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New economic opportunities and children outcomes: negative effects of artisanal mines on primary education

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Abstract

We investigate how artisanal gold mining affect household investment in primary education in Burkina Faso. Using a variety of estimation methods with primary data and secondary data, we find a significant, robust and strong negative effect of artisanal mining on primary school enrolment for boys but not for girls. We explore potential channels and find that direct involvement in mining work does not explain the results. However, children appear to substitute for their parents working in mines (or other activities that developed after the mining boom). In addition, elicited perceived returns to primary education are negatively affected by the presence of mines. Both mechanisms suggest an indirect increase in the opportunity cost of education. We find no evidence of a negative income effect or of a change in school supply which could affect the direct cost of education. Our findings suggest that artisanal mining causes negative externalities on human capital accumulation that need to be addressed if mining is to contribute to poor household livelihoods.

Keywords: Economic opportunities; education; child labour; artisanal mining; Africa

JEL classification: I25, O15, I26, J24, L72, O13, Q33

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1 Introduction

> Quote from a school director, close to a mining site *:*
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> *If we go pick up children [to bring them back to school], they tell us things we cannot believe, like " you are a civil servant, but how much do you earn?" [...] the real problem concerns primary-school aged children.* (cited in Sangli et al. (2022), own translation from French).

Artisanal and small-scale mining (ASM) is a major source of livelihood for rural dwellers worldwide, with at least 100 million people depending on ASM revenues (World Bank, 2009, 2020). In Burkina Faso in particular, artisanal gold mining is a source of income for more than 3 million people or approximately 20% of the population. The conventional wisdom is that, in contrast with industrial mining, ASM helps improve individual standards of living (at least in the short run), especially in rural areas where non-agricultural employment opportunities are limited (Bazillier and Girard, 2020). Yet the media frequently alert on the negative impact of ASM on children who drop out of school to get involved in economic activities that develop nearby mines (mine work, gold cleaning, services, etc.). Although the literature has documented the impacts of new economic opportunities in industry and services on secondary education in other settings (Jensen, 2012; Atkin, 2016), little is known on the effects of new activities in the mining sector on primary education in low-income countries.

In this paper, we investigate the impacts of artisanal gold mines on young children education in Burkina Faso and explore the underlying mechanisms at play. A priori, the impact of new economic opportunities on education is ambiguous. First, it can have a positive income effect and generate an increase in the demand for education. Yet, it may also increase the opportunity cost of schooling either because children are directly involved in the new activity or because they substitute for adult work in the household. A third, and often neglected channel, is that it may affect the expected returns to schooling: if the new activity increases low-skill wages relatively more than high-skill wages, perceived returns to schooling are likely to decrease. To investigate these questions, we leverage exceptionally rich first-hand data collected to this end, as well as secondary data to support the external validity of the findings.

A challenge to estimating the impacts of new economic opportunities is the potential endogeneity of access to these activities. To address this difficulty in the context of ASM, we exploit variations in the opening and location of artisanal mines in space and time. Across space, location is determined by geological conditions, as gold deposits are located solely on or near Birimian greenstone belts (Béziat et al., 2008; Bazillier and Girard, 2020). Over time, the opening of artisanal gold mines boomed after the surge in global gold prices in 2005. To estimate the effect of mine openings, we collected first-hand household data in central Burkina Faso. This data allows us to build a retrospective panel of education enrolment for 3,876 children over time (1990-2014), as well as a retrospective panel of involvement in gold mining for all individuals in the sample. In addition, we collected detailed information on the location of artisanal gold mines that were active in the area over the period, and on income from gold mining related activities. Furthermore, we elicit perceived returns to primary education using the manipulation of stones to capture subjective probabilities (Delavande, 2008; Delavande et al., 2011).

We use secondary data to examine the external validity of the results at the national scale. We exploit four waves of the demographic and health survey (DHS) and combine this information with the position and timing of opening of artisanal mines that we obtained from the Burkinabe National Geological Services. We employ different empirical strategies. With the first-hand data, we estimate simple differences and generalized difference-in-difference models. We test the robustness of our results using several alternative specifications, including the event study estimator from Sun and Abraham (2021) that takes into account the staggered nature of the exposure to new mines. With the DHS data, we rely mainly on difference-in-difference models, and provide a robustness specification using the location of the Birimian belt.

Our main, and rather unsettling result is that exposure to ASM strongly decreases school attendance in primary school for boys (we find no significant decrease for girls). This effect does not simply result from primary-school aged children work in the artisanal mining sector, as they are rarely participating. In contrast, adults living close to an artisanal mine often engage in mining-related activities and decrease their involvement in agriculture: they are less likely to work in agriculture and give higher priority to subsistence crops at the cost of cash crops. This change in adult labour allocation appears to increase child labour in the household: children closer to mines are more likely to be working in agriculture, likely substituting for adult work moving from agriculture to mining. Furthermore, we find that exposure to artisanal mines is associated with lower expected returns from primary schooling. This effect is consistent with the nature of artisanal gold mining, which creates new unskilled jobs where men can earn wages that greatly exceed those available in existing low-skilled activities (unlike women). Finally, we rule out a negative income effect and mechanisms that would affect the direct cost of education..

We contribute to the literature on the impacts of new economic opportunities on education, which finds mixed results. Focusing on secondary schooling in high- and middle-income countries, previous studies have found that access to new economic opportunities have generated either a decrease (Atkin, 2016; Cascio and Narayan, 2022; Kovalenko, 2023) or an increase (Jensen, 2012; Oster and Steinberg, 2013; Heath and Mobarak, 2015; Adukia et al., 2020) in average school enrolment rates. Closer to our study, Ahlerup et al. (2020) show that the presence of mines decreases school attendance across Africa, but focus on larger mines and on adolescents, with less information to explore mechanisms. In contrast to the existing literature, we measure the effect of a new economic activity in the primary sector on *primary* school enrolment, in the context of a low-income country where education levels are low and child labour is frequent.

We also contribute to an emerging micro-economic literature on the local impacts of mines. Most studies have focused on *large* mines and emphasized their negative effects on institutions and the environment (Aragón and Rud, 2016; Berman et al., 2017; Knutsen et al., 2017). Yet, large mines can also raise local revenues and affect positively human development outcomes (Aragón and Rud, 2013; Loayza and Rigolini, 2016; Benshaul-Tolonen, 2019). However, the impacts of artisanal mining are likely to differ in important ways, as ASM generates employs many more, low-skill workers (Girard and Zabsonré, 2021), and technologies that are likely to be detrimental to health (Gibb and O'Leary, 2014). In Burkina Faso in particular, two recent studies at the national level found positive effects of artisanal gold mining on local livelihoods (Zabsonré et al., 2018; Bazillier and Girard, 2020). In the context of Colombia, Mejía (2020) investigates the impact of gold mines on education and child labour and find that gold mining leads to an increase in primary school enrolment, but a decrease in test scores, and no change in child labour. Our originality with respect to this literature is to provide an in-depth exploration of mechanisms, thanks to first-hand data, and to present different findings. .

Finally, we contribute to the wide literature on child labour. Child labour is essentially conceived by economists as a consequence of poverty (Rosenzweig, 1981; Basu and Van, 1998; Baland and Robinson, 2000). However, increases in household income can have an ambiguous effect on child labour, in particular when it is driven by new employment opportunities, which may raise the returns to child work (typically in support roles within the family). Edmonds (2022) provides a detailed review of the empirical evidence and argues that it is important to distinguish between transient opportunities and long-term increases in household income; the former more often leads to an increase in child labor than the latter. Interestingly, even cash transfers, both conditional (Ravallion and Wodon, 2001; De Hoop et al., 2019) and unconditional (Edmonds, 2006; Edmonds and Schady, 2012; Dammert et al., 2018; Daidone et al., 2019; Aygün et al., 2024) have been found to either increase or decrease child labour, depending on the context and program design.[1] One argument is that there may be complementarity between schooling (which typically increases following transfers) and child labour (through the direct cost of schooling). We explore these questions in the context of changes in the local labour markets which expand adult and child work opportunities in the medium term.[2]

Our results have several implications for policies and for future research. It is often argued that non-agricultural employment in general (Haggblade et al., 2010; Van den Broeck and Kilic, 2019; Macours et al., 2022) and ASM in particular (Fisher et al., 2009; Geenen et al., 2021; Goetz, 2022) have the potential to transform rural livelihoods, promote social mobility, increase resilience and alleviate poverty in developing areas. If this is to be the case, policy makers, need not only to invest revenues from these activities in health and education (De la Briere et al., 2017), but also address the negative externalities of these new economic opportunities on human capital. In the light of our results, a direct ban on child labour in mining- as commonly promoted by policy makers for addressing child labour (Basu and Van, 1998)- is unlikely to be effective at mitigating the negative impacts of ASM on education. On the other hand, addressing the complex issue of the low perceived returns to education

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[1] Both positive and negative weather shocks have been found to increase child labour (Beegle et al., 2006; Shah and Steinberg, 2017). Micro-credit interventions have also been found to either increase or decrease labour supply among teenagers in various contexts (Augsburg et al., 2015; Crépon et al., 2015).

[2] While we study non-migrant individuals, the mechanisms which we discuss are closely related to those identified by the literature on migrations. Empirical studies found that migration can affect child labour and education of children remaining at home in either direction (Antman, 2011; McKenzie and Rapoport, 2011; Alcaraz et al., 2012; Luo, 2019).

is necessary.

The next section presents a simple model to discuss how new economic opportunities—such as artisanal mining—can influence child education and labor, followed by a review of relevant empirical evidence. Section 3 presents the data analysed and some descriptive statistics about households and mines. Section 4 describes the identification strategy and our main results while section 5 unpacks the mechanisms at play. The last section discusses the overall findings and concludes.

2 Economic opportunities, education and child labour

To structure our discussion, we propose a simple model of investment in child education and discuss how new economic opportunities may affect this decision through different channels.

2.1 Conceptual discussion

We propose a model that emphasizes three key channels through which new economic opportunities impact education: (1) they enable greater investment in education if they ease liquidity constraints; (2) they may raise the opportunity cost of schooling by increasing the returns to child labour, whether within or outside the household; and (3) they can alter the returns to education, either reducing or enhancing them, depending on whether the opportunities disproportionately benefit low-skilled or high-skilled wages.

Regarding the second effect, child labour may involve intra-household activities. Even if children do not directly work in or near mines for a wage, their marginal productivity at home or for household economic activities may increase if their parents work in mines, as children take on their responsibilities (e.g., in agriculture or household chores). In other words, mining opportunities can raise the opportunity cost of children's time, even if they are not employed in the mines themselves. In our model, we assume that the return to child labour is proportional to the adult wage: when adult wages rise, so do the returns to child labour. Regarding the third effect, in what follows, we focus on a scenario where new economic opportunities lead to an increase in low-skill wages while high-skill wages remain unchanged. This assumption aligns with the context of artisanal gold mining, which predominantly employs low-skilled workers (see section 3). Note that the second effect hinges on the hypothesis that education and child labour cannot be combined. [3]

Model set-up

Consider a household composed of one parent and one child who live together for two periods. In period 1 the household maximizes the net present value of utility in both periods: $u(x_1) + \delta u(x_2)$, where u is concave, $\delta < 1$ captures the time discount rate and x_t represents the consumption of a numeraire in each period ($t = 1,2$). In the first period, the parent and, possibly, the child work for a wage while in the second period, the parent is retired and only the child (now adult) works. There are two possible levels of wage for adults: w_u for unskilled workers and $w_s \geq w_u$ for skilled workers. If the child works in the first period, she earns a fraction $\alpha < 1$ of the unskilled wage of an adult (the child has a lower productivity than the adult). The child may also acquire skills through education in the first period and then be a skilled adult worker in the second period. We assume that education has a direct cost p_e. Education also has an opportunity cost since the child has to give up working in the first period to acquire an education. We assume that the adult is unskilled and that there is no saving or credit.

Decision to invest in education

To decide whether or not to invest in the education of the child, the household compares the net present value of utility without and with education. If the child does not go to school, the budget constraint in the first and second period are respectively: $x_1 \leq (1+\alpha)w_u$ and $x_2 \leq w_u$. The net present value of utility is then: $u((1+\alpha)w_u) + \delta u(w_u)$.

If the child goes to school and has to give up child labour, the budget constraints in the first and second period are respectively: $x_1 + p_e \leq w_u$ and $x_2 \leq w_s$. The utility is then: $u(w_u - p_e) + \delta u(w_s)$. A household invests in education only if the present value of the return to education in period 2 outweighs the cost of education (including the opportunity cost) in the first period. In equations, the

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[3] If children can both work and get educated, there is no trade-off and the "opportunity cost channel" does not apply. Appendix C explores this case and show that our main conclusions regarding the ambiguous effect of new economic opportunities on schooling remain unchanged under this alternative scenario.

child gets educated iff:

$$\delta \left(u(w_s) - u(w_u)\right) \quad \geq \quad u\left((1+\alpha)w_u\right) - u\left(w_u - p_e\right) \tag{1}$$

Increase in the unskilled wage and the decision to invest in education

The countervailing effects of an increase in w_u on the decision to invest in education are immediately visible from the expressions above. First, the left hand side (LHS) of inequality (1) decreases: an increase in w_u decreases the relative gains from education in the second period. The right hand side (RHS) of inequality (2), which captures the costs of education is also affected, albeit in an ambiguous direction.[4] Indeed, the household is richer (and the utility concave), so that the utility loss implied by the directly cost of education (p_e) is smaller, yet the opportunity cost of education (αw_u) has simultaneously increased. In short, depending on the model parameters, an increase in the unskilled wage may lead to an increase or a decrease in investments in education.

To illustrate this conclusion, we choose specific functional forms and parameter values and compute the value of net present utility as a function of w_u with and without education. Figure 1 in Appendix A presents a graphical representation of the value of utility under the two scenarios and the implied choice of education ($e = 0$ or $e = 1$). It illustrates the non-monotonic impact of an increase in w_u on education. At very low values of w_u , the “no education scenario” dominates (the first period costs are too steep), at intermediate levels of w_u, education is preferred because the liquidity constraint on the direct costs of education is relaxed, while at high values of w_u, education is abandoned because returns to education are too low.

