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► **To cite this version:**

Rémi Bazillier, Victoire Girard. The gold digger and the machine. Evidence on the distributive effect of the artisanal and industrial gold rushes in Burkina Faso. 2017. hal-02484234

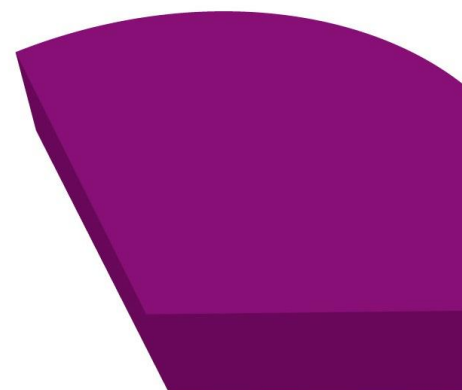
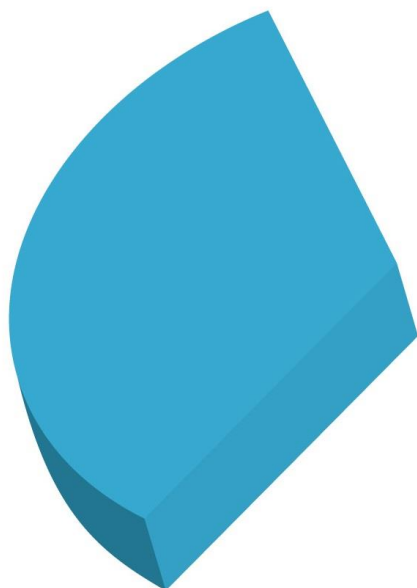
HAL Id: hal-02484234

<https://hal.science/hal-02484234>

Preprint submitted on 19 Feb 2020

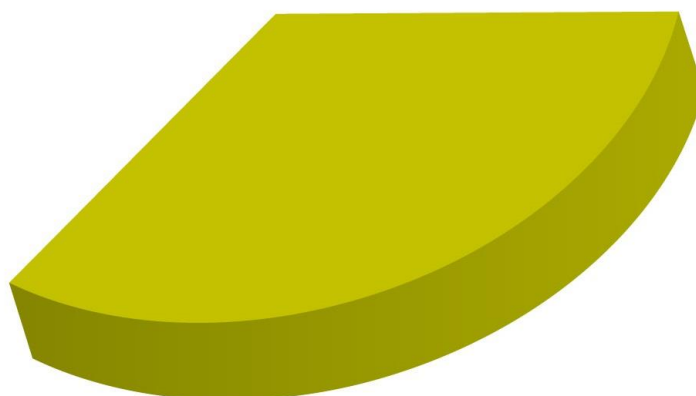
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**The gold digger and the machine.
Evidence on the distributive
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rushes in Burkina Faso**

**Rémi BAZILLIER
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Mise en ligne : 04/12/2017

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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November 28, 2017

Abstract

We use a quasi-natural experiment, the recent gold boom in Burkina Faso, to document the local wealth impact of private *versus* common property management. The net impact of privatizing the management of a natural resource on wealth is subject to theoretical debate. We measure household wealth through consumption and consider two modes of property management: artisanal and industrial mines. Artisanal mines are labor intensive and managed as a common property. Industrial mines are capital intensive and privatize the resource by enclosing their production area. We identify the impact of each mode of gold extraction by exploiting two sources of variation: changes in the gold price and the geological setting of Burkina Faso. We show that a 1% increase in the gold price increases consumption by 0.2% for households neighboring artisanal mines, while we do not find any effect for households neighboring industrial mines. Thus, while the privatization and industrialization of production increases efficiency, in accordance with much of the literature on the commons, the distributive consequences of each mode of property management are such that artisanal mines benefit more to the local communities.

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

* **Acknowledgments:** We would like to thank the INSD and Ministry of mines for providing us data. In particular, this article wouldn't have existed without the support of Patrice Dabire, Alassane Diarra, Adama Nabayaogo, Pascal Nakelse, Ouoba Pagari and Emanuel Yameogo. We thank Matthieu Thune for allowing us to reproduce his figure of the Kalsaka mining site. We thank Lisa Chauvet, Mathieu Couttenier, Wouter Gelade, Michael Grimm, Francois Libois, Quentin Mégret, Pierre Pecher, Grégoire Rota-Graziosi, Juan Pablo Rud, Gerhard Toews; and participants in the Pi working group; the IOEA summer school; the EX4DEV17 workshop; the LEO, CERDI and Paris IX Dauphine seminars; the CSAE, EPCS, INFER, LAGV and DIAL conferences for their insightful comments. All remaining errors are ours.

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1 Introduction

Karma, January 2015: 3 to 6 million euros of material on the construction site of True Gold vanishes into flames after a local community protest (Capitant, 2017). Karma is in Burkina Faso, a country which became the 4th major gold exporter of Africa within 5 years thanks to the heavy investments made by industrial mining companies such as the canadian True Gold. Yet, 43% of the population of the country still lives with less than 1.90 dollars a day in 2014, and the people of Karma displayed quite an extreme form of discontent against the investments of True Gold. The case of Karma is not exceptional, evidence abound on local resistance to industrial mine installations, in particular when local artisanal miners were exploiting the ore before the arrival of the industrial mine (Hilson and Andrew, 2003; World Bank, 2009). We here propose to shed light on one aspect of the tension between local populations and industrial gold mines: the local distributive consequences of artisanal and industrial gold production. Artisanal mining is a labor-intensive low-tech activity that extracts natural resources under the regime of common property management,¹ while the settlement of an industrial mine implies a privatization of the natural resource since they enclose their production areas.

The evolution of gold extraction in Burkina Faso since the late 1990's offers an ideal quasi-natural experiment to assess the local spillovers of artisanal and industrial mines. Burkina Faso has a long tradition of artisanal and small-scale gold mining (ASM). ASM sites function according to a set of informal rules. These rules grant a form of access to the resource to the local population. In 2014, up to 640,800 Burkinabés were directly involved in ASM activities, representing 3.6% of the total population of the country. Importantly, the gold price was multiplied by 4 between 1998 and 2014, directly impacting the benefit of both industrial and artisanal gold mining. Following this price increase, and the adoption of an investor-friendly mining code in 2003, 7 large scale industrial mines opened in Burkina Faso between 2007 and 2014. The settlement of industrial mines pushes away artisanal miners, who lose access to the resource in areas privatized by industrial mines (Côte and Korf, 2016). Since artisanal mining persists in other areas of the country, Burkina Faso offers us an excellent case study to explore empirically the distributive effect of the privatization of a common, here the gold pits. More precisely, we document the effects of both artisanal and industrial mining on the wealth of local populations.

Our identification strategy exploits two sources of variation: a temporal variation and a spatial variation. More specifically, to identify the impact of artisanal mines, we implement a difference-in-difference

¹Seabright (1993) proposes a simple definition of common property resources: “*there exist property rights, but 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)

where the treatment comes from variations in the gold price and the distance to artisanal mines. Given that the gains from artisanal mines are a direct function of the gold price, and knowing the location of both all the registered artisanal mines and the Birimian greenstone belt hosting gold, we are able to document the wealth effect of artisanal mines. To the best of our knowledge, it is the first study providing a causal assessment of artisanal mining on household wealth. For industrial mines, we exploit the difference in the opening years of industrial mines as well as the distance 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 provided by the national statistical agency of Burkina Faso, the INSD. These data have not been exploited over such a long period yet, and we are the first to take advantage of the GPS coordinate of households to track changes at the local level. Throughout the empirical section of the paper, we use households' consumption as the main indicator of households' wealth and well-being (Deaton and Zaidi, 2002). We also investigate general equilibrium effects through the allocation of workers across places and sectors, acknowledge potential variations in local prices, and investigate other dimensions of well-being such as education and health.

Our results first document a strong positive impact of artisanal mining. A 1% change in the gold price increases by 0.2% the consumption for households located close to artisanal mines. During the gold rush (2009 and 2014) these households consumed 15% more than households living away from artisanal mines. Making a rough monetary estimate, a back-of-the-envelope calculation suggests that a high gold price translates into 8 additional cents (in euros) of consumption each day for each person living around an artisanal mine. This additional consumption is economically significant, given that the average household member in our sample consumes 55 cents in euros on an average day.

Moreover, our results are unlikely to be driven by changes in either migration, or local prices. Indeed, we show that mining activities in Burkina Faso are highly seasonal and we document the positive wealth effect of artisanal mines outside the main mining season.² We also document that the positive effect of artisanal mining is concentrated on households who have members working in the agriculture, service, and trade sectors, all activities that allow households to either diversify their income source by mining themselves, or to indirectly benefit from the gold boom by providing gold diggers with good and services (Moretti, 2010).

We then proceed to show that privatized gold resources fail to improve local living conditions in the short run. Our estimates never show any impact of industrial mining on household consumption. Said

²Mining is taking 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 till September for one of the waves), that is during the plantation and growing period where people are needed in the fields. This period also coincide with the rainy season during which ASM activities are illegal since the rain increases the danger of the mines collapsing.

differently, households living close to new industrial mines have not seen any significant change in their consumption, compared to households located farther away. For local populations, the efficiency gains (the strong increase in gold extraction) arising from privatization does not overcome the distributive cost arising from closing artisanal mines.

We therefore contribute to the literature on the effects of privatization of a common. Our results bring empirical evidence to the mostly theoretical debate on the wealth impact of privatization. Open access to the resource may be used as an asset of last resource for poor populations and explain the welfare advantage of commons over privatization for local communities (Baland and Francois, 2005). Thus, while privatization long appeared as the best solution to Hardin (1968)'s "tragedy of the commons", a rich literature debates under which conditions privatization is indeed better than common property management (starting with the seminal books of Wade, 1989; Ostrom, 1990; Baland and Platteau, 1996). Beside assessing under which conditions each management solution may be the most efficient, a strand of this literature highlights that each solution comes with different distributive consequences (for example, Weitzman, 1974; Pattanayak and Sills, 2001; Baland and Francois, 2005; Baland and Bjorvatn, 2013). In particular, Weitzman (1974) shows that despite efficient, privatization can be obtained at a distributional cost, making labor worse off. One step forward, Baland and Francois (2005) show that *everyone* may lose after privatization when markets are incomplete because commons have a role of insurance. However, it is challenging to compute empirical evidence. Our study offers the first systematic empirical evidence we know of on the wealth impact of common *versus* private management of an extractive natural resource.

A second contribution of our paper is to document a positive causal effect of artisanal mining on local wealth. ASM have a bad reputation.³ Yet, a recent World Bank report, aiming at summarizing the state of knowledge on the local impact of mining, acknowledges straightforwardly its complete absence of information on small-scale mining.⁴ Such a knowledge gap is problematic given the amount of people

³For example, the main international initiative focused on ASM, the Communities and Small-Scale Mining Initiative of the World Bank, describes it aims as transforming artisanal mining "*from a source of conflict and poverty into a catalyst for economic growth and sustainable development*". Qualitative research on the topic offers a more nuanced picture, and often outlines the insurance part played by artisanal mine despite its costs (in particular in terms of health and environment). The different chapters in Hilson (2006) offer an excellent overview.

⁴"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, nevertheless, large-scale mining, in all but a few mining areas, accounts for a very high percentage of the volume and value of gold produced in such areas." (World Bank, 2015, p. 11). While indeed industrial mines account for most of the ore production, the labor insensitivity of artisanal mine is such that it is important to distinguish their impact from the impact of industrial mines, and in particular when one studies the local impact of extractive activities. Also acknowledging a lack of systematic evidence on artisanal mine, while abiding to the usual pessimistic perception of artisanal mines, Cust and Poelhekke (2015) call for more research on ASM in the conclusion of their literature review on the local impact of extractive activities: "*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.*"

concerned worldwide “[o]ne widely used estimate is that more than 100 million people globally depend either directly or indirectly on ASM for their livelihoods.” (World Bank, 2009, p. 11), representing 1.5% of the world population, and an even higher share of the population of developing countries where ASM activities are concentrated. Assessing the effect of artisanal mines is a great challenge because artisanal miners keep moving around. The challenge is such that the World Bank just started financing a platform, Delve, solely dedicated to the collection of systematic data and evidence on the impact of artisanal mining. As a result, few existing articles tackle the question. Notable exceptions focus on the degree of lootability of resources from the perspective of conflicts or local institutions. Lujala et al. (2005) show that diamonds that can be mined artisanally –which happen to be lootable– induce more conflicts than other diamonds do. Rigterink (2016) exploits this heterogeneity to argue that an important conflict determinant is the opportunity cost of time for fighters. Still on the conflict and institution vein, Sánchez de la Sierra (2017) shows that the non-lootable coltran leads to a different form of development of stationary bandits in Eastern Congo than the lootable (artisanally exploited) gold do. Without underestimating possible negative effects of ASM on other dimensions of well-being, we provide empirical evidence that ASM activities may have a significantly positive wealth effect.

Lastly, we contribute in two manners to the literature on the local impact of extractive industries. We document the (absence of) wealth effect of opening an industrial mine, and we document this effect after partialing out the impact of artisanal mines. Given the debate on the existence of a resource curse or blessing at the macroeconomic level (as is clear from van der Ploeg, 2011; Venables, 2016, literature reviews), researchers investigated the consequences of extractive activities at the local level (see Cust and Poelhekke, 2015, for an overview). The seminal paper of Aragón and Rud (2013) shows that the expansion of the largest gold mine in Peru had a positive effect on nominal and real income. They provide evidence that the increase in the demand for local inputs has generated positive spillovers for households living in the surrounding of the mine, even after excluding groups that may have benefited directly from the mine expansion. This positive wealth effect of the *expansion of existing mines* is confirmed for other gold mines in Peru, and copper mining in Zambia (Loayza and Rigolini, 2016; Lippert, 2014). Here we show that the *opening* of new industrial mines has no wealth effect, calling for further attention on the distinct impact of opening a new mine versus expanding the production of an existing one. Our result is more consistent with Aragón and Rud (2016) who show that the pollution induced by the increase in gold production in Ghana – partly driven by the opening of new industrial mines – leads to a 40% reduction in farms’ productivity around mines. The last contribution of our paper is that we are able to document the impact of industrial gold mines when we do and don’t control for artisanal mines. Indeed,

while in many cases artisanal mines precede or co-exist with industrial mines (World Bank, 2009), the only published papers we know of which control separately for the existence of industrial and artisanal mines focus on diamonds (as reviewed in Rigterink, 2016). Reassuringly for the credibility of existing estimates on different metals, we show that, in our case, whether we control or not for artisanal mines, the coefficient of industrial mines remains the same.

The paper is organized as follows. In the next section, we provide a presentation of gold mining in Burkina Faso. In section 3, we present the data and identification strategy. In section 4, we present our main results. Section 5 proposes a discussion of these results, including an exploration of labor market effects and seasonality, and the potential effects of migration and prices. We also discuss in that section 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 and how it matches the definition of common property resources. Third, we describe the setting in which the industrial gold boom took place.

