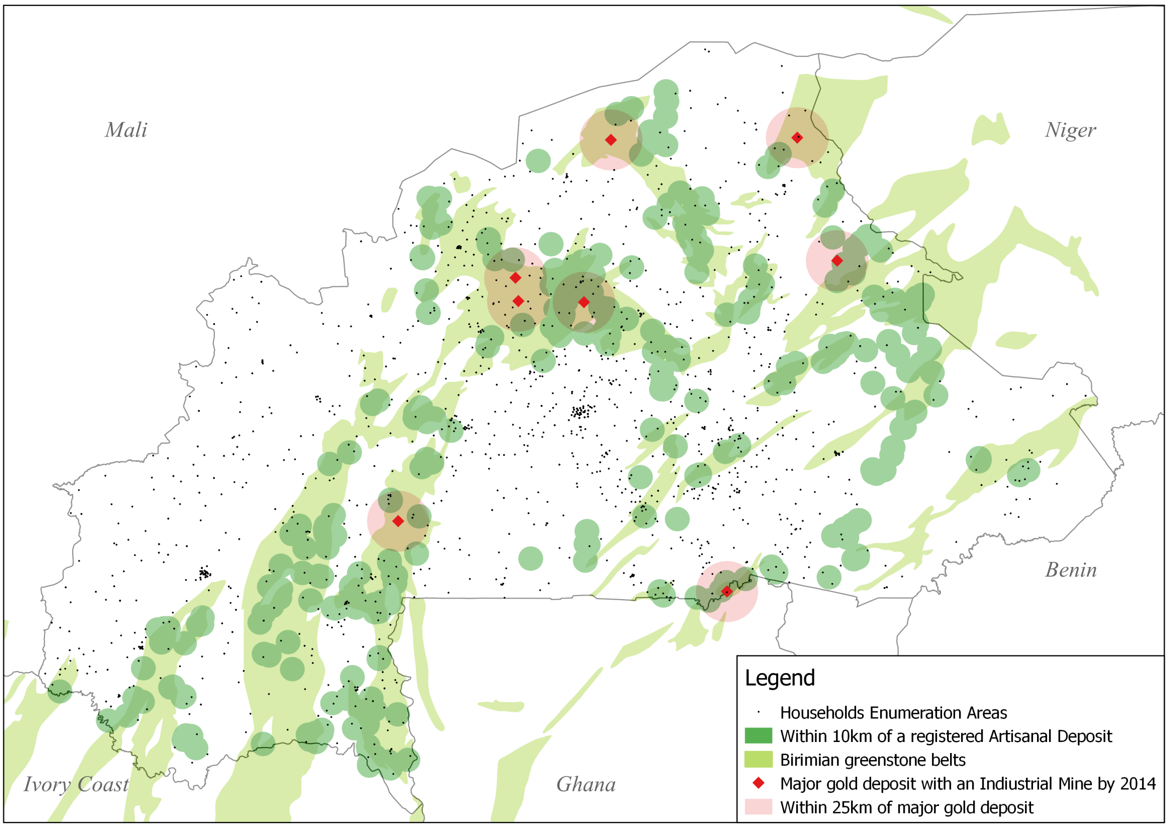
Note: The mean and its clustered standard error are calculated using sample weights. Consumption is measured in CFA francs. Since January 1999, the CFA franc has had a fixed exchange rate with the euro (656 CFA Francs = 1 euro)

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 with last registration date and the name of the permit holder. 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. As a further check, we use the location of the Birimian greenstone belts to define a place as treated by artisanal mines (in the spirit of Fernihough and O'Rourke, 2014, who use coal-prone geological layers). Such a bold geological definition of the treatment provides us with a lower bound for the impact of artisanal mines. The ministry also gave us access to each industrial mine's localization, yearly production, and estimated reserves.

Figure 2 shows the location of artisanal mines with a 10-kilometer buffer in dark green, the Birimian greenstone belt in light green, and the location of industrial with a 25-kilometer buffer in red. When a black dot lies within a green zone, we consider the households in this enumeration area as being "treated" by the artisanal mine according one of our two definitions of the artisanal treatment: either living within 10 kilometers of a registered artisanal mining site (if the zone is dark green) or living above the Birimian greenstone belt (if the zone if light green). As for enumeration areas within a light red zone, households in these enumeration areas live within 25 kilometers of an industrial mine that was running by 2014.

mine location), including year-specific effects is enough to account for each survey specificity.

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



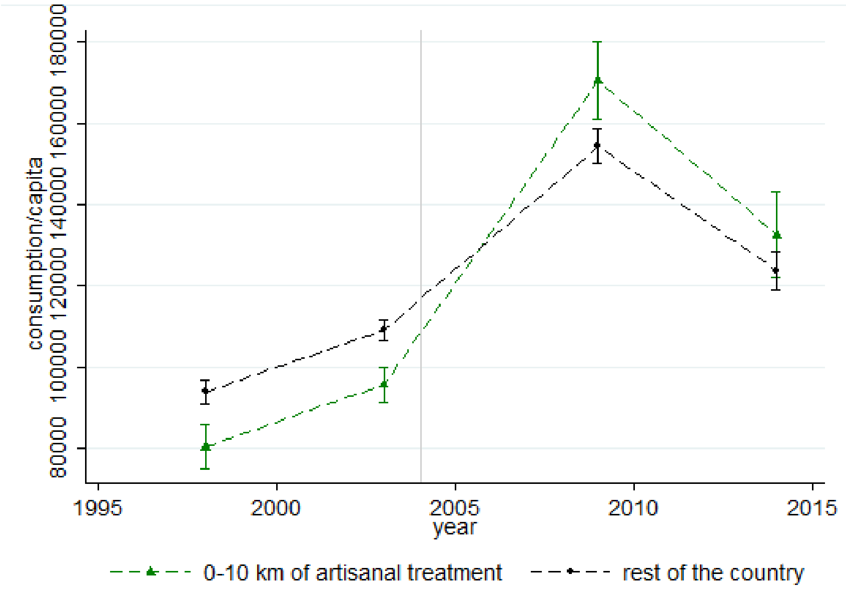
3.2 Identification Strategy

Our aim is to estimate the effect of different gold mining management 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. Alternatively, we use the location of the Birimian greenstone belt. Geologists have shown that in Burkina Faso virtually all gold resources lie in Birimian belts (Béziat et al., 2008). In our baseline specification, we use a 10-kilometer buffer to distinguish treated and non-treated households. We use alternative distance definitions in our robustness checks.

The boom in the gold price provides a time-varying treatment. More specifically, 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 started (in 2009 and 2014). The idea is that the gold price is the main driver of the benefit of

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.

(artisanal) mining activities since it directly determines the expected gains of the miners. When the gold price increases, it may become profitable for households to switch activities or to 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.

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. Our 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. Pre-trends are parallel, although the level of consumption is significantly lower in areas close to artisanal mining deposits in 1998 and 2003. The trends start to diverge 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). $\text{artisanal deposit}_v$ 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.[14] ϵ_{ivt} is the error term. Standard errors are clustered to take into account serial correlation at municipality level (Bertrand et al., 2004).

