The gold digger and the machine. Evidence from the artisanal and industrial gold rush in Burkina Faso *

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February 15, 2017

Abstract

Following the boom in World gold price since the mid 2000s, gold extraction has increased dramatically in Burkina Faso. We take advantage of this quasi-natural experiment to provide an analysis of the impact of both industrial and artisanal extraction of natural resources on households' wealth. We combine the geolocalization of mining sites with the variation in gold prices to identify the impact of mining according to the extraction technique being used. For industrial mining, we take advantage of the opening of new mines to isolate the causal impact. Using household surveys from 1998 to 2014, we show that the opening of new mines have not generated significant backward linkages at the local level since they do not have any impact on households' consumption. In comparison, using the evolution of gold price to identify the effect, we find that artisanal mining has significantly increased household consumption. We show that these results are unlikely to be driven by changes in local prices and we take into account other general equilibrium effects.

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

*Acknowledgments: We would like to thank the INSD for providing us the data we needed for this study. In particular, this article wouldn't have existed without the support of Alassane Diarra, Adama Nabayaogo, Pascal Nakelse and Wouba Pagane at the INSD. We also would like to thank Patrice Dabire and Emanuel Yameogo for data on mines. We thank Quentin Megret, Gerhard Toews, and participants in the Pi working group and the LEO seminar for their comments. All remaining errors are ours.

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1 Introduction

Exploitation of natural resources is often presented as an opportunity for developing countries, where most mineral reserves are located. Although this production generates huge financial flows, the old debate on the resource curse reminds that natural resources abundance is not a sufficient condition to achieve development. Since the seminal papers of **???**, the literature has shown that the abundance of natural resources may have adverse effects on economic development, especially when institutions are weak (**??**). This literature, focusing on the macroeconomic effects of natural resources extraction, outlines two possible mechanisms to understand why natural resources are not always a blessing for countries: renk-seeking and dutch disease. The literature is however scarcer when it comes to understanding the local economic effects of resource abundance. Our paper aims at extending the latter literature strand, bringing evidence from the recent gold rush in Burkina Faso.

Our paper builds upon a recent literature which aims at studying the natural resource curse from a microeconomic perspective. Focusing on household wealth, **?** show 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 have 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. Also in Peru, **?** find that districts with mines have larger consumption per capita and lower povery rates, but also face higher inequalities. Lastly, **?** documents a local positive impact on living standards of an increase in local copper production in Zambia. These papers tend to find a positive wealth effect of the *expansion of existing mines*. But do we obtain similar results when we focus on mines' opening?

Our goal is to provide a country-level study of the local impact of mine *opening* on living standards. The question is essential because existing studies emphasizes that mines' expansion and mines' opening may have different impact at the local level. The increase in gold production between 1997 and 2005 in Ghana – partly driven by a greater number of extraction locations – leads to a 40% reduction in farmers' productivity around the mines (**?**). More generally, the opening of mines in Sub-Saharian Africa leads to significant effects on local employment: women switch from self-employment in agriculture to working in services or leave the labor force, while men switch to manual labor. Work participation decreases by 5.4 percentage points with mine opening (**?**). The specific impact on consumption or income has not been studied yet.

To provide an accurate picture of the local effect of extractive activities, we also document the local impact of artisanal mining. Artisanal mine is one of the "hints" industrial mines use to identify promising

locations to be explored. As a result, artisanal and industrial gold mines often coexist (**?**). But there is little evidence on the local impact of artisanal mines, which may explain the frequent changes of policy recommendations by the World Bank or the IMF (**?**).[1] In particular, the causal effect of artisanal mining on household' wealth is, to our knowledge, an open question in the economic literature. A recent Wold 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.[2] This is particularly problematic since "*[o]ne widely used estimate is that more than 100 million people globally depend either directly or indirectly on ASM for their livelihoods.*" (**?**, p. 11).

Gold mining in Burkina Faso therefore provides an ideal setting to fulfill two important gaps in the literature: there is a need (1) to assess the effect of mine *opening* on income, and (2) to measure the causal impact of *artisanal* mining.

The country switched from 0 to 7 industrial gold mines during our period of interest. Prior to 2008, the country had only one industrial gold mine with small and erratic production levels (the Poura Gold mine). The increase in World gold prices since 2005 made Burkina Faso's gold deposits attractive for industrial investors. As a result, in 2014, the country had 7 fully functional industrial gold mines. Using this case, we are able to isolate the effect of mines opening on income rather than having to study the effects of mines expansion as in **???**.

Moreover, the dramatic change in the gold price between 1998 and 2014 allows us to assess the existence and extent of local spillovers for artisanal mining . Artisanal mining is an important tradition in Burkina Faso. The World Bank estimates that 80,000 to 200,000 individuals were directly involved in artisanal mining in the country in 2009 (**?**, p. 9). Since the gains from artisanal mining are a direct function of the gold price, with the fivefold increase in gold price between 2001 and 2011, we expect that the gains and extent of artisanal mining varies over the period. Knowing the location of most important places – for informal mining – we are able to test the effect of artisanal mining on wealth. To the best of our knowledge, it is the first study providing a causal assessment of artisanal mining on household wealth.

Our identification strategy exploits the spatial and temporal variation of the impact of gold extraction. More specifically, to identify the impact of industrial mines, we implement a difference-in-difference approach using the opening of new mines as a treatment and comparing households close to these mines

[1] While the World Bank or IMF have initially pushed for a formalization of the extraction informal sector (which is small scale and labor-intensive), later recommendations have completely neglected the role of artisanal mining. The focus has been put on the positive spillovers of formal extractive industries. Recommendations are more nuanced today.

[2] *"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."* (**?**, p. 11).

to households farther away. We exploit the difference in the opening years of industrial mines. The validity of the identification strategy relies on the assumption that the effect of industrial mines decreases with distance, and that households in areas both close and far from these mines would have experienced similar performance in the absence of mines. Concerning the impact of artisanal gold extraction, we also implement a difference-in-difference approach. We exploit the change in gold prices and households distance to artisanal mining sites to define our treatment. Throughout the empirical section of the paper, we use households' consumption as the main indicator of households' wealth and well being (**?**). We also investigate general equilibrium effects through the allocation of workers among places and sectors, and acknowledge potential variations in local prices. We are able to isolate the effect 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 be 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.

There is no clear theoretical prediction when it comes to the local impact of extractive activities. **?** argued that industrial extraction is generally an enclave activity without a local impact. However, more recently, the literature has used the notion of the local multiplier (**?**) to argue that industrial mining may have spillovers on the local economy through its impact on local employment, both direct and indirect, and consumption of non-tradables. Mining activities can also affect the price structure (**?**), and the revenue available for government to fund public goods. These channels are likely to be valid also for the case of artisanal mining, although the fiscal impact is likely to be lower.

Our results are very clear. We fail to find any causal impact of industrial mining on household consumption. Said differently, households living close to new mines have not seen any significant change in their consumption, compared to households located farther away. This result is consistent with **?**'s prediction and may be seen as contradictory with the results of **?** in the case of Peru. One important difference between the later study and ours is that they identify the effect of *extending* an existing mine and we are focusing on the effect of *opening* new industrial mines, on locations usually overlapping artisanal mining sites. Does it mean that gold extraction had no effect on wealth in the case of Burkina Faso? It is clearly not the case as we are able to identify a strong positive impact of artisanal mining. The boom has generated a 15% increase in consumption for households located close to artisanal mines compared to those located farther away. We show that our results are not likely to be driven by changes in local prices. We find similar results when controlling for both regions and province specific time trend to control for changes in local prices. Moreover, the composition of the consumption estimate (the share

devoted to food in total consumption spending) is unaffected by mining activities.[3] We then explore the general equilibrium effects. First, we show that migration is not likely to explain our results. We do not find significant differences in terms of number of households living in mining areas. We also do not observe significant changes in the composition of households. Second, we study labor market implications of the gold boom. We show that households in the surrounding of industrial mines are 4% more likely to work in the extractive sector. Nevertheless, the probability to be active in general, or to be employed in a permanent position is unaffected. The artisanal boom slightly increases the probability that people are active while leading to no significant change in labor allocation across sectors. It appears that artisanal mining work is mainly seasonal and complementary with other activities. We do not find any impact on the probability that children attend a formal school. This result is consistent with **?**: we do not find evidence that artisanal mining boom lead to a decline in school attainment.

