Gold Mine Openings and Child Labor in Mali *

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Abstract

Natural resource extraction is a major source of exports in some developing countries, but evidence of its effects on economic development is mixed. Using the opening of industrial gold mines in Mali, we investigate a natural resource shock on child labor. We find that a natural resource shock decreases children's working hours, specifically the working hours for household tasks. However, we do not find significant changes in educational outcomes. We also find that the effects are more substantial for girls, decreasing the gender gap in working hours. These results are consistent with changes in adult employment and occupational choices.

Keywords: child labor, gold mines, education, economic shock, natural resources

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1 Introduction

Human capital investment is crucial for economic development. Child labor is one of the activities that hinder investment in children's human capital. Working children invest less time and effort in schooling; hence have worse educational outcomes both in the short- and long-term (Heady, 2003; Beegle et al., 2008; Emerson, Ponczek, and Souza, 2017; DeGraff, Ferro, and Levison, 2016). Exposure to hazardous conditions in work leads to poorer health conditions in adulthood (Kassouf, McKee, and Mossialos, 2001; Lee and Orazem, 2010). Hence, governments and development organizations have made an effort to reduce child labor, but 264 million children were still at work globally in 2016. Moreover, the prevalence of child labor is higher in countries with lower GDP per capita (Edmonds, 2016). Therefore, understanding how economic development affects child labor is an important issue.

Natural resource extraction is a major source of exports in some developing countries, but evidence of its effects on economic development is mixed. Macro-level evidence often finds capital intensive, foreign-owned large scale industrial mines[1] as a source of resource curse (Sachs and Warner, 2001; Frankel, 2012). However, local economic impacts are often found to be positive (Aragón and Rud, 2013; Fafchamps, Koelle, and Shilpi, 2017). Moreover, studies on the impact of mining activities on children thatlead to a long-term effect of these activities has produced mixed and conflicting results (von der Goltz and Barnwal, 2019; Benshaul-Tolonen, 2019; Zabsonré, Agbo, and Somé, 2018; Santos, 2018).

This paper brings new evidence to the literature on the relationship between income and child labor by examining the impact of a natural resource shock, the opening of industrial gold mines in the West African country of Mali, on child labor. We exploit two exogenous events: i) A new mining code introduced in 1991 that resulted in new foreign direct investment in extractive industries (Organization, 1998)); and ii) increases in global gold prices that made such investments profitable (Mainguy, 2011). Child labor is widespread in Mali. For example, 31 percent of children aged 5 to 17 engaged in economic activities in 2009 (Kippenberg, 2011). We match geo-coded data on 12,468 children aged 5 to 14 years old interviewed between 2001 to 2012 with geo-coded information on new gold mine construction and operation. It allows us to compare children from households living closer to the mines to the children living further away from the mines, before and after the closest mines open while controlling for region- and time-specific confounders. By doing so, we capture the effect of opening industrial gold mines on child labor.

[1]We refer industrial mines to highly mechanized, capital intensive, and large-scale gold mines operated by firms - that are often large. In contrast, Artisanal Small-scale Mines (ASM) are traditional ways to extract gold, most of which are unregistered and operated by local capitals.

We find that the opening of industrial mines reduces child labor by 8.6 hours per week in total. The effects were qualitatively similar across different types of activities. Hours for economic activities decrease by 3.7 hours and household tasks 5.7 hours. The effects are heterogeneous across groups with diffrent demographic characteristics. The reduction in working hours is larger among girls than among boys, decreasing the gender gap in working hours, and is larger among older children aged 12 to 14 than among younger children. However, the decrease in working hours did not lead to improvements in educational outcomes such as years of schooling and current enrollment. The results are robust to the changes in the distance threshold and a more conservative measure of child labor.

Consistent with the findings of Kotsadam and Tolonen (2016), we find that mothers are less likely to work but more likely to work in better-quality jobs conditional on work. We also find a sectoral shift of female workers from agriculture to the sales sector and increased adult male employment in clerical/managerial positions. We also confirm that the effects are not driven by the demographic changes induced by migration. Taken together, the results show that the structural shift in the adult labor market accompanied by the mine opening led to decreased children's working hours through higher household income and increased mothers' presence at home.

These findings reconciles mixed evidence on the initial effects of economic development on child labor. Economic development increases household income, and a large body of research on child labor shows that child labor decreases when household income increases (Basu and Van, 1998; Edmonds, 2005; Edmonds and Pavcnik, 2005; Edmonds and Schady, 2012; Cogneau and Jedwab, 2012).[2] Economic development may lead to accumulation of households' productive assets. Evidence shows that child labor increases when households have more productive assets (Basu, Das, and Dutta, 2010; Cockburn and Dostie, 2007; Edmonds and Theoharides, 2020). Urbanization and increases in local labor demand, other aspects of development, have also been associated with increased child labor. (Fafchamps and Wahba, 2006; Manacorda and Rosati, 2011)[3] This paper shows that under a capital-intensive, industry-driven economic development can de-

[2]This negative correlation between household income and child labor is found in the opposite situation: some studies show that child labor increases facing negative productivity shocks (Beegle, Dehejia, and Gatti, 2006; Duryea, Lam, and Levison, 2007). These results suggest that some households use children's labor as a way to self-insure against risks.

[3]More productive assets at home (e.g. land, livestock) could decrease the relative value of alternative use of a child's time and increase child labor supply (Basu, Das, and Dutta, 2010; Cockburn and Dostie, 2007; Edmonds and Theoharides, 2020). Basu, Das, and Dutta (2010) show that poorer households increase child labor when they have more productive assets at home, but households start to decrease child labor once they have more productive assets than a certain threshold. Besides, the proximity to an urban area may increase children's working hours outside of the households as economic opportunities for children increases with the proximity (Fafchamps and Wahba, 2006). In addition, when local labor demand increases, child labor tends to increase despite the income effect that working in favor of decreasing child labor (Manacorda and Rosati, 2011).

crease children's working hours through changes in adult employment.

Our findings contribute to the discussion of the economic effect of natural resource extraction as well. Previous studies find that mining activities improve household living standards (Aragón and Rud, 2013; Zabsonré, Agbo, and Somé, 2018) and increase household income (Gajigo, Mutambatsere, and Ndiaye, 2012; Weng et al., 2013). Moreover, industrial mines shift employments from agriculture to manual labor and services (Kotsadam and Tolonen, 2016) and increase households' asset wealth (von der Goltz and Barnwal, 2019). Urban areas start to develop around industrial mines[4] due to the resources and infrastructure they require (Fafchamps, Koelle, and Shilpi, 2017). Relatedly, Bazillier and Girard (2020) find that it is Artisanal Small-scale Mines (henceforth ASMs) which increases household consumption. However, the limited literature on the impact of mining activities on child welfare has produced mixed and conflicting results. von der Goltz and Barnwal (2019) show that industrial gold mines decrease infant mortality. By contrast, Benshaul-Tolonen (2019) finds that pollution from industrial mines increases the prevalence of chronic undernutrition. While Santos (2018) show that industrial mines increase child labor and decrease schooling and Ahlerup, Baskaran, and Bigsten (2020) also find that industrial mines decrease adolescent schooling attainments in Colombia and Sub-Saharan Africa, Zabsonré, Agbo, and Somé (2018) find that increases in the price of gold had no impact on child labor in mining communities in Burkina Faso. This paper provides additional evidence that the natural resource shock positively affects child welfare by decreasing children's work engagement, especially household tasks.

The paper proceeds as follows. Section 2 discusses a conceptual framework. Section 3 explains the study setting, and Section 4 describes the dataset and the empirical strategy used for the estimation. We present the estimated results in section 5 and conclude in Section 6.

2 Conceptual Framework

We present a simple framework to structure thinking about the effects of natural resource shock on household labor allocation. Industrial gold mines increase household income and wealth (Aragón and Rud, 2013; von der Goltz and Barnwal, 2019). The increased income may come from increased direct employments at mines. Moreover, we expect the industrial mines to create service and sales jobs through local multiplier, as shown in Moretti (2010).

Under this setting, the effect on child labor is *a priori* ambiguous. Increased labor demand can

[4] We refer industrial mines to highly mechanized, capital intensive, and large-scale gold mines operated by large firms. In contrast, Artisanal Small-scale Mines (ASM) are traditional ways to extract gold, most of which are unregistered and operated by local capitals.

increase children's work as well through mutiple channels. First, even if it is difficult for children to be directly hired at the mine due to its capital-intensive nature, children may be hired in service and sales sectors as shown in Santos (2018). Second, the demand for child labor increases within a household as well. As adult experience increased opportunities for employment, especially in sectors other than in agriculture, vacancies in household farms or household tasks may rise. In this case, the demand for children to substitute adult labor in these activities will increase.

However, following the Luxury axiom posed in Basu and Van (1998), increased wages from the labor demand shock may decrease child labor. Moreover, as found in existing studies, increased household income from adult labor will decrease child labor. (Edmonds and Schady, 2012; Cogneau and Jedwab, 2012) The income effect may work through different channels. Assuming that a child's leisure is a normal good, a household will increase the consumption of children's leisure with the increased income. We call this a "direct" income effect. An indirect income effect would occur if an increased household income leads to a decrease in a secondary adult income earner's economic activities, and the secondary adult income earner replaces children in household work. Kotsadam and Tolonen (2016) argue that the decrease in female employment is due to increased household income from male partner's employment.

Therefore, the direction of eeffects on child labor is determined by which effects dominate the other. If the substitution effect dominates, then we may see children work more, either to contribute to household income and earn money to continue schooling, as shown in Maconachie and Hilson (2016). Moreover, changes in adult labor outcomes will provide a hint on which channel the effects of mine openings may work through.

3 Study Settings

3.1 Gold mining in Mali

Gold has been an important source of the Malian economy since 1235, when the Mali empire was first established (Dibua, 2010; Kusnir, 1999). Historically, extraction was on a small-scale, artisanal basis; for example, only 950kg of gold was produced in Mali in 1987. In 1991, a new mining code providing tax and customs advantages to the mining sector to attract foreign direct investments was introduced. As a result, seven large-scale industrial gold mines started their operations in the following two decades, and the gold production volume increased rapidly. By 1999, 23,668kg of gold was being produced annually. Figure 1 shows that increases in international gold prices started in 2001 led to a further increase in production value and a further expansion of the mining industry. Population and Housing Census of Mali shows that the mining sector's employment share in total employment grew from 9 percent in 1999 to 27 percent in 2009. The share of gold among Mali's export goods has increased to 65 percent by 2019 (International Monetary Fund, 2019).

We consider the opening of industrial gold mines to be exogenous for two reasons. First, the initial expansion of the industrial gold mines began with a policy change - a new mining code in 1991, designed to attract foreign direct investments in the Malian mining sector. The global price increase led to the next expansion - figure 1 also shows that the number of mines increased after 2001 when international gold prices started to increase. Second, the industrial gold mines' locations are limited to those places where gold can be extracted on an industrial basis. Figure 2 shows the locations of gold mines in Mali. Mines are concentrated in the western and southern parts of the country. In fact, it is only two regions where all the mines are located, in Kayes and Sikasso regions.[5] Thus, it is unlikely that the foreign-owned mining companies were attracted to the current locations for characteristics of the local economies, such as the presence of local capital other than the existence of the gold reserves.

3.2 Child labor practice in Mali

Child labor is widespread in Mali. Panel A of Figure 3 shows that children's participation in work decreases over time from 80.4 percent in 2001 to 62.5 percent in 2012, but the 2012 participation rate is still high. The high participation rate comes from helping with household tasks that ranges from 57 to 74 percent. It is consistent with the story where parents view child labor as acceptable or even instructive for children (Kippenberg, 2011). Participation in economic activities is relatively lower, ranging from 20 to 58 percent during this period, and agriculture is the largest sector employing most of working children. Mali's population and housing census shows that 83 percent of the workign children are in agriculture. Other sectors, including the mining sector, hire few children. (Figure A4).

However, unlike the participation rate, working hours did not vary substantially across time. In total, children worked for 23.4 hours in 2001 and 24 hours in 2012 conditional on working. Working hours are less than 19 hours per week for economic activities and 24 hours for household tasks. Considering that International Labour Organization (ILO) and other international organizations use 14 hours and 28 hours as a threshold to define children's engagement in economic activities and domestic work as child labor for the older group of children (aged 12 to 14), these working

[5] The geographical data of mines is obtained from a publicly disclosed dataset used in Benshaul-Tolonen (2019).

hours are not too long.