2.1 How gold affects Burkina Faso

While gold price fluctuations directly determine the benefit of gold extractive activities, Burkina Faso is a price taker on the international gold market. In 2012, its gold production of 28 tons made it the 22nd producing country in the world, way after the 403 tons produced by Russia (indexmundi). Still, gold became central for the economy of the country since the 2000's surge in the gold price (Figure 1). Gold is now the country's main export: it represented 55% of the exports in 2014 (the end year of our study) against only 6% in 1998 (the start year of our study). The surge in the gold price lead to a gold rush by both artisanal and industrial miners as we can see with the surge of quantities produced shown on Figure 1.

The location of gold deposits all over the country is exogenously determined by the geological environment. Burkina Faso lies on top of Birimian greenstone belts, a type of rocks likely to host gold deposits within its core or at its frontiers (Béziat et al., 2008). Following this geological setting, mines are spread over different parts of the country. Burkina Faso hosts hundred of artisanal and small-scale

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



Note: data sources are Gold price from London Gold Fixing; Industrial production from the Ministry of Mines; Artisanal production from Jaques et al. (2003) and the Ministry of Mines.

mines that follow the Birimian rocks (Appendix Figure 10), and hundreds of exploration permits for industrial gold mines that cover virtually all these rocks (Appendix Figure 12). Indeed, while current gold mines exploit some of the major gold reserves that have been known for decades, the country greenstone belts theoretically have the potential to host many more major gold reserves. Comparing the repartition of artisanal mines and industrial research permits over the country in Appendix Figures 10 and 12 makes already clear that both mines compete for overlapping areas. Moreover, if exploration permits are successful and result in the construction of an industrial mine, artisanal miners lose access to the extraction site (Côte and Korf, 2016).

2.2 Artisanal mines

Artisanal and small-scale mines offer an interesting example of common property management of the resource. 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” in the sense of “the absence of a complete set of contractual relations governing which member of the group is entitled or required to do what”. Indeed, as outlined below, several pivotal people have claims over a share of the resource and are in constant re-negotiation. Moreover, newcomers will always find a part in the artisanal gold production process. Second, there is rivalry in consumption

of the resource within the group. Indeed, you will not be able to mine what has been mined by your neighbor. ASM are thus 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, if only by increasing the solidity of each shaft, the quality of tools, building a tube-well for water supply, etc.⁵

Artisanal and small-scale gold mining has been taking place all over Burkina Faso since the 80's droughts, with recent variations in the intensity of the activity following the level of the gold price (Figure 1). The relationship between declared ASM production and the level of the gold price holds despite the fact that an important share of the artisanal production is smuggled (above 50% of the production is smuggled according to most estimates, Werthmann, 2017). According to the 2003 mining code, traditional artisanal exploitations encompass any "*operation that consists in extracting and concentrating mineral substances and use traditional methods and manual processes to retrieve from them disposable merchant products.*"⁶ Concretely, ASM sites look like a collection of narrow shafts that may be several dozen meters deep. Gold diggers go in the shaft to bring the ore up where further work allows to separate gold from useless ground that remain in piles, on the site or its surrounding. In 2003, Jaques et al. (2003) already observed over 200 ASM sites in the country, with a declared production of 0.3 tons of gold that year. In 2015, the known production was multiplied by 13 (reaching 4 tons) and the number of registered mines by about 2 (reaching nearly 400, Ministry of Mines).

Life in the artisanal and small-scale mines of the country kept follows some reasonably stable – informal– rules despite changes to the –formal– legal frame. The legislative frame for gold trade, has changed from a state monopoly over buying and selling gold during most of the 1990's to an opening to private gold posts from 1997 onwards.⁷ However, the organization of extraction on the field remained

⁵Put differently, for (Collier, 2010, p. 1120): "*Artisanal mining is in some respects analogous to the Wild West. As many prospectors crowd in to search, the size of plot is reduced, either in response to political pressure to accommodate more people, or through the sheer physical inability of individuals to retain exclusive control over a large area. This creates an externality: each additional prospector reduces the chance that other prospectors will strike lucky. Hence, the private return exceeds the social return. A second respect in which artisanal mining is inefficient is technological: artisanal mining is not able to reap the scale economies involved in mining, such as pumping out water. Since large-scale technology involves fixed capital investment, artisanal mining gives rise to a third form of inefficiency: plundering the future. With substantial fixed investment, the appropriate pace of exploitation is gradual, so that the installed capital can remain employed for a prolonged period. This implies that some areas will initially be left unprospected. In contrast, artisanal mining prospects all areas at once so that what would otherwise be future rents are dissipated in high current costs. The social inefficiency inherent in artisanal exploitation is demonstrated by the successful growth of De Beers. The company was able to buy out the claims of artisanal producers at their full value under artisanal exploitation and generate a large profit by internalizing these externalities.*"

⁶Traduction is ours, the original version states, in French: "*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.*"

⁷From a legal point of view, from 1986 onward the CBMP, a state owned trading post, was supposed to have monopoly 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 difficulties competing with the private posts that it stopped functioning in 2005. In 2003 a new mining code changed the legislative framework for industrial mine with little effect on artisanal mine save for a slight

largely unchanged since the 1980's.

Several informal rules that organize artisanal sites appear to be stable across years and places (Gueye, 2001; Jaques et al., 2003, 2005; Côte and Korf, 2016; Werthmann, 2017). Some rules organize the production within each shaft and between shafts and tell who gets which share of the ore. The essential actors entitled to bargain a part of the ore of any artisanal mine in Burkina Faso are at the number of two: the gold diggers and other workers, and the shaft owner (who made the investment 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 mosq, or school classrooms.

Artisanal mining authorizations tell us approximately where mining may take place. However, the authorization does not tell us who is mining when and how much. Artisanal mining 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 secured the authorizations. These trading posts then try to enforce a monopoly over the commercialization of the ore that gold diggers extract within the area (or its close surroundings). While this claim is illegal, and gold diggers may and do sell their gold to different gold posts or even smuggle it abroad, private gold posts often manage to reach their aim. Posts holders may enforce their monopoly in different manners, from lending money to gold diggers who need it to open new shafts, and then claiming monopoly over the product of the shaft dug thanks to the loan (Balme and Lanzano, 2013; Hilson and Ackah-Baidoo, 2011), to the extreme case of using physical violence (Werthmann, 2017).

Newcomers are welcome on the mining sites. While gold posts attempts at enforcing a monopoly over 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. A newcomer will either dig a new well or join an existing team. A new well is usually dug at one to three meters from the closest existing well. The

lowering of taxes. Another mining code was voted in 2015, that is after the last household survey that we use. However, our readings lead us to follow the conclusion of Werthmann (2017), p. 4: “*Even after the parastatal firm Comptoir Burkinabé des Métaux Précieux CBMP was liquidated in 2006 and private companies took over, the organization of artisanal gold extraction still largely resembled the pattern outlined above.*”.

⁸Basically, once prospecting gold diggers identify a new spot, either one of them or the owner of the land will invest to open a new shaft. Property rights for shaft locations are informal and follow a first come first served basis. Many shafts can be dug on a single site (up to several hundreds, as long as the site produces). The person who invests to dig the shaft will be called the shaft owner. The shaft owner 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 perceive a lump sum rent or a share of the ore). Hence both the gold diggers, the shaft owner, and people processing the ore have a pay that is a function of 1) the amount and type of their input (which exact work or exact capital) 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). The typical shaft is mined by 4 to 8 gold diggers. A last pivotal actor, present in all registered mines, is the trading post, who is trying to secure a monopoly on buying the gold produced in the perimeter of the artisanal mining authorization.

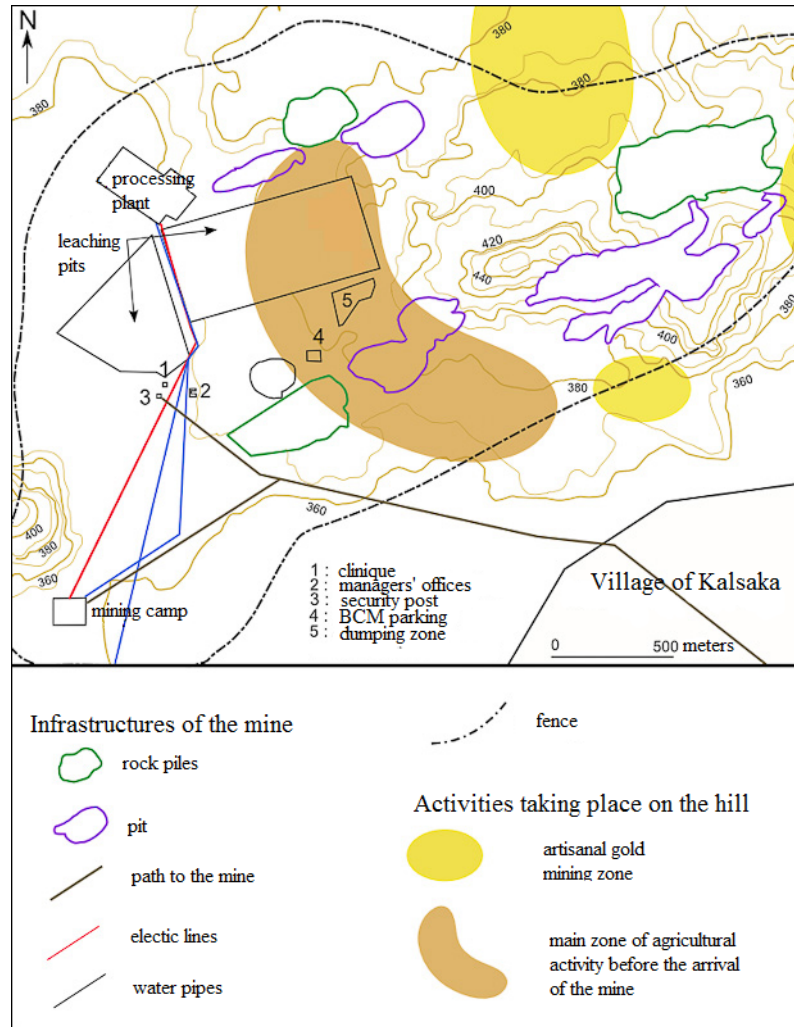
general site organization and location of new wells is either handled by agents of the gold post (it was part of the attribute of state agents during the state monopoly and private gold post somehow took this responsibility over after privatization) or experienced miners in the absence of a gold post (Balme and Lanzano, 2013).

Last but not least, ASM activities are likely to have important local linkages and spillovers. Indeed, these activities have a high labor intensity and gold diggers' needs are likely to induce a high local labor multiplier (Moretti, 2010). Artisanal mining is a highly labor-intensive activity performed by local labor: "*Artisanal mining is pursued by two main groups; members of rural communities who live near mining sites and floating populations from various regions*" (Werthmann, 2017, p. 2). In 2014, up to 640,800 people were active in informal mining in Burkina Faso. This local labor interacts with the local population for services, going from water supply to more or less elaborated forms of prostitution (Werthmann, 2017). Taking the 1 artisanal miner for 5 dependents multiplier used by the UN report (2016), it means that artisanal mining was central to sustain the living of 3,200,000 people in 2014, which corresponds to 18% of the population of the country that year. While the tendency of gold diggers to practice conspicuous consumption on items such as beers, electronic gadgets, or motorcycles, may create tensions with local traditions (Cros and Mégret, 2010), it also participates in redistributing locally 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, wood or metal sieves and calabashes. All these inputs are traded by local shops and several of them can be produced locally, mechanically increasing the number of jobs created around each gold digger.

2.3 Industrial mines

By nature, the recently blooming mining industry is likely to have smaller local spillovers than artisanal miners. Indeed, the production processes of industrial and artisanal gold mines do not have much in common. 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 200,000 gold diggers active in 2011 the industrial mining sector declared to employ 5,194 persons (62% of them being either foreigners or from another region of Burkina Faso, Ministère des Mines et de l'Énergie, 2012). Moreover, industrial mines encourage their (few) employees to limit contact with the local population. One can easily observe a result of this policy in Figure 2 for the mine of Kalsaka (and for other mines from google map): employees' dorms lie within the fence of the industrial mines. As a result, Thune (2011) notes that the

Figure 2: Organization of space within and around an industrial mine, the example of Kalsaka



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

main “losers” at the arrival of the industrial mine in Kalsaka are the shop-keepers, because employees of the industrial mine rely a lot less on them than what gold-diggers used to do. Beside the limitation of direct contacts, 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 and the idea that industrial mines may and sometimes efficiently rely on local content (Aragón and Rud, 2013), it may be the case that industrial mines have a spillover effect. It is thus important to assess the local impact of industrial gold mines.

Importantly, the recent industrial gold boom is independent from local factors. Communities hosting industrial mines have not had a say in their arrival. The country’s mining potential has been known for decades. Up until recently, it wouldn’t attract international investors,⁹ but two key elements changed

⁹The only industrial gold mine in the country, the Poura gold mine had great difficulties and such a scarce production that it closed in 1999 when the gold price was low (Jaques et al., 2003).

during the 2000's: the promulgation of a new mining code in 2003, and the sharp increase in gold prices (Figure 1). The 2003 mining code is the result of an impulsion 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 7 industrial gold mines in function and two in construction. Table 1 presents each of the main industrial mines in more details. All the country gold mines are open pit mines. Two other major mining projects are on their way in the country, one is related to Zinc (production started in 2013) and the other to Manganèse (production expected in 2016).

2.4 The cohabitation of artisanal and industrial mines

We aim to assess how the artisanal and industrial gold rushes have affected the 17 million inhabitants of the country, about half of whom live with less than \$1.90 a day (from 80% in 1998, to 43% in 2014, 2011 PPP, World Bank). In a recent work, Zabsonré et al. (2017) merge together the impact of artisanal and industrial mines of Burkina Faso and document a positive impact of gold mining on municipality level average consumption between 2003 and 2009. We extend the period of analysis and wish to disentangle the impacts of artisanal and industrial mines.

A short look at Figure 1 reminds us how much more efficient industrial mines are in terms of ore production: industrial mines declare about 10 times more gold production than artisanal mines do while the labor force of artisanal mines is more than 40 times bigger than that of industrial mines in 2014. We are in the typical case of what Seabright (1993) calls an “investment externality”: because any investment would confer external benefits on other users of the common, commons typically suffer from under-investment. This externality is, together with the tragedy of commons, the main implementation problem for common property resource management.