The paper is organized as follows. In the next section, we provide a presentation of the institutional context in Burkina Faso for the period covered by the study (1998-2014). In section III, we focus on the effects of industrial mining. Section IV presents the main results for artisanal mining. In section V, we discuss potential general equilibrium effects. Section VI concludes.

2 Institutional context and data

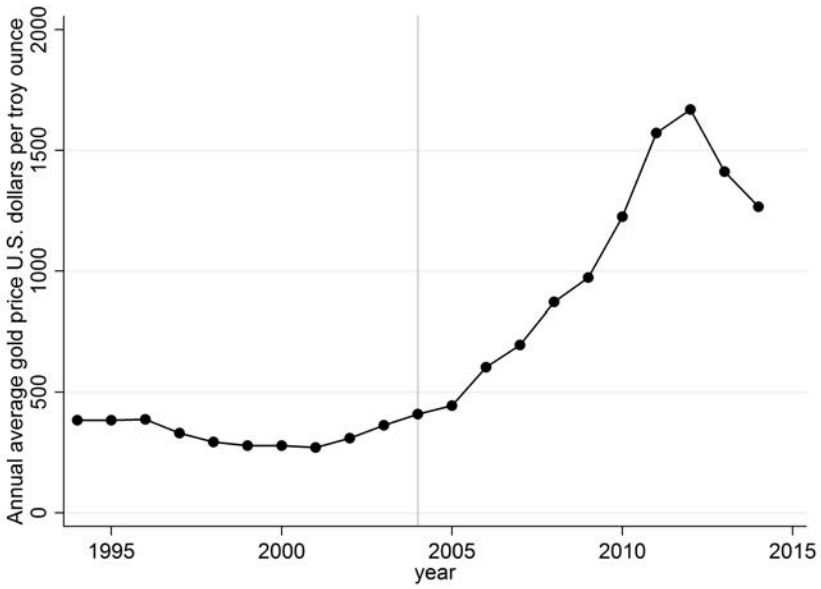
2.1 Institutional context

Burkina Faso is a landlocked Sub-Saharan country, it shares borders with 7 countries, including Mali in the north and Ghana in the south. With 690 dollars gross per capita income in 2014, Burkina Faso belongs to the list of low-income countries. Up until recently, the country first export was cotton (72% of the value of the country's exports in 2007). In 2013, the country had about 17 million inhabitants spread over 13 regions, 45 provinces, and 351 municipalities. Its population density was slightly above the world's average. Burkina Faso is independent from France since 1960. The country's official language is the french; the More, the Dioula and the Peul have the status of national languages. Blaise Campaore was the President between 1987 and 2014. He arrived in power by a *coup d'état* and was elected in 1991, 1998, 2005 and 2010. Popular demonstrations lead to the departure of Blaise Campaore in November 2015. Inter-religious relationships in the country are peaceful, the main groups are the muslims (60% in the 2006 Census), Christians (23%) and animist (15%). In january 2016 Al-Queda perpetuated an attack in the country's capital, Ouagadougou, resulting in 30 death (5 of them from Burkina Faso, other were

[3] If increase in nominal consumption were driven by price increase, we would have observed a shift of consumption (in nominal terms) from clothing or other spending to subsistence spending (food).

foreigners).

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

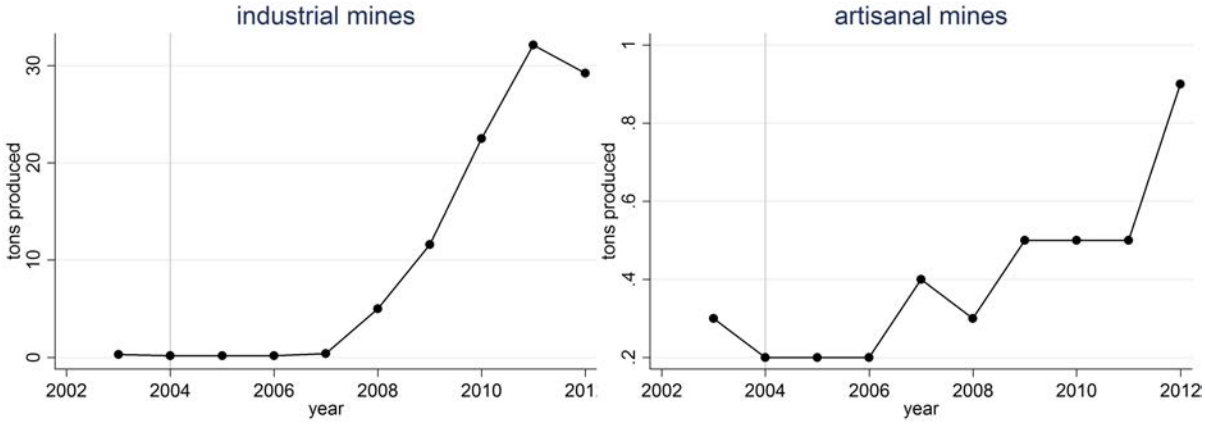


Source: London Gold Fixing

The country's mining potential has been know for decades. However, up until recently, it wouldn't attract international investors. Up until the end of the 2000's, gold production in Burkina Faso was mostly the result of small scale gold production and the erratic outputs of the Poura gold mine (suspended since 1999). However, two key elements changed during the 2000's: the promulgation of a new mining code in 2003 to attract extractive industries, and the sharp increase in gold prices (see figure **??**). As a result, in 2014, Burkina Faso had 7 industrial gold mines in function and two in construction. Table **??** presents each industrial mine 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). Next to the industrial extractive sector, an important share of the population relies on artisanal mining.

Industrial and artisanal gold mines do not have much in common. Both aim at producing gold and are affected by the evolution of the gold prices. However, industrial gold mines are capital intensive, high tech, industries. The few employees of industrial gold mines have mostly formal contracts with a fixed pay and are highly skilled. The opposite is true of artisanal mines: it corresponds to a labor intensive, low skilled activity. Labor is seasonal, informal, and income depends of the -gold- harvest (**?**). As a result, in 2011, about 200,000 people were active in informal mining in Burkina Faso, making it central to sustain the living of 1,000,000 persons (which corresponds to 1 every 17 person in the country, **?**). The artisanal mining sector declared a production of 0.5 tons of gold that year. To put things in

Figure 2: Evolution of the gold production, 2003-2012



Source: Chambre des Mines du Burkina Faso

perspective, the industrial mining sector produced 32.5 tons of gold that year and declared to employ 5,194 persons (62% of them being either foreigners or from another region of Burkina Faso, **?**). While the absolute amount produced by artisanal and industrial mines is hardy comparable, figure **??** shows a clear increasing trend of the quantity produced by both types of mines over the period, an increase clearly following the price increase shown in figure **??** above.

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

Source Ministere des Mines et de l'Energie

2.2 Data

We build a nationally representative dataset that is a repeated cross section of 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. The drawing of enumeration

areas for each survey is such that they may – or may not – overlapp across surveys. All surveys are representative at the level of the 13 regions of Burkina Faso. The 1998, 2003 and 2014 surveys are registered in the World Bank microdata catalog online and the 2014 survey is additionally part of the Living Standards Measurement Study collection. We are the first to exploit the time dimension of these surveys over such a long period.[4]

We were able to geolocalize households by linking the gps code of each village – or neighborhood for cities – corresponding to each enumeration area used in each survey wave. It is another contribution of our work as we needed to reconstruct and exploit the geolocalization of households. Knowing the precise location of each household is essential for our identification strategy and allows us to discuss changes that took place between 1998 and 2014 at a very local level.

The 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 **??** 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.

Table 2: Summary statistics

	Mean	sd
head age	45	0.1
head is male (%)	89	0.002
rural household (%)	74	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 (%)	0.9	0.0006
consumption per capita	180,130	2,503
Total number of households in the sample= 31,036		

The mean and its standard error are calculated using sample weights. Consumption is measured in CFA Francs.