Since economic activities and household tasks comprise child labor together, we examine the effect of the opening of industrial mines on two different types of activities of children in this paper: i) economic activity, which includes any income-generating activity that a child is engaged in regardless of payment status or whom the child is working for, and household tasks, which includes cooking, taking care of younger siblings fetching water.

4 Data and Empirical strategy

4.1 Data

For the main empirical analyses, we combine three datasets, Mali's Demographic and Health Surveys (DHS), information on the location of industrial gold mines in Mali from Benshaul-Tolonen (2019), and opening dates of industrial gold mines from mining companies' official website and Mining Data Online[6]. These datasets provide repeated information on child labor and demographic characteristics over time, information on the geographic location of survey clusters and gold mines, and the opening dates of the mines, all of which are necessary for our analysis. For the supplementary analyses, we use data from the Population and Housing census of Mali conducted in 1987, 1998, and 2009.

Mali's Demographic and Health Surveys (DHS) provide information on children's work, education, and demographic background from the 1996, 2001, 2006, and 2012 waves.[7] It is a repeated cross-sectional household survey that provides a wide range of data in population, health, child labor, and education. It also provides GPS coordinates of the survey clusters and collects information on child labor in a standardized manner.

We measure child labor using working hours of children aged 5 to 17 in the seven days before the interview. The DHS dataset identifies two types of work in which children are engaged: economic activities and household tasks. Economic activities include tasks children undertake on family land, help for family business, fetching water and woods, and any other paid or unpaid economic activities outside of the household. Household tasks refer to activities such as cooking, cleaning, and washing clothes. We sum up children's working hours for both types of work to measure children's time allocation for work. We set 95 hours per week as an upper bound of all types of

[6]https://miningdataonline.com

[7]We excluded the 1987 wave from the main analysis because geolocation of survey clusters was not recorded in the 1987 wave.

children's working hours and coded working hours to be zero if a child did not work in the last seven days before the interview.[8]

Educational outcomes are measured using years of education and the current year's school enrollment. Years of education is a stock variable, so it is less susceptible to short-term changes than the current enrollment. We treat both "attended school at some point this year" and "attending school now" as currently enrolled to avoid the possibility of measurement error, since the survey period typically spans 5 to 6 months and varied from winter to summer.

To identify a cluster as a mining area, we link the GPS coordinates of the survey clusters and the GPS coordinates of all mines and compute the distance to the closest mine. If the cluster is within a 20km radius from the industrial gold mines, we identify a cluster as a mining area. Therefore, the survey clusters within a mining area serve as an ever-treated group since they are exposed to the active mine operations at some point in the sample period. As depicted in Figure 2, mines are located at the country's southwestern border where the gold reserves are. However, it may raise the concern of the systematic difference between the region and the rest of the country. Therefore, we restrict the sample to the surveyed clusters located within a 100km radius of the mines. We discuss the choice of the threshold distances in the next section in more detail.

Table 1 presents the mean and standard deviation of individual- and household-level characteristics of children in mining and non-mining areas before the mine openings. We use the data from pre-opening years to show the average difference in pre-shock variables between the mining and non-mining areas. Column (1) shows that the children living in the mining area are nine years old on average, and about 51.6 percent of them are boys. The average household has 9.8 people, 15.6 percent of households reside in urban areas, and the average wealth quintile is 3.01.[9] The average mother is 37 years old, received 0.5 years of education, while the average father is 50 years old with 1.1 years of education. 89 percent of the children in our sample are living together with their biological mother. Demographic characteristics of non-mining area children and their households are similar to that of mining area children.

Table 2 summarizes the pre-shock outcome variables – participation in and working hours for child labor and educational outcomes in mining and non-mining areas. Column (1) shows that in pre-shock mining areas, 84.1 percent of children were engaged in any type of child labor. Specifically, 41.9 percent of the children participated in economic activities and 75.8 percent in household tasks. Weekly working hours were 20.2 hours for any type of work. Among the 20.2 hours, chil-

[8] 1 percent of the sample is reported to work longer than 95 hours in the previous week, and we check if the results are robust after dropping these observations.

[9] We construct wealth index by principal component analysis using indicators of living standards of the respondent. (e.g. access to electricity, water, and bathroom; materials used to construct walls and floors of the household.)

dren spent 2 hours on economic activities and 18 hours on household tasks. On average, children in the mining area received 0.8 years of education, and 39 percent were in school in the previous school year. The pre-shock outcomes in non-mining areas were similar to those of mining areas. Column (3) shows that the school enrollment is higher in mining areas than non-mining areas, with 5 percent statistical significance, but other outcome variables are on average the same across areas.

In Section 4.3, we estimate the pre-shock trends of outcome variables across mining- and non-mining areas. We aim to establish the ground for the causal estimation by showing the pre-shock parallel trend. The average differences of pre-shock variables prented in this section provides additional supporting evidence to show that the level difference between the areas was small.

4.2 Empirical strategy

Following Kotsadam and Tolonen (2016) and Benshaul-Tolonen (2019), we estimate the following equation to estimate the impact of gold mine expansion on child labor and educational outcome :

$$y_{ijtc} = \beta_0 + \beta_1 20km_j \cdot Open_{jt} + \sum_{d=1}^{5} \text{Distance Bin}_j^d + \sum_{y=1}^{6} \text{Years from open}_t^y + \delta_t + \theta_c + X_{ijct} + \varepsilon_{ijct} \tag{1}$$

where y_{ijtc} is the outcome variable of a child i living in a cluster j located at t years from the opening of the mine. Subscript c denotes the cercle (a sub-regional administrative area).

$20km_{jt}$ is an indicator equals one if a cluster j interviewed at t years from mine opening is located within 20km from an open mine. It serves as a ever-treated group indicator. The control group is the children living in clusters located between 20 and 100km from the gold mines. $Open_{jt}$ is an indicator equals one if a cluster j was interviewed after the closest mine open. It exploits the differences in the opening year of mines and the survey year, and serves as a post dummy in a 2×2 difference-in-difference estimation.[10] Spatial variations are captured by 20km-bin fixed effect, denoted by $\sum_{d=1}^{5}$ Distance Bin_j^d, and time variations by year-from-mine fixed effect, $\sum_{y=1}^{6}$ Years from open_t^y. Distance Bin_j^d is a seriese of indicators, which groups the distance from the closest mine to the surveyed cluster in 20km bins. Years from open_t^y is also a series of binary variables which take the value of one if the relative time from the mine opening falls into the 5-year bins. In this equation, β_1 is our coefficient of interest which we interpret as the changes in child labor in areas in proximity to the active mines, compared to the contempraneous changes

[10] We calculate the years from the mine openings by subtracting the year of mine opening from the interview year. As presented in Table A1, mines open in different years, so the years from mine opening range from -16 to 16 years.

in areas farther away from the mines.

We use 100km as a threshold to restrict the sample and 20km to define the mining area. We use geographic proximity to measure the effect of mines for several reasons. First, the existing literature on mining suggests that the treatment effects of mines are concentrated in adjacent areas. While Aragón and Rud (2013) find effects in the areas within 100km of the mine, other papers such as Kotsadam and Tolonen (2016), Benshaul-Tolonen (2019) and von der Goltz and Barnwal (2019) found the effects among the households residing within a 20km radius of the mines. Evidence on Ghana and Tanzania's commuting behaviors also shows that mines' impact on local economies can be identified within 5–20 kilometers from the mines (Amoh-Gyimah and Aidoo, 2013). Therefore, a threshold of 100km for sample restriction ensures the comparison and ever-treated group's comparability and reduces potential biases due to the systematic difference between the two groups. Second, the geocoordinates in the DHS data are randomly displaced up to 5km and 10km for 1 percent of the sample to prevent the users from identifying the individual households. DHS also recommends using thresholds larger than 5 kilometers. Third, as disccussed in Benshaul-Tolonen (2019), the geocoordinates in the mining data locates the center of the mining area. Thus, using a distance threshold that is too small could introduce more noise or increases the possibility of capturing only the mining sites rather than the communities surrounding the mines. In section 5.4, we assess if our results are robust to changes in these distance thresholds.

To control for the effects from region specific characteristics and survey-year specific events, we include commune- and survey-year fixed effects denoted by θ_c and δ_t.[11] To avoid potential omitted variable bias, which may arise from the variables correlated with distance from gold mines and households' child labor supply decisions, we include X_{ijct} as a covariate vector. The vector includes age, sex, birth order, household size, urban status, each parent's age and years of education, if a child is living with his/her biological parents, and wealth index of a household. To allow for intra-commune heteroskedasticity of standard errors, standard errors are clustered at the commune level.

Since child labor decisions could differ based on the child's age and sex, differential responses from various demographic backgrounds may help understand the effect. To examine this potential heterogeneity of effects, we also estimate:

[11] A commune is a smallest sub-region level administrative area identified in the dataset.

$$
\begin{aligned}
y_{ijct} =& \beta_0 + \beta_1 20km_j \cdot Open_{jt} \cdot H_{ijt} + \beta_2 20km_j \cdot Open_{jt} + \beta_3 H_{ijt} \\
&+ \sum_{d=1}^{5} \gamma_1^d \text{Distance Bin}_j^d + \sum_{d=1}^{5} \gamma_2^d \text{Distance Bin}_j^d \cdot H_{ijt} \\
&+ \sum_{y=1}^{6} \gamma_3^y \text{Years from open}_t^y + \sum_{y=1}^{6} \gamma_4^y \text{Years from open}_t^y \cdot H_{ijt} \\
&+ \delta_t + \theta_c + X_{ijct} + \varepsilon_{ijct}
\end{aligned} \tag{2}
$$

where H_{ijt} is an indicator of a demographic characteristic equals one if a child i in cluster j at year t from opening satisfies specified characteristics. These characteristics include: male children and children aged 5 to 11. The coefficient β_1 captures the effect of mine openings on a remaining demographic group (female children and children aged 12 to 17), β_2 the difference of the effect between the two demographic groups. Therefore, β_1+β_2 provides the effect on the specified demographic group. This sum of the two coefficients is also presented at the bottom of the results table to show the effect on both demographic groups.

4.3 Parallel pre-trends

The causal interpretation of this paper is based on the assumption that the households from the non-mining area serve as a counter-factual of the households of the mining area. Thus, showing parallel pre-trends between mining and non-mining areas is crucial to establishing the causality of the estimated effects.

Figure 4 shows the estimated difference of working hours of children across mining- and non-mining areas over time. The coefficients are estimated by replacing $Open_{jt}$ with a series of indicators for years from opening from Equation (1), omitting 0 to 5 years before the mine openings. The horizontal axes show years from mine openings, the vertical axes the estimated coefficients, and the vertical lines show the 95 percent confidence intervals. Coefficients of the outcome variables of interest are not significantly different from zero at the 5 percent level. That is, we find parallel pre-trends of child labor supply across regions.

Table 3 presents estimates that confirm these results. A pre-trend that is parallel is equivalent to testing the following hypothesis:

$$20km \cdot (\text{11+ years prior}) = 20km \cdot (\text{6-10 years prior}) = 0$$

The p-value for the joint F-test of this difference is presented at the bottom of the table. All p-values are larger than 0.05, so we do not reject the null hypothesis that the two summed coefficients are zero. The result presented in Table A2 shows that the participation rate also shows parallel pre-trends. Taken together, these results satisfy the crucial assumption for the causality of the estimated effects of the opening of industrial gold mines.

5 Results

5.1 Impacts on Child labor

Figure 4 also suggests that children located in mining areas worked fewer hours after mines open. Table 4 complements this by showing the results of estimating Equation (1) with (Panel A) and without (Panel B) control variables. Total working hours decreased by 8.6 hours weekly when industrial mines open in the local area. The effect is statistically significant at the 1 percent level and robust to the inclusion (or not) of control variables (See Column (1) in both panels). The decrease is also economically significant: children in non-mining areas worked 19.9 hours before mines' introduction. It indicates a 43 percent reduction in total working hours. Hours for economic activities decreased by 3.7 hours, and the effect is statistically significant at the 10 percent level. (Column (2)). Considering the comparison group average is 3.1 hours before the mine openings, the magnitude of the effect is sizable. Working hours for household tasks decreased as well, by 5.7 hours per week. The effect is statistically significant at the 5 percent and is economically large (34 percent decrease). The effects are robust to the inclusion of control variables. Therefore, we present results estimated with control variables for the rest of the section. Table A3 and A2 show no effect at the extensive margin, so we focus on the effects on the intensive margin. Taken together, while the probability of children participating in work did not change substantially, the hours of work decreased substantially, especially the working hours for the household tasks. It is not surprising considering that the hours of work for the economic activities are difficult to adjust once a child starts working, and it is mostly the household tasks that the children were doing before the mine openings.