This simple framework illustrates the key trade-offs at play when parents consider investing in their children education and how these trade-offs are modified by new economic opportunities, such as those offered by artisanal mining. The next subsection reviews the existing empirical evidence of the effects of new economic opportunity on education (and child labour) and discusses each of the channels highlighted by the model.

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[4] The first derivative of the RHS of (2) is: $(1+\alpha)u'\left((1+\alpha)w_u\right) - u'\left(w_u - p_e\right)$. The sign of this expression is ambiguous.

2.2 Empirical findings in the literature

In line with the countervailing effects of new economic opportunities on education highlighted above, the empirical literature finds mixed results. In the contexts of oil and gas fracking in the United States or export manufactures in Mexico, Atkin (2016), Kovalenko (2023) and Cascio and Narayan (2022) find an increase in high school dropout rates, as new well-paid jobs are available to non-graduates. In contrast, new IT service centres and the expansion of business process outsourcing in India, as well as the growth of the garment industry in Bangladesh, have lead to increased high-school school enrolment (Jensen, 2012; Oster and Steinberg, 2013; Heath and Mobarak, 2015).

Using the language introduced above, the difference between these contexts may lay in the type of wages mostly impacted by the new opportunities: in the former case, low-sill wages have increased (decreasing the returns to education), while in the latter case, high-skill wages have been more impacted. Interestingly, Adukia et al. (2020) find heterogeneous effects of road construction on middle school enrolment, depending on the local opportunity cost of education (returns to child labour) and the new opportunities the road gave access to (returns to education). As expected, the effects on education are significantly positive in areas connected to higher paying jobs, but the effects turn negative and insignificant in areas where the liquidity constraint is more severe and where the opportunity cost of education is higher. In contrast to our, these studies focus on middle- or high-income countries, on post-primary education and on economic activities in the secondary and tertiary sector.

In contexts similar to ours (gold mining), Ahlerup et al. (2020) show that the presence of mines decreases school attendance for adolescents across Africa. Compared to us, they focus on relatively larger mines and older children. Although the data at hand does not allow them to fully explore the mechanisms at play, their main hypothesis is that substitution of high school for employment in gold mining occurs directly. Qualitative studies tend to challenge this explanation for younger children, on which we focus in this study, as they are not frequently involved in mining activities directly (see section 3). In the context of Colombia, Mejía (2020) finds that exposure to gold mines *increases* school enrolment in primary and high school but *worsens* other education outcomes (grades and continuation to higher education). Furthermore, while children are not working more closer to mines, it is the case for young adults (in terms of our model, returns to higher education - but not primary or secondary education - may have decreased in this context).

Regarding the question of whether education and labour can be combined, there is no consensus in the empirical literature. The fact that conditional cash transfers can increase both education and child labour suggests that children combine work and education in some settings (De Hoop et al., 2019).[5] In our setting, the qualitative literature and our own qualitative evidence suggest that children do combine work and schooling to some extent, although the combination can affect schooling negatively (Hilson, 2012; Maconachie and Hilson, 2016).

2.3 Mines and local development

The recent economic literature on the local impacts of mining have mostly focused on large, industrial mines. Cross-country studies in Africa found that large mines, locally, fuel conflicts (Berman et al., 2017), increase bribe payments (Knutsen et al., 2017), have limited local economic spillovers (Berman et al., 2023) and have mixed effects on income and employment of women and on food security (Kotsadam and Tolonen, 2016; Wegenast and Beck, 2020). Pollution from large-scale gold mines was also found to affect negatively agricultural production in Ghana (Aragón and Rud, 2016), yet similar mines contributed to reduce child mortality overall in Sub-Saharan Africa (Benshaul-Tolonen, 2019). In Peru, industrial gold mines were found to raise local incomes, decrease poverty and increase inequality (Aragón and Rud, 2013; Loayza and Rigolini, 2016).

However, large mines differ greatly from artisanal and small-scale mines, as ASM generates much more employment, in particular for low-skill workers (Girard and Zabsonré, 2021). There are few quantitative studies of the impacts of artisanal mines on household income or other development outcomes such as education. Recently, few quantitative papers confirm that artisanal mines lead to increases in household income, in Burkina Faso in particular (Zabsonré et al., 2018 and Bazillier and Girard, 2020). A recent cross-country study shows that ASM leads to deforestation in Africa, and to modest increases in income (Girard et al., 2022). One of the reason why ASM has received little attention in quantitative studies until very recently is that data on artisanal mines and miners is

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[5] On the other hand, an increase in education induced by a cash transfer is frequently accompanied by an overall decrease in child labour (Ravallion and Wodon, 2001; Edmonds and Schady, 2012; Aygün et al., 2024).

difficult to collect or access (Heemskerk, 2005; Couttenier et al., 2022).[6]

Even if there is little systematic evidence on the impacts of ASM, the media, NGOs and development agencies typically described ASM as a "bad". It is criticized for its adverse effects on the environment, health, social cohesion, and child labour (World Bank, 2020; see our Appendix D for a review of local and international media coverage of artisanal mining in Africa and other regions). For children in particular, mercury poisoning is a serious risk, both directly and indirectly through the contamination of soils, water and food sources (Gibb and O'Leary, 2014; Esdaile and Chalker, 2018). Child labour in mines is another major concern, as the ILO describes ASM as one of the "worst forms of child labour", which needs to be eradicated as a priority (Hilson, 2012). Numerous public interventions aim at addressing problems of low education and child labour among ASM communities, but they are often small in scale and show mixed results (World Bank, 2009; CERFODES, 2014; Marshall and Veiga, 2017; Hilson et al., 2019).

While data and quantitative evidence on ASM are scarce, a rich qualitative literature has emerged on the social and economic importance of ASM globally, and in Africa in particular. Its findings nuance in important ways the common narratives on ASM in the media and among policymakers (Appendix D). In particular, scholars have shown how individual participation in artisanal mining is driven by a wide variety of financial and social motivations, that include investing in better standard of living or in income-generating activities, marrying, improving ones social status, and most importantly, diversifying household income portfolio as a risk management strategy (Maconachie and Binns, 2007a; Grätz, 2009; Okoh and Hilson, 2011).[7] Artisanal mining provides important revenues to local households, and as such contributes to alleviating poverty and coping with shocks in the short term (Fisher et al., 2009; Hilson, 2012; Kervyn de Meerendre, 2013). Linkages also exist between artisanal mining and agriculture: miners are often fore and foremost farmers, and artisanal mining is often practiced off-season by locals, who may invest mining revenues in agriculture (Maconachie and Binns, 2007b; Hilson, 2011; Mkodzongi and Spiegel, 2019). Yet, in this more qualitative literature, the overall im-

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[6] Recent working papers suggest positive effects of gold mining booms on living conditions in Sub-Saharan Africa (Guenther, 2018; Girard et al., 2022; Poignant, 2022). Yet, Guenther (2018) and Poignant (2022) suggest that ASM causes substitution away from agriculture. ASM also appears to cause deforestation at a large scale (Girard et al., 2022; Guenther, 2018).

[7] Our own qualitative fieldwork generated similar findings.

pacts of artisanal mining on development, poverty alleviation, and human capital accumulation in the long run is debated, given that ASM generates negative spillovers on health and the environment, and exploitative modes of production (Kamlongera, 2011; Gibb and O'Leary, 2014; Pokorny et al., 2019; Ofosu et al., 2020).

3 Context and data

3.1 Institutional setting: *Orpaillage* in Burkina Faso

Artisanal gold mining (called *orpaillage* in West Africa) is a particularly relevant activity to investigate the impacts of a new economic opportunity on children education. It has seen an important and rapid boom which started in the mid-2000s, driven by a sharp increase in world prices that is exogenous to West African countries (price-takers in the gold market). In Burkina Faso, gold became the main export of the country (before cotton), providing 55% of the export revenues in 2014 (for only 2% in 2007) and contributing to a large share of government revenues and GDP. Approximately 80% of the country's gold production comes from a few industrial mines which have been established after the reform of the mining code in 2003. However, industrial mines employ a very small number of workers and their local impacts are at best limited (Pokorny et al., 2019; Bazillier and Girard, 2020). On the other hand, artisanal gold mining has stronger linkages with the local economy, and the number of workers in ASM as considerably grown since the mid-2000s.[8]

Indeed, although there is a long tradition of artisanal gold mining in Burkina Faso, this activity became much more profitable after 2006.[9] According to Alvarez et al. (2016), global gold prices are largely transmitted to miners, increasing profitability by more than 80% during the mining boom. As a result, ASM spread throughout Burkina Faso, from 200 sites observed in 2003 to up to 1000 in 2014. More importantly, the number of artisanal miners has increased significantly, from a few tens of thousands

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[8] The context of artisanal gold mining in Burkina Faso is similar to what has been described in other West African countries: see for instance Grätz (2009); Okoh and Hilson (2011); Hilson (2012); Hilson et al. (2019).

[9] See for instance Gueye (2001); Hilson (2002); Jaques et al. (2006); Di Balme and Lanzano (2013); Kevane (2015); Werthmann (2017) for historical perspectives on gold mining in Burkina Faso and West Africa. Although artisanal mining has a longer history in neighbouring countries such as Ghana and Mali, it was limited to specific geographic areas in Burkina Faso until the 1980s, and then progressed slowly throughout the country. It is only in the mid-2000s that the number of artisanal mines grew rapidly due to the increase in global prices. Industrial mining was also largely undeveloped in Burkina Faso until the revision of the mining code in 2003.

in the early 2000s to up to 1 million of artisanal miners in the mid-2010s (Jaques et al., 2006; Di Balme and Lanzano, 2013; Bazillier and Girard, 2020).

ASM is only conducted in specific parts of the country, based on geological conditions. Similar to Ghana and other neighbouring countries, gold deposits are only found in or in proximity of the Birimian greenstone belt (Hilson, 2002; Béziat et al., 2008). This geological formation covers approximately 27% of the country and runs from the North East towards the South West (Jaques et al., 2006). As it can be seen from Figure 2 in Appendix A, virtually all gold mining exploitation is conducted in or next to the Birimian belt, and most of the Birimian belt is exploited by 2010. This means that, importantly for our analysis, both the timing and location of ASM are rather exogenously determined by the world prices and by the geological conditions.

The local conditions of artisanal mining in Burkina Faso have been well documented.[10] When a gold deposit is discovered, a mine usually starts operating without a permit, yet if it functions more than a couple of months, the owner requests a permit from the mining administration to secure its control over the mine[11] However, there is no perfect overlap between official permits and actual mines, since permits can be granted for sites that are not exploited, and several sites operate without permits (Di Balme and Lanzano, 2013; Bazillier and Girard, 2020). This limitation does not affect our main analysis, since our first-hand data includes direct information on mining operation.[12]

The size of gold mining sites varies greatly, as they can employ a few dozens of people up to thousands of workers. Besides diggers, sites generate employment for a variety of people with well-defined and organized functions, which include gold washing, grinding and winnowing, transportation, food and water provision. The lighter tasks, or at least those not related to digging, tend to be performed by children and women (Jaques et al., 2006; Werthmann, 2009; see also Hilson (2012) in Ghana). Gold miners and other workers at ASM sites can either be local inhabitants (for a vast majority, farmers) or migrants from other areas. Local miners tend to work on ASM sites during the non-agricultural

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[10] See for instance the descriptions in Jaques et al. (2006); Werthmann (2009); Di Balme and Lanzano (2013); Kervyn de Meerendre (2013); Pokorny et al. (2019), which provide additional details on the institutional setting. The sites where we conducted qualitative fieldwork also correspond to these descriptions.

[11] Such a permit takes about 3 months to be delivered. Subsequently, the permit has to be renewed every two years.

[12] We use permits to infer the position of mines in the analyses based on DHS data. The lack of perfect overlap with actual mines leads to an attenuation bias: impacts are more difficult to detect so that our results can be regarded as lower bound estimates.

season as a complementary activity when agricultural labour requirements are low. Because our first-hand data sample consists of local farming households, we investigate the impact of the economic opportunities offered by the opening of a new mine on *local* households and their children.[13]

3.2 Data and descriptive statistics

First-hand data

We collected primary data on gold miners and mine location in South-West Burkina Faso. We focus on a relatively small area of approximately 70 by 70 km in the vicinity of the provincial capital of Houndé, a region characterized by cotton production combined with other farming activities. The sample is representative of cotton growing households who account for 95% of the rural population in the area.[14]

The survey took place in January and February 2014 among 1,015 households spread over 40 villages. We collected information on all household members, as well as children, spouses and ex-spouses of the household head who are not household members. This generated a sample of 10,450 individuals, 3,475 of which are aged 7 to 17 in 2014. The household survey includes several modules related to household composition and demographics, education, economic activities, agriculture, wealth, and food consumption, among others. In a separate module, we asked about individual participation to gold mining activities over time. Specifically, we asked every individual who worked on a gold mine at some point of her life a list of questions related to her own work in the mine and to the life cycle of the mine.[15] This allowed us to collect information on mine location, the year when its operations started and ended, and the approximate number of individuals working on the site over time.[16] Thus, the information that we obtain on mines from our first-hand data collection is more complete and

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[13] Anthropological descriptions of mining sites indicate that migrant workers are typically isolated adults and migrant children are almost never observed (Jaques et al., 2006; Werthmann, 2009; Di Balme and Lanzano, 2013).

[14] This data was collected as part of the impact evaluation of an intervention offering insurance to cotton farmers (Stoeffler et al., 2022).

[15] In our survey, mining sites refer exclusively to artisanal gold mines (with pits in which individuals dig for gold). There exist other sites for gold-related activities, for instance treatment sites in which gold residuals are extracted from the material (e.g. mud) coming from the mine. These other sites are not included in our sample of mines..

[16] We asked respondents to estimate the number of workers when they started on the site, at the peak of the activity of the site, and today if the mine is still operating. This allows us to predict the number of workers on the site at any point of time since the site opened.

more precise than the information obtained from mine permit locations which we use in the DHS analysis (see Appendix B).[17] From this data, we construct a historical panel of mine activity in the area. We then compute the distance of each village to the closest active mine at each point of time, which varies over time as new mines open progressively (see Figure 3 in Appendix A). We focus on mines in which at least two individuals worked at some point during their life (to triangulate the recall information).