Our measure of consumption includes information on daily consumption (food, alcohol, tobacco, clothing, etc) and health and education expenditures. We follow **?** and omit exceptional expenditures on ceremonies and durables items (major electronic items or transportation modes for example) since we can not compute the rental equivalent of the later. We assume that the INSD data follows standard requirements and compute ourselves consumption estimates from raw data from each surveys.[5]

[4]The 1998 and 2003 surveys were used for published academic works such as **?**. The 2009 and 2014 surveys have not yet, to the best of our knowledge, led to a publication in an international academic journal, although the UNICEF or French scholars have already published reports or articles exploiting the 2009 data (**??**, respectively).

[5]Unfortunately, we only have the total consumption data (computed by the INSD) and not the raw data for the 2009 survey.

Information on both industrial and artisanal mines comes from original data we obtained from the Ministry of Mines in Burkina Faso. The ministry gave us access to each industrial mines' localization, yearly production, and estimated reserves. For artisanal mines, we obtained the localization of every registered artisanal gold mine, the date of registration of the mine, and name of the permit holder. Obviously, many of artisanal mines are not declared and production of declared mines may have started before the registration. Both aspects may induce a downward bias on our estimates. To take into account the possibility that these mines started producing before the registration, we will identify the effect using the boom of gold price as an exogenous variation, and not the date of registration (we detail this point further in the next section). We can already notice that the location of artisanal mines overlaps with Birimien rocks (see figure **??** in appendix). This is very important as virtually all the gold resources of the country lies in Birimien rocks.[6]

Figure **??** shows the location of enumeration areas from the INSD surveys, industrial and artisanal mines (with buffers of 25 and 10 kilometers respectively).

3 The effects of industrial mining

Our aim in this section is to isolate the causal impact of industrial mines opening on household wealth, proxied by their level of consumption. As reminded in the previous section, seven industrial gold mines are in function in 2014 and two are in construction.

3.1 Theoretical mechanisms: local multipliers

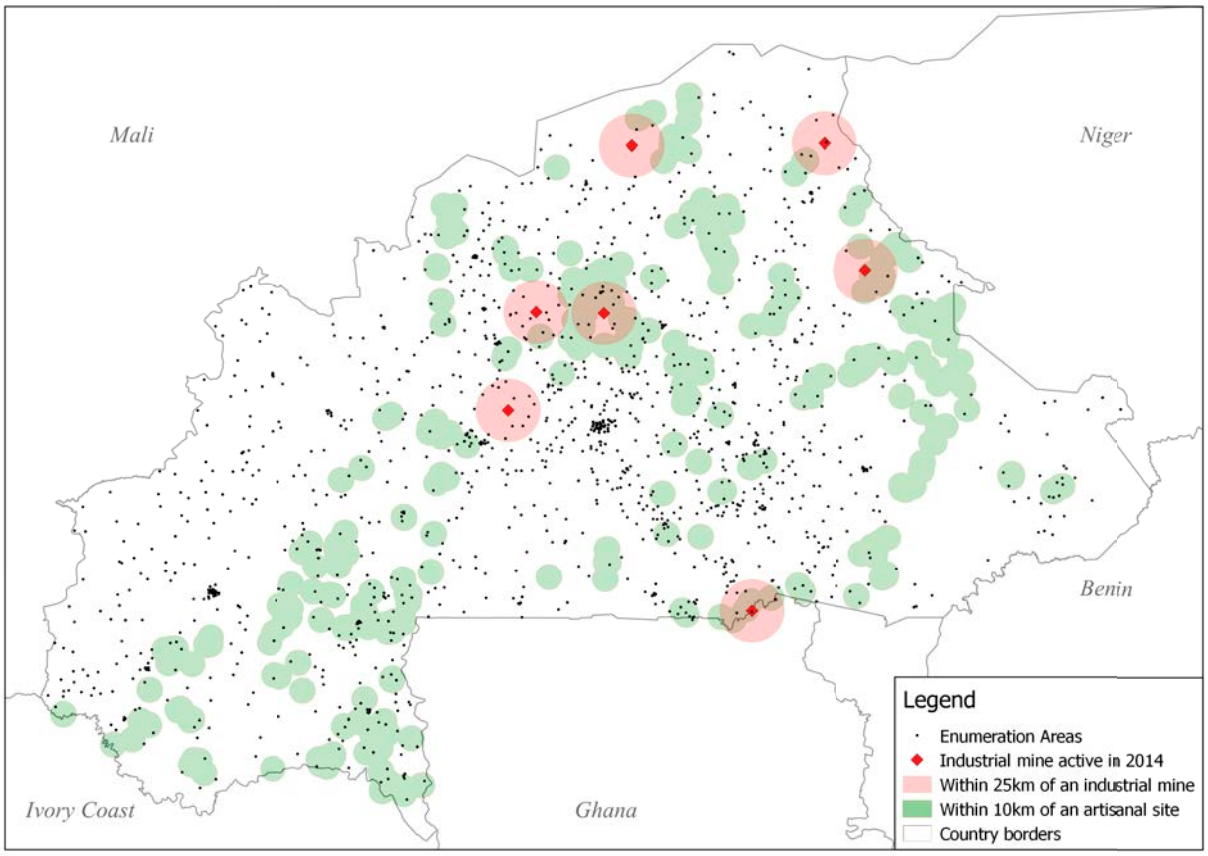
Extractive industries are the typical example of an enclave activity described by **?**. However, it is possible to study possible spillovers (if any) using the local multiplier framework proposed by **?**. **?** build upon this framework to identify the impact of the Yanacocha gold mine on surrounding communities in Peru. We will briefly discuss how this framework can be applied to the case of Burkina Faso.

? argues that increasing the production of a tradable good in one city will have different impacts in the tradable and non tradable sector of this particular city and of other cities. More specifically, consider a city producing different outputs, some are tradable and some are nontradable. The non-tradable sector can be defined as sector-specific and city-specific. The resulting creation of jobs in that sector depends on three factors: (i) consumer preferences for nontradables and the labor intentity of the production

We have checked that these consumption estimates are consistent with the ones built from other surveys, which is the case. As long as any difference in the calculation of consumption is not correlated with our treatment (industrial or artisanal mine) including year specific effect is enough to account for any difference in the calculation of consumption.

[6]This insight has been confirmed by papers in geology (**?**) and discussions with geologists working in Burkina Faso.

Figure 3: Location of enumeration areas for housheold surveys and mining (both industrial and artisanal)



technology in this non-tradable sector, (ii) the type and (wages) of new jobs created in the tradable sector, (iii) the increase of local prices depending on the elasticity of labor and housing supply. The creation of jobs in the tradable sector depends also on three dimensions: (i) the effect of increased wages (following the increase in labor demand) on the competitiveness of other tradable producers, (ii) the localness of the inputs supply chain, (iii) the existence and magnitude of agglomeration economies.

The size of the multiplier will therefore depends on the level of direct local employment and local procurements. **?** show that the Yanacocha mine has increased the demand for local inputs, following a change of the procurement policy. The first effect of an increase in local demand would be an increase in nominal wages for workers directly affected by this change in demand addressed by the mine. If workers are mobile between sectors and the labor supply is not infinite, this would also lead to a nominal wage increase of other workers, who are not directly linked to the mine. The second effect is an increase in local prices that would benefit local producers and home-owners. With perfect labor mobility, real wages would equalize among locations. However, as soon as there is imperfect labor mobility, the demand shock would increase real wages and real income.

The size of the multiplier is primarily a function of the initial demand shock which is a function of the local procurement policy and the employment policy of the mine. Different mines may have heterogeneous effects depending on their policies. The institutional context is also likely to matter.

3.2 Identification strategy

Our aim is to estimate the effect of the opening of an industrial mine on living standards measured by households consumption. As we can see in table **??**, 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.[7] The exploration and construction work are labor-demanding and mines may need to hire local populations for these tasks (especially unskilled labor for construction work).