The question is all the more important that artisanal and industrial gold mines compete for land. Figure 2 takes the example of the mine of Kalsaka to show how the arrival of an industrial gold mine reshape the landscape of where artisanal miners can dig: the industrial mine is enclosed in a fence preventing access to places where they used to go. The mining code gives priority to industrial mines for access to the land and virtually all the gold resources of the country are subject to an authorization of industrial exploration (Appendix Figure 12). Industrial mines in exploratory stages leave artisanal gold diggers work within their concessions because artisanal diggers can be of great help to identify promising places (leading some scholars to consider that the companies free-ride on gold-diggers, Luning, 2014). However, if an industrial exploitation is to take place, gold diggers will almost systematically be forbidden the access to the gold bearing site. Since industrial and artisanal gold mines actually focus on different

Table 1: Major industrial gold mines in Burkina Faso, producing and about to produce in 2014

name	cumulated production in 2014	Estimated gold reserves	production started	Country controlling compagny
Bissa	15.698	34,00	2013	Russia
Essakane	46.885	100,00	2010	Canada
Inata	20.035	22,50	2010	UK
Kalsaka	10.201	20,00	2008	UK
Mana	35.956	35,00	2008	Canada
Taparko	23.058	35,00	2007	Russia
Youga	16.074	25,00	2008	Canada
Karma	0,00	29,00	2016	Canada
Gryphon	0,00	20,00	2016	Australia

Note: data from the Ministère des Mines et de l’Energie of Burkina Faso

sub-portion of the rocks it is in theory possible for them to co-exist but in practice it barely ever happens (World Bank, 2009). Still, there exist instances when a particularly helpful local may be temporarily granted access to a portion of the site, even if these are quite unique cases and never granted to last (Côte and Korf, 2016).

3 Data and Identification

3.1 Data

We build a nationally representative dataset that is a repeated cross section comprising 35,000 households surveyed between 1998 and 2014 by the INSD (the National Institute of Statistics and Demography, based in Ouagadougou). During this period, the INSD carried 4 households surveys including information on households’ consumption: in 1998, 2003, 2009 and 2014. Each survey wave encompasses 8,300 to 10,030 households, who are spread over 426 to 900 enumeration areas in 223 to 301 of the 351 municipalities of the country. The drawing of enumeration areas for each survey is such that they partly overlap across surveys. We have observations at –at least two– different points in time for 96% of the municipalities of our sample.

The 1998, 2003 and 2014 surveys are registered in the World Bank microdata catalog, 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.¹⁰ We are also the first to construct and exploit the geocoding of households place of residence (with the geodesic center of each village, or cities’ neighborhoods). Knowing the precise location of each household is essential for our identification

¹⁰The 1998 and 2003 surveys were used for published academic works such as Grimm and Gunther (2007). The 2009 and 2014 surveys have not yet, to the best of our knowledge, led to a publication in an international academic journal. However, the UNICEF or French scholars have already published reports or articles exploiting the 2009 data (UNICEF, 2013; d’Aiglepiere and Bauer, 2016, respectively), and it is also the data used in Zabsonré et al. (2017).

Table 2: Summary statistics

	Mean	sd
head age	45	0.1
head is male (%)	89	0.002
rural household (%)	75	0.002
head can read (%)	28	0.003
household size	7	0.03
number of workers in the household	4	0.02
head works in agricultural sector (%)	75	0.003
head works in extractive sector (%)	0.01	0.0006
consumption per capita	132,309	957.7
Total number of households in the sample= 34,400		
Note: The mean and its standard error are calculated using sample weights. Consumption is measured in CFA Francs. Since January 1999 the CFA Franc has a fixed exchange rate with the euro (656 CFA Francs = 1 euro)		

strategy and allows us to discuss changes that took place between 1998 and 2014 at a very local level.

The household surveys carried by the INSD have changed names over time, however, their core focus remains unchanged: 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 2 presents an overview of the characteristics of 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.

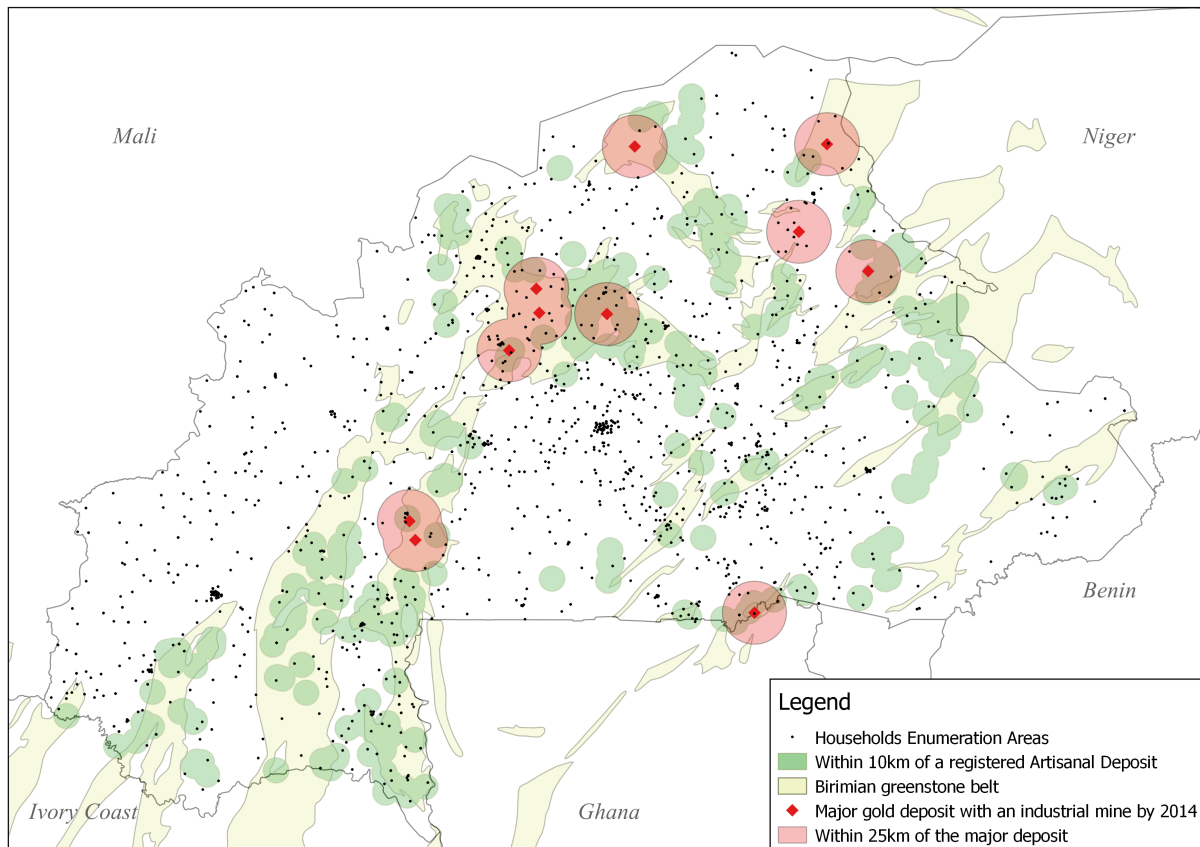
Our measure of consumption includes information on daily consumption (food, alcohol, tobacco, clothing, etc.), rents as estimated by households and health and education expenditures. We follow Deaton and Zaidi (2002) and omit exceptional expenditures on ceremonies, durables items (for example electronic items or jewelry or transportation modes) since we cannot compute the rental equivalent of the later.¹¹

The main challenge for us to answer to our research question, and for anyone interested in artisanal mines, is to obtain the actual location of artisanal mines. We are able to provide a first answer to this challenge thanks to exception data on the geolocalisation of registered artisanal mines in Burkina Faso.¹² The Ministry of Mine of Burkina Faso gave us access to original data on the localization of every regis-

¹¹Items 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 mines location) including year specific effects is enough to account for each survey specificity.

¹²Indeed, as detailed in section 2.2, the government requires artisanal miners to register the mining places and then delivers them one kilometer square authorizations to perform artisanal exploitation. Few miners committed to doing the paper work required, but gold trading posts did it. Gold trading posts have an interest in doing this paperwork because they use their legal recognition by the state to then try to impose their monopoly on the purchase of gold produced in the place where they have secured the mining authorization.

Figure 3: Location of enumeration areas for household surveys and mines (both industrial and artisanal)



tered artisanal gold mine with its date of last registration and the name of the permit holder. Obviously, due to the mobility of artisanal miners, this list does not include every place where artisanal mining is taking place and the list is updated with some delay compared to the moment when mining starts or stops in a place. However, we do know that artisanal mining has taken place at some point in each of these registered places. As a result, this list allows us to compute a first estimate of the impact of artisanal mining. If some treated places belong to the control group, or if some untreated places belong to the treatment group, due to the limitation inherent in recording artisanal mines, the effect we estimate suffers from an attenuation bias. As a further check, we use the location of the Birimian 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 of the impact of artisanal mines. The ministry also gave us access to each industrial mines' localization, yearly production, and estimated reserves.

Figure 3 shows in green the location of artisanal mines with a 10 kilometers buffer, and in red the location of industrial with a 25 kilometers buffer. When a black dot lies within a green zone it means that

we consider the households of this enumeration area as being “treated” by the artisanal mine, because they live within 10 kilometers of an artisanal mining site. As for enumeration areas within a light red zone, households of these enumeration areas live within 25 kilometers of an industrial mine that had opened by 2014.

3.2 Identification Strategy

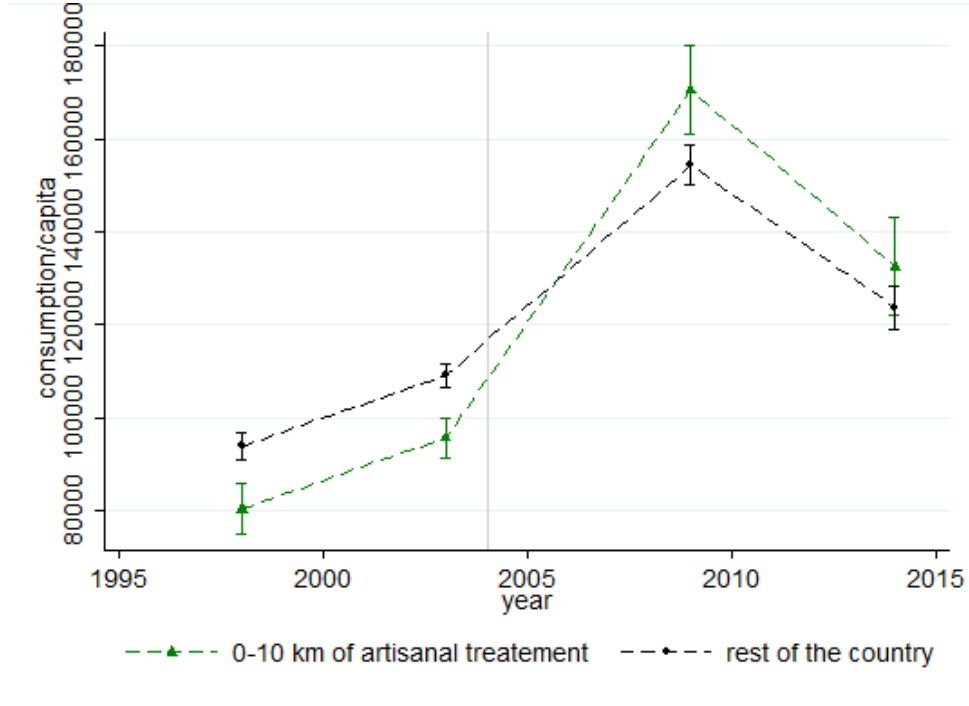
Our aim is to estimate the effect of different gold mining techniques on households’ wealth. In order to identify the effect of mining, we exploit two sources of variation: the gold price boom provides us a time varying treatment and the household distance to gold deposits provides us a source of heterogeneous exposure to potential mines. Our identification strategy is therefore a difference-in-differences based on spatial and temporal variations. In this subsection we successively explain how this allows us to identify the effect of artisanal and industrial mines.

Concerning **artisanal mining**, we identify 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 show that virtually all gold resources lie in Birimian rocks in Burkina Faso (Béziat et al., 2008). In our baseline specification we use a 10 kilometers buffer to distinguish treated and non-treated households, and use alternative distance definition in robustness checks.

The boom in the gold price provides us a time-varying treatment. More specifically, we consider two different time treatments: the log of the actual gold price, and a dummy variable taking the value of 1 after the gold price boom started (in 2009 and 2014). The idea is that the gold price is the main driver of (artisanal) mining activities since it directly determines the expected gains of the miners and their suppliers. 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. The high correlation (0.85) between the declared artisanal production and the gold price confirms this intuition. Moreover, even for a fixed work supply, the money gold diggers get for their gold is a function of the gold price.

The validity of the empirical strategy relies on the assumption that the evolution of consumption in areas far 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 starts in 2004-2006, to be in the ideal setting for a double difference, we shall observe similar trends between 1998 and 2003. Our next survey wave, 2009, already includes the effect of the gold boom. Figure 4 shows for each year the consumption trends of households located within 10 kilometers of place with a gold deposit that may be mined artisanally and those farther away. Figure 4 supports the parallel trend assumption. As we can see, pre-trends are

Figure 4: 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 of that group that year. The treated group encompasses the households living within 10 kilometers of an artisanal deposit. The control group (rest of the country) excludes treated areas and the capital city of Ouagadougou. Bars around each point represent the 95% confidence intervals.

perfectly similar, although the level of consumption was lower in areas located close to artisanal mining deposits. The trends starts to diverge between 2003 and 2009 which is consistent with our hypothesis. The consumption level of households located around artisanal mines catches up or even overtakes the consumption level of households living in the rest of the country after the boom in the gold price.

To estimate more formally the impact of artisanal mines on households' consumption we estimate equation 1:

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

C_{iwt} is the log of the per capita consumption for the household i living in village v of municipality m at time t . α is out coefficient of interest, it tells 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 is high). $\text{artisanal deposit}_v$ is a dummy variable taking the value of 1 if the household is exposed to an artisanal mine. In our baseline estimate this dummy takes the value of 1 if the household lives within 10 km of an artisanal gold deposit and 0 otherwise. X_{it} is

a set of controls. In the baseline specification, it includes age, sex and literacy of the household head, the number of household members and income earners members and a dummy for household living in rural areas. We also add sector of occupation, nature of work, electricity and water supply.¹³ 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 at the municipality level to take into account serial correlation at this level (Bertrand et al., 2004).

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

First, a bias may come from the under-declaration of artisanal mining when we use the census of registered artisanal mines. Importantly, if any contamination of the treatment by the control takes place because of an inappropriate definition of the areas with deposit, 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 rocks. As we see in figure 3, location of Birimian rocks overlap almost perfectly the location of registered artisanal mines. Birimian rocks is likely to be representative of both declared and undeclared mines, hence the contamination of control areas is likely to be small.

Second, our definition of the treatment moment is coarse, and we may consider some places as treated in 2009 and 2014 when there has actually not been any mining taking place 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.