The local effects of large-scale mines can be heterogeneous across children with different demographic characteristics. We examine the heterogeneity of the effects using two different criteria: sex and age. Table 5 presents the estimated results of heterogeneous effects as per Equation (2).

First, we disaggregate by child's gender. Column (1) shows that both boys and girls decrease total working hours – by 9.7 and 7.3 hours. While the difference is not precisely estimated and the effect size is similar between the two genders, there is a notable difference. Column (3) shows that it is girls who led the decrease in working hours for household tasks. Girls decreased their working hours for household tasks by 7.9 hours while the effect on boys was not statistically significant, and the magnitude of the effect is much smaller. On the other hand, boys decreased working hours in economic activities more than girls did, but the difference is small and not statistically significant. The result is not surprising considering longer hours of girls' household tasks before mine openings (20 hours) than boys' (14 hours). It implies that the mine openings decreased the gender gap in household tasks from 6.2 to 1.9 hours.

We find that the impacts were qualitatively the same across age groups, but the magnitude of the impacts differed. Here, we define children 5 to 11 years old as younger children and children aged 12 to 14 years old as older children, following the UNICEF and ILO's convention in child la-bor measurement. This measurement uses a different threshold of working hours to define a child's activity as child labor.12 Estimates presented in Column (4) show that both younger and older children substantially decreased total working hours, and the effects were not statistically distinguishable between the two age groups. Column (5) shows that working hours for economic activities substantially affected younger children while not for older age groups. Younger children are the only group with a statistically significant decrease in working hours for economic activities at 5 percent. Column (6) shows that children from both age groups decreased working hours for household tasks and both coefficients are statistically. However, the effect was much more substantial among older children who worked much longer hours initially – older children worked 26 while younger children did 14 hours before the mine opening. This result shows that the gap in working hours across age decreased from 12.2 to 7.6 hours due to mine openings.

5.2 Impacts on Education

Next, we explore the effect of gold mine openings on children's education. Figure 5 shows the trends of educational outcomes over time. Years of education in Panel A and current year's school attendance in Panel B. Before mine openings, the coefficients are indistinguishable from zero, consistent with parallel pre-trends. However, the coefficients revolve around zero after the mine openings, suggesting null effects on educational outcomes. Table 6 complements the figure and shows no impacts of mine openings on either years of education or current enrollment.

5.3 Mechanism: Adult employment

This subsection analyzes adult employment outcomes to explore the mechanisms for the child labor and education results presented in the previous section. We start by examining the impacts on mothers' employment status. Table 7 suggests that mothers are likely to decrease employment but increased the probability of working in better-quality jobs if they stay employed. We find that the probability of a mother's employment decreased while 29 percentage points more likely to be working in paid jobs and 45 percentage points more likely to be working in cash-paying jobs conditional on working. The probability of working all-year did not change substantially.

We now examine effects on adult occupation. Table 8 shows that, conditional on working, mothers are shifting away from agriculture to sales. Employment in skilled manual labor decreased, and domestic service increased, but effects are smaller. Combined with mothers' employment status, this suggests that the quality of mothers employment has improved. They are now more likely to be working in cash-paying jobs in the sales sector instead of working in the non-paying agricultural and manual labor sector. It is consistent with the findings from Kotsadam and Tolonen (2016). We do not have data on the father's employment status, but conditional on working, fathers' occupational choices also seem to change. Fathers are more likely to work in clerical and managerial positions. This suggestive evidence of increased household income in the mining areas is consistent with previous studies (von der Goltz and Barnwal, 2019; Aragón and Rud, 2013), which would explain our findings.

We complement this analysis using the information from Mali's population census to compare adult employment in provinces with and without industrial gold mines, before and after the mines opened in the province (The description of data and the empirical strategy for this section is in the Appendix A.). The results presented in Table A4 confirms the sectoral shift from agriculture to mining sector among adults. Employment in the agricultural sector decreased by 6.9 percentage points, while employment in the mining sector increased by 3.9 percentage points. However, in the census sample, adult employment rate did not change substantially (Column (1)).

This evidence is consistent with the income effect story. We observe the decrease of female employment, which could plausibly result from husbands working in mines and earning higher income. Moreover, mothers shift away from agricultural jobs to more stable, cash-paying sales positions. Men are also more likely to work in clerical/managerial positions. Therefore, direct income effects should decrease child labor.

Moreover, changes in mothers' employment status induce re-allocation of intra-household labor. By reducing employment, mothers spend more time at home. Since child labor is highly substitutable in household tasks, increased mothers' presence at home decreases child labor in household tasks. It is consistent with our findings that the girls decrease working hours for household tasks substantially while boys do not. Girls are more likely to substitute mothers' work in the household. Therefore, as the mothers are more likely to stay home, girls reduce their household work.

5.4 Robustness Checks

Although demographic characteristics are balanced across regions and parallel pre-trends assumption is satisfied, other confounders correlated with unobserved heterogeneity may exist. Here, we report additional robustness checks to address this concern.

First, our choice of the 20km threshold to determine the mining area may seem arbitrary. The effects may be larger at other thresholds based on the commuting distances and transportation systems as we can include more people affected when we include a larger area. We vary our threshold distance from 10 to 50km to check if the estimated results are robust. As discussed in Section 4.2, we expect the 20km radius to be a reasonable choice and the effects to be mitigated as we move the cutoff further away from mines. Additionally, the mitigated effects in the same direction would show that it was the mine driving the effects. Figure A6 shows that the results are robust when we vary the cutoff distance and that the magnitude of the effects reduces as we move the distance threshold farther. We repeat the main analysis by replacing the 20km dummy with a continuous distance from the closest mine since the figure suggests that the effects gradually decrease with the distance. Table A8 - A10 shows the results are qualitatively the same.

Besides, we assign the areas 30 to 50km around the mines as a neighboring area and the areas 50 to 100km away from the mines as a non-mining area to assess the potential spillover effects to the neighboring areas. Since the neighboring areas of 30 to 50km away from mines are closer to the mines than the non-mining area but do not include the mining areas, the estimated coefficients should capture the spillover effects to the neighboring areas. Estimated results presented in Table 9 shows that the children from the neighboring areas were not affected by the mine openings. Although the estimated coefficients are negative, the coefficients' size is much smaller than the original estimates and are indistinguishable from zero.

Our measure of child labor includes children's engagement in work of all intensity. Therefore, it may seem to have weak relevance for children's welfare, especially since we do not find significant changes in children's educational outcomes. To address this, we repeat the same analysis using a more conservative measure. The measure would define children's economic activity as child labor if they were engaged in economic activities or household tasks for more than certain hours per week, depending on the age group. We follow the definition used by UNICEF here. Specifically, UNICEF defines children's activity as child labor if children aged 5 to 11 did at least one hour of economic activity or at least 28 hours of household tasks. For a child of age 12 to 15, it is classified as child labor if a child did at least 14 hours of economic activity or at least 28 hours of household tasks, following the ILO convention No.138, which states that the national laws or regulations should permit the work of children 13 to 15 years of age on light work, that is, less than 14 hours of economic activities or 21 hours of household tasks. Here, we treat children's working hours as zero if working hours were less than the relevant threshold for each age group and activity. Thus, the result we present here is a more conservative way to measure child labor. Table A11 shows that the effects are similar to what we find in the main analysis, suggesting that the decrease of child labor we find is not coming from children who are at the margin of doing light or no work, but coming from children who were engaged in intensive work.

5.5 Alternative explanations

One may concern that the sectoral shifts in employment may result from the in-migrations attracted to the new employment opportunities. First, we provide suggestive evidence denying this possibility using Population Census data. We do this because DHS data do not provide information on migration for all years within our sample period. The data shows that the age distribution and migration pattern do not substantially differ between the regions with or without mines. Figure A2 shows that the ratio of in-migrants is almost equal across the provinces: 27.1 percent in mining provinces and 27 percent in non-mining provinces. If a new group of workers migrated to the mining areas, then Figure A3 shows that the age distribution did not change in mining provinces differently compared to non-mining provinces. Another evidence we provide is Table A13, which uses demographic characteristics as outcome variables and run the same analysis using the specification without control variables. The results show that the demographic characteristics did not change substantially due to mine openings. The results suggest that mine openings did not change the demographic composition to decrease child labor.

One caveat in the analyses is that it excluded the effect of changes on artisanal and small-scale mines (ASMs). ASMs are known to employ children as the parents consider working in mines as a "family affair" (Hilson, 2012); however, systematic data on the location and operating dates of ASMs in Mali do not exist.[12]

[12]Dataset on ASM itself is rare. The only studies to our knowledge that studies the effect of ASM data are i) Bazillier and Girard (2020) who compared the local economic effect of industrial mines and ASMs using the global gold price increase in Burkina Faso, ii) Zabsonré, Agbo, and Somé (2018) who examined the effect of industrial and

Suppose that there are ASMs in the same localities as the industrial mines, they begin operation simultaneously as the industrial mines, and children are employed in these ASMs as they open.[13] If this is the case, our econometric estimates underestimate the impact of the opening of industrial mines on child labor – specifically, our estimates report the net effects of both industrial mines (which reduce child labor) and ASMs (which increase child labor). In Table A7, we report the impact of mine openings on children's employment and industry choices. While employment as a whole did not increase, Column (3) shows that more children are working in the mining sector, but the magnitude is small. Recall that tasks in industrial gold mines are capital intensive, so it is unlikely that young children work in these gold mines. Then the small increase of child employment in the mining sector is likely to be from ASMs. Taken together, this suggests that we might be underestimating the impacts of the industrial mines, but that the underestimate may be small.

6 Conclusion

This paper provides new evidence on the impact of natural resource shocks on child welfare in terms of child labor and education. Exploiting a plausibly exogenous natural resource shock, we find that an opening of industrial gold mines leads to a significant decrease in children's working hours, while it does not affect participation in work or schooling. By contrast, there was no impact on education-related outcomes. The results are robust to the inclusion of control variables and changes in the distance threshold. The effects are more substantial on girls, decreasing the gender gap in working hours by 4 hours. Different age groups showed different responses. While children aged 12 to 15 reduced their household tasks, children younger than 11 years old decreased substantially for economic activities. We also find mothers decrease employments but work in better quality jobs.

The evidence is consistent with the scenario in which the natural resource shock creates new employment opportunities with higher income for adults. The income effects dominate the labor substitution effect induced by increased demand for children's productive household activities. This result complements the previous findings of the effects of mining activities on children's human capital investment. Santos (2018) finds that gold price shock increased both children and adults' employment and decreased child schooling in Colombia, whereas Zabsonré, Agbo, and

artisanal mines on child labor, and iii) a working paper by Guenther (2019) who uses a novel ASM dataset created by the joint project of Royal Holloway College, UCL and Microsoft.

[13] Hilson (2012) argues that the global gold price increase entailed a boom in small-scale gold mining in southern Mali.

Somé (2018) show the same gold price shock does not affect child labor and education substantially. Both papers examine the effects on child employment only. This paper adds the evidence that while there may not be statistically significant changes at the extensive margin, child welfare may improve at the intensive margin.

This paper shows that the effect of positive income shock on child labor needs to be interpreted with more nuance. The existing literature on child labor views child education as a substitute for child labor. Previous research found that an increased number of schools or incentives for schooling decreased child labor (de Hoop and Rosati, 2014; Edmonds and Shrestha, 2014) and increased household income decreased child labor while increasing child schooling (Edmonds, 2006; Edmonds and Schady, 2012). However, we show that a decrease in child labor does not necessarily lead to increased child schooling when the positive income shock decreases children's work in household tasks mostly. Household tasks are compatible with schooling, so the decrease in household tasks does not increase schooling.