The second source of variation is the household distance to a gold deposit, as a source of heterogeneous exposure to a potential mine. In the main specification, we use 25 km as the threshold to divide households in two categories: far and close to the mine. There is no consensus in the literature on this threshold. For instance, **?** use a 20km buffer in Ghana, while **?** use a 100km buffer in Peru. We choose this threshold taking into account the poor quality of roads and the scarcity of public transportations. It implies that 498 to 768 households live within the potential treatment area for each wave of the survey. Nevertheless, we do provide estimates using different thresholds.

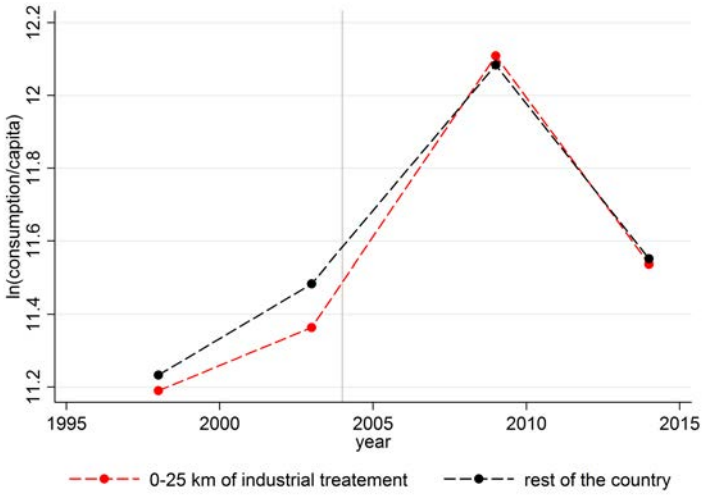
Our identification strategy is basically a difference in difference based on spatial and a temporal variations. We use the distance of households to potential mining sites to distinguish treated from untreated households. The validity of this empirical strategy relies on the assumption that the effect of the mine declines with distance and that the evolution of consumption in areas far and close to the mine would have been similar in the absence of the mine opening. Figure **??** shows the consumption trend before and after the opening of new mines. 1998-2003 is the pre-trend period as none industrial mine was active over this period (neither in terms of production nor in terms of construction).

The period 1998-2003 corresponds to the pre-trend since none of the industrial mine was active over this period (neither in terms of production nor in terms of construction). As we can see, households located within a 25 kilometers' buffer around the mine show similar consumption trend before the "treatment" (here the opening or construction of mines), although the level of consumption is lower in

[7] This 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. Nevertheless, we will test the robustness of our results by changing the definition of the mine beginning year

average.

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



To formally estimate the effect of the opening of a mine, we estimate the following equation:

$$C_{ivt} = \alpha mining_t \times deposit_v + \beta deposit_v + \gamma X_{it} + \delta_m + \eta_t + trend_{r,t} + \epsilon_{ivt} \quad (1)$$

C_{ivt} is the log of the per capita consumption for the household i living in village v of municipality m of region r at time t. $mining_t$ is a dummy variable taking a value of 1 when a mine is opened or in construction, 0 otherwise. $deposit_v$ 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. $\alpha - \beta$ is therefore the estimated impact of the opening of a new mine, in areas where deposits are known. 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. In the extended specification we also add sector of occupation, nature of work, electricity and water supply.[8] We also include municipality fixed effects δ_m, year fixed-effects (η_t) and regional-specific trend ($trend_{r,t}$). ϵ_{ivt} is the error-term. Standard errors are clustered at the municipality level to take into account serial correlation at this level (**?**). We also test the robustness of our results by using different levels of cluster and obtain similar results.

[8]This extended specification is very closed to the one proposed by **?** and seems important to include to allow a comparison of our results. However some of these variables might be seen as endogenous. That is why our baseline specification omits these additional variables.

3.3 Results

Table **??** displays the main results. We do not find any impact of the opening of new industrial mines on households' consumption. In other words, we do not find significant differences of the evolution of consumption between households located close to a deposit (within 25 km) where a mine opened and other households. This result holds whether we control for the location of a major deposit (column 3 and 4) or not (column 1 and 2).[9] In column (5) and (6), we define the treatment differently. Instead of using a dummy equal to one when a mine is opened, we interact this dummy with the gold price. The assumption is that industrial mines are likely to have more spillovers when the gold price is increasing, either because mines increase their production (the correlation between the gold price and total production in Burkina Faso is above 90%), or because they redistribute the increase in profit (following the increase in the gold price while production costs remain constant). The price is exogenous to local conditions (**??**); Burkina Faso gold mines are price takers on the international gold market. We still do not find any significant impact of industrial mining.

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

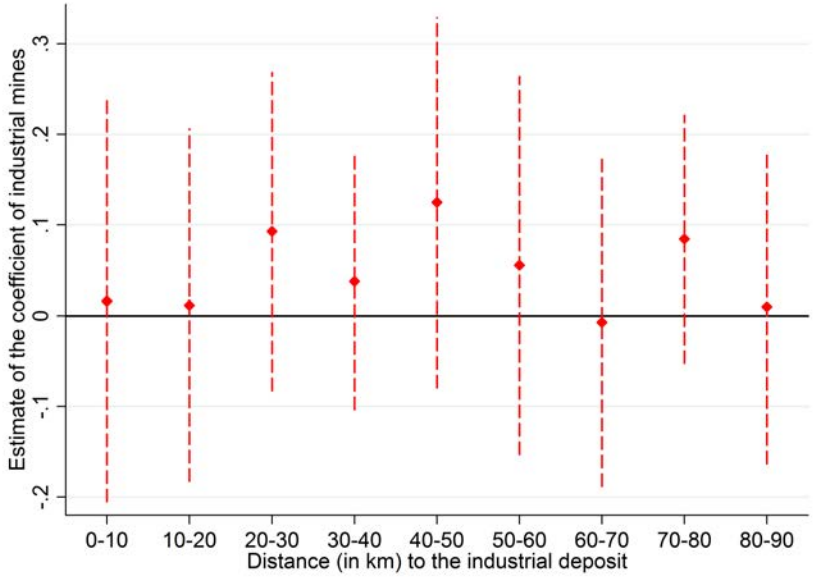
	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.: ln pc Cons.						
major mine 25km	-0.00671	-0.0197	-0.0287	-0.0223		
	(0.0669)	(0.0668)	(0.0806)	(0.0791)		
major deposit 25km			0.0456	0.00536	0.0194	-0.0271
			(0.0605)	(0.0587)	(0.0638)	(0.0609)
major mine 25km					0.00831	0.0124
*ln(gold price)					(0.0119)	(0.0113)
Observations	34,078	34,078	34,078	34,078	34,078	34,078
Extended controls		X		X		X
R-squared	0.409	0.469	0.409	0.469	0.409	0.469
P(major deposit+mine=0)			0.798	0.797		

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

We then change the threshold used to define households close to a $deposit$ in equation **??**. In figure **??**, 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 the opening of new mines had no significant impact on household consumption at the local level.

[9] In the later case, municipality fixed effects captured the time-invariant characteristics of the area.

Figure 5: Impact of industrial mines on consumption by distance to the mine



4 The effect of artisanal mining

From the previous section, we can reasonably conclude that the opening of industrial mines had no significant impact on household consumption at the local level. Does it mean that gold extractions had no effects on household' wealth? To answer properly to this question, we need to take into account the existence of a strong artisanal mining sector and the significant interactions between industrial and artisanal mining. As we already mentioned, artisanal mining has a long tradition in Burkina Faso. It is important to notice that the presence of artisanal miners have been used by industrial mining firms to detect and choose the precise location of their mine (**?**). Artisanal mining production (figure **??**) has started to increase almost simultaneously with the gold price (figure **??**) in 2006. There is a fivefold increase in the production between 2006 and 2012. This increase, in absolute values, is marginal compared to the one of industrial mining (which increase from 0.5 tons in 2006 to 32.5 tons in 2011). However, as we will see, the impact is significant on local consumption. We will briefly summarize the theoretical mechanisms, focusing on similarities and differences with industrial mining, before presenting the identification strategy (which slightly differs from the one used in the previous section) and results.