Given that the treatment and control may contaminate each other; we believe that our results should be interpreted as a lower-bound estimate of the real effect of artisanal mines.

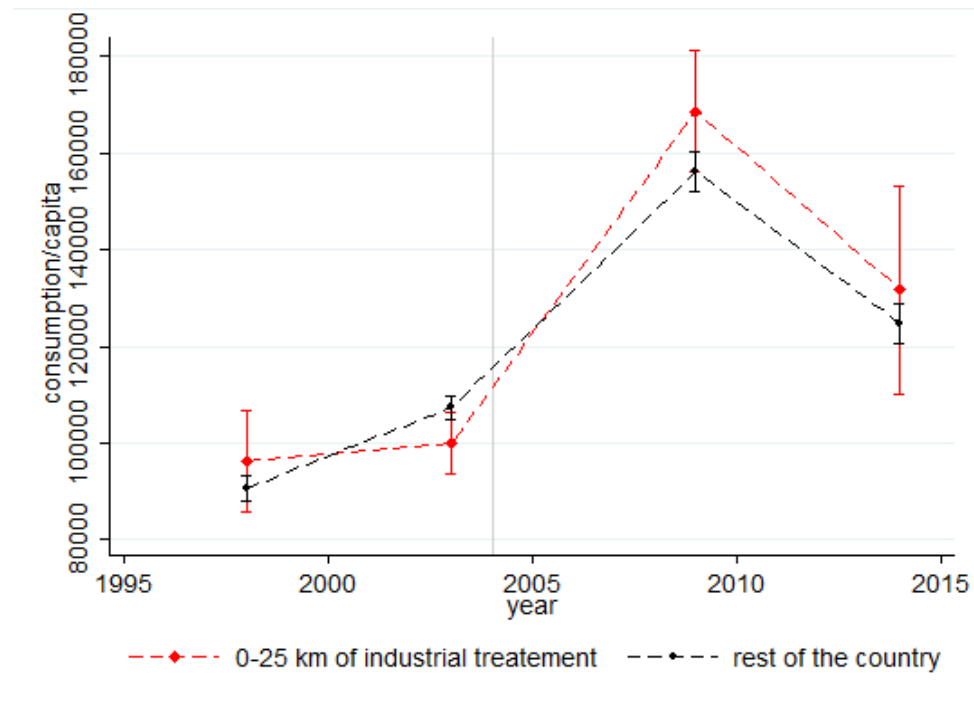
Concerning **industrial mines**, the methodology is very similar as we also use a double-difference exploiting time and spatial variations. Similar to artisanal mining, the spatial source of variation is the household distance to a gold deposit, as a source of heterogeneous exposure to a potential mine. Here, we use a 25 kilometers buffer to divide treated and untreated households.¹⁵ It implies that 498 to 768 households live within the potential treatment area for each wave of the survey.

¹³This specification is very closed to the one proposed by Aragón and Rud (2013). However, some of these variables might be seen as endogenous. We propose alternative specifications omitting these additional variables, results are similar and presented in appendix.

¹⁴Since the survey is a repeated cross-section, the municipality is the smallest geographic entity for which we can include fixed effects. Municipality fixed effects are fine grained since Burkina Faso comprises of 351 municipalities. Since one municipality encompasses several villages we account for the fact that households located close to an artisanal mine may have specific time-invariant specificities through the village specific dummy $deposit_v$.

¹⁵There is no consensus in the literature on this threshold. For instance, Aragón and Rud (2013) use a 20km buffer in Ghana, while Aragón and Rud (2016) use a 100km buffer in Peru. We choose this threshold taking into account the poor quality of roads and the scarcity of public transportations but we choose a larger buffer than for artisanal mining as the demand shock is likely to be less localized. Nevertheless, we do provide estimates using different thresholds.

Figure 5: The evolution of household consumption before and after industrial mines opening



Note: Each point represents the mean level of consumption per capita for households of that group that year. The treated group encompasses the 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 and the capital city of Ouagadougou. Bars around each point represent the 95% confidence intervals.

The time variation comes from the different years of *opening* of the industrial mines during the period of our study. As we can see in Table 1, four mines opened between the 2003 and 2009 surveys (Taparko in 2007, Kalsaka, Mana and Youga in 2008) and three mines opened between the 2009 and 2014 surveys (Essakane and Belahouro in 2010, Bissa in 2013). We also take into account the possible spillovers coming from the construction of these mines. More precisely, we assume that we can expect possible effects two years before the actual first known production.¹⁶ Indeed, the exploration and construction work are intensive in unskilled labor and mines often hire local populations at these moments.

Our identification again relies on the assumption that the effect of the mine declines with distance and that the evolution of consumption in areas far and close to an industrial mine would have been similar in the absence of the mine. Figure 5 shows consumption trends before and after the opening of new mines. 1998-2003 is the pre-trend period as almost none of the industrial mine was active over this period (neither in terms of production 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, but that these variations of trends are never statistically significant. Indeed, the levels of consumption of

¹⁶This choice is based on qualitative interviews with engineers of mining companies and experts from the BRGM. It typically takes about two years to open a mine. We use different coding of industrial mines activity, either averaging or separating the different phases of the mine activity.

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 for the existence of artisanal mines, we estimate the following equation:

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

industrial mine_t is a dummy variable taking a value of 1 when a mine is opened or in construction, 0 otherwise. $\chi + \lambda$ tells 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 of 1 if the household lives within 25 km of the deposit, 0 otherwise. Other variables are similar to the ones included in equation 1 and we again cluster standard errors at the municipality level. The year fixed effects pick any spillovers that industrial mines would have that is averaged at the national level, for example, if industrial mines pay taxes that allow the state to improve the general level of well-being of the population. The state level consequences of natural resources are the subject of a specific debate (van der Ploeg, 2011; Venables, 2016). Existing work on sub-national redistribution of taxes from resource rents in Brazil outlines that resource-induced taxes do not necessarily affect the living standard of the population, even when local authorities report spending in this direction (Caselli and Michaels, 2013). We here focus on the direct impact that industrial mines may have on populations surrounding them.

4 Results

4.1 The effects of artisanal mining

Table 3 documents the positive impact of artisanal mining on household consumption. In columns (1) and (2), we document 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 treatment, we document that a one percent increase in the gold price increases these households' consumption by 0.19% (column

Table 3: The effects of artisanal mines on households' consumption: Baseline estimates

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.: ln pc Cons.						
Artisanal deposit 10km	0.190***				0.167***	
* ln(gold price)	(0.0495)				(0.0465)	
Artisanal 10km		0.242***				0.211***
* gold price boom		(0.0660)				(0.0634)
Artisanal deposit 10km	-1.225***	-0.133***			-1.076***	-0.113**
	(0.325)	(0.0496)			(0.301)	(0.0464)
Birimian belt			0.116**		0.0463	
* ln(gold price)			(0.0477)		(0.0427)	
Birimian belt				0.152**		0.0654
* gold price boom				(0.0627)		(0.0573)
Birimian belt			-0.751**	-0.0827*	-0.293	-0.0268
			(0.310)	(0.0444)	(0.274)	(0.0406)
Observations	34,308	34,308	34,308	34,308	34,308	34,308
R-squared	0.412	0.412	0.411	0.411	0.412	0.412
P(artisanal+boom=0)		0.0100				0.0315
P(Birimian+boom=0)				0.0934		0.375

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, number of household member 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.

1). Alternatively, using a dummy variable taking value one during the gold boom (2009 and 2014), we show that during the gold boom, the consumption spending of households living within 10 kilometers of an artisanal deposit are 24% higher than the spending of households located farther away.¹⁷ 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. 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 when we take into account the positive impact of the gold boom. The net effect is about 11 percentage points.

In columns (3) and (4), we code all households living above Birimian rocks as if they were living close to a gold mine. Birimian rocks are the main gold provider in Burkina Faso, and even if we know that the area lying above Birimian rocks host both declared and undeclared gold mines as well as areas where no mining is taking place, such a coding provide a lower bound estimate of the impact of artisanal mines. Still, we again document a positive impact of artisanal mining of 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 0.12% while the net effect of living close to an artisanal deposit is about 7 percentage points. In columns (5) and (6), we include both definition of the treatment –registered

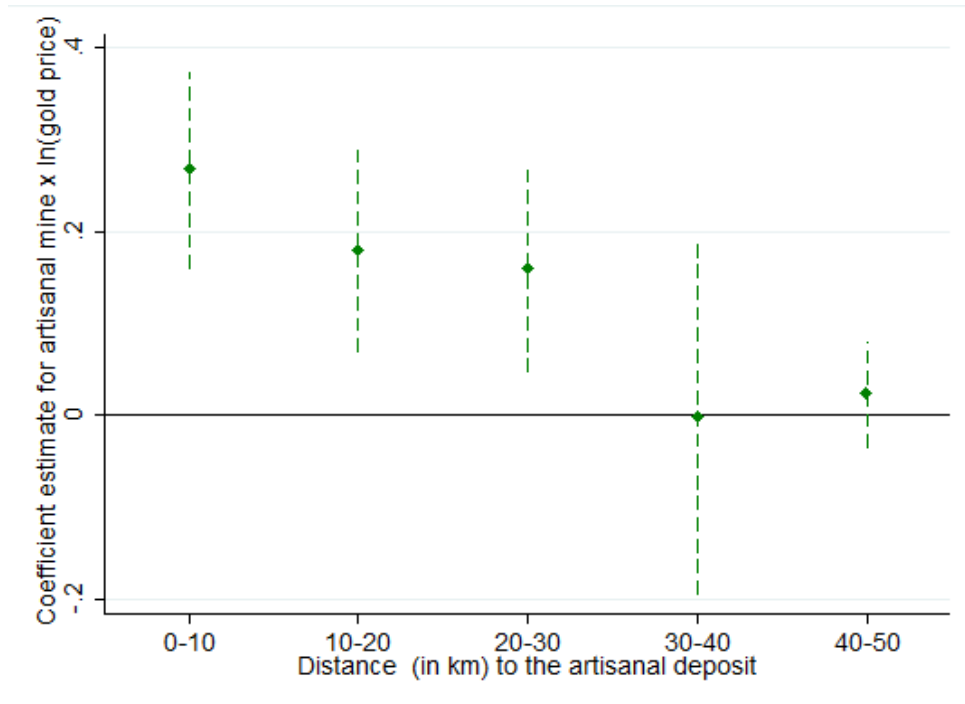
¹⁷Using year-specific dummies yield similar results shown in Appendix Table 12. We favor the specification with the boom-specific dummies as treated places in year 1999 never differ significantly from the baseline while treated places differ strongly from the baseline for both the 2009 and 2014 years (the years of the gold price boom) and their coefficients are statistically impossible to distinguish).

deposits and Birimian rocks— simultaneously. Note that the area of Birimian rocks is larger than the one of artisanal deposits but the latter are almost always located on Birimian rocks. The coefficient of Birimian rocks turns not significant while the effect of artisanal boom is still positive and strongly significant. We do believe that unregistered artisanal mines may affect local consumption. However, registered and illegal mines cohabit and following columns 5 and 6 results, the main effect of illegal mines seems to occur within the 10 kilometers footprint of registered mines. Hence, registered mines give an accurate picture of the landscape of artisanal and small-scale mines in Burkina Faso. Thus, we keep declared mines as our baseline definition of artisanal mines in the rest of the paper.

In figure 6, we show that the positive impact of artisanal mine on households' consumption remain significant up to 30 kilometers away from the artisanal mines. The figure displays the coefficient estimates of the impact of a one percent variation of the gold price on the consumption of households located close to an artisanal deposit, according to the distance between the household and the mine. The coefficient decreases with distance, which is consistent with our identification strategy. The coefficient remains positive and significant for households living within 10 to 20 and 20 to 30 kilometers of an artisanal mine. It turns not significant for household located more than 30 kilometers away from a mine. These results are consistent with a strong impact of artisanal mining, but an impact concentrated on the local area around the mine. Moreover, either the footprint of each registered mine extends up to 30 kilometers around them, or it may be the case that illegal mines are concentrated within this 30 kilometers footprint and we here compute the average impact of both illegal and legal artisanal mines. We are comfortable with both interpretations.

Results are robust to varying the definition of the treated sample, the control samples, the level of fixed effects or accounting for the dependency of the country to cotton. Beside varying the definition of treatment in Table 3 and Figure 6, we show that artisanal mining affects both rural and urban areas (appendix Table 13 columns 1 and 2). Results hold independently of other sample variations —aiming at making the treatment and control sample more comparable— be it excluding the capital city of Ouagadougou (appendix Table 13 column 3), or reducing the sample to households living within 50 kilometers of an artisanal mine (appendix Table 13 column 4). Results also hold if we include trends or year specific effect for each of the 13 regions of the country (appendix Table 13 columns 5 and 6). Lastly, results remain unaffected if we account for the country dependency toward cotton. We consider both the cotton production of each region provided by the FAO and the price of cotton provided by *indexmundi* (columns 1 and 2 of appendix Table 14 respectively), and each time 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, we can see that a 1% change in the cotton price

Figure 6: Impact of artisanal mines on consumption by distance to the deposit



Note: Each point represents the coefficient estimate for artisanal mine $\times \ln(\text{gold price})$ for households living at a certain 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 95% confidence intervals.

increases the consumption of rural households by 0.15%. It is interesting to note that the magnitude of the impact of the price of cotton on consumption is similar to the magnitude of the impact of the price of gold (for which a 1% change leads to 0.18% increase in consumption in the column 2 of appendix Table 14).

Overall, we show that the gold boom in artisanal mines had a significantly positive effect on local living standards. Before the gold boom, mining areas were poorer on average than the rest of the country. This result is important by itself as it is the first country-wide quantification of the wealth effect of artisanal mining. This result is also important because it is consistent with the literature on commons showing that common property resources provide an asset of last resort for the poor. This insurance property has been emphasized mainly for forests (Agarwal, 1990; Pattanayak and Sills, 2001; Godoy et al., 2000; Cavendish, 2000; Wunder, 2001), or land (Humphries, 1990; Chopra et al., 1990), see (Baland and Francois, 2005, p. 214-216) for an overview. As outlined in section 2.2, artisanal mines correspond to a common property management of the gold resource and our results are consistent with a positive wealth effect of this specific common on the poor.