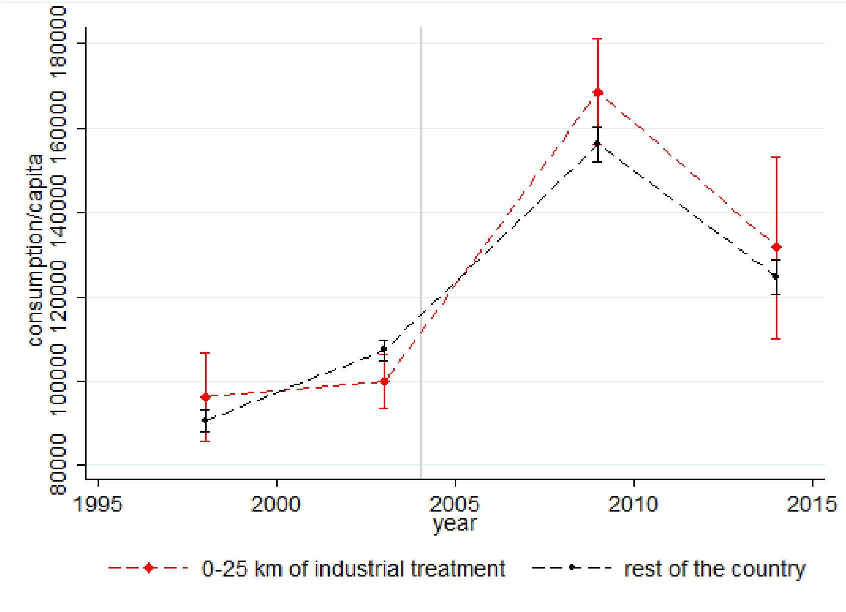
Our identification strategy may lead to two main biases. We acknowledge them both, but argue that they are likely to be, if they exist, attenuation biases.

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. Moreover, we can also propose an alternative measure of artisanal mines' location using the location of Birimian greenstone belts. As can be seen in Figure 2, the location of belts overlaps almost perfectly the location of registered artisanal mines. Birimian belts encompass both declared and undeclared mines.

Second, our definition of the treatment moment is coarse, and we may consider some places as treated 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.

[14]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.

Concerning industrial mines, we also exploit time and spatial variations. Similarly to artisanal mines, 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.[15]

The time variation comes from the years of the opening of the industrial mines. As can be seen in Appendix Table 10, four mines opened between the 2003 and 2009 surveys and four other mines opened between the 2009 and 2014 surveys. We also take into account the possible spillovers coming from the construction of these mines, because exploration and construction are intensive in unskilled labor. We thus assume that effects may be expected two years before production starts.[16]

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. 1998-2003 is the pre-trend period since almost none of the industrial mines were active over this period (neither in terms of production,

[15]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.

[16]This choice, aligned with Tolonen (ming), is based on qualitative interviews with mining company engineers and experts from the BRGM. It typically takes about two years to open a mine.

nor in terms of construction, although the Pourra mine still had a small production in 1998, its last year before closing). We can see that pre-trends do not appear to be parallel. More importantly, there never is a statistically significant difference in samples averages within each year. The levels of consumption of households 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.

To formally estimate the effect of the opening of an industrial mine, while acknowledging the existence of artisanal mines, we propose the following equation:

$$\begin{aligned} \mathrm{C}_{ivt} = \alpha(\text{price}_t \times \text{artisanal deposit}_v) + \beta \text{artisanal deposit}_v \\ + \chi(\text{industrial mine}_t \times \text{major deposit}_v) + \lambda \text{major deposit}_v \\ + \gamma' X_{it} + \delta_m + \eta_t + \epsilon_{ivt} \end{aligned} \quad (2)$$

Where industrial mine$_t$ is a dummy variable taking the value 1 when a mine is open or in construction, 0 otherwise. $\chi + \lambda$ gives the estimated impact of the opening of a new mine, compared to other areas with major known gold deposits, on household consumption. major deposit$_v$ is the exposure to major gold deposits of households living in v. In our baseline estimates, it 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.[17]

4 Results

4.1 The Effects of Artisanal Mining

Table 2 documents the positive impact of artisanal mining on household consumption. Columns (1) and (2) show the impact of gold price variations on households living within 10 kilometers of a registered artisanal mine. Using the gold price as a continuous definition of the time treatment, a 1% increase in the gold price increases these households' consumption by 0.15% (column 1). Alternatively, using a dummy variable taking the value 1 during the gold boom (years 2009 and 2014), we show that during this

[17]The state-level consequences of natural resources are the subject of a specific debate (van der Ploeg, 2011; Venables, 2016). 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). Thus, 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.

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

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.: ln pc Cons.						
Artisanal deposit 10km	0.155***				0.146***	
× ln(gold price)	(0.0463)				(0.0442)	
Artisanal deposit 10km		0.195***				0.182***
× gold price boom		(0.0605)				(0.0602)
Artisanal deposit 10km	-0.998***	-0.104**			-0.939***	-0.0970**
	(0.303)	(0.0466)			(0.286)	(0.0446)
Birimian belt			0.0787*		0.0206	
× ln(gold price)			(0.0451)		(0.0417)	
Birimian belt				0.101*		0.0300
× gold price boom				(0.0575)		(0.0550)
Birimian belt			-0.506*	-0.0520	-0.125	-0.00604
			(0.292)	(0.0404)	(0.267)	(0.0383)
Observations	30,502	30,502	30,502	30,502	30,502	30,502
R-squared	0.367	0.367	0.366	0.366	0.367	0.367
P(artisanal+boom=0)		0.0271				0.0567
P(birimian+boom=0)				0.224		0.670
P(birimian=artisanal)					0.0498	0.0862

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.

period, the consumption spending of households living within 10 kilometers of an artisanal deposit were higher than the spending of households located further away.[18] The negative sign for the artisanal deposit variable in column 2 shows that these areas are poorer on average, consistent with our observations in Figure 1.[19] 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 is about 9 percentage points.

In columns (3) and (4), we code all households living on the Birimian greenstone belt as if they were living close to a gold mine. Since Birimian belts are the main gold provider in Burkina Faso and the area lying above Birimian belts hosts both declared and undeclared gold mines, as well as areas without any mining, such coding provides a lower-bound estimate of the impact of artisanal mines. We again document a positive impact of artisanal mining on consumption even if the magnitude is lower than the one found when using declared mines. A one-percentage-point increase in the gold price increases household consumption by 0.08%, while the net effect of living close to an artisanal deposit is about five percentage points but imprecisely estimated.

[18] Using year-specific dummies yields similar results shown in Appendix Table 11 column 1. We favor the specification with the boom-specific dummies as 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.

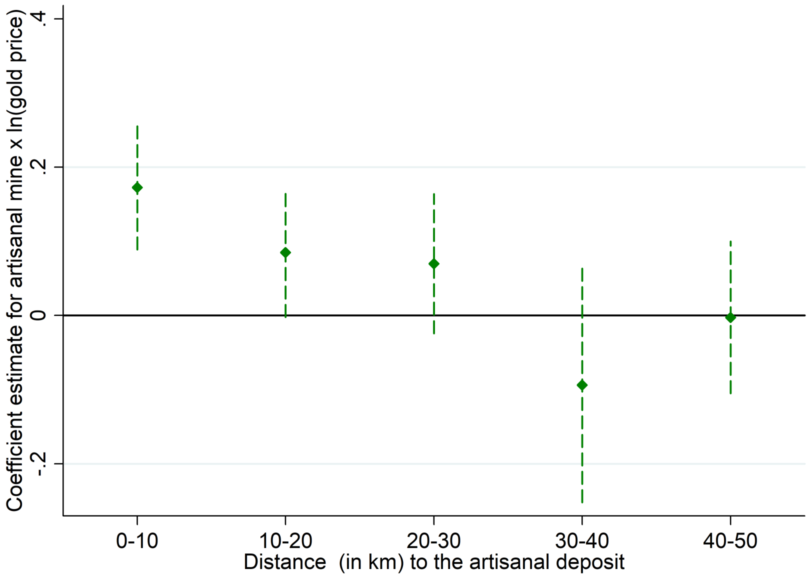
[19] We shall see in section 5.1 that it is actually only specific households, namely those specialized in agriculture, who are poorer in areas surrounding artisanal mines.

In columns (5) and (6), 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. The coefficient of Birimian belts shrinks down and becomes not significant, while the effect of the boom in registered mines remains virtually the same as in columns (1) and (2). We do believe that unregistered artisanal mines may affect local consumption. However, following the results in columns 5 and 6, the main effect of illegal mines seems to be either economically insignificant, or to occur 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.