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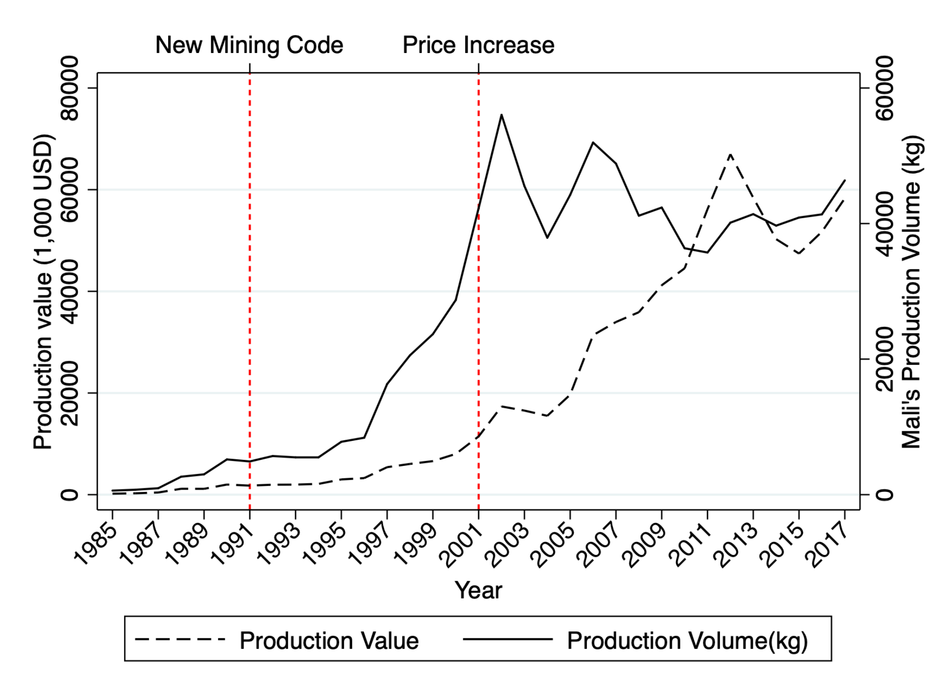
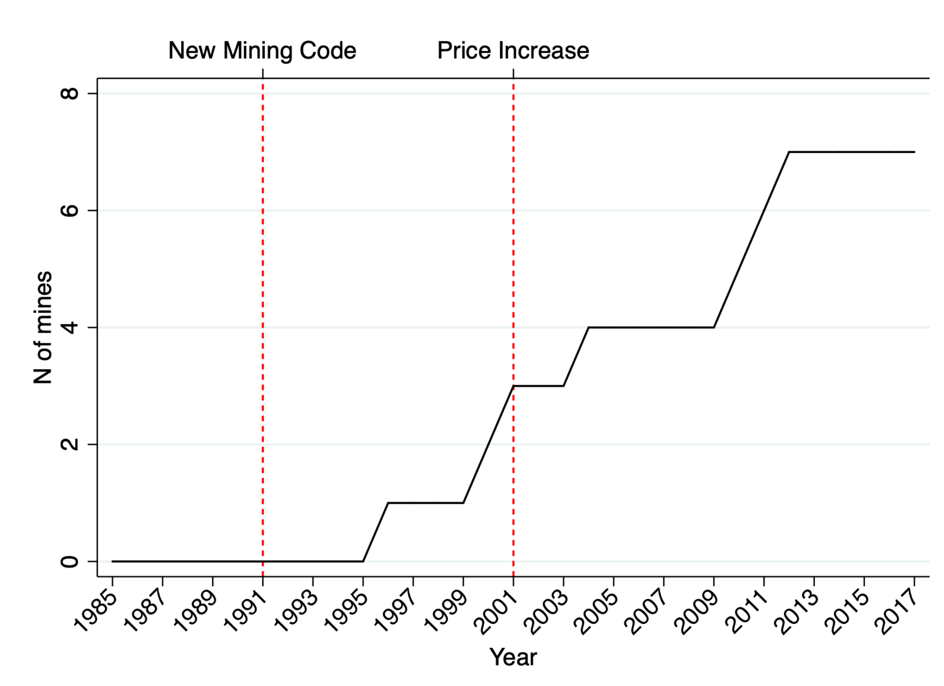
Figure 1: Mali's Gold Production

(a) Production volume and value



(b) Number of industrial mines

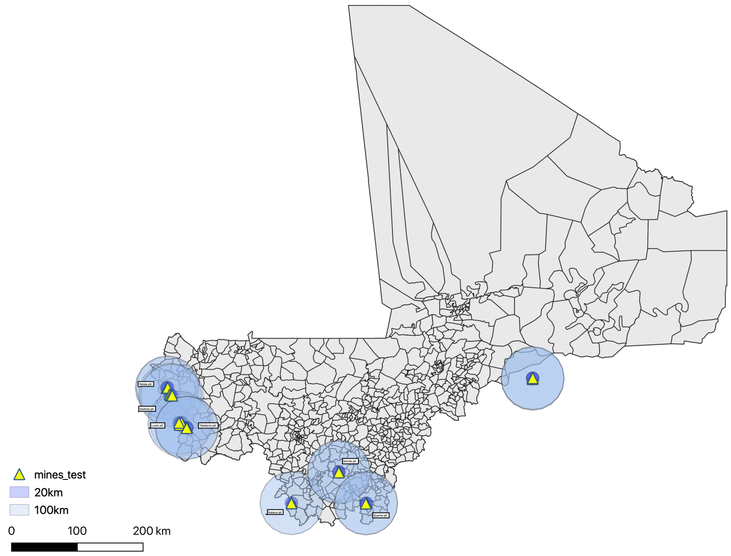


Source: United States Geological Survey Minerals Yearbook

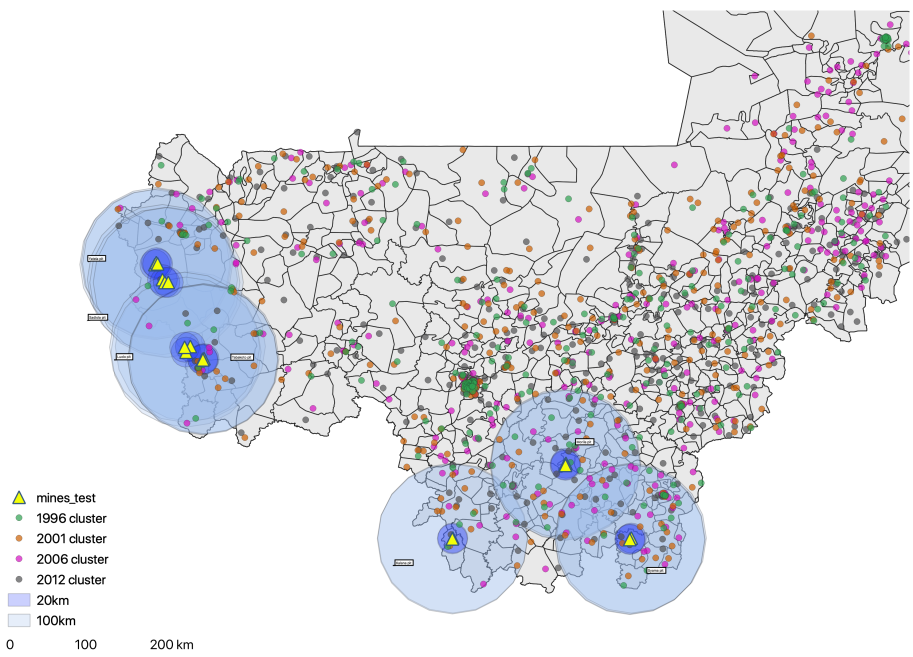
This figure plots trends of global gold prices and Mali's gold production volume. The horizontal axis show years, the vertical axis on the right world price, and the vertical axis on the left Mali's gold production volume. Solid line show the production volume and dashed line the gold price.

Figure 2: Location of Mines, 2018

(a) Mines and its surrounding areas



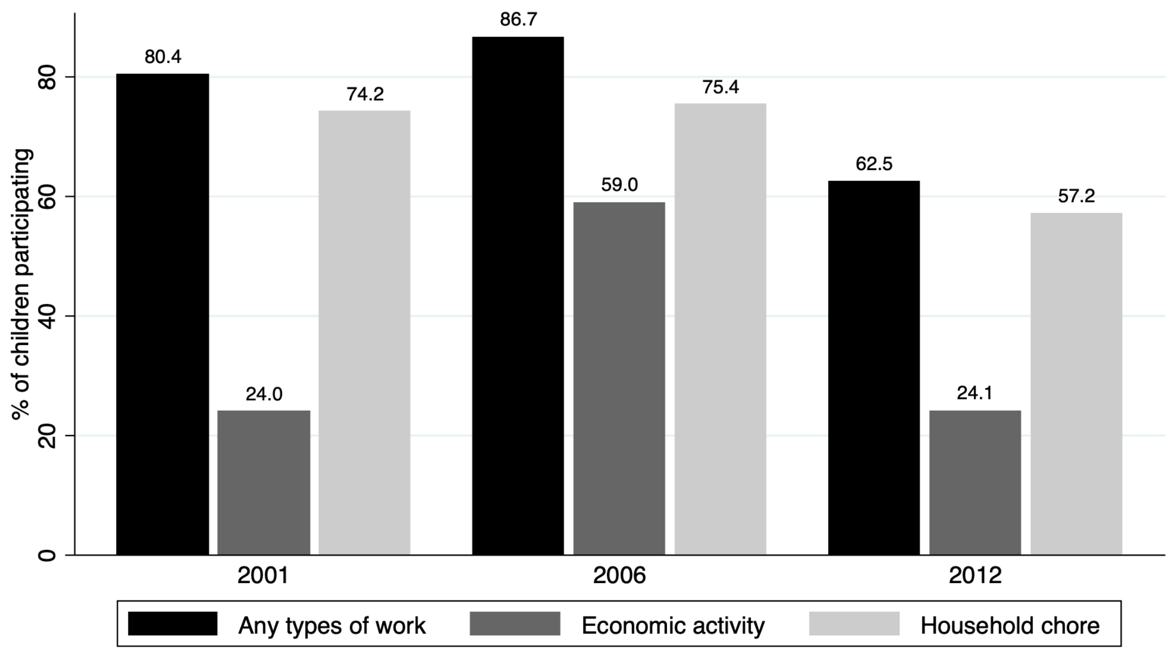
(b) DHS clusters within mining area



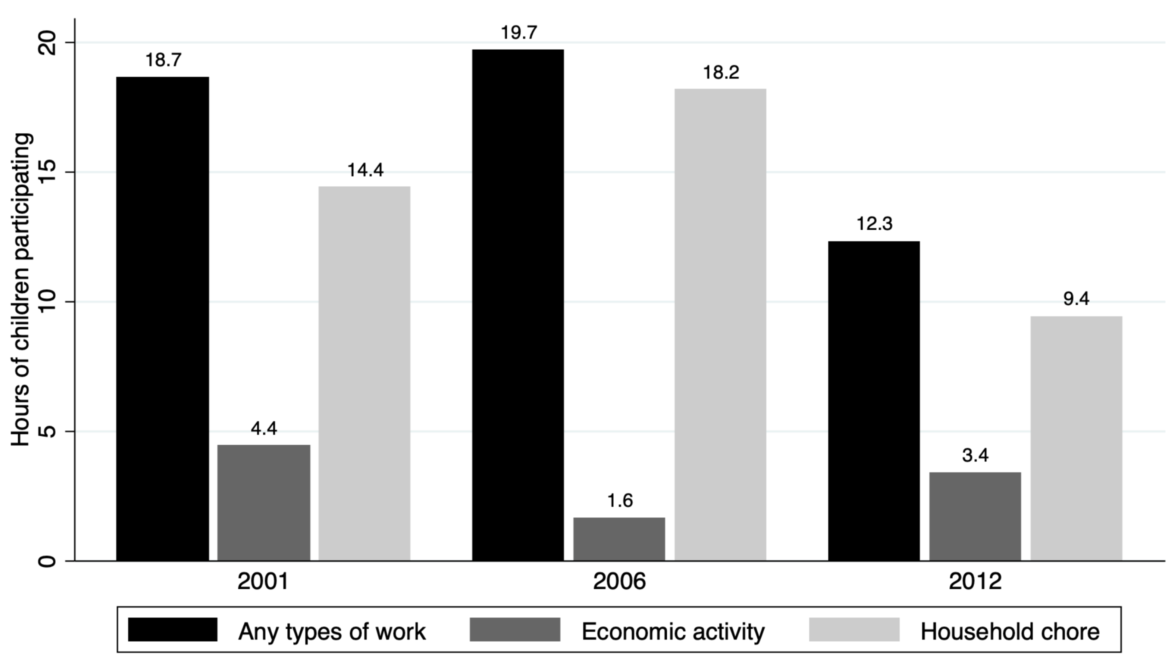
Source: Direction Nationale des Collectivités Territoriales, Demographic and Health Survey 1996-2012, and Benshaul-Tolonen (2019). Panel A plots the boundaries of communes, the lowest level municipality, the location of mines (yellow dots), 20-km radius (dark blue circle) and 100-km radius (light blue circle). Panel B adds the locations of DHS clusters for each rounds, zoomed in around the mine-located regions.