Table 4: The effects of artisanal and industrial mines on households' consumption

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.: ln pc Cons.						
Artisanal deposit 10km	0.191***	0.192***	0.193***	0.193***	0.191***	
* ln(gold price)	(0.0491)	(0.0491)	(0.0492)	(0.0493)	(0.0490)	
Artisanal deposit 10km	-1.238***	-1.240***	-1.248***	-1.249***	-1.238***	
	(0.322)	(0.322)	(0.323)	(0.323)	(0.322)	
Industrial deposit 25km	0.124*	0.124*	0.124*	0.124*	0.123*	0.123*
	(0.0707)	(0.0707)	(0.0720)	(0.0719)	(0.0626)	(0.0659)
Industrial mine 25km	-0.0595				-0.0590	-0.0326
	(0.0696)				(0.0680)	(0.0664)
Industrial mine 25km		-0.00875				
* ln(gold price)		(0.0100)				
Major industrial mine 25 km			-0.0557			
			(0.0799)			
Minor and semi-mechanized mine 25km			-0.118			
			(0.134)			
Major industrial mine 25 km				-0.00821		
* ln(gold price)				(0.0112)		
Minor and semi-mechanized mine 25km				-0.0164		
* ln(gold price)				(0.0192)		
Mine construction 25 km					0.00412	
					(0.0986)	
Observations	34,308	34,308	34,308	34,308	34,308	34,308
R-squared	0.412	0.412	0.412	0.412	0.412	0.410
P(deposit=industrial mine)	0.352					
P(industrial deposit=mine)					0.341	0.169
P(industrial deposit=construction)					0.339	
P(industrial construction=mine)					0.607	
P(deposit= major mine)			0.349			
P(deposit= semi mechanized mine)			0.968			

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, number of household member 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.

4.2 The effects of artisanal and industrial mining

Privatization is presented as efficiency enhancing and a possible solution to the “tragedy of the commons” (Hardin, 1968). Nevertheless, this efficiency may come at a distributional cost such that the net gain isn't granted (Weitzman, 1974; Baland and Francois, 2005). Here, we have a very specific case of a privatization of a common. All industrial mines active in 2014 opened in the 2000s-2010s. Before that, 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 the gold diggers. The opening of an industrial mine therefore corresponds to a privatization of the extraction of the resource lying in these areas (Côte and Korf, 2016). By assessing the local impact of industrial mines, we are able to test whether the efficiency gains of privatization were large enough at the local level to compensate for its local distribution cost.

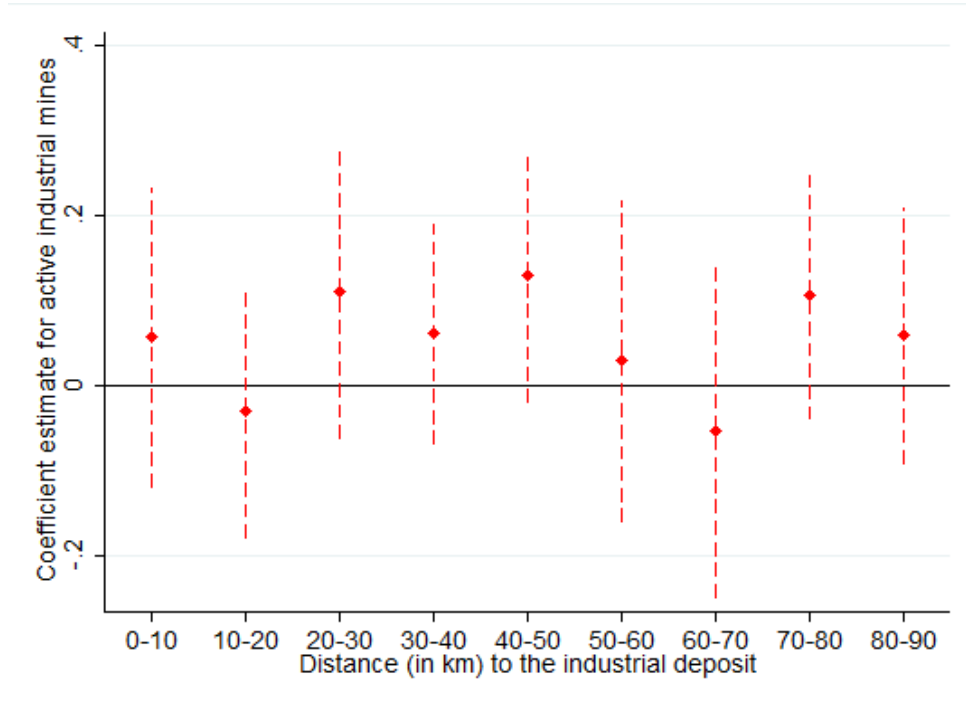
Table 4 shows the (absence of) effect of industrial mines on consumption. Throughout the table,

we control for any specificity of 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. Areas around industrial deposit appear to be slightly richer than the rest of the country. 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 mining found in the previous section is persistent throughout the table. Moreover, the magnitude of the coefficient is perfectly stable.

The absence of effect of industrial mines on households' consumption holds independently of the manner we account for industrial mines. In column (1) of Table 4, we account for industrial mines through a dummy variable equal to 1 from the year the industrial mine starts producing onward. The effect of a mine opening is not significant. In other words, households located around an industrial mine are not richer than those located farther away after the start of the mine production. In column (2), we include an interaction between the industrial mine dummy and the gold price since a high gold price translates in more profit for mines. The effect of industrial mines does not change. In columns (3) and (4), we show that the absence of effect is independent of the size of the industrial mine. We distinguish major industrial mines from smaller industrial mines (using a cutoff on mines reserves: the major mines listed in Table 1 have estimated reserves above 20 tons of gold, the other industrial gold mines we account for here have estimated reserves largely below 5 tons). In column (5), we document that mines construction, just as mines production, has no local impact on households' wealth. We account for the 2 years before a mine opening as the mine's construction period to allow a heterogeneous effect between construction and production. Indeed, the local impact of industrial mines might be concentrated during the period of construction as it is when the mine needs a lot of unskilled workforce. In column (6), 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 mine remains quite stable, independently of whether we control or not for artisanal mines. While, if anything, the coefficient of industrial mines suffers from an attenuation bias when we do not control for artisanal mines, the difference is not statistically significant. One step further, we test whether the opening of an industrial mine has an heterogeneous effect on households according to the fact that artisanal mining is also taking place or not. Given the small sample size we need to be cautious on interpreting the results (at least 500 households live around a major gold deposit each year, half of them also have an artisanal deposit nearby). We document no significant difference of the effect of opening an industrial mine for households living or not in the footprint of an artisanal mine (although the coefficient of the interaction term is of a larger magnitude than the main effect of opening indus-

Figure 7: 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 certain 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 95% confidence intervals.

trial mines, the coefficient is not precisely estimated, appendix Table 15). In an ongoing work, Ahlerup et al. (2016) document heterogeneous effects of mines on education according to the size of the mine. It would be interesting to check the impact of the interaction between industrial and artisanal mines in other settings and on other outcomes.

As previously, we also change the threshold used to define which households are close to a deposit. In figure 7, we show the estimated coefficients for different distance intervals. As we can see, the coefficient is never significantly different from zero. We can reasonably conclude that, as of 2014, the opening of new mines has not had any significant impact on household consumption at the local level.

Our results confirm the insights of the literature considering commons as an insurance: artisanal (common) mines are welfare improving while private (industrial) mines have no welfare impact. Indeed, despite very large efficiency gains from privatized gold extraction, we do not observe any impact of industrial mines on local living standards. This corresponds to a zero local multiplier (in the framework proposed by Moretti (2010) and used to analyze the local effects of industrial mining in other contexts, Aragón and Rud, 2013, 2016; Lippert, 2014; Kotsadam and Tolonen, 2016). Our interpretation of the positive coefficient of major gold deposits is that these deposits correspond to the most promising sites,

that host particularly beneficial artisanal mines before being fenced by the industrial mines (Côte and Korf, 2016). Still, because the potential positive local spillovers of the industrial mines do not allow to offset the negative impact of ending the free access to the resource for local communities, the overall impact of industrial mine is null. Industrial mines may have other benefits, that may appear in the longer run, or at a more macro level.¹⁸ Our results at least shed light on a reason why the arrival of a new industrial mine may trigger local communities discontent.

5 Discussion and Interpretations

After showing a positive effect of artisanal mining on consumption, it would be interesting to understand where this effect comes from. In the literature on the commons, the main effect comes from a direct access to the resource. Households who allocate time to gold extraction might increase their income which will have an effect on the average wealth at the local level. 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 the gold diggers Moretti, 2010; Werthmann, 2017). In this section, we explore different channels through which the effect of artisanal mines may circulate: the labor market, migration and prices. Overall, we show that households in our sample use artisanal mining as a complement to their usual activity. The likelihood that either migration or price shocks explain our results is low.

5.1 Labor market effects and seasonality

The most direct way to explain the positive effect we observe would be through changes in the labor market. Gold extraction offers new earning opportunities to local workers, which might 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 the sector (Aragón and Rud, 2013; Kotsadam and Tolonen, 2016; Aragón et al., 2016). However, Table 5 contradicts both intuitions. In column (1), we show that the probability to have any work is independent from both artisanal and industrial mining activities. In column (2), we estimate the probability to have a permanent work and still find no effect. Finally, we document no effect of mining activities on the probability to work in the extractive sector. Although Table 5 results may seem puzzling, in view of the increase in artisanal production during the gold rush, it shows that the effect of

¹⁸Although these benefits are also subject to a debate, given that mines may also a trigger or at least fuel conflicts (Berman et al., 2017; Berman and Couttenier, 2015; Vanden Eynde, Vanden Eynde), and while industrial mines clearly have structural impacts on the economy (Bonfatti and Poelhekke, 2017), their net macroeconomic impact is subject to a vivid debate reviewed in van der Ploeg (2011); Venables (2016).

Table 5: Labor market effects

Dep. Var.:	(1)	(2)	(3)
	any work	permanent position	work extractive
Artisanal 10 km	0.00111	-0.0118	0.00721
* ln(gold price)	(0.00767)	(0.0459)	(0.00559)
Artisanal 10 km	0.0108	0.0441	-0.0509
	(0.0502)	(0.292)	(0.0365)
Industrial mine 25km	0.00606	-0.00824	-0.0221
	(0.0149)	(0.0710)	(0.0242)
Industrial deposit 25km	0.0163	0.0183	0.0545
	(0.0144)	(0.0494)	(0.0502)
Observations	34,451	25,123	31,073
R-squared	0.133	0.405	0.088
P(deposit=mine)	0.243	0.873	0.268

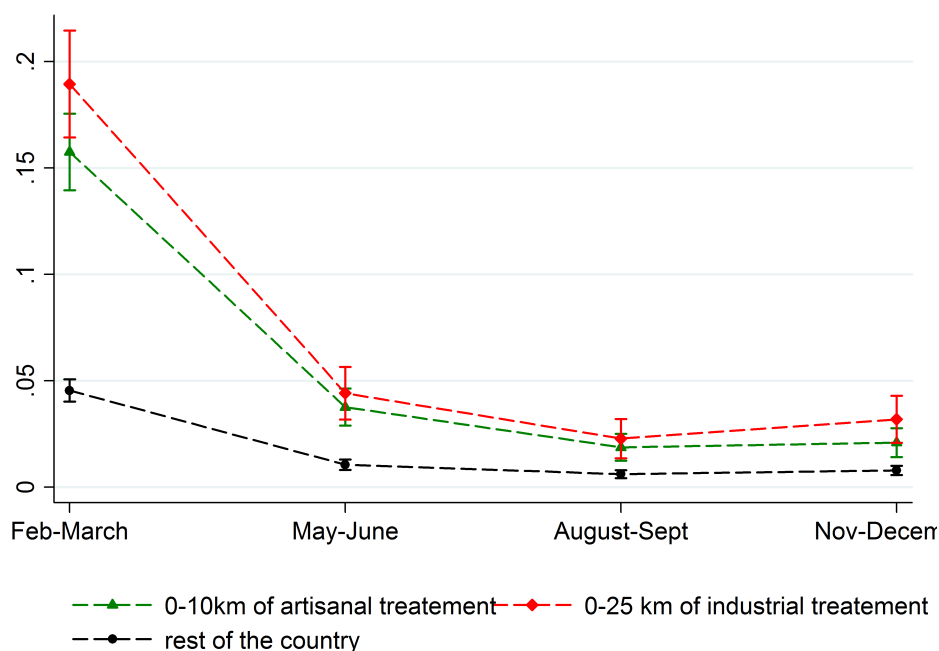
Note: All columns include municipality fixed effects, year fixed effects, and household level controls (age, sex, ability to read, number of household member and adult members, the electricity connection and main source of drinking water of the household), and a control for urban areas. Robust standard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

mining on consumption is not likely to come from a direct massive increase in job opportunities in the artisanal mines.

The exceptional features of the 2014 survey allow us to show that the apparent puzzle of Table 5 –absence of– results 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 for different moments of the year. Figure 8 shows that the share of workers in the extractive sector is highly seasonal and that most people involved in extractive activities live around mines. Extractive activities are defined such that they encompass every form of extraction, be it industrial or artisanal. The seasonality of extractive activities appears everywhere: be it around industrial mines, artisanal mines or the rest of the country. Extractive activities are concentrated in the first and to a lower extent the second period of the year. Since households were surveyed during the second and third period, when most people left the extractive sector to go back to their usual activities, it is easy to understand why we observe no impact of the gold rush on the labor market in Table 5.¹⁹ The seasonality of extractive activities has at least two causes. First, artisanal mining activity takes place at the moment when there is nothing to do in the fields (Jaques et al., 2005), and the rainy season, marking the beginning of the seeding period, starts in May for most of the

¹⁹The 1998 and 2003 surveys took place around the second period while the 2009 survey took place around the third period. For consistency, all results presented for the period 1998-2014 in this article rest on data for the second period of 2014. Results are robust to using the third quarter of 2014. We do not know where gold-diggers practice their activity, but it seems clear that seasonal gold diggers are strongly accumulated around gold deposits, be them under the concession of industrial or artisanal mines. Yearlong gold diggers are way less numerous and it is not clear whether they bypass the government ban by staying in Burkina Faso or migrate in 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 is 17.6 million in 2014, 3.3 million of whom live within 10 kilometers of an artisanal deposit.

Figure 8: 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 them artisanal or industrial. 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 and the capital city Ouagadougou. Bars around each point represent the 95% confidence intervals.

country.²⁰ Second, because the peak of the rainy season puts artisanal mines at danger of collapsing, the government forbids artisanal activities between June and October (although there are evidence that the interdiction is not always followed it clearly decreases the extent of the activity Compaoré, 2011). In either case, one important implication of Figure 8 is that mining does not appear to lead many households to abandon definitively other activities such as agriculture. Rather, mining activities appear to be a seasonal complement to pre-existing activities. Moreover, mining is mainly practiced by households who live close to artisanal mines: appendix Figure 11 shows that the probability to work in the extractive sector decreases quickly with the distance to the mine.

Finally, we document how the gold rush benefited households in certain sectors of activity while leaving others unaffected. Table 6 displays results for sub-samples defined by whether any household member works in the following sectors: agriculture, extractive industries, services, trade or public sec-

²⁰Of 65 places with records 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/>). To check that this inter-region variation in the moment of the rainy season does not affect our results, we show that they are unaffected by the omission of each region in a row. Appendix In particular, the entire Sahel region is the one where the rainy season starts only in June. However, omitting each region in a row leaves our results unchanged as shown in Appendix Table 16.