Figure 5 shows that the positive impact of artisanal mines on household consumption decreases with distance to the mine. 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 household and the mine. The coefficient remains positive and is borderline significant (p-value at 0.109) for households living within 10 to 20 kilometers of an artisanal mine. It becomes not significant for households located more than 20 kilometers from a mine. These results are consistent with a strong impact of artisanal mining, but this impact is concentrated on the local area around the mine, which is consistent with our identification strategy. Either the footprint of each registered mine extends up to 20 kilometers around them, or it may be the case that unregistered mines are concentrated within this 20-kilometer footprint, and then we are computing the average impact of both illegal and legal artisanal mines. We are comfortable with both interpretations.

The results are robust to varying the definition of the treatment, the treated sample, the control sample, or accounting for the dependency of the country on cotton. In Table 2, we vary the spatial definition of the treatment using either buffers around declared artisanal mines or the Birimian greenstone belt; we also obtain similar results when we define the treatment at the municipality level (considering that an entire municipality is treated as soon as it hosts at least one artisanal mine, Table 11 column 4, in which case the main effect of the artisanal deposit is absorbed in the municipality fixed effects). Moreover, the results are robust to varying the definition of the time dimension of the treatment, be it with year specific dummies or the gold price (Tables 2 and Appendix Table 11 column 1), or a one-year lag of the gold price (Table 11 column 3). The results also hold independently of other sample variations –aiming at making the treatment and control samples more comparable– such as excluding either urban or rural areas; reducing the sample to either households living within 50 kilometers of an artisanal mine or house-

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 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., and estimate all the coefficients in a single equation. Bars around each point represent the 90% confidence intervals.

holds not living within 25 kilometers of an industrial mine; including the capital city of Ouagadougou (Appendix Table 12, columns 1 to 5 respectively). The results also hold when excluding each of the four years of the sample one by one (Appendix Table 12, columns 5 to 9), or each of the 13 regions one by one (Appendix Table 13). Lastly, the results remain unaffected when accounting for the country's dependency on cotton. We consider both each region's cotton production provided by the FAO and the price of cotton provided by indexmundi, and we allow for a heterogeneous impact on rural households (note that the main effect of cotton price variation is absorbed by year fixed effects). While production data does not yield precise estimates, a 1% change in the cotton price increases the consumption of rural households by 0.23% (Appendix Table 14 columns 1). Interestingly, the magnitude of the impact of the price of cotton on consumption is close to the magnitude of the impact of the price of gold (for which a 1% change leads to a 0.15% increase in consumption).

Overall, we show that the gold boom in artisanal mines had a significantly positive effect on local living standards. This result is important first because it allows to put in perspective the bad reputation of artisanal mines, it is the first country-wide quantification of the effect of artisanal mining on local economic conditions. This result is also important because artisanal mines correspond to a common

Table 3: The effects of artisanal and industrial mines on household consumption

	(1)	(2)	(3)	(4)	(5)
Dep. Var.: ln pc Cons.					
Artisanal deposit 10km	0.154***	0.134***	0.156***	0.154***	
× ln(gold price)	(0.0461)	(0.0486)	(0.0460)	(0.0460)	
Artisanal deposit 10km	-0.996***	-0.880***	-1.008***	-0.997***	
	(0.301)	(0.309)	(0.301)	(0.301)	
Industrial mine 25km	-0.0470			-0.0436	-0.0442
	(0.0757)			(0.0749)	(0.0739)
Industrial mine 25km		-0.0220			
× ln(gold reserves)		(0.0219)			
Industrial deposit 25km		0.0125			
× ln(gold reserves)		(0.0182)			
Major industrial mine 25 km			-0.0733		
			(0.0818)		
Minor industrial mine 25km			0.0811		
			(0.0882)		
Industrial mine construction 25 km				0.0281	
				(0.0931)	
Industrial deposit 25km	0.111		0.117	0.108	0.116*
	(0.0705)		(0.0709)	(0.0694)	(0.0657)
Observations	30,502	20,699	30,502	30,502	30,502
R-squared	0.367	0.374	0.367	0.367	0.365

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.

property management of the gold resource. Our results are consistent with a positive effect of this specific common on local population and local labor.

4.2 The Effects of Artisanal and Industrial Mining

All industrial mines active in 2014 opened in the 2000s-2010s. Before that, many of the areas where industrial mines settled were exploited by 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. 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).

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 a major gold deposit. We keep our preferred specification to account for the effect of artisanal mines (registered artisanal deposit multiplied by the gold price). The positive effect of artisanal mines found in the previous section is persistent throughout the table, and the magnitude of the coefficient is perfectly stable.

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 the industrial mine started producing onward. Households located around an industrial mine are not richer than those located further away after mine production starts. 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).[20] In column (4), mine construction, just like mine production, has no local impact on household consumption. We account for the 2 years before a mine opens as the mine's construction period to allow for a heterogeneous effect between construction and production. Indeed, the local impact of industrial mines might be concentrated during the period of construction since that is when the mine needs a lot of unskilled workforce. The household sample size does not allow us to document precisely what happens in the localities such as Kalsaka, where artisanal mining stops at the arrival of an industrial mine, however, in column (5), we test the effect of industrial mines alone (without controlling for artisanal mining). We still do not find any significant impact.

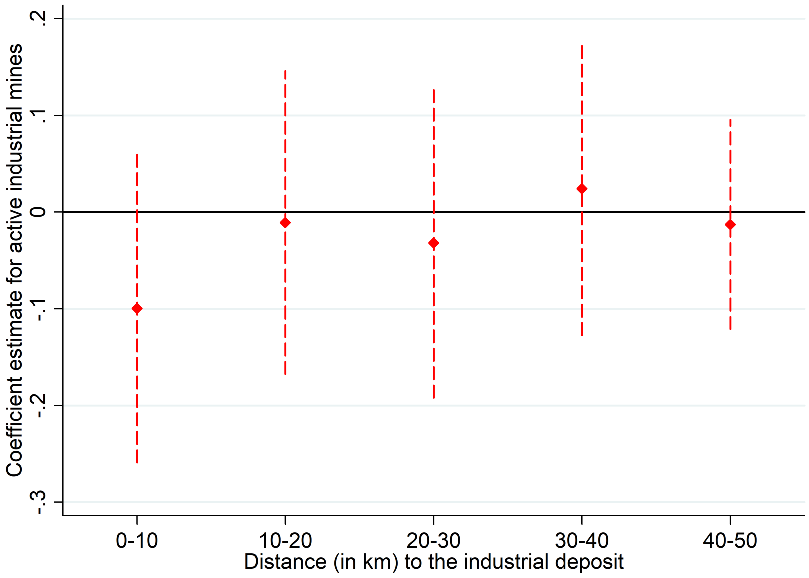
Importantly for the existing literature on the local impact of opening an industrial mine, the coefficient of industrial mines remains perfectly stable, independently of whether we control or not for artisanal mines (comparison of the coefficient between columns 1 and 5 of Table 3). We also consider 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).

As previously, we also change the threshold used to define the proximity of households to a deposit. In Figure 6, we show the estimated coefficients for different distance intervals. The coefficient is never significantly different from zero. 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.

Our results confirm 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. Artisanal (common) mines increase consumption, while industrial (private) mines do not. Beyond the question of direct impact through hiring labor, our results also imply that the local multiplier of industrial mines in Burkina Faso

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

Figure 6: 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 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., and estimate all the coefficients in a single equation. Bars around each point represent the 90% confidence intervals.

is zero (in the framework proposed by Moretti, 2010, which may lead to positive spillover of extending an industrial mine in other contexts, Aragón and Rud, 2013). 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 reason why the arrival of a new industrial mine may locally trigger discontent.

5 Discussion and Extensions

After having shown that artisanal mining has a positive effect on consumption, it would be interesting to understand where this effect comes from. 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. Local multipliers may amplify this direct effect, if the additional income leads to a local demand shock which will benefit other groups (groups providing inputs or services to gold diggers, Moretti, 2010; Werthmann, 2017). In this section, we explore different channels through which the effect of artisanal mines may be transmitted: the labor market, migration, and prices. Overall, we show that households use artisanal mining as a complement

Table 4: 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 10 km	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 10 km	-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 mine 25km	0.0145	-0.0388	0.0607	-0.0173	-0.0145**	-0.0158	-0.00111	0.0109*
	(0.0165)	(0.0648)	(0.0546)	(0.0301)	(0.00718)	(0.0112)	(0.00290)	(0.00565)
Industrial deposit 25km	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
P(deposit=mine)	0.133	0.891	0.838	0.235	0.775	0.689	0.854	0.351

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.

to their usual activity. The likelihood that either migration or price shocks explain our results is low.