Figure 3: Status of Child Labor

(a) Child employment



(b) Children worked

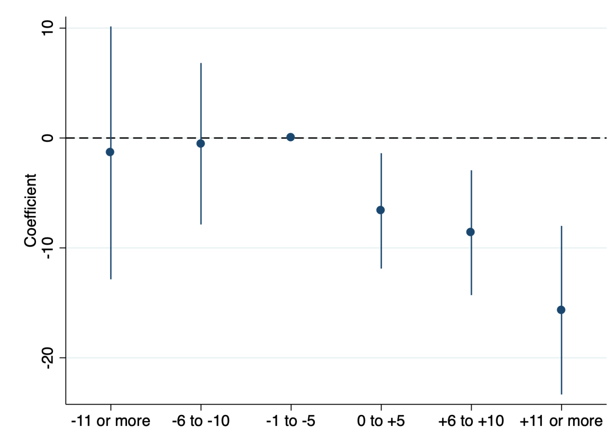


Source: Author's calculation, DHS Mali

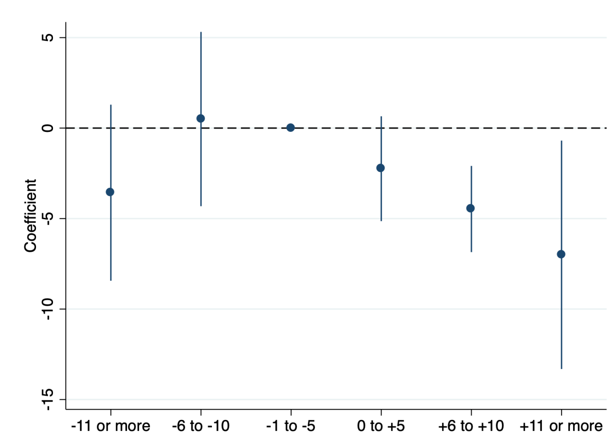
Note: This figure presents the share of working children in Mali. Panel A presents percentage of children participating in the activities among all children aged 5-14 and Panel B presents number of hours children engaged in each activity from 2001 to 2012.

Figure 4: Impacts on Working Hours of Children

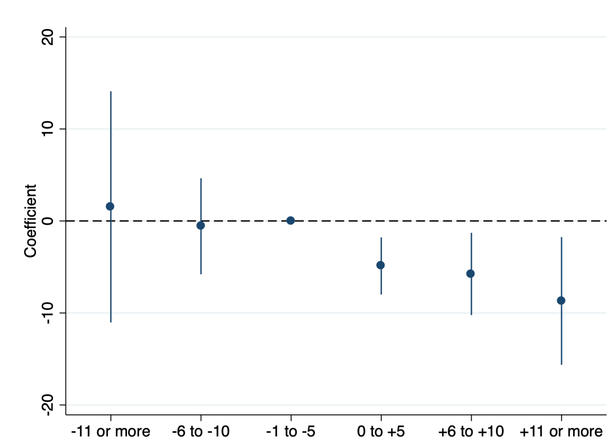
(a) Any types of work



(b) Economic Activities



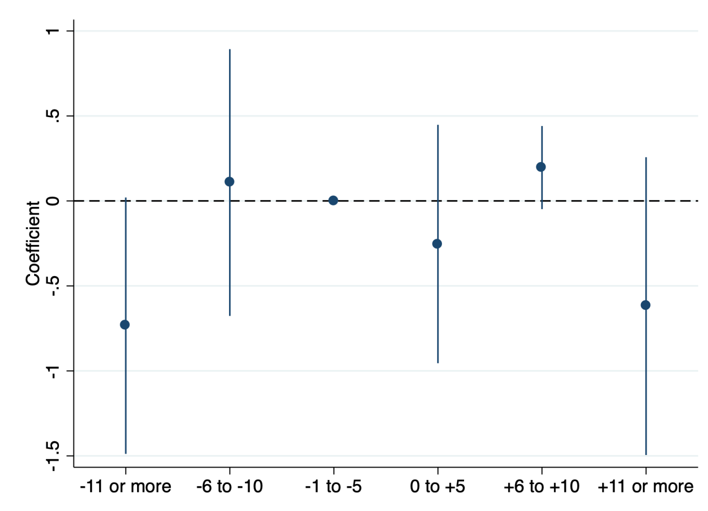
(c) Household work



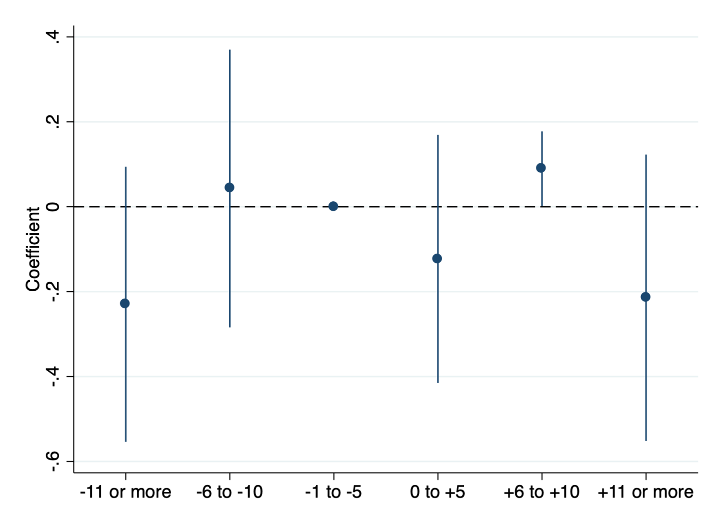
Note: This figure plots estimated effects of mine openings on working hours of children in mining areas. The horizontal axes show years from mine openings and the vertical axes the estimated coefficients. Navy dot show the estimated coefficients and the vertical lines the 95 percent confidence intervals. 0 to 5 years prior to opening is used as a reference period. Panel A, B, and C presents results for working hours for all types of work, economic activities, and household chores.

Figure 5: Impacts on Educational Outcomes

(a) Years of education



(b) Current year attendance



Note: This figure plots estimated effects of mine openings on educational choices of children in mining areas. The horizontal axes show years from mine openings and the vertical axes the estimated coefficients. Navy dot show the estimated coefficients and the vertical lines the 95 percent confidence intervals. Panel A, B, and C presents results for years of education and current year school attendance.

Table 1: Balance of Demographic Variables Across Areas

	Mining	Non-mining	Mining vs. Non-mining	N
	(1)	(2)	(3)	(4)
Age	9.22	9.21	0.00983	6078
	[2.77]	[2.84]	(0.110)	
Male	0.519	0.504	0.0151	6077
	[0.500]	[0.500]	(0.0111)	
N of HH members	9.88	9.47	0.411	6078
	[3.90]	[3.88]	(0.670)	
Live in urban area	0.136	0.160	-0.0238	6078
	[0.343]	[0.366]	(0.133)	
Mother's age	37.4	36.8	0.581	6078
	[10.1]	[9.43]	(0.733)	
Fathers's age	50.4	49.0	1.48	6078
	[10.6]	[10.6]	(1.53)	
Mother's education	0.494	0.658	-0.164	6078
	[1.70]	[1.96]	(0.237)	
Fathers's education	1.10	1.04	0.0591	6078
	[2.59]	[2.55]	(0.422)	
Biological child	0.878	0.886	-0.00827	6078
	[0.328]	[0.318]	(0.0244)	
Wealth index (quintile)	3.01	3.13	-0.119	6078
	[1.19]	[1.27]	(0.330)	

Notes: Column 1 and 2 reports means of baseline variables for subjects residing in mining and non-mining areas. Columns 3 report mean differences between the mining and non-mining areas. Standard deviations are in brackets, and standard errors, clustered at the commune level, are in parentheses. * denotes significance at 0.10; ** at 0.05; and *** at 0.01.

Table 2: Balance of Outcome Variables Across Areas

	Mining	Non-mining	Mining vs. Non-mining	N
	(1)	(2)	(3)	(4)
Participation: Any work	0.846	0.822	0.0244	3996
	[0.361]	[0.383]	(0.0281)	
Participation: Economic activity	0.495	0.344	0.151	3995
	[0.500]	[0.475]	(0.111)	
Participation: Household work	0.705	0.752	-0.0465	3981
	[0.456]	[0.432]	(0.0498)	
Hours: Any work	23.6	20.4	3.20	3996
	[22.0]	[20.9]	(3.00)	
Hours: Economic activity	7.34	3.17	4.17	3990
	[15.1]	[10.2]	(4.30)	
Hours: Domestic work in HH	16.8	17.3	-0.524	3973
	[18.0]	[18.7]	(2.08)	
Years of education	0.832	0.746	0.0856	5985
	[1.45]	[1.50]	(0.124)	
Currently enrolled	0.395	0.309	0.0856**	6057
	[0.489]	[0.462]	(0.0369)	

Notes: Column 1 and 2 reports means of baseline variables for subjects residing in mining and non-mining areas. Columns 3 report mean differences between the mining and non-mining areas. Standard deviations are in brackets, and standard errors, clustered at the commune level, are in parentheses. * denotes significance at 0.10; ** at 0.05; and *** at 0.01.

Table 3: Hours Worked by Years

	Any work	Economic activity	Household work
	(1)	(2)	(3)
20km $\times$ 11+ yrs prior	0.189	-2.704	2.339
	(3.364)	(2.355)	(2.281)
20km $\times$ 6-10 yrs prior	-0.344	0.122	-0.115
	(3.820)	(2.873)	(2.747)
20km $\times$ 1-5 yrs post	-6.157**	-2.115	-4.540***
	(2.977)	(1.942)	(1.666)
20km $\times$ 6-10 yrs post	-6.370	-3.483**	-4.358
	(3.857)	(1.372)	(3.187)
20km $\times$ 11+ yrs post	-14.433***	-6.735*	-7.685***
	(3.684)	(3.399)	(2.868)
N	11792	11769	11699
R-Squared	0.225	0.130	0.229
Mean of Dep. Var.	19.933	3.084	17.029
P-val.: joint F-test	0.982	0.067	0.459

Notes: All columns include year-from-open, cercle and survey year fixed effects. Additional controls include a child's age, birth order, the number of household members, whether a child is the biological children of the household member, living in urban area, mother and father's age and years of education, and wealth index score. Standard errors, clustered at commune level, are in parentheses. Sample weights used were provided by DHS. * denotes significance at 0.10; ** at 0.05; and *** at 0.01.

Table 4: Hours Worked

	Any work	Economic activity	Household work
	(1)	(2)	(3)
Panel A: Demographics controlled			
20km × Open	-8.602***	-3.731*	-5.674***
	(2.425)	(2.069)	(2.106)
N	11792	11769	11699
R-Squared	0.227	0.132	0.230
Mean of Dep. Var.	19.933	3.084	17.029
Panel B: Naive estimates			
20km × Open	-7.907***	-3.554*	-5.065*
	(2.826)	(2.095)	(2.592)
N	11793	11770	11700
R-Squared	0.092	0.085	0.111
Mean of Dep. Var.	19.933	3.084	17.029

Notes: In Panel A, all columns include control variables listed in the notes of Table 3. In the bottom panel, all fixed effects are included but additional demographic control variables are excluded. Standard errors, clustered at commune level, are in parentheses. Sample weights used were provided by DHS. * denotes significance at 0.10; ** at 0.05; and *** at 0.01.

Table 5: Heterogeneous Effect on Hours Worked

	By gender			By age		
	Any work	Economic activity	Household work	Any work	Economic activity	Household work
	(1)	(2)	(3)	(4)	(5)	(6)
20km × Open	-9.761***	-2.634	-7.907***	-10.729***	-2.757	-9.461***
	(3.008)	(1.639)	(2.563)	(3.404)	(3.620)	(2.898)
20km × Open × Male	2.441	-1.877	4.300			
	(2.596)	(2.623)	(3.788)			
20km × Open × Age 5-11				2.322	-1.422	4.658**
				(2.792)	(3.096)	(1.852)
N	11792	11769	11699	11792	11769	11699
R-Squared	0.231	0.138	0.233	0.232	0.138	0.235
Mean of Dep. Var.	19.933	3.084	17.029	19.933	3.084	17.029
20km · Open + Interaction	-7.320	-4.510	-3.607	-8.407	-4.179	-4.803
P-value.: 20km · Open + Interaction	0.004	0.136	0.240	0.001	0.036	0.017

Notes: All columns include control variables listed in the notes of Table 3. Standard errors, clustered at commune level, are in parentheses. Sample weights used were provided by DHS. * denotes significance at 0.10; ** at 0.05; and *** at 0.01. Areas outside of 20km radius are considered as treated and control area.