Table 6: Heterogenous effect according to households members occupation

	(1)	(2)	(3)	(4)	(5)
Sample: any hh member works in Dep. Var.: ln pc Cons.	agri	extractive	services	trade	public sector
Artisanal deposit 10 km	0.124***	-0.105	0.269**	0.247**	0.0758
* ln(gold price)	(0.0383)	(0.255)	(0.117)	(0.108)	(0.152)
Artisanal deposit 10 km	-0.794***	0.919	-1.512*	-1.603**	-0.492
	(0.252)	(1.745)	(0.785)	(0.734)	(1.016)
Industrial mine 25km	-0.0993	0.507	0.209	-0.207	-0.265
	(0.0724)	(0.331)	(0.176)	(0.129)	(0.274)
Industrial deposit 25km	0.129*	-0.419	0.192	-0.0517	0.477*
	(0.0703)	(0.536)	(0.180)	(0.138)	(0.287)
Observations	25,159	381	4,579	5,839	3,477
R-squared	0.187	0.444	0.145	0.128	0.121
P(deposit=mine)	0.672	0.864	0.111	0.125	0.414

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.

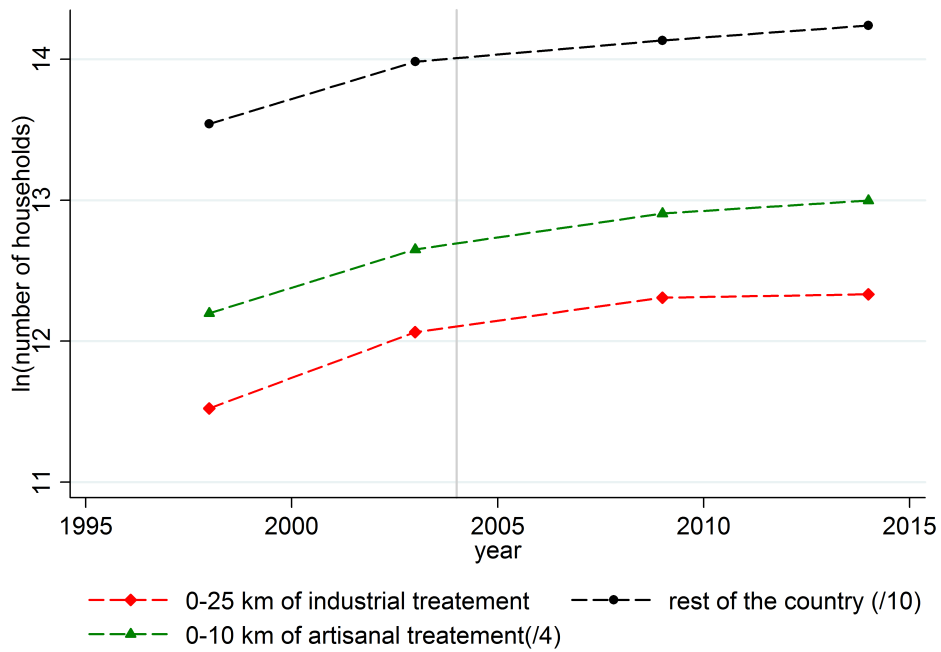
tor. The artisanal gold rush has heterogenous effects according to households' sector of activity while industrial mines have not significant impact.

Households who benefit the most from the artisanal gold boom are households able to either diversify their income by practicing gold digging part time, or to answer to the demand shock created by the gold boom (answering gold diggers demand in goods and services). These households are the ones where at least one member work in agriculture, trade, or services (columns 1, 3 and 4 of Table 6). The magnitude of the effect is particularly strong for households in trade and services (columns 3 and 4), this difference in magnitude is consistent with an interpretation of our results in terms of local spillovers, where the gold boom benefits households who answer to the demand shock induced by gold diggers.

Public servants offer us the perfect counter-factual (Table 6 column 5). They have full time formal jobs, hence neither the time nor a need to go gold digging. Moreover, their pay is fixed by the State. Hence it makes sense that their consumption level does not change with the gold price, no matter how close they live from an artisanal mine.

Lastly, the artisanal mining boom does not significantly impact households related to the extractive sector. These are households where at least one member practices an extractive activity outside the main period of artisanal mining. Although we have to be cautious on the interpretation of this result due to the low number of observations, we can think of two reasons why the gold boom does not affect these households. First, column (2) encompasses employees of the 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 may encompass some full-time gold diggers, in which case it means gold diggers don't receive a significant share of the increase in benefits induced by the gold boom (which rather go to intermediaries and local traders, consistent with columns 3 and 4 results and Côte and Korf, 2016).

Figure 9: Evolution of the population of Burkina Faso



Note: Each point represents the total population in this area (with some scale transformations). The treated groups encompass 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 and the capital city Ouagadougou.

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 wealth around artisanal mines would not be the result of a wealth increase as such, but the effect of a population change. However, several observations are inconsistent with this interpretation.

First, Figure 9 shows that the population growth has a similar pace around mines and in the rest of the country. To do so, 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. Figure 9 shows that the artisanal gold rush does not induce any significant inflow of permanent population.

Second, we can go further and show that not only the absolute number of households, but also their characteristics, are barely affected by the artisanal gold boom. In Table 7, we check whether migration within the extended family has increased. The gold boom does not affect the size of households, nor their sex composition or level of education (columns 1, 4 and 5). The artisanal mining boom seems to slightly increase the share of kids in a household while leaving the share of young unaffected (columns 2 and 3).

Table 7: Effects on households composition

Dep.Var.:	(1)	(2)	(3)	(4)	(5)
	nb household members	share kid	share young	share male	share can read
Artisanal deposit 10 km	-0.106	-0.0147*	-0.0101	0.00927	-0.00422
* ln(gold price)	(0.196)	(0.00818)	(0.00826)	(0.00767)	(0.0160)
Artisanal deposit 10 km	0.713	0.0947*	0.0625	-0.0628	0.0129
	(1.292)	(0.0497)	(0.0528)	(0.0505)	(0.106)
Industrial mine 25 km	0.0448	0.0157	0.000932	0.00190	-0.0229
	(0.444)	(0.0317)	(0.0131)	(0.0103)	(0.0269)
Industrial deposit 25 km	-0.0950	-0.0163	-0.00603	0.00178	-0.00432
	(0.381)	(0.0220)	(0.0149)	(0.0111)	(0.0220)
Observations	34,657	34,420	34,420	34,657	34,648
R-squared	0.103	0.026	0.037	0.026	0.342
P(deposit=mine)	0.914	0.981	0.763	0.687	0.319

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.

Overall, the little impact of the gold boom on households' characteristics is restricted to increasing the number of child, a result inconsistent with a self-selection of rich individuals into migration to mining places.

In interpreting Figure 9 and Table 7 results, it is important to keep in mind that artisanal mining is a seasonal activity (as we saw in Figure 8). 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 the 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.²¹ 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 to assess whether the mining boom affects local prices. Indeed, all our estimates correspond to nominal consumption figures and the local demand shock induced by the gold boom might affect local prices, leading to an increase in nominal consumption that would not reflect the real consumption level. We are unfortunately not able to compute price indexes for all our survey dates. However, several observations make us confident that we capture the real impact of the artisanal gold boom on consumption rather than its nominal impact.

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

²¹And that any money they send back to their family will increase these family consumption, creating another source of attenuation bias of our estimates since some families that we consider as "untreated" actually benefit from the gold boom thanks to the remittances of migrant gold diggers.

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 servant to the trader, since everyone faces similar prices. Instead, the fact that in Table 6, the artisanal gold boom affects consumption only for households who are able to either directly or indirectly participate in gold digging activities is consistent with an increase of the real consumption of these households (the consumption of public servant is unaffected by the artisanal gold rush).

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 poor because then it is closer to subsistence consumption. In Burkina Faso, according to the World Bank, 44% of the population lives with less than 1.90 dollar a day in 2014 (2011 PPP), and the poverty rate reached 82% in 1998, the starting year of our study. With such a poverty rate, if prices were increasing, many households would need to re-allocate their spending to ensure a minimum food intake.

Table 8 shows that the spending shares of households living around mines or in the rest of the country do not evolve differently at the moment of the gold price boom or the opening of an industrial mine. This essential result remains true for the entire sample or when we restrict it to urban or rural places only, or use the dummy of the gold boom to define the treatment instead of the continuous log of the gold price.²² Table 8 means that the food spending shares of households living around artisanal mines do not surge with the gold price, an observation inconsistent with a surge in local prices. Thus, it seems unlikely that the significant changes in consumption patterns that we observe after the artisanal gold rush in Figure 4, Table 3 and Figure 6 stem from a pure nominal impact of mining on local prices. Rather, results are consistent with a persistent increase in households' wealth, when the gold price is high, for households living around artisanal sites.

One possible interpretation of 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 shall stop with their departure. We saw in Figure 8 that the peak of artisanal

²² A surprising feature Table 8 is the sign of the consumption variable: at the opposite of Engel's law. We investigate further what happens with disaggregated results year by year in Appendix Table 17. We can see that during years 1998, 2003 and 2014 the share of consumption dedicated to food is a negative function of the level of consumption, the reverse is true only for year 2009. What is essential for us here: we also can see that living close to an artisanal deposit has no impact on consumption during 3 out of 4 periods. When living close to an artisanal mine affects consumption spending, during the year 2003, it actually *decreases* consumption (column 2 of Table 17). A negative relation between the share of spending dedicated to food and the presence of an artisanal mine is inconsistent with a high level of prices around mining sites (if anything it could be interpreted as a lower level of prices in these areas during the year 2003). The same is true for living close to a major gold deposit: if anything, prices may have been lower there than in the rest of the country during the year 1998 while there is no significant difference after an industrial mine opens (as coefficient on mine and deposit partial out).

Table 8: Food spending do not evolve following the gold boom

Household sample:	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var. : share of food spending in total consumption	all	rural	urban	all	rural	urban
Artisanal deposit 10 km	0.0129	0.0137	0.0127			
* ln(gold price)	(0.00978)	(0.0106)	(0.0211)			
Artisanal deposit 10 km				0.0197	0.0168	0.0131
* gold price boom				(0.0131)	(0.0146)	(0.0265)
Artisanal deposit 10 km	-0.0823	-0.0864	-0.142	-0.0103	-0.00711	-0.0673
	(0.0650)	(0.0703)	(0.155)	(0.0124)	(0.0128)	(0.0413)
Industrial mine 25km	-0.0207	-0.0104	-0.0125	-0.0205	-0.00995	-0.00930
	(0.0199)	(0.0205)	(0.0432)	(0.0198)	(0.0205)	(0.0420)
Industrial deposit 25km	-0.00442	-0.0109		-0.00444	-0.0108	
	(0.0161)	(0.0171)		(0.0162)	(0.0172)	
ln pc. Cons.	0.0203***	0.0235***	0.0136**	0.0202***	0.0235***	0.0136**
	(0.00317)	(0.00386)	(0.00661)	(0.00316)	(0.00386)	(0.00660)
Observations	34,544	22,677	11,867	34,544	22,677	11,867
R-squared	0.294	0.224	0.171	0.294	0.224	0.171
P(deposit=mine)	0.119	0.251	0.773	0.121	0.260	0.826

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

mining takes place in winter while the different survey we use record consumption in spring or summer. Thus, if the presence of migrant gold diggers induces tension on local prices, this tension is already relaxed at the moment of collection of our consumption data.

Another complementary interpretation is that the artisanal gold boom has a negligible impact on the prices of everyday consumption items during most of the year. Indeed, we can show that the share spent on food through the different semesters of 2014 perfectly follows the logic of Engel: the higher the level of consumption the lower the share of spending allocated to food, no matter whether the place is a mining place or not, for three out of four survey periods. Estimates of consumption level and spending shares widely overlap across places within each period of survey while they widely diverge across time (consistent with the fact that the winter season is the moment of the gap between agricultural seasons, appendix Figures 13 and 14; while Figure 15 provides a general overview of consumption by season). It still could be the case that there is a price difference between places close to mines – be them industrial or artisanal – and the rest of the country in winter. Indeed, Figure 14) shows a significant difference in food spending shares of about three percentage points while the levels of consumptions are similar (Figure 13). However, this difference is small. Moreover, and more importantly, our main results rest on data collected outside winter, and are thus unaffected by this potential winter-specific difference.

Lastly, in table 9, we show additional evidence supporting the idea that our results are not driven by changes in local prices. In column (1), the dependent variable is the answer to the following question: “What is the minimum income level you would need to fulfill your basic needs?”. If there were a boom

Table 9: Additional proxies of living standards

Dep. Var.:	(1) ln(minimum income)	(2) ln(rent)	(3) alimentation issue
Artisanal deposit 10 km	-0.00160	0.131	0.0288
* ln(gold price)	(0.0700)	(0.0913)	(0.0293)
Artisanal deposit 10 km	0.0655	-0.881	-0.208
	(0.470)	(0.608)	(0.196)
Industrial mine 25km	-0.0810	0.356***	0.0146
	(0.0948)	(0.0787)	(0.0323)
Industrial deposit 25km	0.0373	-0.0709	-0.0640
	(0.0725)	(0.0798)	(0.0416)
Observations	26,822	33,980	43,169
R-squared	0.345	0.875	0.200
P(deposit=mine)	0.609	0.000236	0.275

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 2009 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. alimentation issue is a dummy taking value 1 if the household answered yes to the question “Did you face difficulties to fulfill food households 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, number of household member 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.

in local prices (compared to the prices in control areas), we would expect a positive and significant coefficient for the artisanal boom. It is not the case, the coefficient is not significant. In the second column, we calculate the impact on rents. 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, the dependent variable is the answer to the following question: “Did you face difficulties to fulfill food households needs during the last year”. The result is not significant. We should note however that the share of household stating they had difficulties have fallen tremendously between 2003 - 2009 (where more than 60% of households said they had difficulties) and 2014 (where there were 30%). Most of the variation is however captured by time fixed effects and we do not detect significant differences of the evolution of these difficulties between control and treated areas.

5.4 Effects on health and education

While the focus of this article is on consumption patterns as a signal of wealth, it can be interesting to investigate the impact of artisanal and industrial mines on the two other main dimensions of human development, namely, health and education. Artisanal mining has a bad reputation in both dimensions while scholar have documented ambiguous effects of industrial mines (Aragón and Rud, 2016; Ahlerup et al., 2016; Corno and de Walque, 2012; Hilson, 2006). We are not perfectly equipped to investigate these aspects that each would deserve a dedicated study but we can at least show what our data tell us.