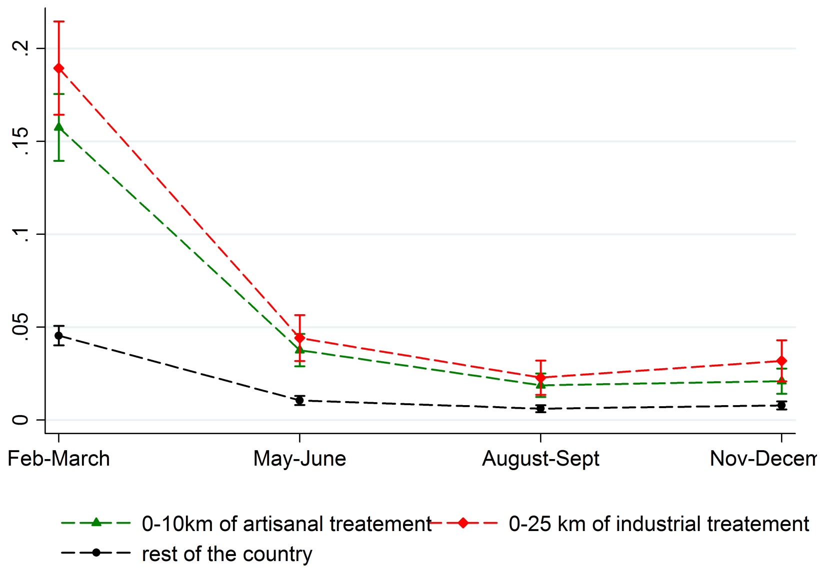
5.1 Labor Market Effects and Seasonality

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., 2016). However, Table 4 contradicts both intuitions. Column (1) shows that the probability of having a work is independent from both artisanal 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 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). [21] However, 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.

The exceptional features of the 2014 survey allow us to show that the apparently puzzling –absence

[21]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).

Figure 7: 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.

of– results in Table 4 is simply 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 7 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, but given the formal nature of employment in industrial mines, we interpret the seasonality as driven by the timing of artisanal mining. 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 and 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 4.[22]

[22]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 it is not clear whether they 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.

The seasonality of extractive 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 season, marking the beginning of the seeding period, starts in May for most of the country.[23] 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 7 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 13 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 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 (where money is stored at home or in a secret place).

Finally, we document how the gold rush benefited households in certain sectors of activity while leaving others unaffected. Table 5 displays the results for sub-samples defined by whether the household head works in the following sectors: agriculture, extractive industries, services, trade, public servant or health and education. Both the artisanal and industrial gold rushes have heterogeneous effects according to households' sector of activity.

Households who benefit the most from 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 with at least one member working in agriculture, trade, or services (columns 1, 3, and 4 of Table 5). The magnitude of the effect is particularly strong for households in trade and services (columns 3 and 4).[24] Public servants offer the perfect counter-factual (Table 5, column 5). They have full-time formal jobs, hence neither the

[23]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 13.

[24]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 (Appendix Table 15).

Table 5: Heterogeneous effect according to the sector of occupation

	(1)	(2)	(3)	(4)	(5)	(6)
Sample: hh head works in	agriculture	extractive	services	trade	public servant	health education
Dep. Var.: ln pc Cons.						
Artisanal 10 km	0.122***	-0.469	0.417***	0.286*	-0.0576	0.0694
× ln(gold price)	(0.0380)	(0.467)	(0.124)	(0.149)	(0.0974)	(0.138)
Artisanal 10 km	-0.782***	3.841	-2.377***	-1.944*	1.125	-0.252
	(0.250)	(3.192)	(0.849)	(1.000)	(0.699)	(0.886)
Industrial mine 25km	-0.0673	0.681**	-0.549***	-0.203	-0.0949	-0.113
	(0.0824)	(0.328)	(0.188)	(0.166)	(0.224)	(0.110)
Industrial deposit 25km	0.120	1.075***	-0.187	0.265	0.742**	0.326
	(0.0739)	(0.403)	(0.189)	(0.175)	(0.306)	(0.330)
Observations	22,406	198	1,611	1,963	522	831
R-squared	0.311	0.680	0.480	0.425	0.617	0.631
P(deposit=mine)	0.453	0.00269	0.0102	0.765	0.181	0.494

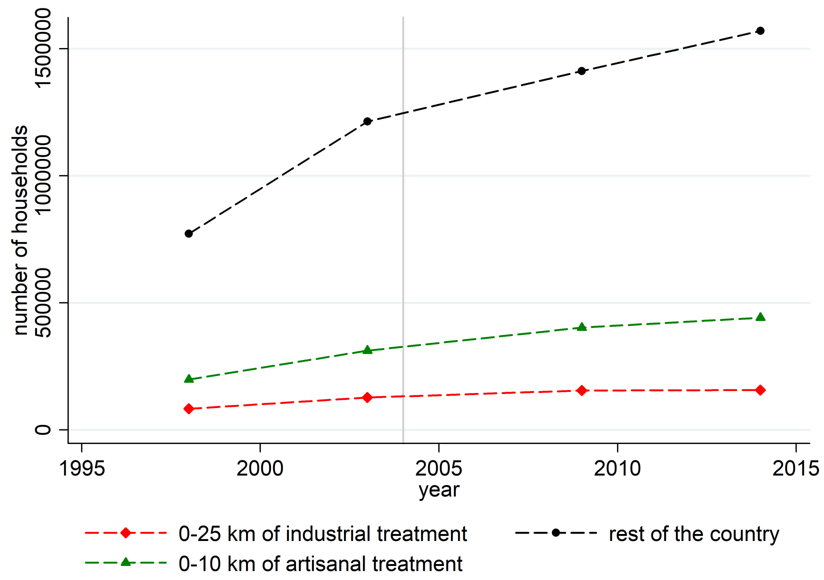
Note: All columns include municipality fixed effects, year fixed effects, and household-level controls (age, sex, ability to read, the sector of occupation and nature of work of the household's head, the number of household members and adult members, the electricity connection and main source of drinking 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.

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).

Importantly, 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 with at least one member practicing an extractive activity outside the main period of artisanal mining. Thus column 2 covers two groups. First, column (2) encompasses 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 encompasses 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 active in the service sectors are both the main beneficiaries of the artisanal mining boom and the main looser of the opening of an industrial mine (column 3). While imprecise, we can also note the sizable and negative coefficients of industrial mine opening on the other "winners" of the artisanal mining boom (people active in the agriculture or trade sectors). These results would be consistent with a decrease in the artisanal activity following the privatization of the area by the settlement of an industrial

Figure 8: 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.

mine, translating into a decrease of the benefits for artisanal miners' providers. However, this is only suggestive evidence, 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. However, several observations are inconsistent with this interpretation.

First, migrating to settle in agriculture is unlikely, and households working in agriculture do benefit of a local mining boom (Table 5).

Second, Figure 8 shows that population growth is similar around mines and in the rest of the country at the moment of the gold boom. To compute this figure, we take advantage of the fact that our dataset is a repeated cross section: for each survey round, the statistical agency drew a new sample of households, and it provides weights that ensure that the sample is representative nationally. Figure 8 shows that the artisanal gold rush does not induce any significant inflow of permanent population.

Third, we can go further and show that not only the absolute number of households, but also their characteristics were not affected by the artisanal gold boom. In Table 6, we check whether migration

Table 6: 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 10 km	-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 10 km	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 mine 25km	0.178	-0.0176	1.457	-0.00178	-0.000604	0.0107	0.00446
	(0.489)	(0.0326)	(1.336)	(0.0283)	(0.00931)	(0.0113)	(0.0261)
Industrial deposit 25km	-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.