4.1 Theoretical mechanisms: specificity of artisanal mining

Similar to our discussion on industrial mining, the local multiplier framework (**?**) may be used to understand the possible local impact of artisanal extraction. As we have seen in the previous section, the local multiplier is triggered by an initial demand shock in the tradable sector (here artisanal mines).

Artisanal mines employ local labor, whose preferences for non-tradables are likely to increase demand for goods and services produced locally such as services, food, housing. Workers from industrial mines generally come from farther away and may have limited connections with local populations and markets. According to (**?**), over 60% of industrial mines workforce was non-local.

Moreover, artisanal mines rely on inputs that are more likely to be produced, or at least sold, locally. The demand for plastic basin and batteries for instance is met by local shops and thereby can increase local trade. Nevertheless, artisanal mines are also more likely to induce a crowding-out effect in the labor market if individuals switch jobs to become artisanal miners (it won't be the case if artisanal miners were unemployed or if artisanal mining is a seasonal activity, compatible with another activity especially in agriculture). Lastly, the local multiplier is also function of the change in local prices. Since artisanal mining is more connected to the local economy, this impact is likely to be stronger than for industrial mining, especially for home owners, local food producers or retailers. The last difference is the magnitude of the initial demand shock. We saw in figure **??**, that the increase in artisanal production has been much weaker than the industrial one, in *absolute* terms. Hence, although artisanal mining is more likely to be be connected to the local economy, the magnitude of the effect is not clear, *a priori*.

4.2 Identification Strategy

As previously, our goal is to compare the consumption of households located close to areas where mining can take place to the consumption of households living farther away. The challenge is to identify the location of artisanal deposits and the timing of artisanal mining.

To identify locations of artisanal deposits, we use the census of all registered artisanal mines provided by the Ministry of Mines. Indeed, any registered artisanal mine needs to be located around an artisanal deposit. We then propose to use the gold boom as a time varying treatment. More precisely, two definitions of the boom will be used: a dummy variable taking the value of 1 after the gold price boom started (in 2009 and 2014), and the gold price itself. The idea is that the gold price is the main driver of (artisanal) mining activities since it determines the expected income. 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 gold price confirms this intuition. Moreover, the Gold price, defined at the World level, is exogenous to the local context since Burkina Faso is a price taker on the gold market. We thus prefer to use the gold price rather than the artisanal production directly since the latter is prone to measurement errors, and because local production may be endogenous to local economic conditions. Lastly, we prefer to use the gold price boom rather than the date of the registration of artisanal mines to define our treatment because

the date of effective beginning of artisanal mining activities is not known precisely. We know that mining was taking place at the date of registration, but we do not know how long it took for miners to register, how much time miners were settled on the ground before they decided to register, and for how long after registration mining takes place. That is why we use the gold boom as an exogenous shock to measure the time-varying impact of potential artisanal mining activities on known artisanal deposits (the deposit variable is by construction time invariant).

This identification strategy may lead to two main biases. We argue that these are likely to beif they exist, attenuation biases.

First, a bias may come from the under-declaration of artisanal mining. Indeed, artisanal mine is inherently an informal activity and unobserved artisanal mines may be located in areas identified as the control group in our study. Nevertheless, we are confident that the location of declared artisanal mines (represented in figure **??**) is representative of both declared and undeclared artisanal mines: when we map artisanal extraction sites with a 10 kilometer buffer, we cover almost all Burkina Faso's Birimien rocks, which means that we take in account virtually all the gold deposits of the country. Hence the contamination of control areas is likely to be small. Moreover, if any contamination of the treatment by the control takes place because of an inappropriate definition of the areas with deposits, this mechanically implies an attenuation bias of our results.

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.

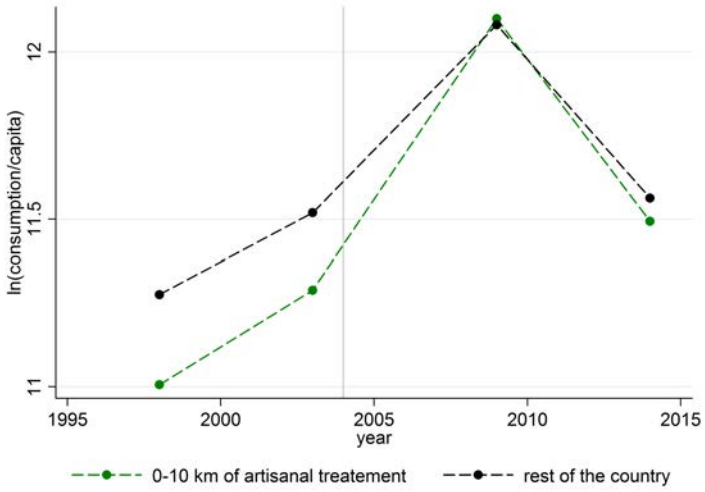
Given that the treatment and control may contaminate each other; we argue that our results should be interpreted as a lower-bound estimate of the real effect of artisanal mines.

Another difference in the empirical strategy for artisanal mine is the size of the buffers we use to define the spatial treatment. As a baseline, we choose 10 kilometers as the threshold between close households and the others. This lower threshold is justified by the specificity of artisanal activities compared to industrial ones. The main demand shock that may come from artisanal mining comes from the demand of miners for local goods and services. It is likely to be much more localized that the demand coming from an industrial mine. Nevertheless, to ensure that our results are not driven by this somehow arbitrary choice, we will present robustness checks using alternative definitions of distance.

With these differences, the identification strategy remains a difference-in-difference based on spatial and temporal variations. We use the distance (here 10 kilometers) to distinguish treated and not-treated

households. And 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. As the boom in gold price (and artisanal gold production) starts in 2006, we need to show similar trends between 1998 and 2003. The next wave of the survey, 2009, will include the effect of the beginning of the gold boom. Figure **??** shows the consumption trends of households located within 10 kilometers of an artisanal mines and those farther away. As we can see, pre-trends are perfectly similar, although the level of consumption was lower in areas located close to these mines. The trend starts to diverge between 2003 and 2009 which is consistent with our hypothesis.

Figure 6: The evolution of household consumption before and after the gold price boom



The estimated equation is given by equation **??**.

$$C_{ivt} = \alpha(boom_t \times deposit_v) + \beta deposit_v + \gamma X_{it} + \delta_m + \eta_t + trend_{r,t} + \epsilon_{ivt} \quad (2)$$

Equation **??** is similar to equation **??** except for the definition of the treatment. In equation **??** $boom_t$ is a dummy variable taking value 1 from 2004 onwards (because the gold price peak started in 2004) and 0 before. $distance_v$ is the exposure to the deposit of households living in v. In our baseline estimates, it is a dummy variable taking the value of 1 if the household lives within 10 km of an artisanal deposit, 0 otherwise. $\alpha - \beta$ is therefore the estimated impact of the artisanal mining boom, in areas where deposits are known.

4.3 Results

Results are given in table **??**. We find a strong and positive impact of artisanal mining on household consumption. In column (1) and (2), we only control for the location by including municipality fixed effects. During the gold boom, households within 10 kilometers of an artisanal deposit are found to consume 15% more than households located farther away. In column (3) and (4), we include dummies taking the value of 1 for households living 10 kilometers of an artisanal deposit. The negative sign for the deposit variable shows that these areas are poorer on average. The treatment (the artisanal boom in areas close to deposits) is again found to have a positive effect on consumption. We reject the hypothesis that the sum of artisanal deposit and artisanal boom coefficients is equal to zero. The net effect of living close to an artisanal deposit is positive when we take into account the positive impact of the artisanal boom. The net effect is about 15 percentage points.[10] In columns (5) and (6), we use the gold price as a continuous definition of the treatment. We still find that areas within 10 kilometers of an artisanal mine are poorer on average but the effect of the gold price increase is positive and significant. A one percent increase in the gold price is found to increase household consumption by 0.16%.