In Table 10, we investigate the evolution of the probability to be sick for households living next

Table 10: Health effects: the probability to be 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	0.00346	0.00450	-0.0219***	-0.0183**	0.0110
* ln(gold price)	(0.0110)	(0.00759)	(0.00814)	(0.00858)	(0.0109)
Artisanal deposit 10 km	-0.0265	-0.0264	0.140***	0.113*	-0.0728
	(0.0707)	(0.0488)	(0.0537)	(0.0579)	(0.0723)
Industrial mine 25km	0.0300	0.0235	0.0121	0.00220	0.0448**
	(0.0260)	(0.0144)	(0.0152)	(0.0175)	(0.0220)
Industrial deposit 25km	-0.00340	0.00991	0.00162	-0.00155	-0.00447
	(0.0171)	(0.0105)	(0.0110)	(0.0157)	(0.0145)
Observations	33,893	117,847	35,103	39,882	48,594
R-squared	0.047	0.031	0.034	0.041	0.051
P(deposit=mine)	0.313	0.00734	0.347	0.973	0.0273

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.

to artisanal and industrial gold mines. The only health proxy we have in our panel data is the answer to the question “have you been sign 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 increases the capacity of households to take care of their health. However, artisanal mine display terrible working condition and use polluting substances such as mercury, which might have a negative effect on health (contributing to the bad reputation of artisanal mines). 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 their spending, but these mines may also heavily pollute (Aragón and Rud, 2016). Overall, we document a significant improvement in the health of 6 to 16 years old children during the artisanal gold boom (columns 3 and 4). Industrial gold mines do not appear to improve significantly the health outcome of populations in their surrounding, if anything, they seem to decrease the health of 0 to 5 years old children (column 5).

Finally, we investigate the possible effects on education. Once again, expected results are ambiguous. The income effect increases school enrollment, while the increase of job opportunities (especially for the low-skilled for artisanal mining) reduce the incentive to attend school. Artisanal mines are a usual suspect of increasing school dropouts (Ahlerup et al., 2016). In table 11, we document the effect of mining activities on the probability to be at school for different household members. We find no effect of the artisanal boom for children between 0 to 16, knowing that school is compulsory from 6 to 16 in Burkina Faso. We do observe a fall of school enrollment for individuals above 16 years-old during the artisanal gold rush. A one percent increase in the gold price reduces the probability to be at school by 0.008% in areas closed to artisanal mines. The effect is rather limited and should be replaced in a context of a very low school enrollment above 16 years old in general. We do find that the opening of industrial

Table 11: Education effects: the probability to be at school

Sample	(1) household head	(2) above 16 years old	(3) 11 to 16	(4) 6 to 10	(5) 0 to 5
Dep. Var: education ongoing					
Artisanal 10 km	0.00390	-0.00810**	0.0237	0.0221	-0.0324
* ln(gold price)	(0.00270)	(0.00362)	(0.0285)	(0.0227)	(0.0216)
Artisanal deposit 10 km	-0.0249	0.0540**	-0.168	-0.133	0.184
	(0.0177)	(0.0236)	(0.188)	(0.150)	(0.143)
Industrial mine 25km	0.00533	-0.00574	0.0378	0.0639**	-0.0463
	(0.00592)	(0.00919)	(0.0427)	(0.0316)	(0.0289)
Industrial deposit 25km	-0.00573	-0.00579	-0.0122	-0.00246	0.0174
	(0.00386)	(0.00652)	(0.0316)	(0.0252)	(0.0214)
Observations	34,533	118,536	35,964	39,984	7,433
R-squared	0.030	0.066	0.194	0.203	0.188
P(deposit=mine)	0.951	0.158	0.489	0.0555	0.313

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.

mines increase the probability for children between 6 and 10 years-old to be at school. The later effect is consistent both with corporate responsibility investment in education made by industrial mines, or with the idea that seeing formal jobs and expatriate workers in the formal mine may lead pupils and parents to re-evaluate the benefits of education (Ebeke et al., 2015).

6 Conclusion

This paper takes advantage of a quasi-natural experiment to provide the first country-wide analysis of the wealth impact of common *versus* private property management of a natural resource. We show that the common property management of artisanal mines significantly increases households' consumption. For households living around artisanal mines, a one percent change in the gold price increases households' consumption by 0.2%. Overall, we estimate that the 2009-2014 boom in the gold price increases consumption by about 8 cents of euros per day and person for people living around artisanal mines. This additional consumption is economically significant, given that the average household member in our sample consumes 55 cents in euros on an average day. In comparison, despite the huge amount of wealth generated by private industrial gold mines from the country's perspective, the opening of these mines has not yet generated enough backward linkages at the local level to significantly affect households' consumption. These results are robust, in particular, results are unaffected by changes in the size of the treatment and control groups (varying distance buffers to define each group or using geological information) or changes in the definition of the time treatment (defined with the world gold price or a dummy for the moment of the price boom).

Consistent with the literature on commons, the production processes in common property artisanal

mines are less efficient than in the privatized industrial mines. Yet, consistent with the literature focused on the distributive consequences of privatization, we document that artisanal mines have a positive wealth effect while we do not document any local wealth effect of industrial mines. Our results thus align particularly well with the theoretical prediction of (Baland and Francois, 2005)

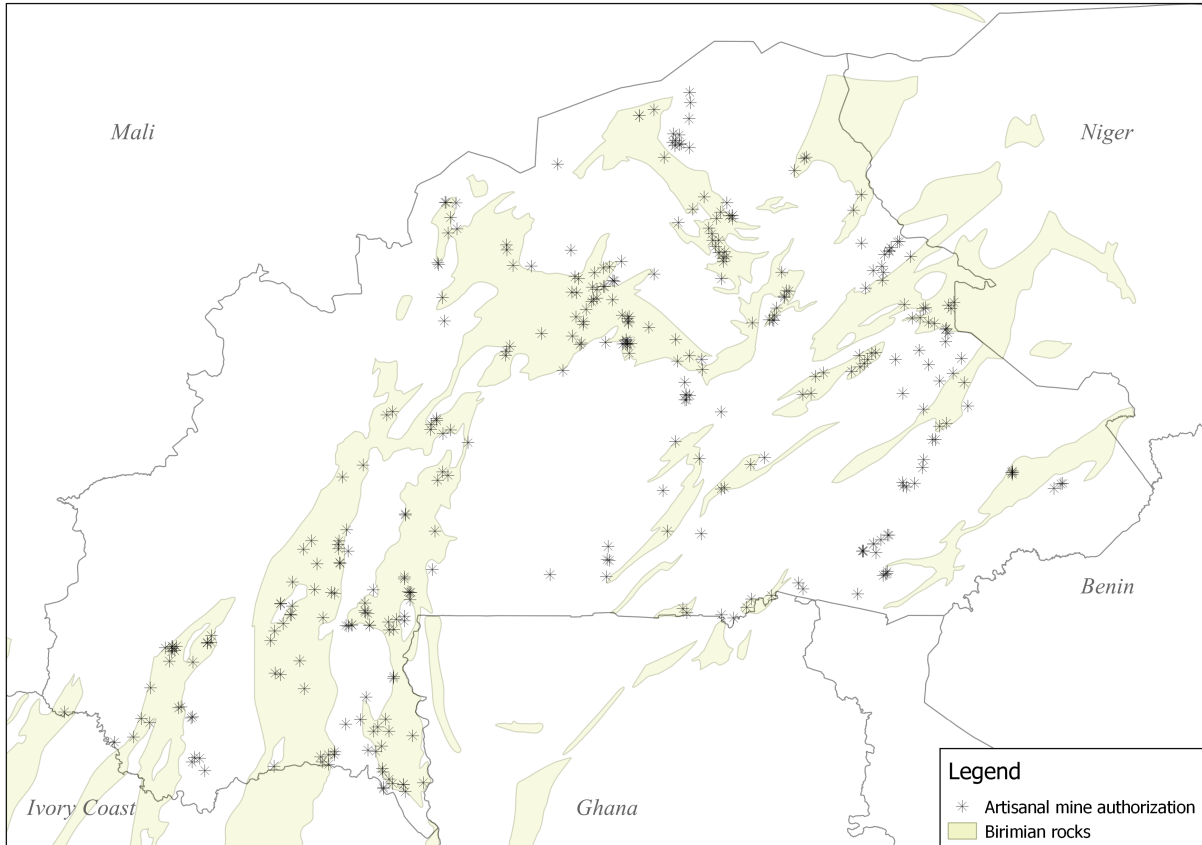
Moreover, our results complement the literature on the local impact of extractive activities in two important manners. First, we are the first paper to directly and empirically assess the impact of artisanal mining on wealth with nationally representative data. Second, we show that omitting artisanal mines from our econometric estimates (as is the case in almost all of the literature on the local impact on industrial mines) does not affect our estimates for industrial mines: independently of the specification, opening an industrial gold mine does not affect local wealth.

These results are important for both researchers and policy makers. Indeed, violent protests by local communities may lead to an important waste of resources, such as the millions of euros that vanished into flames in Karma in January 2015. Yet, artisanal and industrial gold mines typically target neighboring but not completely overlapping area, leaving room to improve cohabitation between the two, if we believe in the insurance properties of artisanal mines.

7 Appendix

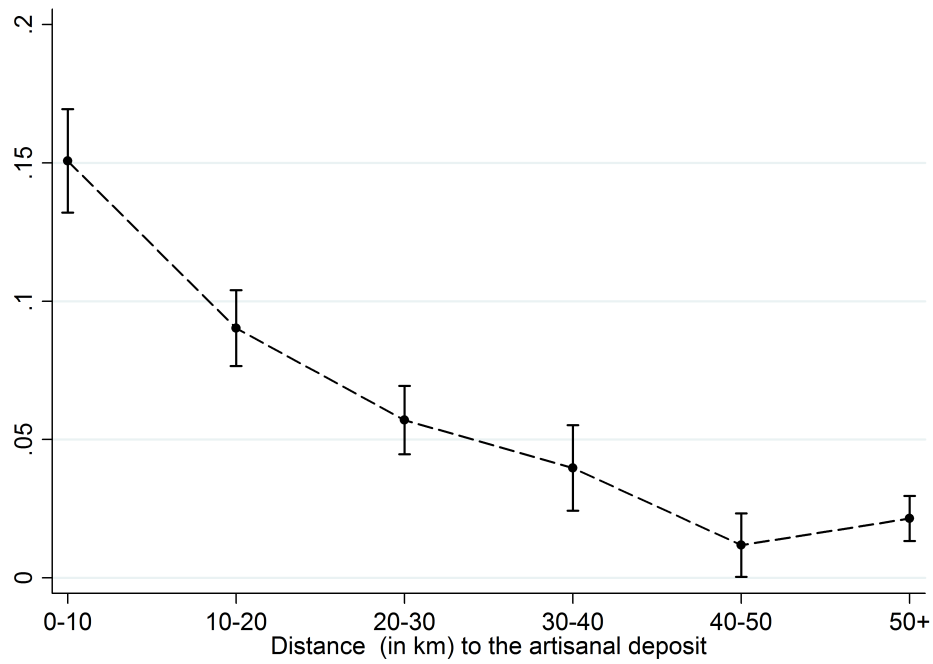
7.1 Appendix figures

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



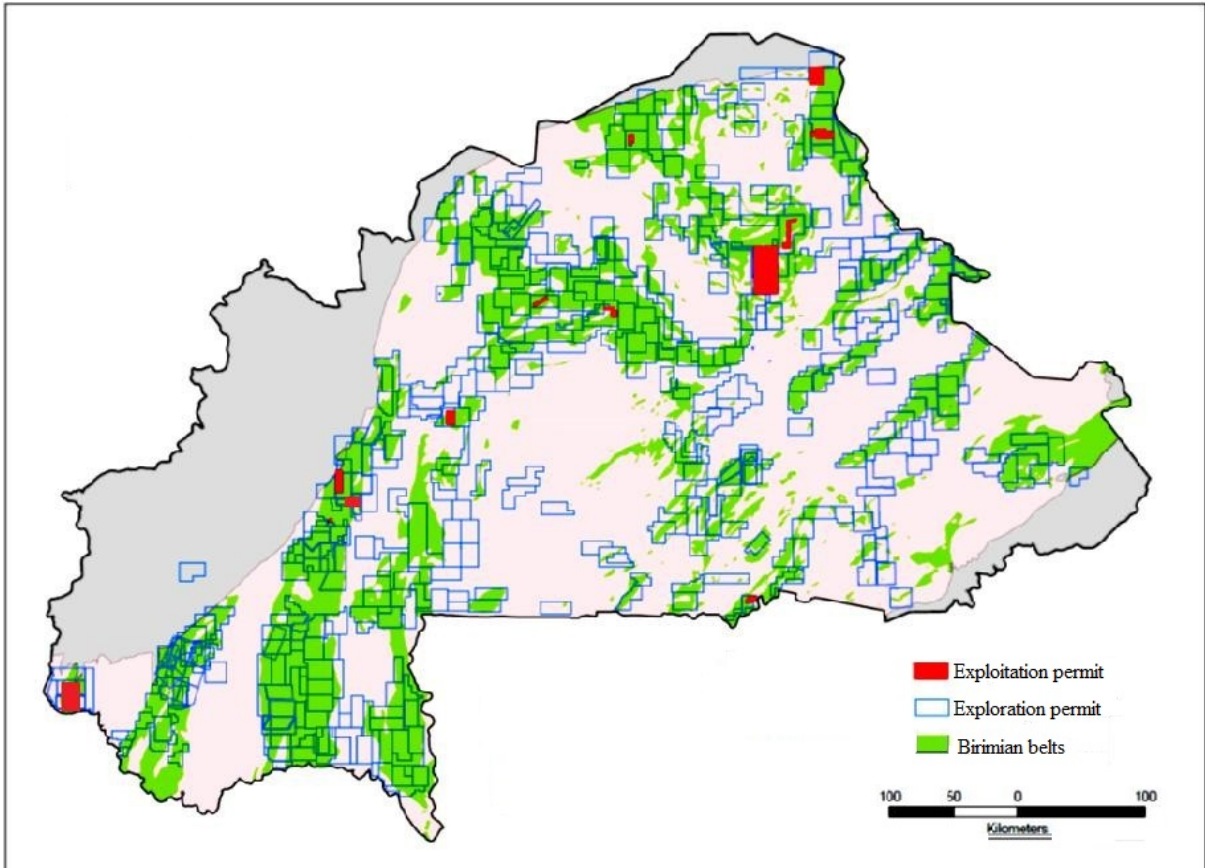
Note: authors' calculation

Figure 11: The probability that the household head works in extractive activities decreases with the distance to artisanal mines