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.

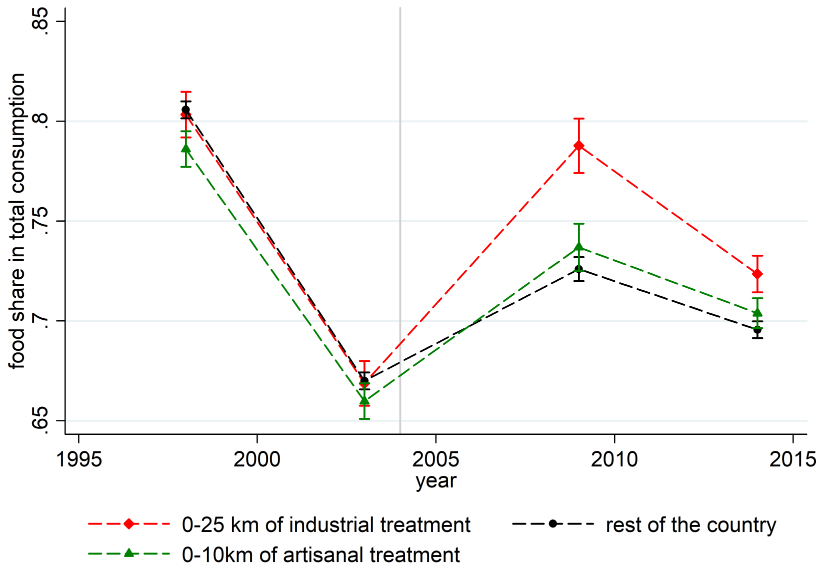
When interpreting the results in Figure 8 and Table 6, it is important to keep in mind that artisanal mining is a seasonal activity (as seen in Figure 7). Although artisanal gold mines often attract hundreds to thousands of gold diggers, migrant gold diggers will not be surveyed as households belonging 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[25]. In other words, we show a positive impact on consumption which is persistent after short-term migrants' return.

5.3 Changes in the Price Structure

A last challenge to interpret our results is assessing whether the mining boom affects local prices. Indeed, all our estimates rest on nominal consumption figures. The local demand shock induced by the gold boom might affect local prices, leading to an increase in nominal consumption that may not reflect the real consumption level. We are unfortunately not able to compute price indexes throughout our survey dates. However, several observations make us confident that there is a real impact of the artisanal gold boom on consumption rather than a pure nominal impact.

[25] Any money 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" actually benefited from the gold boom thanks to the remittances (Appendix Figure 13 does show migration to go mining).

Figure 9: Percentage of the total consumption allocated to food



Note: Each point represents the share of consumption that households from that group spent on food that year. The treated groups encompass households living either within 10 kilometers of an artisanal deposit or households living within 25 kilometers from a deposit that would host an industrial mine by 2014. The control group (rest of the country) excludes the treated areas. Bars around each point represent the 95% confidence intervals.

First, 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 5), 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., 2013). 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.

Figure 9 shows that for each year, the spending shares on food of households living around artisanal mines and in the rest of the country are statistically impossible to distinguish. Suh an observation is inconsistent with a surge in local prices around artisanal mines.

We can however observe in Figure 9 a significant change in the share of consumption spending dedicated to food around industrial mines, in particular in 2009. Such changes may for example be consistent with industrial mines inducing pollution which reduces agricultural productivity (Aragón and Rud, 2016). If any of this happens, Figure 9 is consistent with households around industrial mines actually being poorer in real terms than households in the rest of the country.

One possible interpretation for the absence of impact of the artisanal gold boom on consumption share is that artisanal activities are seasonal. Thus, even if the arrival of gold diggers may lead to an inflation of local prices, this inflation fades away when they leave. As seen in Figure 7, the peak of artisanal mining takes place in winter while the different surveys we use record consumption in spring or summer. Thus, even if the presence of migrant gold diggers may induce tension on local prices, the tension may already be relaxed when the consumption data was collected.

However, it may also be the case that the artisanal gold boom has a negligible impact on the prices of daily consumption items. Indeed, using the detailed 2014 data, we can show that the share spent on food throughout the different terms perfectly follows Engel's logic: the higher the level of consumption, the lower the share of spending allocated to food, no matter whether a place hosts mining or not. Estimates of the consumption level and spending shares widely overlap across locations within each survey period, while they widely diverge over time (consistent with the fact that there is a gap between agricultural seasons in winter, Appendix Figures 14 and 15; while Figure 16 provides a general overview of consumption by season). It could still be the case that there is a price difference between places close to mines – be they industrial or artisanal – and the rest of the country in winter. Indeed, Appendix Figure 15 shows a significant difference in food spending shares of about three percentage points during winter, while the consumption levels are similar (Figure 14). However, this difference is small. In any case, and more importantly, our main results rely on data collected outside winter, and are thus unaffected by this potential winter-specific difference.

Lastly, in Table 7, we show additional evidence supporting the idea that our results are not driven by changes in local prices. In column (1), 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 second column, we calculate the

Table 7: Additional proxies of living standards

	(1)	(2)	(3)
Dep. Var.:	ln(minimum income)	ln(rent)	food issue
Artisanal 10 km	-0.0155	0.0813	0.0392
× ln(gold price)	(0.0686)	(0.0898)	(0.0287)
Artisanal 10 km	0.160	-0.555	-0.277
	(0.462)	(0.596)	(0.192)
Industrial mine 25km	-0.126	0.294***	-0.0336
	(0.116)	(0.0890)	(0.0372)
Industrial deposit 25km	0.0472	-0.0591	-0.0495
	(0.0745)	(0.0832)	(0.0414)
Observations	23,725	30,198	38,066
R-squared	0.306	0.897	0.194
P(deposit=mine)	0.413	0.00278	0.0865

Note: ln(minimum income) corresponds to 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. Robust standard errors are clustered at the municipality level. *** p<0.01, ** p<0.05, *p<0.1.

impact on rents that are the least tradable good. We find a positive impact of the opening of new industrial mines, consistent with the local multiplier framework. 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 however 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%). Most of the variation is thus captured by time fixed effects, and we do not detect significant differences in the evolution of these difficulties between the control and treated areas with respect to artisanal mines.

Overall none of the results of this section are consistent with a surge of prices during the artisanal mining boom. Thus, results presented in the rest of the article are unlikely to be driven by a pure nominal consumption effect. Some results in this section are however consistent with a possible increase in prices at the opening of industrial mines, in which case households living around industrial mines would be poorer in real terms than what the data allows us to pick up.[26]

5.4 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,

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

Table 8: 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 10 km	0.00708	0.00679	-0.0159**	-0.0147*	0.00914
× ln(gold price)	(0.0114)	(0.00783)	(0.00691)	(0.00820)	(0.0109)
Artisanal 10 km	-0.0500	-0.0412	0.101**	0.0890	-0.0603
	(0.0737)	(0.0506)	(0.0459)	(0.0556)	(0.0723)
Industrial mine 25km	0.0315	0.0227	0.00657	-0.00616	0.0162
	(0.0296)	(0.0169)	(0.0163)	(0.0209)	(0.0198)
Industrial deposit 25km	-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
P(deposit=mine)	0.320	0.0171	0.455	0.860	0.199

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.

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., 2016; Aragón and Rud, 2016; Corno and de Walque, 2012; Hilson, 2006; Tolonen, ming). We are not perfectly equipped to investigate these aspects which would each deserve a dedicated study, but we can present some preliminary results.

In Table 8, we investigate the evolution of the probability of being sick for households living next to artisanal and industrial gold mines. The only health proxy that is consistently recorded throughout our survey data is the answer to the question "Have you been sick or injured in the last 15 days?" The expected 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 (Tolonen, ming). These mines may also pollute in larger amounts (with consequences on local health, Aragón and Rud, 2016).