Table 4: The effects of artisanal mines on households' consumption: Baseline estimates

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.: ln pc Cons.						
artisanal boom 10km	0.142**	0.140**	0.227***	0.222***		
	(0.0552)	(0.0555)	(0.0627)	(0.0608)		
artisanal deposit 10km			-0.101***	-0.0967***	-1.042***	-1.064***
			(0.0266)	(0.0257)	(0.253)	(0.243)
artisanal deposit 10km					0.165***	0.169***
*ln(gold price)					(0.0424)	(0.0412)
Observations	34,078	34,078	34,078	34,078	34,078	34,078
Extended controls		X		X		X
R-squared	0.410	0.470	0.411	0.470	0.410	0.470
P(artisanal deposit+boom=0)			0.0204	0.0234		

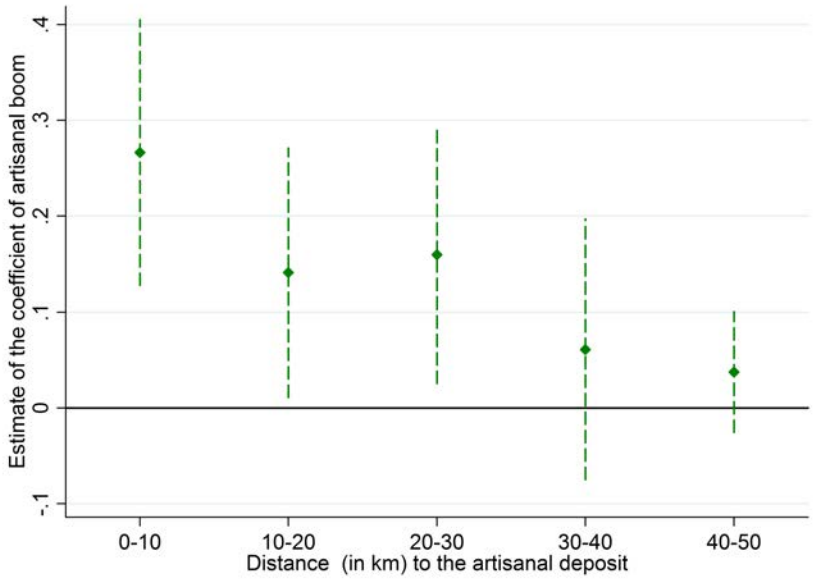
Note: All columns include municipality fixed effects, year fixed effects, region specific trends, and household level controls (age, sex and ability to read of the household's head, number of household member and adult members), and a control for urban areas. Extended control additionally account for: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

In figure **??**, we show the different coefficient estimates for the impact of the gold boom on households located close to a deposit, using alternative buffers to define the proximity to a deposit. The coefficient is decreasing with distance, which is consistent with our identification strategy. The coefficient remains positive and significant for households living in a 20-30 kilometers area of an artisanal mine. It turns not significant for household located more than 30 kilometers away from a mine. This result shows

[10]The artisanal boom increases consumption of households within 10 km of an artisanal mine by 25%, however these households live in zones that are initially poorer and their consumption spending are on average 9.6 (column 3) to 9.2% (column 4) smaller than the spending of households living in the rest of the country.

that the effect of artisanal mining is very localized and positive spillovers are limited to a close area.

Figure 7: Impact of the artisanal boom on consumption by distance to the deposit



In table **??**, we include artisanal and industrial mines simultaneously. Results are perfectly similar. We still find no significant effects of industrial mining while the effect of artisanal mining is positive and significant. Note that the magnitude of coefficients are almost similar with the ones obtained in tables **??** and **??**, which is an additional evidence of the validity of our identification strategy.

We provide additional robustness checks presented in table **??**. In columns (1) and (2), we show the results when we omit the regional specific trend included in all previous estimates. In column (3) and (4), we include province specific dummies instead of regional dummies. There are 45 provinces and 13 regions. By doing so, we are able to control for time-variant specific characteristics at the province level. That is particularly important as it is one way to control for the effect of a possible price boom following the gold rush. We will discuss this concern in more details in the next section. In columns (5) and (6), we change the definition of the control group, restricting it to households located within 100 kilometers of a mine. We also exclude households located in Ouagadougou, the capital. In all specifications, we always find a non-significant impact of industrial mining and a positive and significant impact of artisanal mining. For artisanal mining, the estimated coefficient ranges from 0.206 (when controlling for province specific trend) to 0.28 (when no trend is included). The coefficient was 0.22 in the baseline estimate. We find similar results when we include only industrial mining and only artisanal mining. We also find perfectly similar results when standard errors are clustered at the province level (instead of municipality).

Table 5: The effects of artisanal and industrial mines on households' consumption

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.: ln pc Cons.						
major mine 25km	-0.0190	-0.0317	-0.0361	-0.0298		
	(0.0748)	(0.0750)	(0.0873)	(0.0856)		
major deposit 25km			0.0407	0.000717	0.0142	-0.0326
			(0.0646)	(0.0621)	(0.0684)	(0.0654)
major mine 25km					0.00699	0.0110
*ln(gold price)					(0.0130)	(0.0124)
artisanal boom 10km	0.143**	0.141**	0.227***	0.222***		
	(0.0554)	(0.0557)	(0.0629)	(0.0609)		
artisanal deposit 10km			-0.102***	-0.0965***	-1.035***	-1.056***
			(0.0267)	(0.0258)	(0.254)	(0.245)
artisanal deposit 10km					0.164***	0.168***
*ln(gold price)					(0.0425)	(0.0413)
Observations	34,078	34,078	34,078	34,078	34,078	34,078
Extended controls		X		X		X
R-squared	0.410	0.470	0.411	0.470	0.410	0.470
P(major deposit+mine=0)			0.950	0.696		
P(artisanal deposit+boom=0)			0.0216	0.0230		

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

Lastly, we change the coding of industrial mining. In the baseline estimates, the dummy takes the value of 1, two years before the opening of the mine, in order to capture the effects of the construction of the mine. We check if our results persist when the dummy takes the value of 1 only when the mine opens. Results are similar which means that the effects are not driven by the construction of the mine only.[11]

5 Discussion

5.1 Changes in the price structure

One specific concern is that the evolution in nominal consumption may be driven by an increase in prices at the local level. Unfortunately, the level of local prices is unknown before 2014. One channel of the local multiplier is this price impact, since the increase in local demand may push prices, which will have a positive effect on local producers or suppliers. The net impact is therefore positive only if the real income increases. We are dealing with this concern in two ways.

The first way to deal with this concern is the inclusion of province trends. By doing so, we are able to control for time-varying province characteristics, including the local level of prices. Results are presented in table **??** (columns 3 and 4), next to results without any trends (columns 1 and 2). We can see

[11] Results are available upon request for the change in the clustering level and the coding of industrial mines.

Table 6: Robustness tests

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.: ln pc Cons.	no trends		province trends		reduced sample	
major mine 25km	-0.000198	0.0150	-0.0653	-0.0534	-0.0413	-0.0278
	(0.0727)	(0.0732)	(0.0918)	(0.0911)	(0.0855)	(0.0845)
major deposit 25km	0.0539	0.0114	0.0557	0.0172	0.0367	-0.00425
	(0.0686)	(0.0651)	(0.0647)	(0.0645)	(0.0670)	(0.0644)
artisanal boom 10km	0.280***	0.271***	0.220***	0.206***	0.235**	0.210**
	(0.0706)	(0.0718)	(0.0714)	(0.0685)	(0.0979)	(0.0994)
artisanal deposit 10km	-0.149***	-0.135***	-0.0874**	-0.0791**	-0.0935**	-0.0715
	(0.0332)	(0.0358)	(0.0347)	(0.0310)	(0.0417)	(0.0434)
Observations	34,078	34,078	34,078	34,078	17,922	17,922
Extended controls		X		X		X
R-squared	0.397	0.455	0.418	0.477	0.399	0.437
P(major deposit+mine=0)	0.485	0.736	0.897	0.635	0.952	0.681
P(artisanal deposit+boom=0)	0.0190	0.0172	0.0258	0.0329	0.0855	0.103

Note: All columns include municipality fixed effects, year fixed effects, and household level controls (age, sex and ability to read of the household's head, number of household member and adult members), and a control for urban areas. Extended control additionally account for: the sector of occupation and nature of work of the household head and the electricity connection and main source of drinking water of the household. Columns (3) and (4) includes province specific trends. In columns (5) and (6), sample is restricted to households located within 100 kilometers of a mine and excluding households living in Ouagadougou. Robust standard errors are clustered at the municipality level. *** p<0.01, ** p<0.05, *p<0.1.

that results are perfectly similar. Note also that in our baseline estimates, we already capture the effects of any national price increase by including year fix effects, and the effects of any non-linear regional price increase by including region-year fix effects. However, the price effect might still be problematic if the evolution of price is different in the treated areas (10 kilometers around an artisanal mine) and the control areas (farther than 10 kilometers), and that this evolution is such that varying trends and fixed effects at the region, province and municipality levels do not capture any part of the variation.