Some variables are only available for 2014, including those capturing expectations of household heads regarding returns to education. Eliciting expectations from respondents with low levels of education is challenging. Both the concept of probability and hypothetical questions are typically poorly understood. Following Delavande et al. (2011), we use visual aids to elicit subjective probabilities. Specifically, household heads wre asked the following question: "among a group of 20 individuals who left school at grade Z, how many of them will have a house with solid walls when they are 30 year-old?". We asked this question for grade 2 and for grade 6 (end of primary school). The respondent answered the question by moving 20 stones in one or the other category (solid house or not solid house). The difference between the number of stones in each grade provides a measure of expected returns from education. One limitation is that we only obtained expectations from the household head, not from children or other household members who contribute to schooling decisions.[18]

We also collected qualitative information throughout the quantitative survey and conducted additional qualitative fieldwork in June 2016. This fieldwork included several interviews, two mining site visits and focus groups with gold miners, as well as 10 focus groups with farmers which included questions on gold mining activities (see Stoeffler et al., 2022). The nationally representative datasets used for external validity are presented in Appendix B.

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[17] Mine permits correlate only imperfectly with actual mine activities, as they can be obtained before or after a mine becomes active. They also remain when deposits are exhausted and mines stop operating or have very reduced activity. Besides, our household locations are precise, while DHS clusters are randomly moved by 10 km to maintain confidentiality.

[18] Unfortunately, we did not collect health related information that would allow us to measure mercury poisoning. Yet, our detailed information on children activities in mining sites help rule our that (many) children directly manipulate mercury (see Table A.4). Nevertheless, they may be poisoned through the inhalation of toxic vapours or the consumption of contaminated water and food.

Measures of exposure to mines, education, and child labour

As we do not expect a linear relationship between the distance to the mine and its impact on rural dwellers, we rely on two measures of exposure. First, we use a binary variable indicating whether the village is within 10 km of a mine in a given year. Second, we construct a continuous measure which is the opposite of the log of the distance to the closest mine in a given year. We use a 10 km threshold because beyond this distance, it becomes more difficult to commute daily to work at the site, especially for women and children. In addition, about a third of the whole sample is located within 10 km of a mine in 2014. Both variables correlate well with the likelihood that an individual work at a gold mining site. Our results are generally robust when we use a 6 km or a 12 km indicator (instead of 10 km) as a threshold for households living close to gold mining sites.

We combine the information on mines with a historical panel at the individual level indicating for all individuals aged 6 and older whether they worked in a gold mining site in any given year, and for individuals aged 6 to 30 whether they attended school in any given year.[19] To measure education we rely on a binary variable (labelled "in school") that takes value one if the child attended school that year. We focus on primary school age children (7 to 12) because secondary schools often require rural children to move out of the household and live close to the secondary school during the school year.[20]

In terms of child labour, we measure various types of work. We identify directly children who have worked in gold mining each year. We also measure work in agriculture in the last year and in the last 7 days. To study outcomes related to agriculture, we also construct a panel at the household level using information on cotton and cereal farming over the last six years (we used a recall period of 2008 to 2014). This allows us to measure the impact of mines on agricultural choices and production over a

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[19] Note that because we asked in 2014 school enrolment history to individuals aged 30 and younger, we know school enrolment in 1990 only for individuals aged 6 at that time (those born in 1984, 30 years before 2014). In 1991, we have information on individuals aged 6 and 7 at the time (born in 1984 and 1985), and so forth. We need to wait until 2001 to have some individuals born in 1984 reaching the age 17 in our sample. As a consequence, some of our analyses focus on the years 2001-2014 for which all primary and secondary school ages (6 to 17) are represented. These years are also those when the distance to mine changes the most, as mines start appearing mostly after 2000 (see Figure 3). Because mines opened more recently and gold mining questions were asked to *all* individuals, this issue of age structure does not arise when it comes to participation to gold mining activities.

[20] We are thus likely to miss many of these children in the DHS data because they may not have been captured as resident of the household. However, we are likely to interview more of theses children in the first-hand data as we asked information about children of the household head whether they are in the household or not. While primary school officially starts at age 6, few children start by then. Only 13% of all 6-year old children are in school in the pooled DHS data. This number increases to 33% for 7-year old.

limited period of time.

Descriptive statistics on mines, miners and households

The number of active mines in our study area increased from only one mine before 1999 to 16 mines in 2014 (Figure 3 in Appendix A). As new mines opened, the average distance to the closest mine decreaseed (from 28.4 km before 1999 to 11.1 km in 2014) and the share of the sample within 10 km of a mine increaseed (from less than 0.03 before 1999 to 0.36 in 2014). Most of the gold deposits were found in or near the Birimian belt, and no mine appeared in the sedimentary area (see section 3.1).

Households in the first-hand sample are large and 79% of them have children aged 7 to 12 year old (household descriptive statistics are reported in Table A.2 in appendix). Household heads have low levels of education (on average 1.2 years of education). While the average household dietary diversity score (HDDS) is not critically low (average of 7.84) during the period of the survey (post-harvest), the use of harmful coping strategies is widespread (average of 0.44).[21] Cotton is the main crop in terms of cultivated area. Table A.1 in appendix shows descriptive statistics for all individuals and for children aged 6 to 17. Children represent more than a third of the sample, and the average age in the full sample is very young (25). Almost 4% of the sample has worked on a mining site in the last 12 months, but only 1% of the children aged 6 to 17.

Focusing on individuals who worked on a mining site in the 12 months before the survey, important differences emerge between adult men and women, the latter representing 36% of adult miners (Table A.3). Men spend twice the number of days working at the mine per year compared to women (61 days vs 31). Men income per day is also higher, with a median income of 952 CFA vs 500 CFA for women (approximatively 2 USD vs 1 USD). The difference is even larger for the median total income over the last year (40,000 CFA vs 10,000 CFA), as men spend more days in mining. Women median income is equivalent to the daily agricultural wage for hired labour (based on our data on agricultural

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[21] HDDS ranges from 0 to 12 (a higher score indicates higher food *security*). It consists in a count of food item families consumed at least once in the last 7 days: cereals, roots, vegetables, fruits, meat, eggs, fish, pulses, milk, oil, sugar, and miscellaneous. Harmful coping strategies range from 0 to 4 (a higher score indicates higher food *insecurity*). It is a count of food related coping strategies employed because of a loss of income in the last 12 months: eating only leaves, not eating for a full day, reducing the number of meals, and reducing the quantity of meals. See for instance Leroy et al. (2015) for a discussion of food security indicators.

activities). As a result, artisanal gold mining is a more substantial economic opportunity for men compared to women. The difference in daily income is likely driven by the differences in occupation across genders: 79% of the men are diggers, whereas only 1% of the woman participate in digging. Women are mostly prospectors, gold cleaner, and to some extent winnowers, water sellers and traders. These activities are very marginal for men.

When it comes to children, differences between male and female individuals are attenuated (Table A.4). Girls represent 46% of the child sample and work a similar number of days in the mine on average (44 for girls vs 50 for boys). While 55% of the boys are diggers (and 2% of the girls), median income per day does not differ as much (625 CFA vs 394 CFA). Diggers are mostly older boys (15-17), and very few children of primary school age work in mines. For boys and girls below 15, occupations and income is similar to those of women, as both women and young children perform mostly "lighter tasks" (see section 3.1).

Descriptive statistics for variables from the DHS survey used in the analysis at the national scale are displayed in Table A.5 for the pooled sample. Primary school enrolment is low (32% of the pooled sample) and slightly higher for boys, although there is an increasing time trend over the period.

4 Empirical strategy and results: new economic opportunities and children's education

4.1 Empirical strategy

We seek to estimate the impact of living close to an artisanal mine on a child's education. Our first-hand data allows us to exploit the exact location and opening date of each mine. Our first identification strategy compares children exposed or not to mines over time, controlling for age and year fixed effects. Exposure of mines is either an indicator of mine within 10 km of the household or the opposite of the log of the distance to the closest mine.

Formally, we estimate the following model:

$$Y_{i,t,a} = \beta_0 + \beta_1 T_{i,t} + \beta_2 T_{i,t} * M_i + \beta_3 M_i + \alpha_t + \gamma_a + \varepsilon_{i,t} \tag{2}$$

where $Y_{i,t}$ is an indicator of whether a child i is at school in year t, T_t captures the child's exposure to mine in year t, M_i takes value 1 for male children, α_t captures year fixed effects and γ_a age fixed-effects (we also estimate a specification with age-year interaction fixed effects to take into account specific cohort effects). We include all individuals between 7 and 17 year old in our main estimation but also present results restricting the sample to the 7 to 12 year old.[22] Standard errors are clustered at the village level.

The main identifying assumption is that, in the absence of mines and for a given year,areas exposed to mines would have had education levels similar to areas not exposed. To formally test this assumption, we run a placebo regression, where we restrict attention to years before the gold boom (2006) and verify that education levels do not differ by future exposure to mines:

$$Y_{i,t,a} = \beta_0 + \beta_1 T_{i,t=2014} + \beta_2 T_{i,t=2014} * M_i + \beta_3 M_i + \alpha_t + \gamma_a + \varepsilon_{i,t} \; if \; t < 2006 \tag{3}$$

where $T_{i,t=2014}$ indicates *future* treatment in 2014. We expect $\beta_1 = 0$. In other words, the subsequent development of a mine close to a given child, should not be correlated to its education level before the mine boom.[23]

We also present results based on a generalized difference-in-difference estimation where we include village fixed effects. The identification of the impact of mines then relies on the comparison of children living in the same villages, before and after the opening of a new mine in the vicinity of this village. In addition, we run a specification with household fixed effects where the identification relies on the comparison of children of the same household whose exposure differed because of the opening of new mines over time. Finally, we use the event study estimator from Sun and Abraham (2021) to take into account the staggered treatment across villages.

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[22] Results are robust to different age categories such as including individuals aged 6 and/or 18 year-old. In this data set, we are confident that we capture children who left for secondary school because detailed schooling outcomes for all children of the household head were recorded, regardless of their current place of residence.

[23] In an alternative placebo specification, we exclude the few observations close to mines before 2006 (which may have been already affected by the proximity of mines). Results are unchanged (available upon request).

An important question relates to migration and sample selection: is the composition of the sample affected by the presence of mines, and our results driven by this change in sample composition? To address this possibility, we re-estimate our main model by restricting attention to children of the household heads, whether or not they reside in the household (we have information on non-household members for children of the household head). In other words, we verify that our results are robust to focusing children born in the village of interest, regardless of their current residence or migration status. Three additional pieces of evidence help rule out a sample composition effect. First, household size is not correlated with the presence of a mine at the time of the survey. Second, the rates of migration of entire households are small and uncorrelated to the presence of mine.[24] Finally, household head's year of installation as independent farmers is also uncorrelated with the presence of a mine.[25]

We present additional robustness tests by restricting attention to specific samples where we expect the estimated impact to hold. We estimate specifications focusing on mines in which 100 individuals or more are working in year t; or on years post 2001 and on individuals below 16 (to obtain a panel which includes all ages for each year). Finally, we restrict attention to specific ages and estimate our main model on the sample to children who reached that age (we choose age 7 and 12 which correspond to regular entry in primary and secondary school).

Turning to labour outcomes, we use a specification similar to equation 2 when estimating the impact of exposure to mine on the likelihood to work in mining in a given year for age categories 7-17 and 18-59. For outcomes related to agriculture, we use the same specification as 2 at the household level for the years 2008-2014 (the recall period used for agriculture). For other outcomes, such as work in agriculture (individual level) and expected returns to education (household level), we only have cross-sectional information in 2014 and then run a simple difference:

$$Y_{i,a} = \beta_0 + \beta_1 T_{i,2014} + \beta_2 T_{i,2014} * M_i + \beta_3 M_i + \alpha_a + \varepsilon_i \tag{4}$$

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[24] In a separate part of our quantitative survey, we asked key informants about the arrival and departure of households in the village over a five-year period. They mention only one household per year on average. Furthermore, these rates are not correlated to the presence of mine (in a regression framework similar to the one introduced above).

[25] Households heads were asked about the date at which they joined cotton cooperatives and started cultivating cotton (a good proxy for their installation as farmers).

4.2 Empirical results

Main results

We first estimate the effect of artisanal mines on education with our first-hand data. Table 1 reports the estimations of the impact of exposure to mines on the likelihood that children attend school when aged 6 to 17 (Columns 1 and 2) or 7 to 12 (Columns 3 and 4), controlling for age and year fixed effects. The results indicate that mines have a strong and negative impact on school attendance: children living within 10 km of a mine are 7.6 percentage points less likely to attend school, and this effect reaches 9.3 percentage points for children of primary school age. The effect is stronger for boys: for girls, school attendance is not affected by exposure to mines (the coefficient on exposure in Columns 2 and 4 is not significant), while for boys, the impact of being within 10km of a mine amounts to 13.3 to 15.8 percentage points. When using a continuous measure of exposure, the gender contrast is similar. The size of the impact indicates that halving the distance to the closest mine translates into a 3.6 percentage points lower attendance for boys aged 6 to 17 and a 4.8 percentage points lower attendance for primary school aged boys (Columns 2 and 4 Panel B).[26]

To verify the external validity of our findings, we estimate the impact of artisanal mining on education using our DHS data and information on mining permits. Table 2 reports the results, using our two measures of exposure: a binary indicator of close proximity (less than 20 km) in panel A and a continuous measure of proximity in panel B. The first two columns report the results of the estimation of a simple difference-in-difference (as described in Appendix B) based on the last two waves of the DHS survey, while the last two columns include previous waves (1993 and 1999).