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: the economic gain that households obtain from artisanal mines allows better health conditions. 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 income effect should increase school enrollment around artisanal mines, while the increase in job

Table 9: 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 10 km	-0.0172	0.0501**	-0.0415	-0.0817	0.0773
× ln(gold price)	(0.0176)	(0.0250)	(0.163)	(0.143)	(0.102)
Artisanal 10 km	0.00273	-0.00751**	0.00458	0.0144	-0.0166
	(0.00269)	(0.00382)	(0.0247)	(0.0215)	(0.0156)
Industrial mine 25km	0.00319	0.00322	0.0362	0.0578	-0.0207
	(0.00603)	(0.00959)	(0.0456)	(0.0373)	(0.0303)
Industrial deposit 25km	-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
P(deposit=mine)	0.779	0.498	0.563	0.113	0.635

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.

opportunities (especially for the low-skilled for artisanal mining) reduces the incentive to attend school (Ahlerup et al., 2016). The opposite is true around industrial mines (Ebeke et al., 2015). In Table 9, we document the effect of mining activities on the probability of being at school for different age samples.

We find no effect of the artisanal boom for 0 to 16 years old children. We do 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 0.05% in areas close to artisanal mines. The effect is rather limited and should be considered knowing that school enrollment above 16 is very low in general and that school is compulsory exactly from 6 to 16 in Burkina Faso. 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.

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 a 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 5 cents in euros per person per day for people living around artisanal mines. This additional consumption is economically significant, given that the average household member in our sample consumes 50 cents in euros a day on average. 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 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 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. This prevention 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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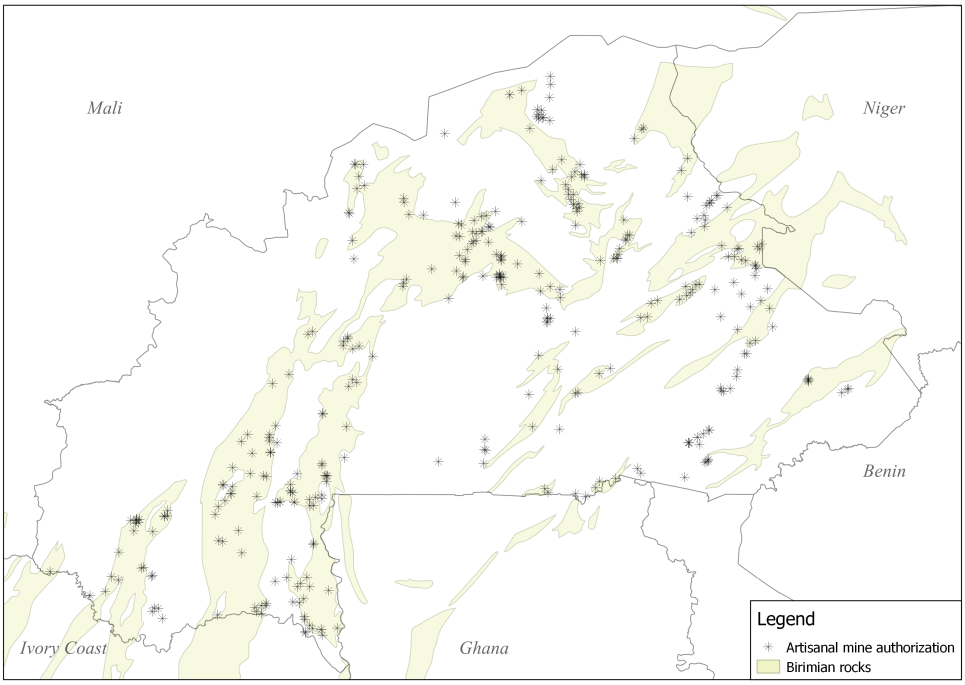
7 ONLINE APPENDIX, NOT FOR PUBLICATION

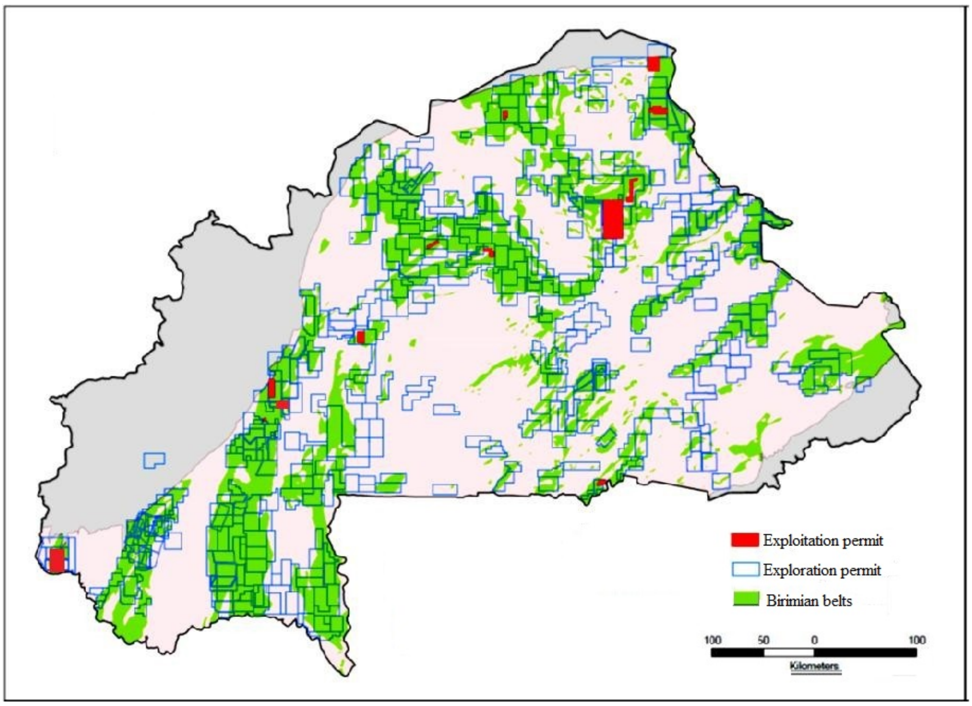
7.1 Appendix Figures

Figure 10: The overlap of Birimian greenstone belts and artisanal exploitation permits



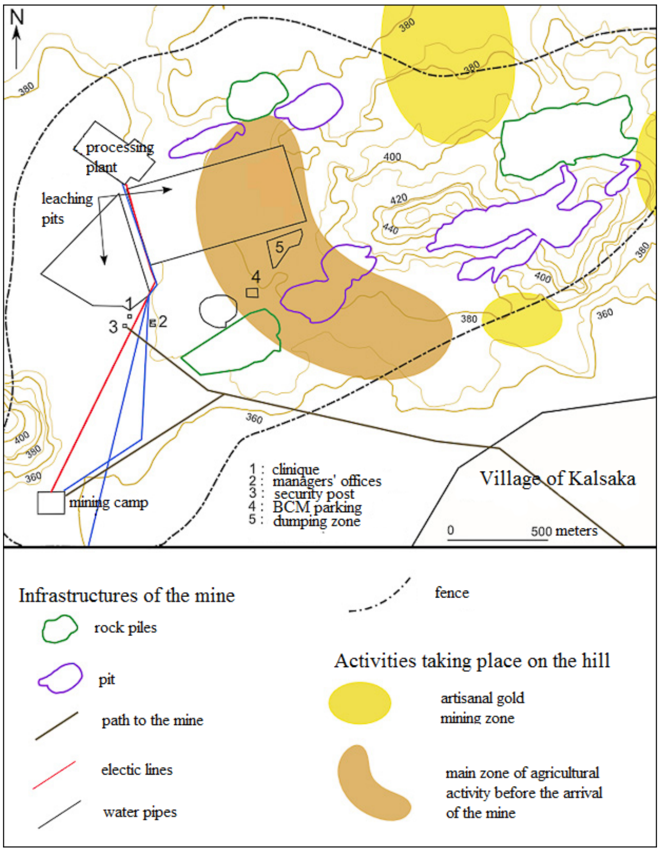
Note: authors' calculations

Figure 11: The overlap of Birimian greenstone belts and industrial exploration permits