Table 6: Educational Outcomes

	Years of Education			Currently enrolled		
	(1)	(2)	(3)	(4)	(5)	(6)
20km × Open	-0.175	-0.045	-0.700	-0.089	-0.086	-0.234*
	(0.282)	(0.262)	(0.633)	(0.105)	(0.109)	(0.136)
20km × Open × Male		-0.267*			-0.009	
		(0.136)			(0.051)	
20km × Open × Age 5-11			0.705			0.188***
			(0.489)			(0.063)
Control	Yes	Yes	Yes	Yes	Yes	Yes
N	14809	14809	14809	14962	14962	14962
R-Squared	0.338	0.341	0.350	0.238	0.245	0.246
Mean of Dep. Var.	0.755	0.755	0.755	0.318	0.318	0.318
20km · Open + Interaction		-0.312	0.005		-0.095	-0.046
P-value.: 20km · Open + Interaction		0.323	0.979		0.374	0.645

Notes: All columns include control variables listed in the notes of Table 3. Standard errors, clustered at commune level, are in parentheses. Sample weights used were provided by DHS. * denotes significance at 0.10; ** at 0.05; and *** at 0.01.

Table 7: Mother's Work

	Work	Paid work	Paid in cash	Worked all year
	(1)	(2)	(3)	(4)
20km × Open	-0.276*	0.292***	0.454***	0.082
	(0.145)	(0.103)	(0.142)	(0.092)
N	11857	9717	9140	11884
R-Squared	0.254	0.291	0.370	0.207
Mean of Dep. Var.	0.857	0.756	0.463	0.208

Table 8: Adult occupation

	Agriculture	Sales	Clerical, Manager, Technician	Skilled Manual labor	Unskilled Manual labor	Domestic service
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Mother's occupation						
20km × Open	-0.307**	0.178**	-0.008	-0.117**	-0.034	0.002*
	(0.123)	(0.072)	(0.007)	(0.058)	(0.032)	(0.001)
N	11857	11857	11857	11857	11857	11857
R-Squared	0.543	0.225	0.119	0.127	0.199	0.009
Mean of Dep. Var.	0.408	0.235	0.011	0.022	0.008	0.000
Panel B: Father's occupation						
20km × Open	-0.136	-0.039	0.060*	-0.011	-0.021	0.026
	(0.124)	(0.049)	(0.033)	(0.021)	(0.019)	(0.016)
N	11776	11776	11776	11776	11776	11776
R-Squared	0.603	0.180	0.267	0.092	0.067	0.056
Mean of Dep. Var.	0.543	0.102	0.059	0.050	0.010	0.008

Notes: All columns include control variables listed in the notes of Table 3. Standard errors, clustered at commune level, are in parentheses. Sample weights used were provided by DHS. * denotes significance at 0.10; ** at 0.05; and *** at 0.01.

Table 9: Spillover Effects on Areas Farther Away From Mines

	Any work	Economic activity	Household work
	(1)	(2)	(3)
Panel A: Naive estimates			
30-50km × Open	-0.292	0.896	-1.578
	(2.991)	(1.397)	(2.912)
N	10113	10092	10026
R-Squared	0.080	0.066	0.101
Mean of Dep. Var.	20.807	2.987	18.002
Panel B: Demographics controlled			
30-50km × Open	-1.158	0.780	-2.462
	(2.453)	(1.276)	(2.637)
N	10112	10091	10025
R-Squared	0.220	0.116	0.224
Mean of Dep. Var.	20.807	2.987	18.002

Notes: All columns include control variables listed in the notes of Table 3. Standard errors, clustered at commune level, are in parentheses. Sample weights used were provided by DHS. * denotes significance at 0.10; ** at 0.05; and *** at 0.01. Areas outside of 20km radius are considered as treated and control area.

A Adult Employment using Census Data

I examine adults' employment choices. This section lays out the data and empirical strategies I used for these analyses.

A.1 Data

I use population and housing census data of Mali in 1987, 1998 and 2009, accessed through IPUMS international, to complement main analyses with evidences on changes in sector choices and migration pattern. Census data includes more detailed information on adult and children's employment outside of the household such as sector of the employment. However, I cannot use the same identification strategy since census data does not include geolocation information of the survey clusters, so I use coarser identification for this analysis using administrative level where mines are located.

A.2 Empirical Strategy

I estimate the effect of mine openings on adult employment outcome as per following equation:

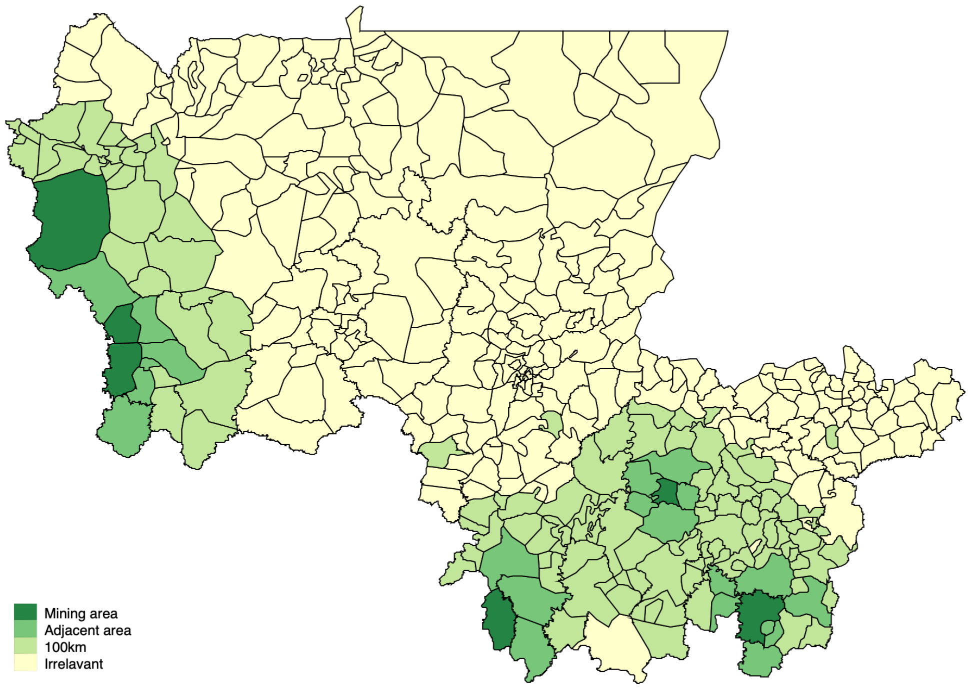
$$\begin{aligned} y_{ijy} =& \beta_0 + \beta_1 Mine\_Cercle_{jy} \cdot 1998_i + \beta_2 Mine\_Cercle_{jy} \cdot 2009_i + \beta_3 Mine\_Cercle_{jt} \\ &+ \eta_c + \nu_y + X_{ijy} + \varepsilon_{ijy} \end{aligned} \tag{3}$$

where y_{ijcy} is the employment status of adult i in cercle c in year y.

The key independent variable is $Mine\_Cercle_{jy}$, a dummy variable equals to one if an industrial gold mine is located in cercle c in year y. Population census data do not include geolocations of surveyed clusters. Thus, I restrict the sample to regions where mines are located in which case cercles that are located within the boundary of mining regions but out of mining cercles serve as a comparison group in these analyses. Since some mines are located in close proximity to each other but opened in different years, and time interval between each census waves is 10 or more years, I use survey years for timing variations. In 1987, all mines are yet to open. In some cercle, mines start to operate in the early and mid-90s. In some areas, mines start to operate in early 2000s. Therefore, β_3 captures the effect of all active mines whereas β_2 captures the effect of some active mines. Note that the short- and long-term effects of opening mines are mixed in β_3.

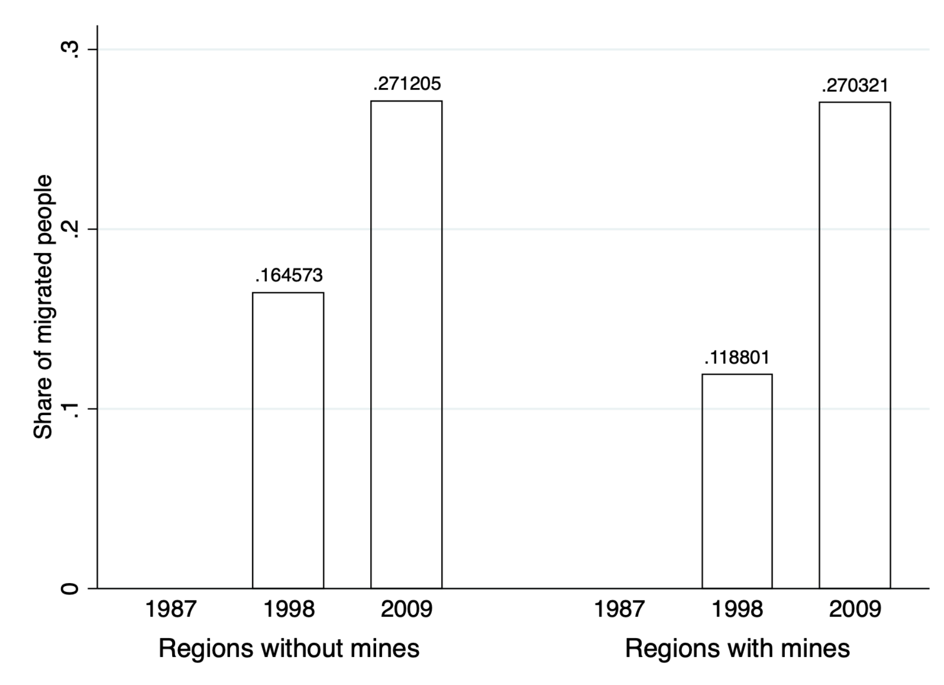
B Additional tables and figures

Figure A1: Map of Mining- and non-mining areas using municipalities



Note: This figure identifies the commune where mines are located and its surrounding communes..

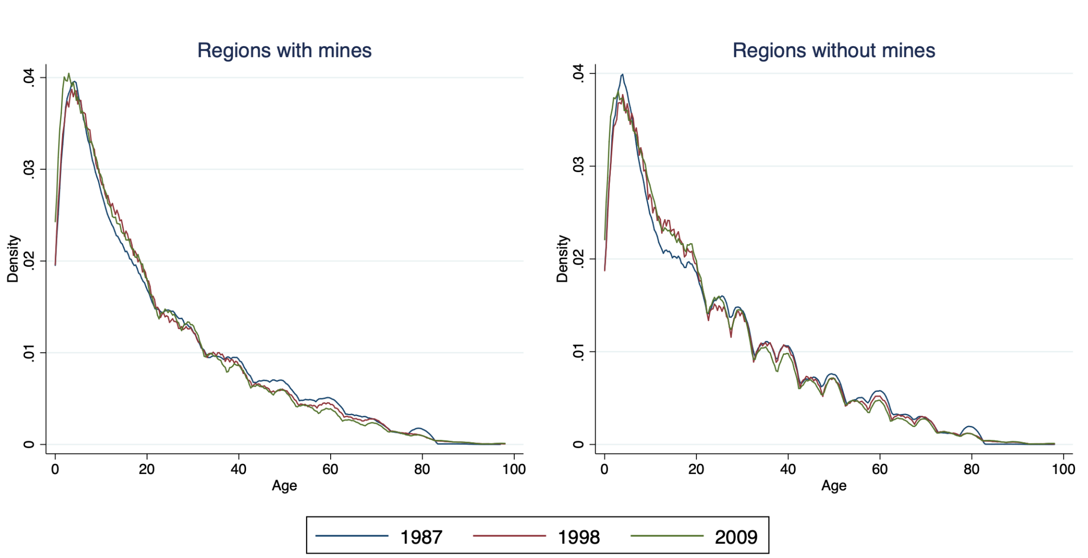
Figure A2: In-migration to the mining regions



Source: Author's calculation, Mali Census

Note: This figure plots the share of migrated people by regions with or without mines. The horizontal axis show years, and the vertical axis the share of migrated people.

Figure A3: Changes in the age distribution over time

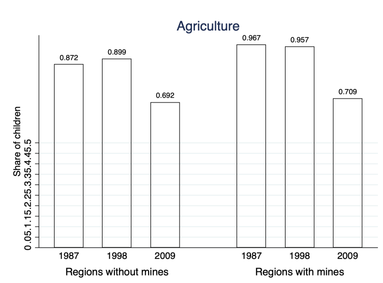


Source: Author's calculation, Mali Census

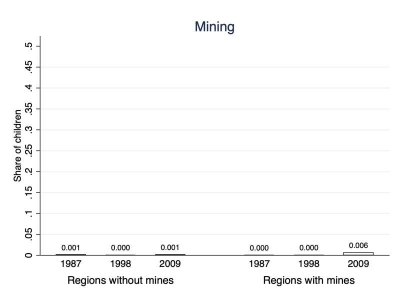
Note: This figure plots the changes in the distribution of the age across waves in the mining region (left) and the non-mining regions (right). The horizontal axis show age in years and the vertical axis the kernel density. Blue line shows the age distribution in 1987, the red line in 1998, and the green line in 2009.