The second way is to see the impact of mining on the allocation of spending across items. If local prices have increased more than the income, it should induce a change in the share of total budget dedicated to some expenses for each given level of budget. For instance, the share of food should increase. If prices at the local level are increasing, households may have to increase their nominal spending on food, potentially at the expense of other spending. In table **??**, we show the effects on the share of food, the share of health and the share of school. Since we analyze determinants of consumption *shares*, we add the *level* of consumption as a control. We do not find any significant effects of the gold rush on the share of spending. This is inconsistent with the idea that the positive impact of artisanal mining is driven by an increase in local prices.

Lastly, in table **??**, we show additional evidence supporting the idea that our results are not driven by local changes in 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 was a boom in local prices (compared to the prices in control areas), we would expect a positive and significant coeffi-

Table 7: Impact on spending shares

	(1) Share food	(2) Share health	(3) Share school
major mine 25km	-0.0121	0.00571	-0.000672
	(0.0214)	(0.00479)	(0.00239)
major deposit 25km	0.00705	0.00199	-0.000406
	(0.0129)	(0.00218)	(0.000978)
artisanal boom 10km	0.0213	-0.00145	0.00175
	(0.0130)	(0.00251)	(0.00181)
artisanal deposit 10km	-0.00981	-0.000861	0.000776
	(0.00802)	(0.00103)	(0.000959)
ln. pc. consumption	0.00554	0.00133	0.00211
	(0.00896)	(0.000831)	(0.00135)
Observations	34,078	25,951	25,951
R-squared	0.413	0.204	0.183
P(major deposit+mine=0)	0.775	0.0765	0.600
P(artisanal deposit+boom=0)	0.325	0.332	0.0443

Note: All columns include municipality fixed effects, year fixed effects, and household level controls (age, sex and ability to read of the household's head, number of household member and adult 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.

cient 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 has been captured by time fixed effects and we do not detect significant differences between control and treated areas in that context.

5.2 Migration

One additional challenge for identification may come from migration explained by the Gold rush. If new workers are migrating to these areas, and these workers are on average richer than the local population, the positive effect we have found may be driven by the positive selection in migration. We argue that it is not likely to be the case. In table **??**, we show that the number of households living in areas located close to mines did not grow at a different rate to areas located farther away. This graphical exploration is complemented by a more formal estimate of the determinants of household composition (table **??**) to check if migration within the extended family has increased. It does not seem to be the case. First, there is no increase in the number of household members following the gold rush (column 1). Second, there is

Table 8: Additional living standards determinants

	(1) ln(min non poor)	(2) ln(rent)	(3) food issue
major mine 25km	-0.00631	0.170*	0.0152
	(0.116)	(0.102)	(0.0405)
major deposit 25km	-0.0510	0.0250	-0.0697*
	0.0458	0.0782	-0.00551
artisanal boom 10km	(0.0693)	(0.0674)	(0.0329)
	(0.0896)	(0.123)	(0.0397)
artisanal deposit 10km	0.00521	-0.0580	-0.0232
	(0.0591)	(0.0361)	(0.0299)
Observations	18,178	33,621	34,212
R-squared	0.335	0.863	0.210
P(major deposit+mine=0)	0.467	0.167	0.142
P(artisanal deposit+boom=0)	0.345	0.698	0.262

Note: All columns include municipality fixed effects, year fixed effects, and household level controls (age, sex and ability to read of the household's head, number of household member and adult 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.

no increase in the number of "other households' members" (the extended family). The share of kids, the share of young people and the share of women have not changed.[12]

Figure 8: Evolution of the population of Burkina Faso

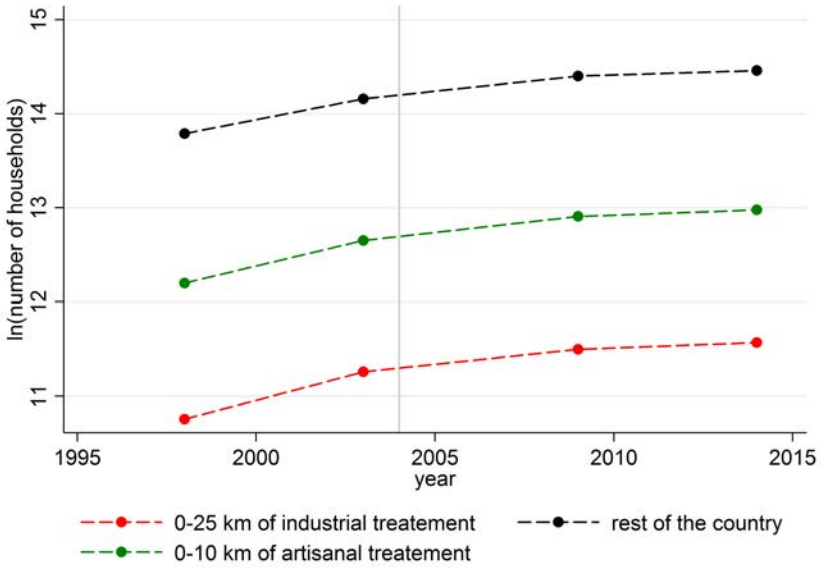


Table 9: Effects on households composition

	(1) $\text{nb}_h h_m embers$	(2) nbotherm	(3) sharekid	(4) shareyoung	(5) sex
major mine 25km	0.242	0.0490	-0.0108*	-0.0119	-0.00200
	(0.211)	(0.0408)	(0.00619)	(0.0124)	(0.00577)
major deposit 25km	-0.0913	0.000547	0.00346	6.73e-05	-0.00228
	(0.320)	(0.115)	(0.0127)	(0.00839)	(0.00951)
artisanal boom 10km	-0.0518	-0.0385	-0.00122	0.00362	-0.00284
	(0.124)	(0.0444)	(0.00440)	(0.00449)	(0.00394)
artisanal deposit 10km	0.0425	-0.0520	0.00213	-0.0127*	-0.000937
	(0.188)	(0.0570)	(0.00653)	(0.00746)	(0.00523)
Observations	42,523	42,523	42,403	42,403	298,151
R-squared	0.209	0.072	0.066	0.084	0.002
P(major deposit+mine=0)	0.653	0.671	0.522	0.293	0.654
P(artisanal deposit+boom=0)	0.955	0.0727	0.876	0.145	0.433

Note: All columns include municipality fixed effects, year fixed effects, and household level controls (age, sex and ability to read of the household's head, number of household member and adult 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.

Table 10: Labor market effects

	(1) any_work	(2) $work\_extractive$	(3) $permanent\_position$	(4) $education\_ongoing$
major mine 25km	0.00470	0.0421*	0.00140	-0.00611
	(0.00996)	(0.0224)	(0.0190)	(0.0182)
major deposit 25km	-0.00989	-0.0208	-0.0327	0.0585**
	(0.0176)	(0.0149)	(0.0267)	(0.0228)
artisanal boom 10km	0.0171*	-0.00476	0.0130	0.00102
	(0.00877)	(0.00289)	(0.0196)	(0.0115)
artisanal deposit 10km	-0.0127	0.00700	-0.0445	0.0204
	(0.0122)	(0.00517)	(0.0325)	(0.0167)
Observations	195,964	153,044	91,126	63,944
R-squared	0.182	0.054	0.257	0.532
P(major deposit+mine=0)	0.735	0.0244	0.213	0.00272
P(artisanal deposit+boom=0)	0.679	000	0.225	0.105

Note: All columns include municipality fixed effects, year fixed effects, and household level controls (age, sex and ability to read of the household's head, number of household member and adult 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.