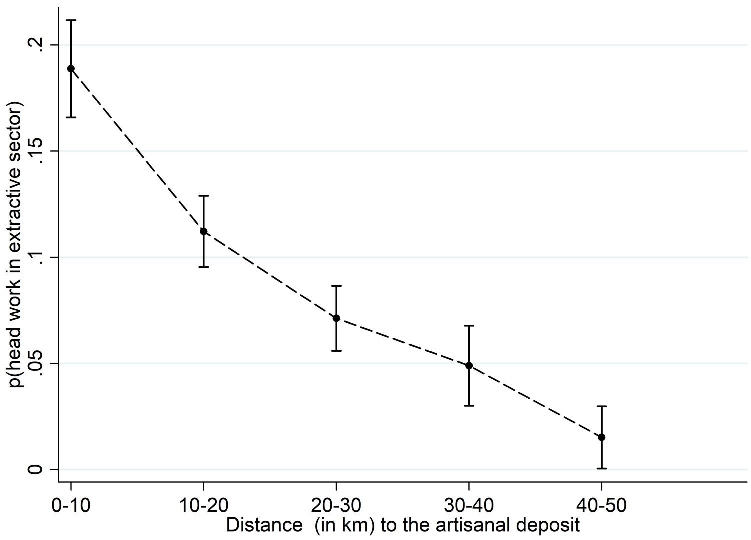
Note: source: http:www.burkina-emine.com, translation is ours

Figure 12: Organization of space within and around an industrial mine, the example of Kalsaka



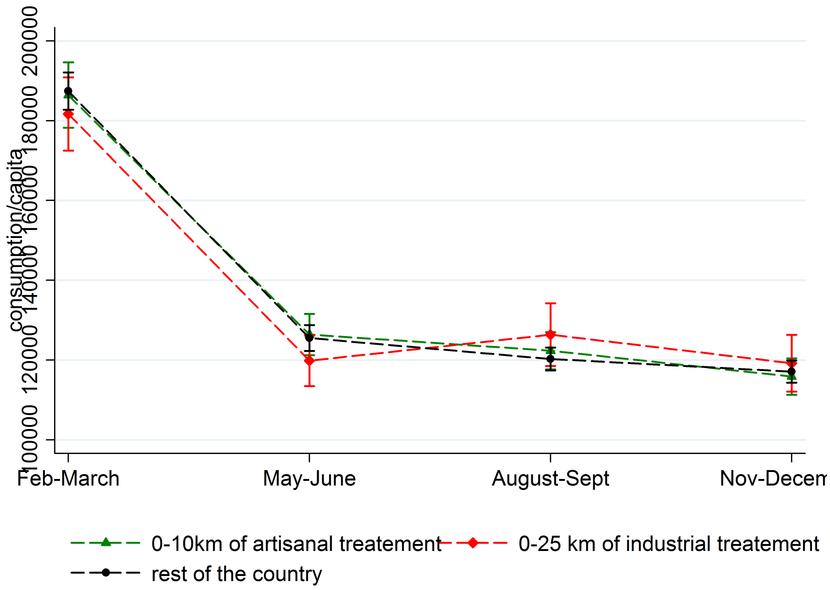
Note: Figure from Thune (2011), translation is ours.

Figure 13: The probability to work in the extractive sector decreases with the distance to artisanal mines



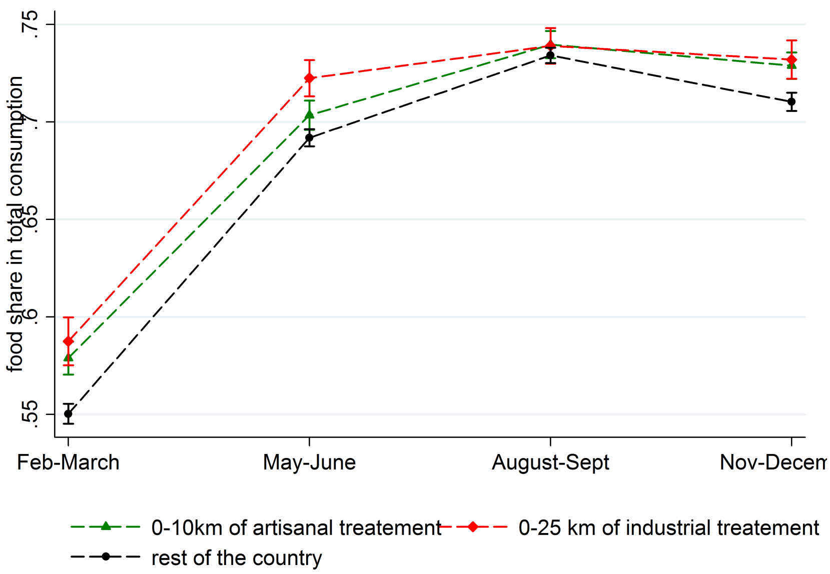
Note: Each point represents the share of household heads who are involved in the extractive sector in the 1st survey period in 2014 (February-March), according to the distance of the household to an artisanal mine. The extractive sector encompasses all forms of extraction, be they artisanal or industrial.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

Figure 14: Consumption spending per season in 2014



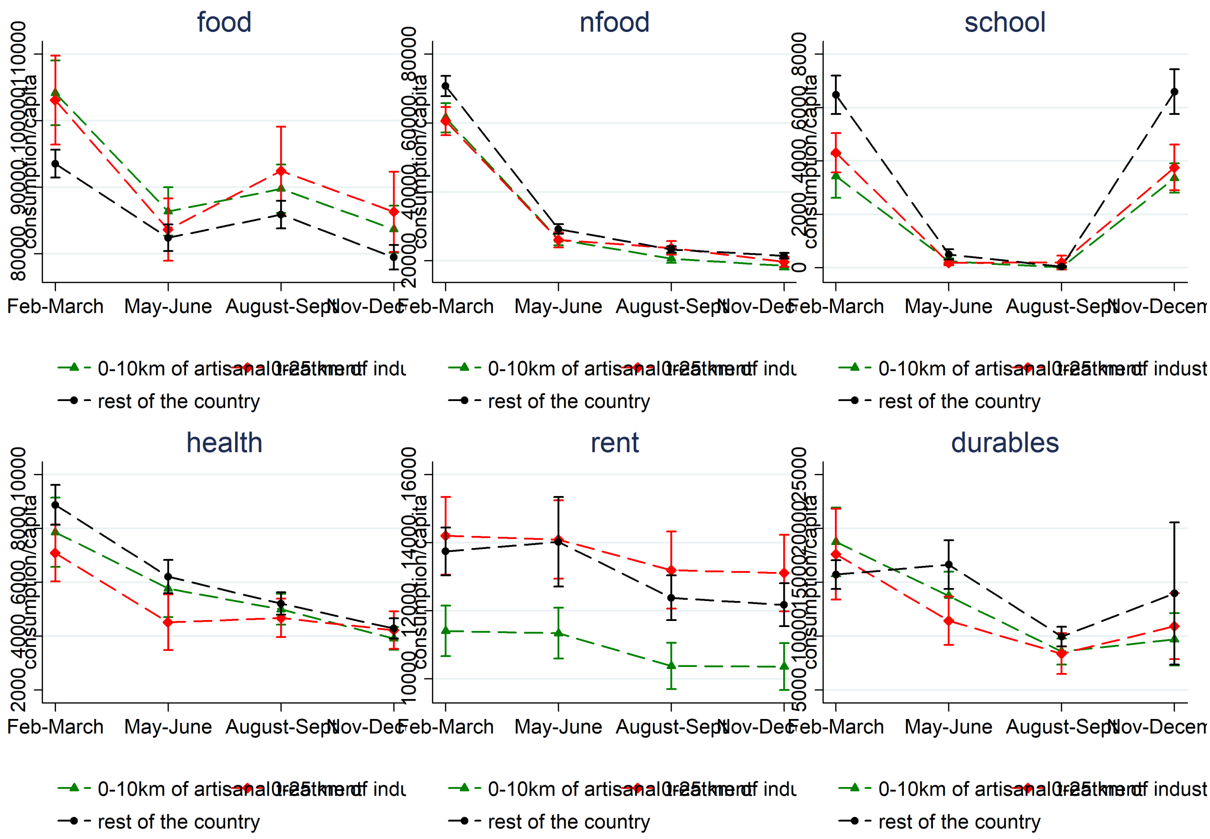
Note: Each point represents average per capita consumption for each period and location. The treated groups are defined spatially and encompass either households living within 10 kilometers of an artisanal deposit, or households living within 25 kilometers of a deposit that would host an industrial gold mine by 2014. The control group (rest of the country) excludes the treated areas. Bars around each point represent the 95% confidence intervals.