Figure A4: Child employment in different sectors

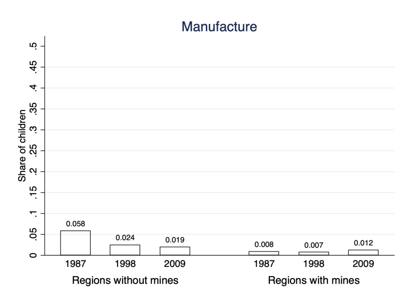
(a) Agriculture



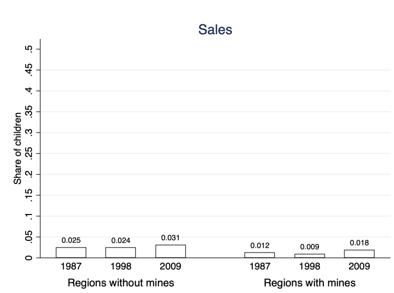
(b) Mining



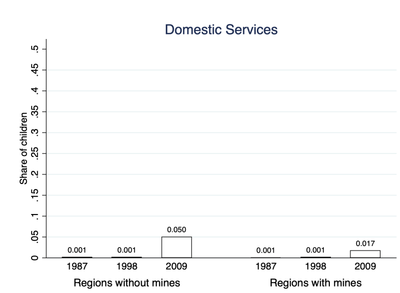
(c) Manufacture



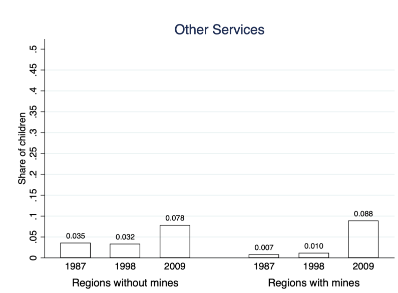
(d) Sales



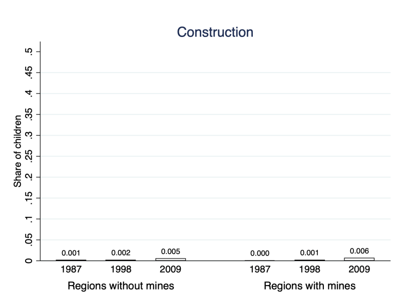
(e) Domestic services



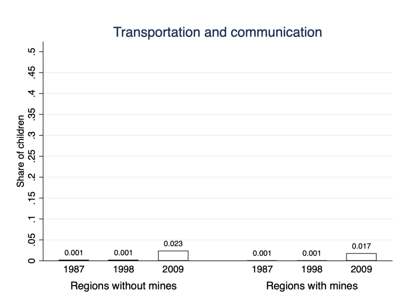
(f) Other services



(g) Construction



(h) Transportation / Communication

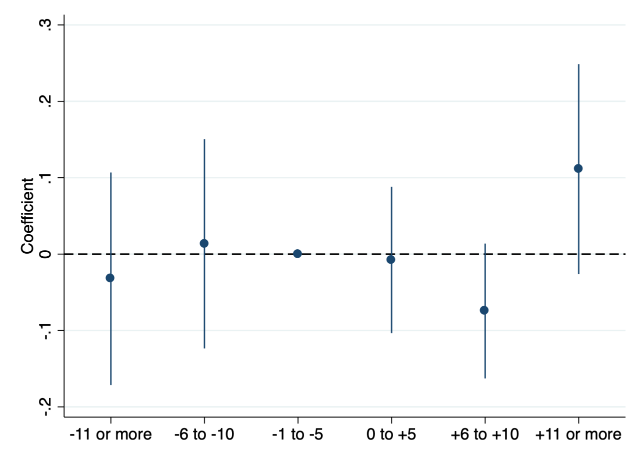


Source: Author's calculation, Mali Census

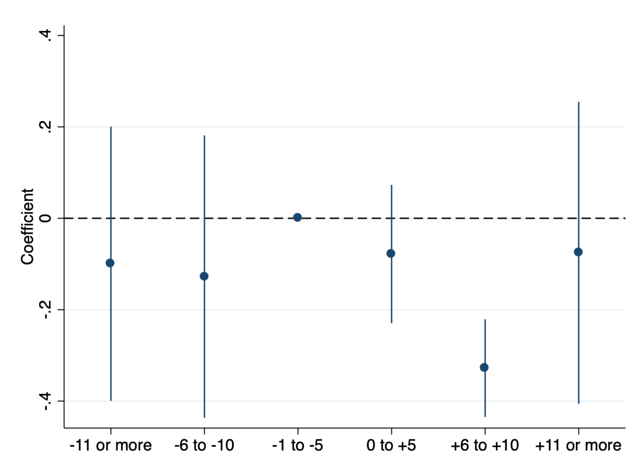
Note: This figure plots the share of children employed each sector among all children aged 5 to 17, in each census wave, by mining and non-mining areas. The horizontal axes show years and areas. and the vertical axes the share of children in each sector.

Figure A5: Impacts on child labor participation

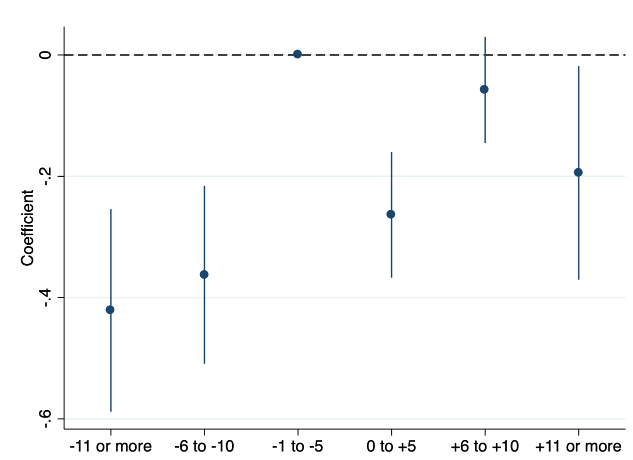
(a) Any types of work



(b) Economic activities



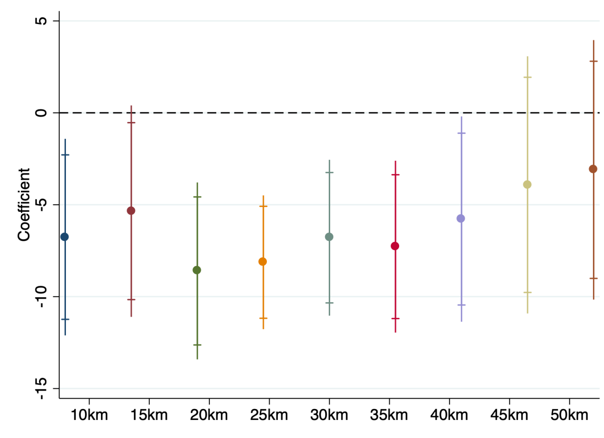
(c) Household work



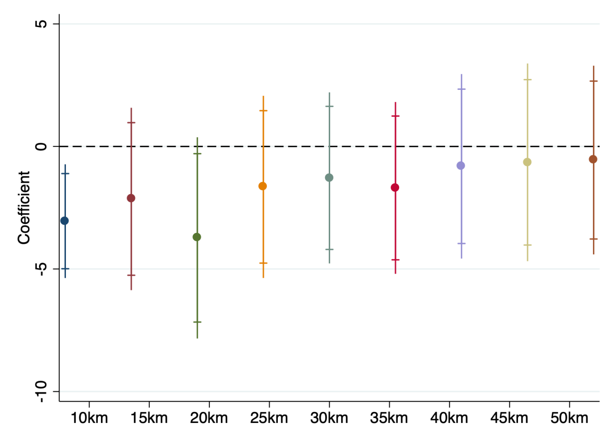
Note: This figure plots estimated effects of mine openings on children's participation in work in mining areas. The horizontal axes show years from mine openings and the vertical axes the estimated coefficients. Navy dot show the estimated coefficients and the vertical lines the 95 percent confidence intervals. 0 to 5 years prior to opening is used as a reference period. Panel A, B, and C presents results for working hours for all types of work, economic activities, and household chores.

Figure A6: Impacts on Working Hours of Children

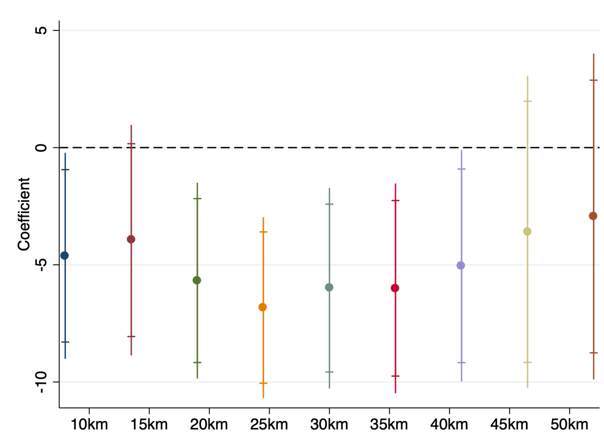
(a) Any types of work



(b) Economic Activities



(c) Household work



Note: This figure plots estimated effects of mine openings on working hours of children in mining areas, varying the treshold distance to define mining area. The horizontal axes threshold distance used to define mining areas and the vertical axes the estimated coefficients. The vertical lines represent the 95 percent confidence intervals. Panel A, B, and C presents results for working hours for all types of work, economic activities, and household chores.

Table A1: List of Gold Mines in Mali

Name	Open	Closed	Re-open
Yatela Pit	2001		
Sadiola Pit	1996		
Loulo Pit	2011		
Tabakoto Pit	2012		
Kalana Pit	2004		
Morila Pit	2000		
Syama Pit	1990	2001	2011

Table A2: Child Worked by Years

	Any work	Economic activity	Household work
	(1)	(2)	(3)
20km × 11+ yrs prior	-0.014	-0.091	-0.402***
	(0.062)	(0.154)	(0.078)
20km × 6-10 yrs prior	0.011	-0.132	-0.370***
	(0.073)	(0.197)	(0.077)
20km × 1-5 yrs post	-0.003	-0.077	-0.260***
	(0.058)	(0.094)	(0.071)
20km × 6-10 yrs post	-0.051	-0.314***	-0.036
	(0.061)	(0.069)	(0.064)
20km × 11+ yrs post	0.122	-0.074	-0.188**
	(0.076)	(0.176)	(0.088)
N	11794	11793	11770
R-Squared	0.238	0.283	0.213
Mean of Dep. Var.	0.832	0.343	0.762
P-val.: joint F-test	0.769	0.799	0.000

Notes: All columns include control variables listed in the notes of Table 3. Standard errors, clustered at commune level, are in parentheses. Sample weights used were provided by DHS. * denotes significance at 0.10; ** at 0.05; and *** at 0.01.

Table A3: Child Worked

	Any work	Economic activity	Household work
	(1)	(2)	(3)
Panel A: Demographics controlled			
20km × Open	0.001	-0.028	0.065
	(0.046)	(0.106)	(0.059)
N	11794	11793	11770
R-Squared	0.235	0.281	0.210
Mean of Dep. Var.	0.832	0.343	0.762
Panel B: Naive estimates			
20km × Open	0.014	-0.031	0.087
	(0.049)	(0.108)	(0.059)
N	11795	11794	11771
R-Squared	0.109	0.203	0.101
Mean of Dep. Var.	0.832	0.343	0.762

Notes: In Panel A, all columns include control variables listed in the notes of Table 3. In the bottom panel, all fixed effects are included but additional demographic control variables are excluded. Standard errors, clustered at commune level, are in parentheses. Sample weights used were provided by DHS. * denotes significance at 0.10; ** at 0.05; and *** at 0.01.