The estimates confirm that the presence of mines decreases school attendance significantly more for boys than girls: the point estimate on exposure for the whole sample is negative but not significantly different from zero (Column 1), yet the distinction between girls and boys indicates that mines have a significantly different effect for boys and girls, in the direction of a decrease in school attendance for boys. Furthermore, the effect on boys is large: the coefficients reported in Column 2 of Table 2 suggest that boys living within 20 km of a mine are 5 percentage points less likely to attend school. This effect

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[26] When distance d is halved, the change in $[-ln(d)]$ is: $[-ln(d)]-[-ln\frac{d}{2}]=ln(2)\simeq 0.693$. We thus multiply the sum of coefficients (A+B) by $ln(2)$ to obtain the effects of halving the distance. Average distance to mines is approximately 11 km in 2014.

becomes 7.6 percentage points when we include previous waves of the DHS. These estimated impacts of mine represents 11 to 16% of the mean attendance for boys in 2010 (which was 0.47). Similarly, the coefficient on the continuous measure of exposure indicates that halving the distance to the closest mine is associated with a 2.3 percentage points decrease in school attendance (column 2, panel 2).[27] Yet, in these estimations, the test of significance of the overall effect of exposure for boys (summing the first two estimated coefficients) suggests that the coefficients are, at best, significant at 13%. These results suggest that our results from the Houndé region generalize to the rest of Burkina Faso, although they are less precisely estimated at the national scale.

All estimation strategies lead to the same general conclusion regarding the impact of artisanal mines on primary school education: children are less likely to go to primary school when a mine open in the vicinity of their village. The effect is concentrated on boys and is large: even the more conservative estimates suggest that boys likelihood to attend primary school decrease by 11% of the mean attendance rate in 2010 when they live within 20 km of the nearest mine.

Robustness

As detailed in section 4.1, the main identifying assumption is that education would have been similar across areas, would mines not have opened. To verify that the places exposed to mines had similar education levels to other places, before mines opened, we run placebo regression where we restrict attention to years before the gold boom (2006) and confirm that education levels do not differ by future exposure to mines in our first-hand data (see Table A.7 in appendix).

In Table 3 we report the results of estimations with village fixed-effect (a generalized difference-in-difference estimation). Table 4 shows results with household fixed-effect, where the identification relies on the comparison of children of the same households who, due to the opening of new mines, differ in their exposure to mines. The impact on boys remains remarkably stable, both in size and significance, when we include these fixed effects. As in our main specification, the estimated coefficients for girls are never significantly different from zero.

Our results are robust to alternative specifications or samples. They hold when we introduce year and

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[27] For column 4, panel 2, the corresponding effect is a decrease of 3 percentage points. The average distance to the closest mine open in 2010 is 38 km in our main sample of children.

age interactions (Table A.8, column 1), focuses attention on larger artisanal mines employing more than 100 workers (column 2), restrict the sample to the biological children of the household head regardless of their residence (so that short term migrants or endogenous household composition effects are muted, column 3), or restrict attention to the period post-2001 to have all school ages (below 16) represented each year (column 4, see footnote 19 above). In all cases the obtained coefficients are very close to the original estimations and confirm the strong and negative impact of mines on boys education. In Table A.9, where we restrict attention to two critical ages, so as to have only one observation for each child. We chose age 7 where most children enter primary school (columns 1 and 2) and age 12 where transition to secondary school should take place (columns 3 and 4). We find again a strong and negative impact of mines on boys education: living within 10 km of a mine at age 7 decreases the likelihood that a boy starts primary school by 14 percentage points and the likelihood that he is still attending school at 12 by almost 14 percentage points as well. Interestingly, at 12 we also find a negative impact of mines on girls education (significant with the binary exposure measure): girls appear 4.6 percentage point less likely to be attending school when living close to a mine. A last robustness check is reported in Figure 4 in Appendix A, where we show the coefficients from the Sun and Abraham (2021) event study estimation. This specification, which takes into account the different timing of mine opening in our study area, confirms the negative impact of mines on children immediately after a mine opens nearby.

For our nation-wide analysis, we test the robustness of the results using the location of the Birimian belt (an exogenous geological condition) instead of the actual location of mines. Table A.6 reports an estimation where exposure to mines is proxied by the presence of the Birimian belt (see section 4.1). These estimations confirm the negative impact of mines on education. Yet, the difference between boys and girls is not as strong, as the coefficient on the interaction between exposure and gender (boy) in 2010 is never significantly different from zero.[28] When previous waves of the DHS are included, the estimated impact is significant for both genders (Columns 3 and 4), and suggest that children are almost 10 percentage points less likely to attend school when they are exposed. These results confirm the robustness of the nation-wide analysis, and that the findings obtained in the Houndé region are not

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[28] Nevertheless, the impact of exposure is significant for boys only when we rely on the last two waves of the DHS (Column 2), as indicated by the p-value reported at the bottom of the table.

fundamentally different from those obtained for the rest of Burkina Faso.

5 Mechanisms

In this section, we turn to investigating the potential mechanisms that can explain the strong negative impact of artisanal mines on education, for boys in particular. The conceptual discussion proposed in Section 2 highlights three potential channels through which ASM may affect education: liquidity constraint, opportunity cost, and returns to education. The first channel should a priori lead to an increase rather than a decrease in education, except if gold mines depress local real incomes. While this may seem unlikely, we examine this possibility and dismiss it. The second channel would imply an increase in child labour (in competition with schooling). We investigate this possibility, considering both labour in (and around) mines and household tasks (proxied by farm work in our primary data) and find evidence in favour of increases in child labour on farms. We then turn to examining whether perceived returns to education have decreased (third channel), making use of original data collected for this purpose. We consider the possibility that impacts may differ by gender for each of these channels.

5.1 Mines and liquidity constraints

In our conceptual framework, we discuss how an increase in the income from mining may decrease the utility cost of education (by making a household richer), leading to an increase in education. Because our empirical results point to a decrease in investment in education, we discuss here whether household real income has decreased following the opening of mines (contrary to our expectation). This could be the case if for example local prices have considerably increased, or if schools have closed, effectively increasing the distance to be travelled to go to school and thus the cost of education.

An income effect?

As mentioned earlier, the existing quantitative literature finds that artisanal mines tend to increase rather than decrease income in Burkina Faso (see section 2). We do not have data that allows to formally challenge this conclusion either in our first-hand sample or in the DHS sample, as measures of income or consumption are not available. Yet, both datasets include information on nutrition, food security and assets, as well as information on local prices for our first-hand data.[29] We use child nutrition and household asset positions as indicators of household material well-being and investigate whether proximity to mines is correlated with these variables. With the first-hand data we perform a cross-section comparison for food security and asset variables, as we have no retrospective information on these dimensions. On the DHS data, we use the same specifications as for our main results.

Using our first-hand data, we find that mines are not correlated with a lower level of food diversity or food security (columns 1 to 3, Table A.11) or by lower levels of assets (columns 4 to 6). Furthermore, local prices and inflation do not appear to be affected by the presence of mines. In fact, the levels of prices are very similar across villages and overall inflation is small.

These conclusions are confirmed with DHS data. We find no impact of mines on children height-for-age z-scores, across estimation strategies (columns 1 and 2, Table A.12). As for weight-for-height (columns 3 and 4), the difference-in-difference estimations suggest that children may be lighter closer to mines, yet this effect disappears when including previous waves of data. Regarding asset position, we find no impact of mines on household assets or on the likelihood that the household belongs to the bottom two quintiles (Table A.13). We conclude that overall, mines do not seem to affect negatively material well-being in exposed areas (neither do they appear to lead to an improvement in child nutrition or asset position).

Change in the direct cost of education (supply-side effect)?

We now turn to the possibility that mines imply a change in the direct cost of education, through a supply channel. The direction of this effect is unclear. On the one hand, local income growth may fuel new investments in school infrastructure, which is likely to affect school enrolment positively (Kondylis and Manacorda, 2012). On the other hand (and more in line with a negative effect on education), local teachers absenteeism may increase (if teachers are tempted to work in mines) and schools or classes may close. Our first-hand data helps assess some of these possibilities, as we col-

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[29] We asked key informants to report prices on three items commonly purchased in the village (fuel, maize and rice) at the time of the survey as well as five and ten years before the survey.

lected information on school location and opening date. First, we asked households about the distance to school and we find no correlation between this distance and the presence of a mine (Table A.10, column 1).[30] Second, our sample includes 27 teachers (members of sampled households) and none of them declared having worked in a mine over the past 12 months (similar to the other individuals who have formal employment in our sample). Third, we have some information about teacher absenteeism. More specifically, in the household survey, we asked about school attendance over the week preceding the survey, and, in case the child missed school, we asked whether it was due to teacher absence. The prevalence of teacher absenteeism appears uncorrelated with exposure to mine (Table A.10, column 2).[31] Finally, we verify that our results on education are robust to the inclusion of distance to school as a control variable, and find that the coefficients are not affected when we include this control variable (Table A.10, columns 3 and 4). These overall results suggest that school supply is unlikely to have changed after the opening of a mine, leaving the direct cost of education unchanged. We conclude that it is unlikely that households face tighter liquidity constraints following the opening of mines.

5.2 Mines and the opportunity cost of education: child labour

If mines employ children directly or if children substitute for their parents (who work in mine or other activities that develop with the mine boom) in the fields, child labour may increase, leading to a decrease in education. Our first-hand data include detailed and retrospective information for both adults and children regarding their work in mines, as well as information on agricultural labour over the week preceding the survey. This allows to directly investigate whether children work in mine and whether we find evidence for a substitution of adult for child labour in fields.

Columns 1 to 4 of Table 5 report the impact of exposure to mine on the likelihood to work in mine for the period 1990-2014 for different age categories. Columns 1 and 2 indicate that children aged 7 to 17 exposed to mines are more likely to be directly employed in a mine: living within 10km of a mine is associated with a 1 percentage point increase in this likelihood of working in a mine. Interestingly the

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30. We estimate Equation 4 with distance to school as a dependent variable (we use the presence of a school within 30 minutes of walking distance). The coefficient on exposure to mine is small and unsignificant. This is not surprising in our setting, where mining revenues are not captured by communities and not likely to generate investments in public goods.

31. We estimate Equation 4 with absenteeism as a dependent variable. The coefficient on exposure to mine is small and unsignificant.

effect is not significantly different by gender. The size of the effect is relatively modest compared to the share of children involved in other labour activities such as agriculture.[32] Columns 3 and 4 report the results for adults: on average living within 10 km of a mine increases the likelihood to work in a mine by 3 percentage points, a 100% increase from the sample average. Adult men are more likely to work in mines than women: the point estimate for women (column 4) is not statistically different from zero.

The results on farm labour suggest that exposed children are more likely to work in fields when using the continuous measure of exposure (columns 5 to 8, Table 5). Halving the distance to a mine is associated with a 3.1 percentage points increase in the probability to have worked in agriculture in the last 7 days for a child aged 7 to 17 (from a mean likelihood of 0.31). This effect is similar for boys and girls. In contrast, exposed adults are less likely to work in agriculture, whether male or female (the impact is significant again when we use the continuous measure of exposure). Halving the distance is associated with a 2.7 percentage point decrease in the likelihood to work in agriculture (from an average likelihood of 0.47). These results are thus consistent with a substitution of adult labour for child labour in agriculture.[33]

To further probe into the change in the structure of labour occupation on farms, we analyse how agricultural activities are affected by the presence of mines. To this end, we use data on areas and yields for cotton (the main cash crop), maize (both a cash and a high-yield subsistence crop) and sorghum (the main, safer subsistence crop) for the six harvests preceding the survey (2008-14).[34] Results reported in Table 6 suggest that households closer to mines invest less in cash crop production and substitute cash crops area for low-yield subsistence crops (sorghum). As cash crops (cotton in particular) requires more attention, input and labour than low-yield subsistence crops, this substitution confirms that the presence of mines leads to a structural change with adults more involved in non-farm

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[32] In our sample, 72% of the 6-14 year old worked in agriculture in the last 12 months vs 1% in mining- always outside of the pit. While working on mining sites may be detrimental to young children in many ways (Boutin and Jouvin, 2022), the effect is not sufficient for explaining the magnitude of the drop in education.

[33] As mentioned above, these results are based on a cross-section estimation as we have no panel information for farm labour.

[34] For more details on agricultural production and crop portfolio choices in the area, see Stoeffler et al. (2022). Cotton production is the main source of income locally. Households decide on investments in cotton production in the context of multiple constraints related to land, capital, credit, risk, and, importantly, labour availability. Our qualitative data indicate that family labour becomes scarcer because of the competition generated by artisanal mining, although other household members sometimes “compensate” household heads for not contributing to the household agricultural production.

activities. Our results can be interpreted as children being mobilized to compensate for this allocation of household adult work outside of agriculture: children farm work increases.[35]

In sum, child labour appears to increase in the vicinity of gold mines, not so much because children are directly involved in mining, but rather because they are more likely to participate to agricultural tasks in the household. The extensive margin increase in child labour in mining is much lower than the extensive margin decrease in school attendance (the latter being around 15 percentage points). These results confirm what the descriptive statistics already suggested: young children are not massively abandoning school in order to go working in mines. Yet children are more involved in farm work closer to mines and for these types of tasks, we cannot rule out that the relatively modest increase on the extensive margin hides large effects on the intensive margin: the large share of children who work in agriculture may work longer hours when living close to a mine. As for the contrast between boys and girls, we find no evidence of a difference in their increased propensity to be involved in work closer to mine, suggesting that this mechanism is unlikely to account for the gender differential in the impact of schooling. [36]

5.3 Mines and perceived returns to education

Another explanation for the negative impact of mines on children education relates to changes in the perceived returns to education. To the extent that mines offer new jobs to local uneducated individuals, households may decrease their valuation of the added value of education on the labour market.

To investigate this conjecture, we engaged in the difficult task of measuring expected returns to education in our survey, as detailed in Section 3. In practice, we measure the expected probabilities to own a solid house as an adult, when leaving school at grade 2 and at grade 6. The difference in these probabilities between grades captures the return to finishing primary school. Table 7 presents regression results. In column 1, the dependent variable is the return to primary education while in column 2 it is the probability to own a house with a grade 6 education, controlling for the same probability with a grade 2 education. Exposure to mines appears to decrease the perceived return of finishing primary

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[35] Manacorda (2006) investigates a similar substitution between child work and work from other household members in the case of an exogenous increase of child labour in 1920s America.