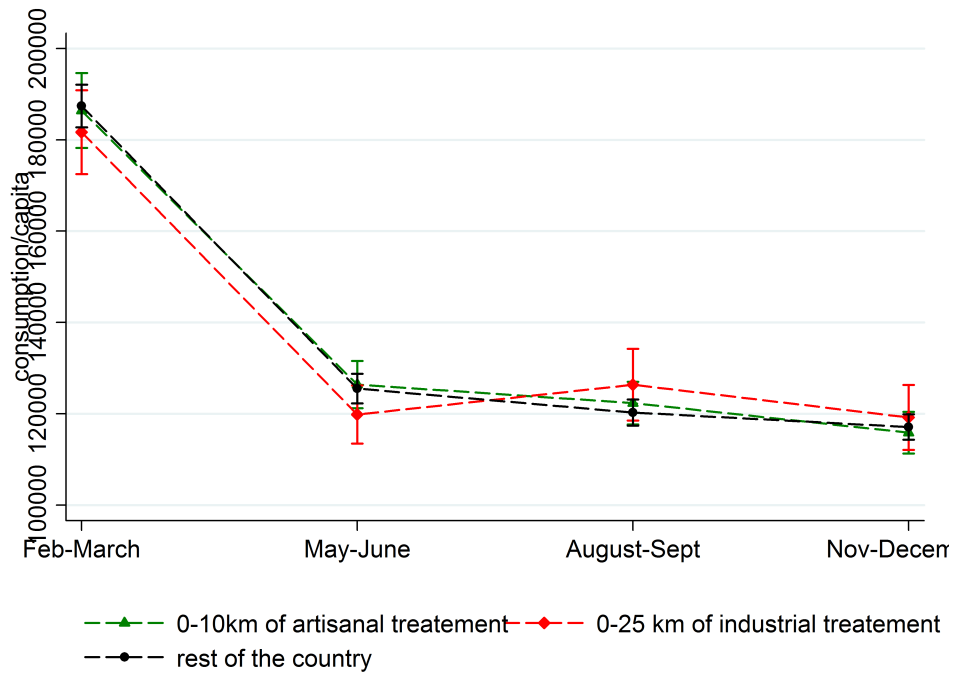
Note: Each point represents the share of household heads who are involved in the extractive sector in the 1st period of survey in 2014 (February-March), according to the distance of the household to an artisanal mine. The extractive sector encompasses all forms of extraction, be them artisanal or industrial.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

Figure 12: The overlap of Biriminan greenstone belts and industrial exploration permits



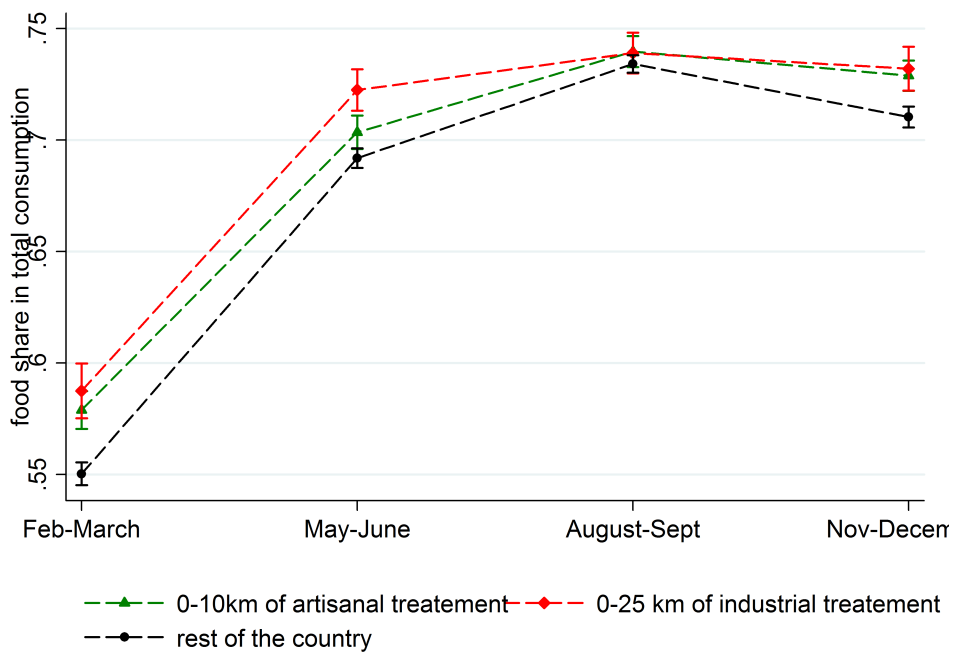
Note: source: <http://www.burkina-emine.com>

Figure 13: Consumption spending by seasons in 2014



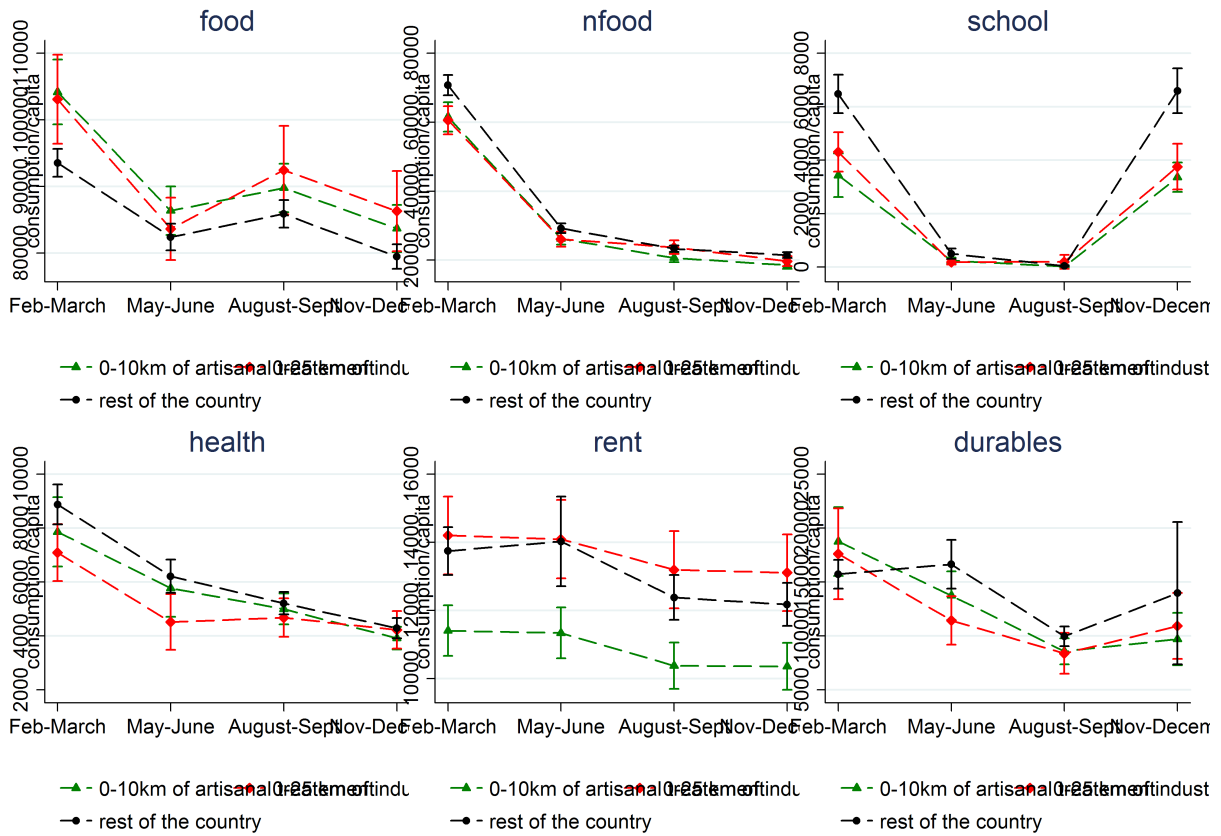
Note: Each point represents average per capita consumption for each period and location. The treated groups are defined spatially and encompass either households living either within 10 kilometers of an artisanal deposit, or households living within 25 kilometers of a deposit that will host an industrial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

Figure 14: Share of food in consumption spending by seasons 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 and the capital city Ouagadougou. Bars around each point represent the 95% confidence intervals.

Figure 15: Evolution of spending by item and seasons 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 and the capital city Ouagadougou. Bars around each point represent the 95% confidence intervals. Results are consistent with an increase in absolute spending for almost every aspects of consumption in winter even if the increase is not equally distributed among items (explaining why the share of spending on food is smaller in winter than in other seasons).

7.2 Appendix tables

Table 12: Year specific reaction of places close to artisanal mines.

	(1)	(2)
Dep. Var.: ln pc Cons.		
Artisanal deposit 10km	-0.158** (0.0616)	
Artisanal deposit 10km*year 2003	0.0407 (0.0515)	
Artisanal deposit 10km*year 2009	0.283*** (0.0998)	
Artisanal deposit 10km*year 2014	0.253*** (0.0714)	
Birimian belt		-0.0675 (0.0497)
Birimian belt*year 2003		-0.0241 (0.0377)
Birimian belt*year 2009		0.148* (0.0890)
Birimian belt*year 2014		0.127* (0.0659)
Observations	34,308	34,308
R-squared	0.412	0.411

Note: All columns include municipality fixed effects, year fixed effects, and household level controls (age, sex, ability to read, number of household member 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: Robustness to the definition of the control area and the level of fixed effects.

Dep. Var.: ln pc Con	(1) samples		(3) excluding observations from Ouagadougou	(4) areas more than 50 km of an artisanal deposit	(5) including in the specification region specific time trends		(6) region*year specific effects
	only rural	only urban					
Artisanal deposit 10 km	0.121*** (0.0407)	0.180*** (0.0521)	0.155*** (0.0463)	0.161*** (0.0498)	0.147*** (0.0370)	0.140*** (0.0335)	
* ln(gold price)							
Artisanal deposit 10 km	-0.780*** (0.266)	-1.161*** (0.357)	-0.998*** (0.303)	-1.037*** (0.327)	-0.942*** (0.237)	-0.905*** (0.216)	
Observations	22,541	11,767	30,502	28,264	34,308	34,308	
R-squared	0.336	0.436	0.367	0.384	0.419	0.425	

Note: All columns include municipality fixed effects, year fixed effects, and household level controls (age, sex, ability to read, number of household member 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)
Dep. Var: ln. pc. Cons.		
Artisanal deposit 10 km	0.191***	0.184***
* ln(gold price)	(0.0489)	(0.0476)
Artisanal deposit 10 km	-1.233***	-1.187***
	(0.321)	(0.311)
cotton production	-0.01000	
	(0.00773)	
rural * cotton production	0.0114	
	(0.00802)	
rural * cotton price		0.150*
		(0.0842)
Observations	34,308	34,308
R-squared	0.412	0.412

Note: All columns include municipality fixed effects, year fixed effects, and household level controls (age, sex, ability to read, number of household member 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: The effect of industrial mines opening for households living close to an artisanal mine

	(1)
Dep. Var: ln. pc. Cons.	
Artisanal deposit 10 km	0.197***
* ln(gold price)	(0.0522)
Artisanal deposit 10 km	-1.260***
	(0.342)
Industrial mine 25km	-0.0355
	(0.0889)
Industrial deposit 25km	0.150**
	(0.0758)
Artisanal deposit * ln(goldprice)	-0.102
* Industrial mine 25km	(0.0784)
Artisanal deposit 10 km	-0.00885
* Industrial deposit 25km	(0.0174)
Observations	34,308
R-squared	0.413

Note: All columns include municipality fixed effects, year fixed effects, and household level controls (age, sex, ability to read, number of household member 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 16: Excluding one by one each of the 13 regions (one region excluded per column)

Dep. Var: ln. pc. Cons.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Artisanal deposit 10 km	0.196*** (0.0521)	0.188*** (0.0504)	0.219*** (0.0478)	0.172*** (0.0459)	0.193*** (0.0525)	0.197*** (0.0507)	0.155*** (0.0465)	0.191*** (0.0519)	0.179*** (0.0519)	0.210*** (0.0523)	0.189*** (0.0521)	0.189*** (0.0506)	0.201*** (0.0536)
* ln(goldprice)	-1.261*** (0.342)	-1.215*** (0.328)	-1.442*** (0.314)	-1.134*** (0.303)	-1.259*** (0.345)	-1.266*** (0.333)	-1.003*** (0.305)	-1.232*** (0.340)	-1.179*** (0.337)	-1.359*** (0.344)	-1.210*** (0.341)	-1.201*** (0.333)	-1.303*** (0.351)
Artisanal deposit 10 km	-0.0480 (0.0767)	-0.0597 (0.0701)	-0.0550 (0.0725)	-0.0176 (0.0758)	-0.122 (0.0792)	-0.0548 (0.0706)	-0.0657 (0.0694)	-0.0474 (0.0699)	-0.0795 (0.0681)	-0.0810 (0.0835)	-0.0603 (0.0700)	-0.0288 (0.0669)	-0.0597 (0.0714)
Industrial mine 25km	0.131* (0.0725)	0.122* (0.0729)	0.138* (0.0728)	0.154** (0.0777)	0.141* (0.0823)	0.123* (0.0716)	0.117* (0.0685)	0.119* (0.0718)	0.131* (0.0685)	0.120 (0.0855)	0.122* (0.0712)	0.0450 (0.0519)	0.123 (0.0770)
Observations	31,176	32,749	31,447	31,992	31,583	32,422	29,848	31,808	30,614	31,621	32,322	31,937	32,177
R-squared	0.416	0.415	0.411	0.414	0.416	0.416	0.368	0.416	0.420	0.413	0.413	0.419	0.414

Note: All columns include municipality fixed effects, year fixed effects, and household level controls (age, sex, ability to read, number of household member 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 17: The relationship between mines and food spending year by year

	(1)	(2)	(3)	(4)
Sample restricted to year:	1998	2003	2009	2014
Dep. Var. : share of food spending in total consumption				
Artisanal deposit 10 km	-0.0117 (0.0143)	-0.0239** (0.0113)	-0.00248 (0.0193)	0.00358 (0.00844)
Industrial mine 25km			0.0391 (0.0443)	-0.00449 (0.0191)
Industrial deposit 25km	-0.0379* (0.0203)	-0.0199 (0.0253)	-0.0671*** (0.00793)	0.00241 (0.0138)
ln pc. Cons.	-0.0622*** (0.00820)	-0.0210*** (0.00689)	0.103*** (0.00690)	-0.0436*** (0.00523)
Observations	8,031	8,085	8,176	10,252
R-squared	0.418	0.341	0.465	0.275
P(deposit=mine)			0.533	0.872

Note: All columns include municipality fixed effects and household level controls (age, sex, ability to read, number of household members), and a control for urban areas. There is no industrial mine in 1998 and 2003 hence the absence of coefficient. As of artisanal mine there is no within year variation within artisanal mining places hence the presence only of the dummy "Artisanal deposit 10km". Robust standard errors are clustered at the municipality level. *** p<0.01, ** p<0.05, *p<0.1.

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