Table A4: Adult Employment

	Employed	Agriculture	Mining	Manufature	Construction	Sales	Domestic service	Other sectors
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mining cercle × 1998	-0.000	0.009	0.002	-0.001	-0.000	-0.010	-0.001	0.002
	(0.028)	(0.011)	(0.003)	(0.003)	(0.002)	(0.007)	(0.007)	(0.005)
Mining cercle × 2009	-0.006	-0.069**	0.039**	0.005	0.003	0.018	-0.002	0.007
	(0.035)	(0.027)	(0.019)	(0.004)	(0.004)	(0.011)	(0.008)	(0.008)
1998	-0.092***	0.000	0.000	-0.004*	0.001	0.003	-0.013***	0.013***
	(0.017)	(0.008)	(0.000)	(0.002)	(0.001)	(0.003)	(0.004)	(0.003)
2009	-0.137***	-0.064***	0.002**	-0.000	0.009***	0.011***	-0.015***	0.056***
	(0.018)	(0.011)	(0.001)	(0.003)	(0.002)	(0.004)	(0.005)	(0.003)
N	453518	300725	300725	300725	300725	300725	300725	300725
R-Squared	0.252	0.361	0.211	0.027	0.020	0.130	0.039	0.159
Mean of Dep. Var.	0.757	0.904	0.000	0.019	0.003	0.032	0.017	0.024

Notes: Standard errors, clustered at the year-cluster level, are in parentheses. Sample weights used were provided by DHS. * denotes significance at 0.10; ** at 0.05; and *** at 0.01.

Table A5: Adult Male Employment

	Employed	Agriculture	Mining	Manufature	Construction	Sales	Domestic service	Other sectors
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mining cercle × 1998	-0.014	-0.000	0.002	-0.003	-0.002	0.004	-0.003	0.001
	(0.011)	(0.012)	(0.003)	(0.004)	(0.003)	(0.007)	(0.009)	(0.006)
Mining cercle × 2009	0.018	-0.070***	0.040**	0.002	0.003	0.023**	-0.005	0.008
	(0.015)	(0.026)	(0.019)	(0.004)	(0.006)	(0.011)	(0.012)	(0.008)
1998	-0.006	-0.005	0.000	-0.004*	0.003*	0.009***	-0.020***	0.016***
	(0.004)	(0.009)	(0.000)	(0.003)	(0.002)	(0.003)	(0.005)	(0.005)
2009	-0.052***	-0.090***	0.003**	0.005	0.016***	0.032***	-0.025***	0.058***
	(0.008)	(0.012)	(0.001)	(0.003)	(0.003)	(0.005)	(0.007)	(0.004)
N	212576	184366	184366	184366	184366	184366	184366	184366
R-Squared	0.139	0.392	0.259	0.029	0.021	0.128	0.048	0.179
Mean of Dep. Var.	0.901	0.876	0.000	0.025	0.005	0.028	0.026	0.040

Notes: Standard errors, clustered at the year-cluster level, are in parentheses. Sample weights used were provided by DHS. * denotes significance at 0.10; ** at 0.05; and *** at 0.01.

Table A6: Adult Female Employment

	Employed	Agriculture	Mining	Manufature	Construction	Sales	Domestic service	Other sectors
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mining cercle × 1998	0.011	0.034**	-0.002	-0.002	0.000	-0.029**	0.001	-0.002
	(0.046)	(0.016)	(0.002)	(0.003)	(0.000)	(0.014)	(0.004)	(0.005)
Mining cercle × 2009	-0.029	-0.050	0.032*	0.007	0.000	0.006	0.002	0.002
	(0.056)	(0.032)	(0.018)	(0.005)	(0.000)	(0.019)	(0.005)	(0.011)
1998	-0.165***	-0.003	0.001	-0.001	0.000	-0.003	-0.006**	0.012***
	(0.031)	(0.010)	(0.001)	(0.003)	(0.000)	(0.006)	(0.003)	(0.003)
2009	-0.209***	-0.034**	0.002*	-0.007**	0.001***	-0.020*	-0.002	0.061***
	(0.031)	(0.014)	(0.001)	(0.003)	(0.000)	(0.011)	(0.003)	(0.005)
N	240942	116359	116359	116359	116359	116359	116359	116359
R-Squared	0.135	0.277	0.120	0.014	0.002	0.173	0.049	0.106
Mean of Dep. Var.	0.636	0.937	0.000	0.012	0.000	0.038	0.006	0.006

Notes: Standard errors, clustered at the year-cluster level, are in parentheses. Sample weights used were provided by DHS. * denotes significance at 0.10; ** at 0.05; and *** at 0.01.

Table A7: Child Employment

	Employed	Agriculture	Mining	Manufature	Construction	Sales	Domestic service	Other sectors
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mining cercle × 1998	-0.033	0.007	-0.001	-0.001	-0.001	-0.008	0.002	0.003
	(0.035)	(0.011)	(0.001)	(0.002)	(0.001)	(0.008)	(0.002)	(0.006)
Mining cercle × 2009	-0.018	-0.045	0.014*	0.006*	-0.001	0.005	0.000	0.021
	(0.041)	(0.029)	(0.007)	(0.003)	(0.002)	(0.008)	(0.005)	(0.023)
1998	-0.101***	-0.002	-0.000	-0.002	0.001**	-0.003	-0.002	0.007*
	(0.021)	(0.007)	(0.000)	(0.002)	(0.001)	(0.002)	(0.001)	(0.004)
2009	-0.213***	-0.203***	0.001*	-0.000	0.005***	-0.002	0.008***	0.192***
	(0.027)	(0.015)	(0.001)	(0.002)	(0.001)	(0.002)	(0.003)	(0.014)
N	324611	133984	133984	133984	133984	133984	133984	133984
R-Squared	0.154	0.237	0.056	0.019	0.009	0.052	0.077	0.178
Mean of Dep. Var.	0.567	0.972	0.000	0.008	0.000	0.008	0.001	0.010

Notes: Standard errors, clustered at the year-cluster level, are in parentheses. Sample weights used were provided by DHS. * denotes significance at 0.10; ** at 0.05; and *** at 0.01.

Table A8: Hours Worked (Using continuous distance)

	Any work	Economic activity	Household work
	(1)	(2)	(3)
Panel A: Demographics controlled			
ln(Distance) × Open	3.372**	0.694	2.912**
	(1.401)	(0.800)	(1.381)
N	11792	11769	11699
R-Squared	0.227	0.131	0.230
Mean of Dep. Var.	19.933	3.084	17.029
Panel B: Naive estimates			
ln(Distance) × Open	2.911	0.544	2.565
	(1.765)	(0.838)	(1.650)
N	11793	11770	11700
R-Squared	0.092	0.084	0.112
Mean of Dep. Var.	19.933	3.084	17.029

Notes: In Panel A, all columns include control variables listed in the notes of Table 3. In the bottom panel, all fixed effects are included but additional demographic control variables are excluded. Standard errors, clustered at commune level, are in parentheses. Sample weights used were provided by DHS. * denotes significance at 0.10; ** at 0.05; and *** at 0.01.

Table A9: Heterogeneous Effect on Hours Worked (Using continuous distance)

	By gender			By age		
	Any work	Economic activity	Household work	Any work	Economic activity	Household work
	(1)	(2)	(3)	(4)	(5)	(6)
ln(Distance) × Open	3.770**	0.290	3.727**	3.873**	0.739	3.419**
	(1.725)	(0.771)	(1.719)	(1.657)	(1.181)	(1.654)
ln(Distance) × Open × Male	-0.819	0.657	-1.519			
	(1.129)	(0.861)	(1.513)			
ln(Distance) × Open × Age 5-11				-0.572	-0.052	-0.591
				(1.397)	(0.952)	(1.199)
N	11792	11769	11699	11792	11769	11699
R-Squared	0.230	0.137	0.233	0.231	0.137	0.236
Mean of Dep. Var.	19.933	3.084	17.029	19.933	3.084	17.029
ln(Distance) · Open + Interaction	2.950	0.947	2.208	3.301	0.687	2.828
P-value.: ln(Distance) · Open + Interaction	0.022	0.353	0.126	0.025	0.384	0.043

Notes: In Panel A, all columns include control variables listed in the notes of Table 3. In the bottom panel, all fixed effects are included but additional demographic control variables are excluded. Standard errors, clustered at commune level, are in parentheses. Sample weights used were provided by DHS. * denotes significance at 0.10; ** at 0.05; and *** at 0.01.

Table A10: Educational Outcomes (Using continuous distance)

	Years of Education			Currently enrolled		
	(1)	(2)	(3)	(4)	(5)	(6)
ln(Distance) × Open	0.045	0.063	0.028	-0.016	-0.007	-0.013
	(0.057)	(0.058)	(0.091)	(0.024)	(0.026)	(0.026)
ln(Distance) × Open × Male		-0.040			-0.019	
		(0.042)			(0.012)	
ln(Distance) × Open × Age 5-11			0.008			-0.006
			(0.068)			(0.011)
Control	Yes	Yes	Yes	Yes	Yes	Yes
N	14809	14809	14809	14962	14962	14962
R-Squared	0.338	0.341	0.350	0.238	0.245	0.246
Mean of Dep. Var.	0.755	0.755	0.755	0.318	0.318	0.318
ln(Distance) · Open + Interaction		0.022	0.036		-0.026	-0.019
P-value.: ln(Distance) · Open + Interaction		0.715	0.484		0.279	0.430

Notes: All columns include control variables listed in the notes of Table 3. Standard errors, clustered at commune level, are in parentheses. Sample weights used were provided by DHS. * denotes significance at 0.10; ** at 0.05; and *** at 0.01.

Table A11: Child work (Conservative measure of child labor)

	Pr(Participation)			Hours worked		
	Any work	Economic activities	Household chores	Any work	Economic activities	Household chores
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Demographics controlled						
20km × Open	-0.110	-0.066	-0.065*	-8.210***	-3.765*	-5.246**
	(0.071)	(0.092)	(0.037)	(2.672)	(2.047)	(2.178)
N	11794	11794	11794	11794	11794	11794
R-Squared	0.145	0.126	0.190	0.178	0.123	0.169
Mean of Dep. Var.	0.368	0.144	0.248	14.555	2.884	10.802
Panel B: Naive estimates						
20km × Open	-0.097	-0.053	-0.059	-7.529**	-3.565*	-4.809*
	(0.078)	(0.096)	(0.044)	(2.953)	(2.089)	(2.601)
N	11795	11795	11795	11795	11795	11795
R-Squared	0.074	0.099	0.106	0.076	0.084	0.087
Mean of Dep. Var.	0.368	0.144	0.248	14.555	2.884	10.802

Notes: In Panel A, all columns include control variables listed in the notes of Table 3. In the bottom panel, all fixed effects are included but additional demographic control variables are excluded. Standard errors, clustered at commune level, are in parentheses. Sample weights used were provided by DHS. * denotes significance at 0.10; ** at 0.05; and *** at 0.01.

Table A12: Heterogeneous Effect on Hours Worked (Conservative measure of child labor)

	By gender			By age		
	Any work	Economic activity	Household work	Any work	Economic activity	Household work
	(1)	(2)	(3)	(4)	(5)	(6)
20km × Open	-8.692***	-2.783*	-6.520***	-13.402***	-3.394	-12.422***
	(3.081)	(1.614)	(2.428)	(3.353)	(3.592)	(2.648)
20km × Open × Male	1.212	-1.672	2.526			
	(2.459)	(2.622)	(3.352)			
20km × Open × Age 5-11				6.164**	-0.676	9.015***
				(2.777)	(3.139)	(1.551)
N	11794	11794	11794	11794	11794	11794
R-Squared	0.182	0.130	0.172	0.187	0.130	0.180
Mean of Dep. Var.	14.555	2.884	10.802	14.555	2.884	10.802
20km · Open + Interaction	-7.480	-4.455	-3.994	-7.238	-4.070	-3.407
P-value.: 20km · Open + Interaction	0.008	0.138	0.185	0.008	0.041	0.104

Notes: In Panel A, all columns include control variables listed in the notes of Table 3. In the bottom panel, all fixed effects are included but additional demographic control variables are excluded. Standard errors, clustered at commune level, are in parentheses. Sample weights used were provided by DHS. * denotes significance at 0.10; ** at 0.05; and *** at 0.01.

Table A13: Demographic change

	Age	=1 Male	HH size	Live in urban area	Female HH head	Mother's years of education	Father's years of education
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
20km × Open	-0.205	-0.052*	-1.146	0.020	0.007	0.381	0.164
	(0.240)	(0.028)	(0.697)	(0.057)	(0.031)	(0.324)	(0.612)
N	14989	14988	14989	14989	14989	14989	14989
R-Squared	0.011	0.009	0.112	0.764	0.064	0.110	0.105
Mean of Dep. Var.	9.174	0.504	9.330	0.118	0.047	0.632	1.039

Notes: All fixed effects are included. Standard errors, clustered at commune level, are in parentheses. Sample weights used were provided by DHS. * denotes significance at 0.10; ** at 0.05; and *** at 0.01.