[36] For this outcome, we cannot use DHS data to explore the external validity of these finding because it include information on child labour for the 2010 wave only.

school: the added value of finishing primary school is perceived to be 21% lower in exposed villages (Column 2, panel A, ratio between estimated coefficient on exposure and the mean of the dependent). These results suggest that rural households have adapted their perceived returns to education to the new economic environment: when exposed to mines, they estimate that the added value of finishing primary school is lower. This is consistent with the nature of artisanal gold mining, a low-skilled activity in which the returns to primary education are low, but that can, at least in some cases, provide high incomes compared to other low-skilled activities (as discussed in section 3.2).[37]

Unfortunately, the questions on returns were not asked separately for girls and boys. However, there are strong reasons to suspect that perceived returns would decrease more for boys than for girls in the vicinity of mines. First, a majority of artisanal miners are men, and they earn (much) more than women and (much) more than in other low-skill activities. To be more specific, in our first-hand data, two third of the artisanal adult miners are men and they earn four times more than women over a year (both in terms of average and median income, see Table A.3 and section 3.2). Men work more days per year in this activity on average but also, their average daily wage is much larger than that of women: the mean is three times larger and the median twice as large. In contrast, men and women earn similar daily wages in agriculture, the main low-skill alternative to gold mining locally. Furthermore, women median daily wage in gold mining is equal to their daily wage in agriculture (500 FCFA per day). Men, in contrast can hope for much more when spending a day at the mine rather than working on somebody's field (twice as much when using the median, seven times as much when using the average). In short, mines increase earning possibilities in low-skilled activities more for men than for women.

A second important argument in support of a gender differentiated effect of mine on returns to education relates to the different nature of (perceived) returns to education by gender. For example Gemignani and Wodon (2017) analyse gender roles and girls education in Burkina Faso and report that a majority of interviewed individuals declare the benefit from education to be different for boys and girls, in particular because economic returns are larger for boys. When prompted about the re-

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[37] There is no correlation between education and income from mining, among miners in our sample. On the other hand, literacy and numeracy are valuable in cotton production for the purchase of input on credit and the management of cotton cooperatives.

turns to girls education, they mention the benefits of literacy in the household, the contribution to the education of children or improvements in health and hygiene (in addition to labour-market returns).[38] If the economic component of perceived returns to education is less important for women than for men, the impacts of new economic opportunities on these returns may also be lower.

All in all, our econometric results suggest that a key mechanism for explaining the decrease in education caused by mines may be the decreased in expected returns to education. This mechanism is also compatible with a stronger effect on schooling for boys than for girls, given the gender gap in income in mining and the gendered nature of perceived returns to education.

6 Discussion and conclusion

This article investigates the effects of a new economic activity, artisanal gold mining, on education and child labour in rural Burkina Faso. By analysing detailed first-hand data from the Houndé region, we show that that the presence of mines substantially decreases education for primary school-aged boys. This effect is large: living less than 10km from a mine decreases school attendance by 15.8 percentage points for boys aged 7-12. These results are robust to a wide range of specification and robustness checks. Moreover, the findings obtained at the local level in the Houndé region tend to generalize to the rest of the country based on the analysis of DHS data.

While the media typically blames child labour in mine for this adverse effect on education, our detailed first-hand data indicates that the mechanism is different, as primary school-aged children rarely work directly on the mining site. Instead, we find evidence for a substitution of child labour for adult labour in agriculture in the presence of artisanal mining (due to adult work in mines). This structural transformation is also visible in the changes in agricultural productivity caused by gold mines. This first mechanism suggests that an increase in the opportunity cost of education is causing a decrease in schooling. A second important mechanism is the decrease in the expected returns to education caused by the access to gold mining. Indeed, artisanal mining is a low-skilled economic opportunity that is more profitable than agricultural wage labour (the main low-skill alternative). The wage differential

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[38] Similar information regarding returns to boys education is not available. Parents were only asked about the differences in the effects of education across gender.

is particularly large for men, which may explain that the negative effects of mines on education is mostly driven by a decrease in schooling for boys.

Although a few studies have shown that new economic activities can affect education negatively, they have focused on middle school and high school enrolment in middle-income and high-income contexts, and on new activities in the secondary and tertiary sectors. In a very poor environment, we provide evidence of a negative impact on primary school education, driven by a new economic opportunity in the primary sector. Our findings are likely to generalize to a variety of settings on the African continent, as suggested by a broad qualitative literature on artisanal mining and a few recent quantitative studies. Thus, our results contribute to the emerging literature on micro-evidence for a local resource curse. Moreover, the mechanisms at play indicate that other new economic activities are likely to produce similar negative effects on education in the presence of market failures (in labour, land, childcare, etc.) and of lower (perceived) returns to schooling in the new economic activity compared to the previous activities.

These findings suggest that traditional solutions, such as enforcing a ban on child employment in mines, are unlikely to address the negative effects of mines on education. Besides, the magnitude and the causes of the effect on education cast doubts on the potential of small-scale intervention targeting children working directly in mines for addressing the decrease in schooling. On the other hand, addressing the low education quality and the lack of youth employment opportunities in these settings may contribute to alleviating the negative effects of mines on education. In sum, our results suggest that if artisanal mining opportunities are to increase income and transform livelihoods, the negative externalities on human capital accumulation need to be addressed.

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Tables

Table 1: Artisanal mine exposure and school attendance, first-hand data

	(1) Age 7-17	(2) Age 7-17	(3) Age 7-12	(4) Age 7-12
Panel A: Proximity to closest mine - binary measure				
Exposure (A)	-0.082^{***}	-0.042	-0.093^{***}	-0.036
	(0.026)	(0.027)	(0.029)	(0.033)
Exposure*boy (B)		-0.090^{***}		-0.122^{***}
		(0.028)		(0.033)
pvalue(A + B = 0)		0.000		0.000
Panel B: Proximity to closest mine - log measure				
Exposure (A)	-0.035^{**}	-0.015	-0.036^{*}	-0.007
	(0.015)	(0.014)	(0.018)	(0.019)
Exposure*boy (B)		-0.051^{***}		-0.071^{***}
		(0.012)		(0.015)
pvalue(A + B= 0)		0.001		0.000
Mean of dep.	0.31	0.31	0.38	0.38
N	58410	58410	36369	36369

Source: First-hand data.

Note: The dependent variable is school attendance. Pooled OLS specification for 1990-2014. Sample of children (age 7-17) in columns (1) and (2) and of primary school aged children (age 7-12) in columns (3) and (4).

Controls include age and year fixed effects. Standard errors, in parenthesis, are clustered at the village level.

* $p \leq 0.1$, ** $p \leq 0.05$, *** $p \leq 0.01$.

Table 2: Artisanal mine exposure and school attendance, difference-in-difference estimation, DHS data

	(1)	(2)	(3)	(4)
Panel A: Proximity to closest mine in 2010 - binary measure				
Exposure2010*DHS2010 (A)	−0.025	0.002	−0.025	0.011
	(0.034)	(0.038)	(0.038)	(0.041)
Exposure2010*DHS2010*boy (B)		-0.052^{*}		-0.076^{**}
		(0.031)		(0.037)
Exposure2010*DHS2003			−0.002	0.008
			(0.039)	(0.042)
Exposure2010*DHS2003*boy				−0.027
				(0.037)
Exposure2010*DHS1999			−0.026	−0.012
			(0.042)	(0.045)
Exposure2010*DHS1999*boy				−0.028
				(0.040)
pvalue(A + B = 0)		0.168		0.128
Panel B: Proximity to closest mine in 2010 - log measure				
Exposure2010*DHS2010 (A)	−0.018	−0.001	−0.005	0.016
	(0.021)	(0.024)	(0.026)	(0.027)
Exposure2010*DHS2010*boy (B)		-0.034^{*}		-0.044^{*}
		(0.018)		(0.023)
Exposure2010*DHS2003			0.011	0.016
			(0.027)	(0.027)
Exposure2010*DHS2003*boy				−0.012
				(0.023)
Exposure2010*DHS1999			0.010	0.029
			(0.027)	(0.027)
Exposure2010*DHS1999*boy				−0.037
				(0.024)
pvalue(A + B= 0)		0.128		0.348
Mean of dep.	0.38	0.38	0.33	0.33
N	20536	20536	29354	29354

Source: Burkina Faso DHS data, waves: 2010, 2003 and for colums 3 and 4 1999 and 1993.

Notes: The dependent variable is school attendance. Attention is restricted to children aged 7 to 12 residing in rural areas.

Controls include age and province fixed effects. Standard errors, in (), are clustered at the DHS cluster level.

* $p \leq 0.1$, ** $p \leq 0.05$, *** $p \leq 0.01$.

Table 3: Artisanal mine exposure and school attendance, village fixed-effects specification, first-hand data

	(1) Age 7-17	(2) Age 7-17	(3) Age 7-12	(4) Age 7-12
Panel A: Proximity to closest mine - binary measure				
Exposure (A)	-0.028	0.016	-0.026	0.037
	(0.019)	(0.023)	(0.023)	(0.029)
Exposure*boy (B)		-0.096^{***}		-0.131^{***}
		(0.028)		(0.033)
pvalue(A + B = 0)		0.002		0.001
Panel B: Proximity to closest mine - log measure				
Exposure (A)	-0.028^{***}	-0.008	-0.031^{***}	-0.002
	(0.010)	(0.009)	(0.011)	(0.009)
Exposure*boy (B)		-0.050^{***}		-0.070^{***}
		(0.011)		(0.014)
pvalue(A + B= 0)		0.000		0.000
Mean of dep.	0.31	0.31	0.38	0.38
N	58410	58410	36369	36369

Source: First-hand data.

Note: The dependent variable is school attendance. Pooled OLS specification for 1990-2014. Sample of children (age 7-17) in columns (1) and (2) and of primary school aged children (age 7-12) in columns (3) and (4).

Controls include age and year fixed effects, and village fixed-effects. Standard errors, in parenthesis, are clustered at the village level.

* $p \leq 0.1$, ** $p \leq 0.05$, *** $p \leq 0.01$.

Table 4: Artisanal mine exposure and school attendance, household fixed-effects specification, first-hand data

	(1) Age 7-17	(2) Age 7-17	(3) Age 7-12	(4) Age 7-12
Panel A: Proximity to closest mine - binary measure				
Exposure (A)	-0.030	0.019	-0.031	0.036
	(0.018)	(0.021)	(0.023)	(0.027)
Exposure*boy (B)		-0.109^{***}		-0.143^{***}
		(0.028)		(0.033)
pvalue(A + B = 0)		0.000		0.000
Panel B: Proximity to closest mine - log measure				
Exposure (A)	-0.024^{***}	-0.003	-0.026^{**}	0.005
	(0.009)	(0.008)	(0.010)	(0.008)
Exposure*boy (B)		-0.055^{***}		-0.074^{***}
		(0.012)		(0.015)
pvalue(A + B= 0)		0.000		0.000
Mean of dep.	0.31	0.31	0.38	0.38
N	58410	58410	36369	36369

Source: First-hand data.

Note: The dependent variable is school attendance. Panel specifications with household fixed-effects for 1990-2014 in columns (1) and (3), 2001-2014 in columns (2) and (4). Pooled OLS specification for 1990-2014. Sample of children (age 7-17) in columns (1) and (2) and of primary school aged children (age 7-12) in columns (3) and (4).

Controls include age and year fixed effects. Standard errors, in parenthesis, are clustered at the village level.

* $p \leq 0.1$, ** $p \leq 0.05$, *** $p \leq 0.01$.

Table 5: Effect of exposure to artisanal mines on labour, first-hand data

	Work in mine				Farm work - cross-sectional			
	(1) Age 7-17	(2) Age 7-17	(3) Age 18-59	(4) Age 18-59	(5) Age 7-17	(6) Age 7-17	(7) Age 18-59	(8) Age 18-59
Panel A: Proximity to closest mine - binary measure								
Exposure (A)	0.010*	0.011	0.030*	0.013	0.029	0.037	−0.071	−0.074
	(0.005)	(0.008)	(0.016)	(0.012)	(0.068)	(0.068)	(0.046)	(0.049)
Exposure*boy (B)		−0.000		0.042*		−0.019		0.008
		(0.008)		(0.023)		(0.022)		(0.019)
pvalue(A + B = 0)		0.074		0.049		0.795		0.147
Panel B: Proximity to closest mine - log measure								
Exposure (A)	0.003*	0.003	0.012**	0.002	0.045*	0.044*	−0.039**	−0.037**
	(0.002)	(0.002)	(0.005)	(0.004)	(0.024)	(0.023)	(0.014)	(0.015)
Exposure*boy (B)		0.001		0.025***		0.003		−0.005
		(0.002)		(0.007)		(0.006)		(0.005)
pvalue(A + B= 0)		0.016		0.002		0.076		0.006
Mean of dep.	0.01	0.01	0.03	0.03	0.31	0.31	0.47	0.47
N	67290	67290	84515	84515	3400	3400	5973	5973

Source: First-hand data.

Note: Columns (1)-(4): the dependent variable is working on a mining site in the last year. Pooled OLS specification for 1990-2014. Columns (5)-(8): the dependent variable is working as a farmer in the last 7 days in columns (5)-(8). Cross-sectional OLS specification for 2014.

Sample of children (age 7-17) in columns (1)-(2) and (5)-(6), and working-age adults (age 18-59) in columns (3)-(4) and (7)-(8).

Controls include age and year fixed effects for (1)-(4), and age fixed effects for (5)-(8). Standard errors, in parenthesis, are clustered at the village level.

* $p \leq 0.1$, ** $p \leq 0.05$, *** $p \leq 0.01$.

Table 6: Effect of exposure to artisanal mines on agriculture, first-hand data

	(1) Cotton yields	(2) Cotton area	(3) Maize yields	(4) Maize area	(5) Sorghum yields	(6) Sorghum area	(7) Hired labor
Panel A: Proximity to closest mine - binary measure							
Exposure	-79.327^{**}	-0.205	-111.306	-0.203	130.957^{***}	0.409^{***}	-0.009
	(29.448)	(0.454)	(94.409)	(0.333)	(35.912)	(0.140)	(0.046)
Panel B: Proximity to closest mine - log measure							
Exposure	-42.454^{***}	-0.106	-97.315^{***}	-0.050	39.335^{**}	0.242^{***}	-0.008
	(13.020)	(0.265)	(30.694)	(0.186)	(16.733)	(0.064)	(0.012)
Mean of dep.	746.52	3.11	1318.97	2.20	417.57	1.12	0.62
N	7070	7070	7070	7070	7070	7070	7070

Source: First-hand data.