5.3 Labor market effects

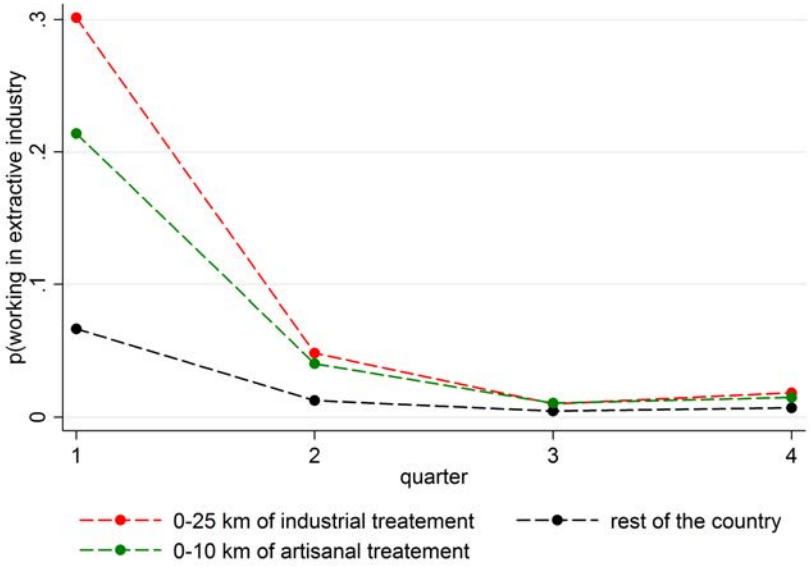
Lastly, we would like to investigate the effect of the gold rush on the labor market. The gold rush may have direct and indirect effects. If miners are local workers, we may expect a positive effect on the probability to work in the extractive sector. As we can see in the second column of table **??**, we find a positive and significant impact of industrial mining. We find that the probability to work in this sector is increasing by around 4% following the opening of a mine. However, we do not find any significant effect on the probability to have any work (column 1), which suggests that there is a substitution with other activities. As the share of workers in this sector is very low, the magnitude of the effect is also very

[12] As the typical migrant is a young man, we should observe a decrease in the share of kids, an increase in the share of young people and a decrease in the women share.

limited.

For artisanal mining, we do not find any impact on the probability to work in the extractive sector (which includes informal mining). This result may be seen as surprising but reflects the seasonality of artisanal mining activities. For the 2014 survey, we have quarterly data that allow us to back up this assertion. Figure **??** shows the share of workers in the extractive sector around industrial mines, artisanal mines and in other areas. Interestingly, work in that sector appears to be concentrated in the first and to a lower extent the second semester. The non-significant results in table **??** can be explained because households were surveyed during the third semester for all the data used in table **??**.[13] One important implication is that mining does not appear to lead to a switch from other activities, such as agriculture. We also find that the artisanal boom has a positive impact on the probability to have any work, which is consistent with the idea that the artisanal boom have lead to positive spillovers in other sectors. Lastly, we do not find any significant impact on the probability to have a permanent position. For education, we also do not find any significant effect. The later result is consistent with **?**: we do not find evidence that the artisanal mining boom lead to a decline in school attainment.

Figure 9: Share of workers in the extractive sector (2014)



[13] Households were only surveyed that semester in the 1998 to 2009 surveys, which is why we also consider activity in the third semester of 2014 in table **??**.

6 Conclusion

This paper takes advantage of a quasi-natural experiment to provide an analysis of the impact of artisanal and industrial extraction of natural resources on households' wealth. We show that despite the huge amount of wealth generated by industrial gold mines from the country's perspective, the opening of these mines have not generated enough backward linkages at the local level to affect households' consumption. Artisanal mining in comparison significantly increases households' consumption, by about 15%. These results are robust to changes in definitions of the treatment and control groups (change in the area considered as treated, and changes in the definition of the treatment with dummies or the gold price). We also show that these results are unlikely to be driven by changes in local prices since they are unaffected by the inclusion or omission of locality specific trends and that the composition of the aggregated consumption is unaffected.

These results complement the existing literature, which focuses on the expansion of existing industrial mines, in two dimensions. First, we shed light on the impact of opening industrial mines on household consumption. Second, we are the first paper to directly and empirically assess the impact of artisanal mining. These results are important for policy makers. Indeed, on the ground, whether artisanal and industrial mining are substitutes depends of the juridic characteristics of mining concessions. Moreover, these results call for further investigation into the necessary conditions for industrial mines to induce changes at the local level through local procurement policy.

7 Appendix

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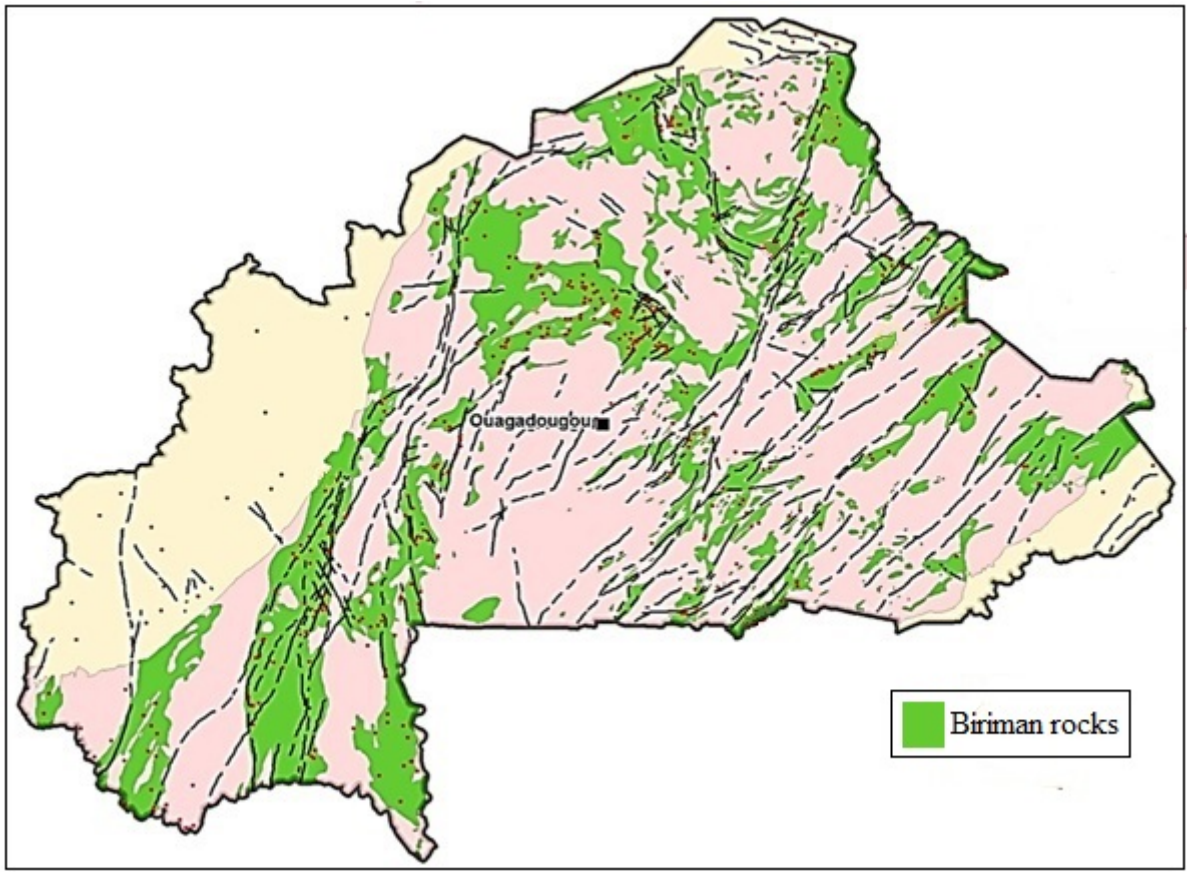
Figure 10: Biriminan rocks in Burkina Faso



Source: http://www.burkina-emine.com

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