Figure 15: Share of food in consumption spending per season in 2014



Note: Each point represents average spending on food in total consumption for each period and location. The treated groups are defined spatially and encompass either households living either within 10 kilometers of an artisanal deposit, or households living within 25 kilometers of a deposit that will host an industrial gold mine by 2014. The control group (rest of the country) excludes treated areas. Bars around each point represent the 95% confidence intervals.

Figure 16: Evolution of the level of spending by item and per season in 2014



Note: Each point represents average spending per capita for each consumption item, period, and location. The treated groups are defined spatially and encompass either households living 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. Bars around each point represent the 95% confidence intervals. Results are consistent with an increase in absolute spending for almost every aspect of consumption in winter even if the increase is not equally distributed among items (which explains why the share of spending on food is smaller in winter than in other seasons).

7.2 Appendix tables

Table 10: Industrial 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
Seguenega	1.7	5	2013	Australia
Bissa	15.7	34	2013	Russia
Guiro	0.1	1.6	2015	Canada
Karma	0	29	2016[b]	Canada
Niorka	0	20	2016[b]	Australia
Poura	0	7	2017[b]	Australia

Note: data from the Ministere des Mines et de l'Energie of Burkina Faso. [a] estimation from time of feasibility studies. [b] 2014 plan of year of production start

Table 11: Robustness to the definition of the artisanal mines treatment.

	(1)	(2)	(3)	(4)
Dep. Var.: ln pc Cons.				
Artisanal deposit 10km	0.0358			
×year 2003	(0.0527)			
Artisanal deposit 10km	0.222**			
×year 2009	(0.0943)			
Artisanal deposit 10km	0.213***			
×year 2014	(0.0719)			
Artisanal deposit 10km		0.195***		
× gold price boom		(0.0605)		
Artisanal deposit 10km			0.136***	
× lagged ln(gold price)			(0.0406)	
Artisanal deposit in Municipality				0.142***
× ln(gold price)				(0.0458)
Artisanal deposit 10km	-0.126**	-0.104**	-0.870***	
	(0.0602)	(0.0466)	(0.267)	
Observations	30,502	30,502	30,502	30,502
R-squared	0.367	0.367	0.367	0.367

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 12: Robustness to the sample definition.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Sample:	only rural	only urban	within 50km of an artisnal deposit	without areas surrounding industrial mines	with Ouagadougou	omit 1998	omit 2003	omit 2009	omit 2014
Dep. Var.: ln pc Cons.									
Artisanal deposit 10km	0.121***	0.221***	0.152***	0.180***	0.190***	0.148***	0.156***	0.120***	0.210**
× ln(gold price)	(0.0407)	(0.0648)	(0.0511)	(0.0527)	(0.0495)	(0.0460)	(0.0490)	(0.0441)	(0.0837)
Artisanal deposit 10km	-0.780***	-1.454***	-0.977***	-1.146***	-1.225***	-0.965***	-1.002***	-0.772***	-1.329**
	(0.266)	(0.458)	(0.335)	(0.346)	(0.325)	(0.307)	(0.327)	(0.287)	(0.517)
Observations	22,541	7,752	27,351	27,001	34,308	23,706	23,698	23,114	20,988
R-squared	0.336	0.431	0.374	0.365	0.412	0.334	0.355	0.419	0.413

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: 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 10km	0.158***	0.150***	0.185***	0.137***	0.149***	0.159***	0.153***	0.154***	0.128***	0.172***	0.148***	0.152***	0.161***
× ln(gold price)	(0.0500)	(0.0474)	(0.0464)	(0.0438)	(0.0494)	(0.0483)	(0.0467)	(0.0496)	(0.0381)	(0.0500)	(0.0493)	(0.0482)	(0.0504)
Artisanal deposit 10km	-1.011***	-0.965***	-1.214***	-0.901***	-0.964***	-1.018***	-0.987***	-0.986***	-0.843***	-1.111***	-0.945***	-0.958***	-1.041***
	(0.327)	(0.308)	(0.304)	(0.289)	(0.324)	(0.316)	(0.306)	(0.325)	(0.244)	(0.328)	(0.322)	(0.316)	(0.330)
Industrial mine 25km	-0.0565	-0.0460	-0.0427	0.00345	-0.0669	-0.0424	-0.0463	-0.0381	-0.0699	-0.103	-0.0478	-0.0111	-0.0443
	(0.0863)	(0.0762)	(0.0790)	(0.0839)	(0.0873)	(0.0768)	(0.0760)	(0.0765)	(0.0729)	(0.0847)	(0.0759)	(0.0709)	(0.0772)
Industrial deposit 25km	0.124*	0.110	0.128*	0.137*	0.115	0.111	0.110	0.107	0.117*	0.123	0.110	0.0308	0.107
	(0.0721)	(0.0729)	(0.0722)	(0.0782)	(0.0820)	(0.0713)	(0.0705)	(0.0715)	(0.0675)	(0.0843)	(0.0709)	(0.0515)	(0.0768)
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	0.369	0.367	0.364	0.365	0.367	0.370	0.368	0.370	0.369	0.367	0.368	0.365	0.367

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 15: Heterogeneous effect according to sector of occupation: gold boom treatment

	(1)	(2)	(3)	(4)	(5)	(6)
Sample: hh head works in					public	health
	agriculture	extractive	services	trade	servant	education
Artisanal 10 km	0.160***	-0.323	0.582***	0.364*	-0.100	0.0414
× gold price boom	(0.0527)	(0.686)	(0.157)	(0.198)	(0.0700)	(0.172)
Artisanal 10 km	-0.0809*	0.809	-0.0393	-0.297	0.815***	0.176
	(0.0451)	(0.652)	(0.205)	(0.188)	(0.132)	(0.188)
Industrial mine 25km	-0.0618	0.728*	-0.557***	-0.160	-0.0977	-0.108
	(0.0829)	(0.380)	(0.176)	(0.159)	(0.207)	(0.109)
Industrial deposit 25km	0.120	1.067**	-0.200	0.257	0.744**	0.324
	(0.0746)	(0.449)	(0.191)	(0.175)	(0.306)	(0.332)
Observations	22,406	198	1,611	1,963	522	831
R-squared	0.311	0.678	0.482	0.425	0.617	0.631
P(artisanal=boom)	0.408	0.00478	0.00712	0.629	0.176	0.487
P(deposit=mine)	0.408	0.00478	0.00712	0.629	0.176	0.487

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.

Table 14: Robustness to controlling for cotton production and prices

	(1)	(2)	(3)
Dep. Var: ln. pc. Cons.			
Artisanal deposit 10km	0.151***	0.156***	0.157***
× ln(gold price)	(0.0435)	(0.0460)	(0.0466)
Artisanal deposit 10km	-0.975***	-1.007***	-1.012***
	(0.285)	(0.301)	(0.305)
Rural area × ln(cotton price)	0.231**		
	(0.0981)		
ln(cotton production)		0.00145	0.000218
× ln(cotton price)		(0.00210)	(0.00326)
Rural area × ln(cotton production)			0.00139
× ln(cotton price)			(0.00251)
Observations	30,502	30,502	30,502
R-squared	0.368	0.367	0.367

Note: Cotton production is known at the region level. 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.