Note: Pooled OLS specification for 2008-2014. Sample of all households. The dependent variable is the yield and area for cotton in columns (1)-(2), maize in columns (3)-(4), and sorghum in columns (5)-(6) respectively; it is an indicator of hired labour in column (7).

Controls include year fixed effects. Standard errors, in parenthesis, are clustered at the village level.

* $p \leq 0.1$, ** $p \leq 0.05$, *** $p \leq 0.01$.

Table 7: Artisanal mine exposure and expected returns to education, first-hand data

	(1) Returns Δ P(house)	(2) P(house) grade 6
Panel A: Proximity to closest mine - binary measure		
Exposure	-0.461^{*}	-0.427^{**}
	(0.230)	(0.188)
P(house) grade 2		0.641^{***}
		(0.032)
Panel B: Proximity to closest mine - log measure		
Exposure	-0.130	-0.133^{*}
	(0.093)	(0.078)
P(house) grade 2		0.640^{***}
		(0.032)
Mean of dep.	2.19	6.80
N	1004	1004

Source: First-hand data.

Note: Cross-sectional OLS specification for 2014. Sample of all households. Expected returns to educations are ellicited from household heads using stones. The question is "out of 20 children, how many will have a solid house if they achieve a given grade?. Dependent variables: difference in expected probability between grade 2 and grade 6 in column (1); expected probability at grade 6 in column (2), controlling for expected probability at grade 2.

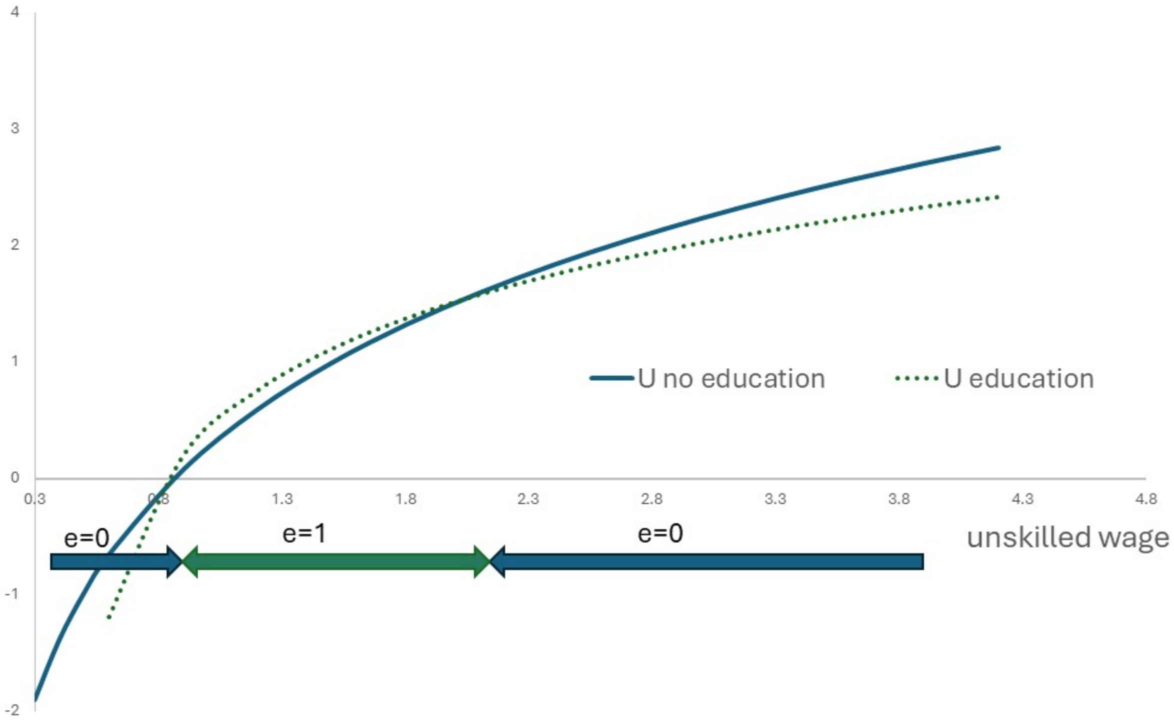
Additional controls include age and number of year of education of the household head, an indicator of children aged 6 to 14 year old in the household, and enumerator fixed-effects. Standard errors, in parenthesis, are clustered at the village level.

* $p \leq 0.1$, ** $p \leq 0.05$, *** $p \leq 0.01$.

Online Appendix

Appendix A Additional figures and tables

Figure 1: Household utility, with and without education, as a function of unskilled wage



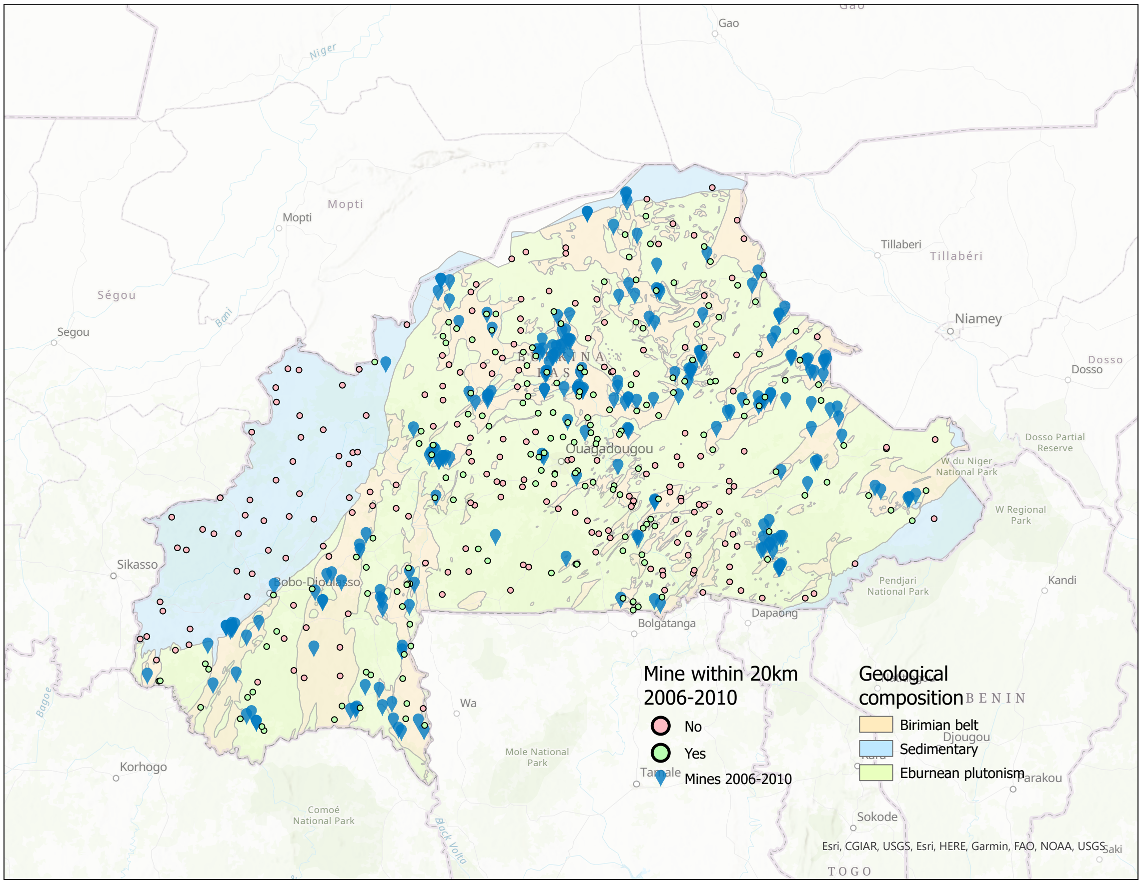


Figure 2: Location of mine permits and DHS clusters in 2010

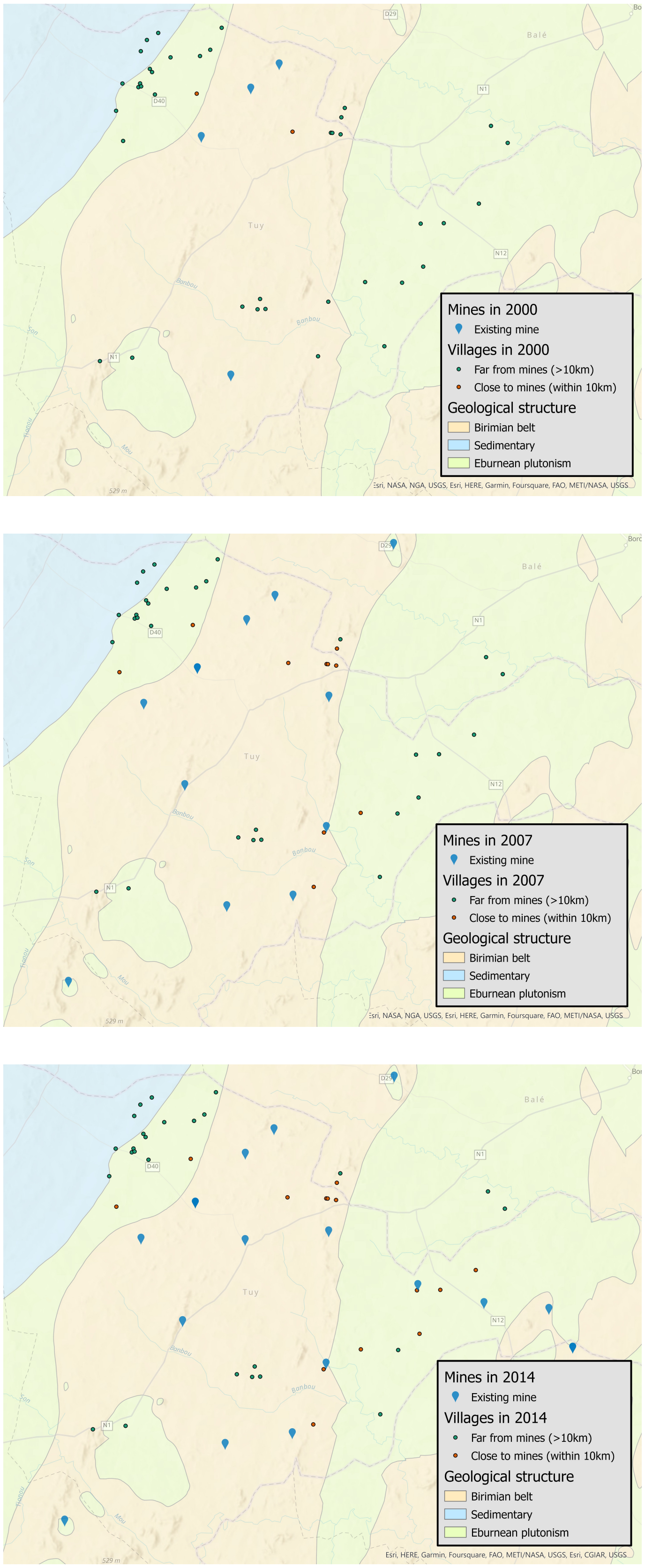


Figure 3: Location of mines and Houndé villages within 10km in 2000, 2007 and 2014

Figure 4: Artisanal mine exposure and school attendance, Sun & Abraham (2021) event study estimation

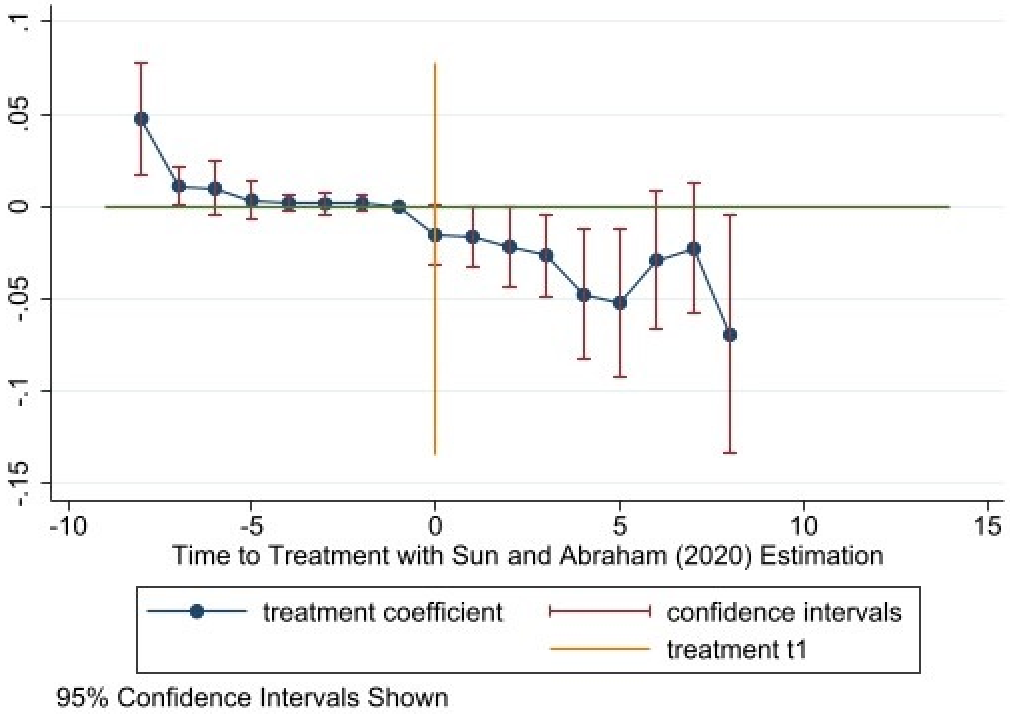


Table A.1: Descriptive statistics, individuals, first-hand data

	All individuals		Children (6-17)	
	mean	sd	mean	sd
Distance to the closest mine	11.17	5.40	11.03	5.44
Log distance to the closest mine	2.11	1.09	2.09	1.11
Mine within 10km	0.36	0.48	0.37	0.48
Worked in mine (last year)	0.04	0.19	0.01	0.11
Age (year)	25.08	15.59	11.00	3.55
Female individual	0.55	0.50	0.49	0.50
Age 7-12	0.20	0.40	0.53	0.50
Age 13-17	0.14	0.34	0.37	0.48
Age 18-59	0.58	0.49	0.00	0.00
Age 60 and above	0.04	0.20	0.00	0.00
Biological child of the household head			0.70	0.46
Enrolled in school			0.47	0.50
Observations	10416		3876	

Source: First-hand data.

Note: Variable descriptive statistics for individuals in 2014. See text for mining variables description.

Table A.2: Descriptive statistics, households, first-hand data

	mean	sd	p25	p50	p75
Distance to the closest mine	11.02	5.32	6.78	11.39	15.02
Log distance to the closest mine	2.04	1.08	1.91	2.43	2.66
Mine within 10km	0.37	0.48	0.00	0.00	1.00
Household size	12.29	7.34	7.00	11.00	16.00
Age of the household head	43.80	12.93	34.00	42.00	53.00
Has a child aged 7-12	0.79	0.41	1.00	1.00	1.00
Household head education (years)	1.19	2.48	0.00	0.00	0.00
Food consumption score (FCS)	40.49	15.53	29.00	37.00	49.00
Diet Diversity Score (HDDS)	7.84	1.56	7.00	8.00	9.00
Coping strategies (count)	0.44	0.92	0.00	0.00	0.00
Cotton yields (kg)	977.40	339.67	750.00	1000.00	1200.00
Cotton area (ha)	4.02	4.11	1.75	3.00	5.00
Maize yields (kg)	1633.42	816.71	1015.38	1542.86	2066.67
Maize area (ha)	2.58	2.37	1.00	2.00	3.50
Sorghum yields (kg)	670.66	427.50	400.00	600.00	800.00
Sorghum area (ha)	1.41	1.72	0.00	1.00	2.00
Hired labor	0.77	0.42	1.00	1.00	1.00
Returns to grade 2 (stones)	4.61	4.18	1.00	4.00	7.00
Returns to grade 6 (stones)	6.80	4.29	4.00	6.00	10.00
Observations	1015				

Source: First-hand data.

Note: Variable descriptive statistics for households in 2014. FCS is a weighted sum of the number of days of consumption of food item families in the last 7 days. Its formula is: 2 * Cereals/Tuber + 4 * Meat/Fish/Egg + 4 * Milk + 0.5 * Oil/Fats + 1* Fruit + 1* Vegetables + 3 * Pulses + 0.5 * Sugar. HDDS consists in a count of food item families consumed at least once in the last 7 days: Cereals, Roots, Vegetables, Fruits, Meat, Eggs, Fish, Pulses, Milk, Oil, Sugar, and Miscellaneous. It ranges from 0 to 12 (a higher score indicates higher food security). Coping strategies is a count of food related harmful coping strategies employed because of a loss of income in the last 12 months: eating only leaves, not eating for a full day, reducing the number of meals, and reducing the quantity of meals. It ranges from 0 to 4 (a higher score indicates higher food insecurity). See text for mining and returns to education variables description.

Table A.3: Descriptive statistics on adult gold miners, first-hand data

	Adult men			Adult women		
	mean	sd	p50	mean	sd	p50
Age	29.27	9.01	27	31.36	9.89	30
Days working at the mine	60.75	67.30	42	30.98	38.82	20
Occupation: digger	0.79	0.40	1	0.01	0.11	0
Occupation: prospector	0.08	0.27	0	0.37	0.48	0
Occupation: gold cleaner	0.05	0.22	0	0.31	0.46	0
Occupation: winnower	0.01	0.10	0	0.10	0.30	0
Occupation: trader	0.01	0.10	0	0.05	0.21	0
Occupation: water seller	0.01	0.12	0	0.12	0.32	0
Mining income (12 mo)	113,982	242,138	40,000	26,884	71,066	10,000
Mining income per day	3,771	15,477	952	1,184	1,759	500
Observations	498			276		

Source: First-hand data.

Note: The sample includes individuals aged 18 and above, in 2014, who worked in mines at least one day in the 12 months preceding the survey. Income is in CFA (1 USD is approximatively 500 CFA).

Table A.4: Descriptive statistics on children gold miners, first-hand data

	Men below 18			Women below 18		
	mean	sd	p50	mean	sd	p50
Age	15.44	1.71	16	14.46	2.12	15
Days working at the mine	50.34	44.03	30	43.69	42.77	25
Occupation: digger	0.55	0.50	1	0.02	0.15	0
Occupation: prospector	0.15	0.36	0	0.50	0.51	1
Occupation: gold cleaner	0.20	0.41	0	0.33	0.48	0
Occupation: winnower	0.00	0.00	0	0.00	0.00	0
Occupation: trader	0.00	0.00	0	0.07	0.26	0
Occupation: water seller	0.07	0.27	0	0.07	0.26	0
Mining income (12 mo)	68,763	124,023	27,000	20,862	34,192	10,000
Mining income per day	1,300	2,074	625	930	1,596	394
Observations	55			46		

Source: First-hand data.

Note: The sample includes children aged 6-17, in 2014, who worked in mines at least one day in the 12 months preceding the survey. Income is in CFA (1 USD is approximatively 500 CFA).

Table A.5: Descriptive statistics, DHS data

	(1) all		(2) men		(3) women	
	mean	sd	mean	sd	mean	sd
Log(distance mine active in 2010)	3.43	(0.75)				
Within 20 km of mine active in 2010	0.27	(0.44)				
Within 5km of Birimian belt	0.56	(0.50)				
Age	9.34	(1.73)	9.34	(1.73)	9.34	(1.74)
Attends school	0.32	(0.47)	0.36	(0.48)	0.29	(0.45)
Works outside the hh	0.06	(0.24)	0.06	(0.24)	0.06	(0.24)
Helps family	0.50	(0.50)	0.56	(0.50)	0.43	(0.49)
Does chores	0.72	(0.45)	0.61	(0.49)	0.84	(0.36)
Height for age z-score	-1.49	(1.67)	-1.56	(1.66)	-1.41	(1.68)
Weight for height z-score	-0.82	(1.27)	-0.83	(1.27)	-0.80	(1.27)

Source: Burkina Faso DHS data, waves: 1993, 1999, 2003, 2010.

Notes: The sample includes all children age 7 to 12 living in rural areas (29354 observations except for child labour variables (available in 2010 only) 11123 observations). Anthropometric indicators are available for children below 5 only (17580 observations). The distance to a mine active in 2010 corresponds to the distance between the DHS cluster and the closest mine with a permit active in 2010. Age is in years. "Attends school" takes value 1 if the child was going to school at the time of the survey. "Works outside the hh" takes value 1 if the child is working, but not in a family business. "Helps family" takes value 1 if the child is working in a family business (including agriculture). "Does chores" takes value 1 if the child is fetching water, wood, cleaning, cooking etc... Height for age z-score and weight for height z-score are available in the DHS data (they are computed based on the WHO Child Growth Standards).

Table A.6: Birimian belt location and school attendance, DHS data

	(1)	(2)	(3)	(4)
ExposureBelt*DHS2010 (A)	-0.044	-0.029	-0.094^{**}	-0.077^{*}
	(0.030)	(0.034)	(0.039)	(0.041)
ExposureBelt*DHS2010*boy (B)		-0.028		-0.036
		(0.027)		(0.036)
ExposureBelt*DHS2003			-0.060	-0.056
			(0.040)	(0.041)
ExposureBelt*DHS2003*boy				-0.010
				(0.037)
ExposureBelt*DHS1999				-0.012
				(0.032)
ExposureBelt*DHS1999*boy				0.008
				(0.042)
pvalue(A + B= 0)		0.071		0.012
Mean of dep.	0.38	0.38	0.33	0.33
N	20536	20536	29354	29354

Source: Burkina Faso DHS data, waves: 2010, 2003 and for colums 3 and 4 1999 and 1993.

Notes: The dependent variable is school attendance. Attention is restricted to children aged 7 to 12 residing in rural areas.

The variable "ExposureBelt" takes value 1 if the DHS cluster is located within 5km of the Birimian belt.

Controls include age and province fixed effects. Standard errors, in (), are clustered at the DHS cluster level.

* $p \leq 0.1$, ** $p \leq 0.05$, *** $p \leq 0.01$.

Table A.7: Placebo estimations: late exposure and school attendance, first-hand data

	(1) Age 7-17	(2) Age 7-17	(3) Age 7-12	(4) Age 7-12
Panel A: Proximity to closest mine - binary measure				
Late Exposure (A)	−0.028	−0.015	−0.030	−0.014
	(0.033)	(0.033)	(0.039)	(0.037)
Late Exposure*boy (B)		−0.032		−0.041
		(0.023)		(0.025)
pvalue(A + B = 0)		0.237		0.242
Panel B: Proximity to closest mine - log measure				
Late Exposure (A)	0.002	0.005	0.005	0.008
	(0.019)	(0.017)	(0.023)	(0.020)
Late Exposure*boy (B)		−0.009		−0.008
		(0.009)		(0.012)
pvalue(A + B= 0)		0.869		0.998
Mean of dep.	0.22	0.22	0.26	0.26
N	28938	28938	20184	20184

Source: First-hand data.

Note: The dependent variable is school attendance. Pooled OLS specification for 1990-2005. Sample of children (age 7-17) in columns (1) and (2) and of primary school aged children (age 7-12) in columns (3) and (4). Late exposure is defined as future exposure to mines in 2014 (placebo treatment).

Controls include age and year fixed effects. Standard errors, in parenthesis, are clustered at the village level.

* $p \leq 0.1$, ** $p \leq 0.05$, *** $p \leq 0.01$.

Table A.8: Artisanal mine exposure and school attendance, robustness, first-hand data

	(1) Age-year interactions	(2) Larger mines	(3) Biological children	(4) After 2000
Panel A: Proximity to closest mine - binary measure				
Exposure (A)	−0.041	−0.036	−0.053	-0.047^{*}
	(0.026)	(0.027)	(0.037)	(0.028)
Exposure*boy (B)	-0.096^{***}	-0.094^{***}	−0.066	-0.074^{**}
	(0.028)	(0.030)	(0.041)	(0.029)
pvalue(A + B = 0)	0.000	0.001	0.006	0.001
Panel B: Proximity to closest mine - log measure				
Exposure (A)	−0.015	−0.015	−0.021	−0.021
	(0.014)	(0.014)	(0.017)	(0.013)
Exposure*boy (B)	-0.053^{***}	-0.042^{***}	-0.037^{**}	-0.042^{***}
	(0.012)	(0.010)	(0.016)	(0.011)
pvalue(A + B= 0)	0.001	0.003	0.007	0.001
Mean of dep.	0.31	0.31	0.39	0.34
N	58410	49569	31249	44742

Source: First-hand data.

Note: The dependent variable is school attendance. Pooled OLS specifications for 1990-2014 in columns (1)-(3). Sample of children (age 7-17).

Controls include age and year fixed effects, and age and year interactions in column (1). "Larger mines" is defined as exposure to mines with more than 100 workers in column (2). Sample of biological children of the household head only in column (3). Years 2001-2014 in column (4). Standard errors, in parenthesis, are clustered at the village level.

* $p \leq 0.1$, ** $p \leq 0.05$, *** $p \leq 0.01$.

Table A.9: Artisanal mine exposure and school attendance at 7 and 12, first-hand data

	(1) Age 7	(2) Age 7	(3) Age 12	(4) Age 12
Panel A: Proximity to closest mine - binary measure				
Exposure (A)	-0.073^{**}	-0.005	-0.106^{***}	-0.046^{*}
	(0.036)	(0.038)	(0.025)	(0.027)
Exposure*boy (B)		-0.142^{***}		-0.136^{***}
		(0.033)		(0.039)
pvalue(A + B = 0)		0.002		0.000
Panel B: Proximity to closest mine - log measure				
Exposure (A)	-0.022	0.010	-0.047^{***}	-0.022
	(0.020)	(0.023)	(0.016)	(0.015)
Exposure*boy (B)		-0.072^{***}		-0.065^{***}
		(0.018)		(0.014)
pvalue(A + B= 0)		0.004		0.000
Mean of dep.	0.41	0.41		
N	7010	7010		

Source: First-hand data.

Note: The dependent variable is school attendance at age X=7 in columns (1) and (2) or X=12 in columns (3) and (4). OLS specification. School enrolment and distance to mine is computed at age X using 2014 survey data. Years vary from 1991-2014 for X = 7 to 2006-2014 for X = 12.

Fixed effects: year when individual was age X. Sample includes individuals reaching age X during the time period before 2014. Standard errors, in parenthesis, are clustered at the village level.

* $p \leq 0.1$, ** $p \leq 0.05$, *** $p \leq 0.01$.

Table A.10: Artisanal mines and school supply, first-hand data

	School supply		Robustness	
	(1) School construction	(2) Absenteeism	(3) In school	(4) In school
Panel A: Proximity to closest mine - binary measure				
Exposure (A)	-0.045	0.020	-0.079^{***}	-0.039
	(0.043)	(0.016)	(0.026)	(0.026)
Exposure*boy (B)				-0.091^{***}
				(0.027)
pvalue(A + B = 0)				0.000
Panel B: Proximity to closest mine - log measure				
Exposure (A)	-0.003	0.005	-0.035^{**}	-0.015
	(0.025)	(0.004)	(0.015)	(0.015)
Exposure*boy (B)				-0.051^{***}
				(0.012)
pvalue(A + B= 0)				0.001
Mean of dep.	0.64	0.01	0.31	0.31
N	640	3462	58410	58410

Source: our first-hand data.

Note: Column (1): the dependent variable is the existence of school within 30 minutes of walking distance. Pooled OLS specification for 1999-2014. Sample of all villages. Year fixed effects. Column (2): the dependent variable is a dummy variable for teacher absent (present less than 5 days in the previous week). Sample of children (age 7-17) who are attending school. Column (3) and (4): the dependent variable is school attendance. Pooled OLS specification for 1990- 2014. Sample of children (age 7-17). Controls include age and year fixed effects. Standard errors, in parenthesis, are clustered at the village level.

* $p \leq 0.1$, ** $p \leq 0.05$, *** $p \leq 0.01$.

Table A.11: Artisanal mine exposure and household food consumption, first-hand data

	Food security			Assets		
	(1) FCS	(2) HDDS	(3) Coping strategies	(4) Solid walls	(5) Has a cart	(6) Land cultivated (ha)
Panel A: Proximity to closest mine - binary measure						
Exposure	−1.923	−0.164	0.073	−0.035	−0.010	0.392
	(1.474)	(0.147)	(0.080)	(0.041)	(0.042)	(1.130)
Panel B: Proximity to closest mine - log measure						
Exposure	−0.727	−0.066	0.037	−0.014	−0.000	0.455
	(0.693)	(0.085)	(0.036)	(0.018)	(0.016)	(0.785)
Mean of dep.	40.49	7.84	0.44	0.16	0.58	10.33
N	1009	1009	1009	1009	1009	1009

Source: First-hand data.

Note: Cross-sectional OLS specification for 2014. Sample of all households. Dependent variables: Food Consumption Score (FCS) in column (1); Household Diet Diversity Score (HDDS) in column (2); Food coping strategies in column (3).

FCS is a weighted sum of the number of days of consumption of food item families in the last 7 days. Its formula is: 2 * Cereals/Tuber + 4 * Meat/Fish/Egg + 4 * Milk + 0.5 * Oil/Fats + 1* Fruit + 1* Vegetables + 3 * Pulses + 0.5 * Sugar. HDDS consists in a count of food item families consumed at least once in the last 7 days: Cereals, Roots, Vegetables, Fruits, Meat, Eggs, Fish, Pulses, Milk, Oil, Sugar, and Miscellaneous. It ranges from 0 to 12 (a higher score indicates higher food security).

Coping strategies is a count of food related harmful coping strategies employed because of a loss of income in the last 12 months: eating only leaves, not eating for a full day, reducing the number of meals, and reducing the quantity of meals. It ranges from 0 to 4 (a higher score indicates higher food insecurity).

Standard errors, in parenthesis, are clustered at the village level.

* $p \leq 0.1$, ** $p \leq 0.05$, *** $p \leq 0.01$.

Table A.12: Artisanal mine exposure and child nutrition, DHS data

	height for age z-score		**weight for height z-score**	
	DD	**DD - full**	**DD**	**DD - full**
	(1)	(2)	(3)	(4)
Panel A: Proximity to closest mine in 2010 - binary measure				
Exposure2010*DHS2010 (A)	0.028	-0.062	-0.343^{***}	-0.088
	(0.114)	(0.126)	(0.105)	(0.118)
Exposure2010*DHS2010*boy (B)	0.166	0.150	0.095	-0.115
	(0.117)	(0.151)	(0.102)	(0.133)
pvalue(A + B = 0)	0.086	0.457	0.013	0.067
Panel B: Proximity to closest mine in 2010 - log measure				
Exposure2010*DHS2010 (A)	-0.016	-0.044	0.224^{***}	0.058
	(0.066)	(0.069)	(0.063)	(0.066)
Exposure2010*DHS2010*boy (B)	-0.063	0.007	-0.072	0.068
	(0.074)	(0.091)	(0.062)	(0.080)
pvalue(A + B= 0)	0.250	0.611	0.017	0.040
Mean of dep.	-1.49	-1.49	-0.83	-0.8
N	12083	17580	12083	17580

Sources: Burkina Faso DHS data. Notes: The dependent variables are height for age z-scores (col 1, 2) and weight for height z-score (col 3, 4). Attention is restricted to children below 5 residing in rural areas.
Difference-in-difference estimations. In col 2 and 4, all survey waves are included. Controls include age and province fixed effects. Standard errors, in (), are clustered at the DHS cluster level.

* $p \leq 0.1$, ** $p \leq 0.05$, *** $p \leq 0.01$.

Table A.13: Artisanal mine exposure and asset position, DHS data

	asset quintile		**poor**	
	DD	**DD - full**	**DD**	**DD - full**
	(1)	(2)	(3)	(4)
Panel A: Proximity to closest mine in 2010 - binary measure				
Exposure2010*DHS2010	−0.079	−0.050	0.025	0.029
	(0.092)	(0.135)	(0.034)	(0.053)
Panel B: Proximity to closest mine in 2010 - log measure				
Exposure2010*DHS2010	−0.005	0.029	−0.005	−0.010
	(0.058)	(0.078)	(0.022)	(0.029)
Mean of dep.	2.53	2.57	0.50	0.50
N	16188	22721	16188	22721

Sources: Burkina Faso DHS data. Notes: The dependent variables are asset quintiles as provided by the DHS data, based on an index score (col 1, 2) and a binary variable "poor" indicating whether the household belongs to the bottom two quintiles (col 3, 4). Difference-in-difference estimations. In col 2 and 4, all survey waves are included. Controls include province fixed effects. Standard errors, in (), are clustered at the DHS cluster level.

* $p \leq 0.1$, ** $p \leq 0.05$, *** $p \leq 0.01$.

Appendix B Nation-wide analysis

DHS data, mine permits and Birimian belt location

To complement our main analysis in a specific area of Burkina Faso and generalize our results, we use secondary data sources at the national scale. For that purpose, we use data from the four waves of the Demographic and Health Surveys conducted in Burkina Faso (in 1993, 1999, 2003 and 2010). This data contains information on school attendance of all children living in the sample households. We rely on the rural sample of the survey, since artisanal gold mines typically employ rural dwellers. This data includes an approximate GPS location for each household included in the sample. This location provided by the DHS survey is an approximation for two reasons. First, it is the location of the centre of the cluster of interviewed households, rather than the location of the household itself. Second, the GPS coordinates have been randomly displaced by up to 10 km to ensure that confidentiality is maintained.

Artisanal gold mines location is obtained from georeferenced mine permits provided by BUMIGEB (the Burkina Faso Office for Mines and Geological services). We only use permits obtained for artisanal gold mines, not industrial mines. BUMIGEB also provides the starting date (and renewal date) of these permits. The number of permits grow substantially after the surge in gold prices in 2006. We also know about the location of the Birimian greenstone belt (from BUMIGEB data) which is the geological formation that hosts gold deposit in West Africa (see section 3.1). The vast majority of mine permits are located within (or in close vicinity) of the belt. Based on the GPS location of households, we build a variable indicating whether households are living in the belt or within 5km of the belt.

Measures of exposure to mines

To construct a child's exposure to mines in the DHS sample, we rely on the location and timing of gold mining permits and the approximate GPS location of the interviewed household. We focus on permits active in 2010, the year of the DHS survey and compute the distance of each DHS cluster to the closest mine in 2010. For this dataset, the binary indicator of exposure to mines uses a threshold distance of 20 km for two reasons. First, given the DHS rule of random displacement for rural clusters up to 10 km, a 20 km radius around the mine allows us to include households who live up to 10 km from a mine.[39] Second, a sufficient number of children live within 20 km of a mine (30% in 2010, vs only 8% within 10 km), which is important for the power of our estimation (i.e. our ability to detect an impact if there is one). As an alternative measure of exposure, we also use the location of Birimian greenstone belt and call exposed household living within 5km of the belt.[40]

Identification strategy

For our nation-wide analysis, we rely on a slightly different identification strategy than with the first-hand data, given that our data on mine location at a given point of time are less precise. Besides, DHS data are repeated cross-sections, and geographic factors correlated with mine locations are more likely to exist. Specific local characteristics may influence the appearance of mines and we may worry about the endogeneity of mines location. For example, if we simply compare education in 2010 between areas strongly exposed to mines and other areas, we may confound the effect of mines and that of pre-existing differences between these two types of areas. To overcome this concern, we exploit the timing of the mining boom, as in Bazillier and Girard (2020). As described above, after the surge in gold prices in 2006, investments in artisanal gold mining intensified and mines flourished in rural areas. We rely mainly on difference-in-difference estimations and compare areas by their degree of exposure to mines in 2010, before mines developed (using the 2003 wave of the DHS) and after (using the 2010 wave of the DHS). If exposure is correlated with time-invariant characteristics, these characteristics are differentiated out.

More formally, we estimate the following model :

$$Y_{i,w,a,p} = \alpha + \beta W_{2010} + \gamma W_{2010} * T_{2010} + \delta T_{2010} + \eta X_i + \theta_a a + \vartheta_p p + \varepsilon_i \tag{5}$$

where $Y_{i,w,a,p}$ is one if child i, surveyed in wave w, aged a and living in province p, attends school;

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[39] Households within 10 km from a mine are likely to be particularly affected, as they can easily travel for the day to the site. Bazillier and Girard (2020) use a radius of 10 km as a threshold of distance to mine with LSMS data (which are not randomly displaced). We use a 10 km radius when it comes to our first-hand data.

[40] There are 56% of household living within 5 km of the belt. More than 75% of households within 20 km of a mine are also located on the belt.

W_{2010} takes value 1 if the child was surveyed in 2010; T_{2010} captures the exposure to mines in 2010 of the child and X_i is a vector of control including the child's gender.[41] To allow the impact of mines to differ for boys and girls we also run estimations where we interact the treatment with the child's gender. The inclusion of age and province fixed effects implies that the identification of γ, the main coefficient of interest, relies on children of the same age living in the same province but differently exposed to mines. We compute DHS cluster robust standard errors.

The main identifying assumption is that mines did not appear in areas where education was on a different trend. To test for this possibility (and, to some extent, to account for it), we include previous waves of the DHS (1993 and 1999 in addition to 2003 and 2010) and also estimate the following model:

$$Y_{i,w} = \alpha + \sum_{w} \beta_w W_w + \sum_{w} \gamma_w W_w * T_{2010} + \delta T_{2010} + \eta X_i + \theta_a a + \vartheta_p p + \varepsilon_i \tag{6}$$

If areas where mines operate are on similar education trends as non-exposed areas, we expect $\gamma_{1999} = \gamma_{2003} = 0$ (the 1993 wave constitutes the omitted category).

As a robustness check, we also estimate the effect of living close to the Birimian belt (similar to Bazillier and Girard, 2020). As detailed above, Birimian greenstones are a major source of gold in the sub-region and virtually all the gold of Burkina Faso lies in the Birimian belts (Béziat et al., 2008). The geological structure of the sub-soil is largely uncorrelated with soil characteristics or climatic variations and it is reasonable to assume that the localization of the belts has not influenced local development before the discovery of gold.[42] Combining the location of the Birimian greenstone belts with the location of DHS clusters, we construct a binary variable B indicating whether each DHS cluster is within 5 km of the belt (as in Bazillier and Girard, 2020). Specifically, re-estimate equations 5 and 6, replacing T_{2010} by B.

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[41] Only the 2010 wave also contains information on child labour. Thus, we cannot estimate impacts on child labour. Because the delimitation of provinces has changed over the period covered by the surveys, we use the GPS location of household to determine to which province (based on their 2010 delimitations) they belong to.

[42] The overlay of the Birimian greenstone belts with a climatic and a soil composition maps confirms that the belts spread over very different soil and climate types (Bazillier and Girard, 2020).

Appendix C Additional details on the conceptual framework

Investing in education, when education and child labour can be combined

When a child can go to school and work at the same time, an increase in low-skilled wage still leads to an ambiguous impact on the decision to invest in education. To see it consider the inequality to be satisfied in this case for parents to educate their child:

$$\delta\left(u(w_s)-u(w_u)\right) \quad \geq \quad u\left((1+\alpha)w_u\right)-u\left((1+\alpha)w_u-p_e\right) \tag{7}$$

The only change with the case presented in Section 2 is the RHS of inequality (7). Now the effect of an increase in w_u on this expression: it decreases the RHS, relaxing the constraint.[43] Yet, as before, the LHS of inequality (7) decreases as well (an increase in w_u decreases the relative gains from education in the second period) and, as a result, the overall effect on (7) is ambiguous.

Using the same model parameters as in Section 2, the Figure below plots the household utility three possible scenarios (1. no education, 2. education when child labour and education are not substitute and 3. education when child labour and education are substitute). In addition, it shows the ranges of unskilled wage for which the household would choose education, under both scenarios (wide arrows at the bottom of the graph). As expected, it is larger when the child can combine school and child labour.

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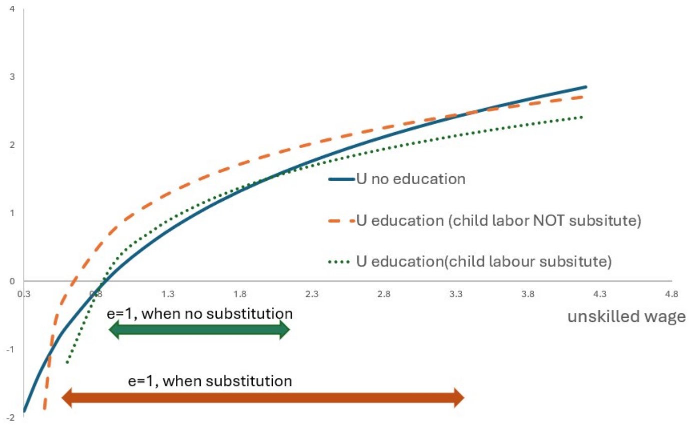
[43] The first derivative of the RHS of (4) is: $(1+\alpha)\left[u'\left((1+\alpha)w_u\right)-u'\left((1+\alpha)w_u-p_e\right)\right]$, which is unambiguously negative given the concavity of the utility function.

Figure 5: Household utility, with and without education, as a function of unskilled wage



Appendix D ASM sample news coverage

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Accidents in artisanal mines in Burkina Faso: “Burkina Faso : au moins 63 personnes tuées par une explosion accidentelle dans une mine d’or artisanale”, le Monde, February 22, 2022, https://www.lemonde.fr/afrique/article/2022/02/22/burkina-faso-au-moins-55-personnes-tuees-par-une-explosion-sur-un-site-d-or-artisanal_6114679_3212.html.

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