CDEP-CGEG WORKING PAPER SERIES

CDEP-CGEG WP No. 57

Local Industrial Shocks and Infant Mortality

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April 2018

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April 22, 2018

Abstract

Local industrial development has the potential to improve health and well-being, while also damaging health through exposure to harmful pollution. It is an empirical question which of these effects dominate. Exploiting the quasi-experimental expansion of African large-scale gold mining, I find that local infant mortality rates decrease by more than 50% alongside rapid economic growth. The instantaneous reduction is comparable to overall gains in infant survival rates in the study countries from 1970 to today. The results are robust to migration. Local industrial development—despite risk of pollution—may be an effective tool to reduce infant mortality in developing countries.

Keywords: Industrial Development, Natural Resources, Gold Mining, Infant Mortality, Sustainable Development Goals
JEL classification: O12, O13, I15, J13

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One in nine children born in developing countries dies before its fifth birthday[1] and Sub-Saharan Africa has among the highest rates of child mortality in the world. Achieving the sustainable development goals for infant mortality—12 neonatal deaths and 25 deaths under the age of 5 per 1000 live births—by 2030 poses a significant challenge in the region as several countries in West and Central Africa are off-track to meet the target (Wang et al., 2014).

Lack of economic development is one reason for the high child mortality rates: curable and preventable conditions such as lower respiratory infections, diarrheal diseases, malaria (Black et al., 2003; Dupas, 2011), and undernutrition (Black et al., 2013a) contribute to the high health burden in developing countries. In fact, maternal and early-life undernutrition is a leading cause of global child mortality, responsible for up to 45% of child deaths (Black et al., 2013a). Analysis of global data shows that country-wide infant mortality rates increase with negative aggregate income shocks (Baird et al., 2011).

On the other hand, poor environmental conditions, such as airborne and waterborne pollution are threats to infant health in developing countries (Greenstone and Hanna, 2014; Jayachandran, 2009).[2] The low environmental quality and high disease burden in developing countries come from high marginal utility of income: when facing a health-wealth tradeoff, poor households prefer consumption today over investing in environmental quality (Greenstone and Jack, 2015).

I explore if investment in extractive industries, in particular the large-scale gold mining sector, changes local infant mortality rates in Sub-Saharan Africa. The effect is a priori ambiguous: on the one hand it can increase infant mortality rates by polluting the environment, affecting agricultural production (Aragón and Rud, 2015). On the other hand it can reduce

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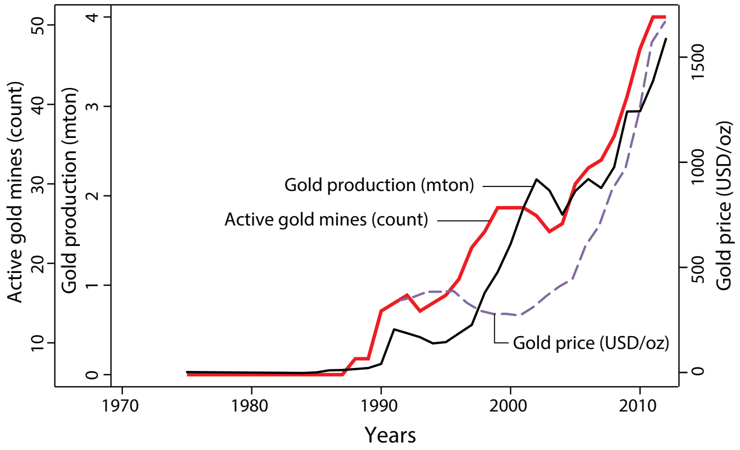
[1] Millennium Development Goals, Child Mortality, The World Bank, 2014. See http://www.worldbank.org/mdgs/child_mortality.html)

[2] There is a larger literature on the health costs of exposure to pollution in developed countries, e.g. Almond et al., 2009; Black et al., 2013b; Chay and Greenstone, 2003; Currie and Schmieder, 2009; Currie et al., 2011; Currie et al., 2017 and Moretti and Neidell, 2011.



Data from IntierraRMG. Calculations author's own.

Figure 1: Illustration of the natural experiment

Notes: The data in Figure 1A comes from IntierraRMG and the calculations are the author's own.

infant mortality rates by bringing economic development (Aragón and Rud, 2013), and jobs in manual labour and services (Wilson, 2012; Kotsadam and Tolonen, 2016). The effect of the health-wealth trade-off on infant mortality in the region is an empirical question. It will depend not only the magnitudes of the environmental change and wealth gains but the margins for health improvements. The health-wealth tradeoff generated by a polluting industry is bound to be weaker in contexts with high child mortality due to poverty, and in particular, malnutrition.

The recent gold mining boom in nine African countries—Burkina Faso, Cote d'Ivoire, Democratic Republic of Congo, Ethiopia, Ghana, Guinea, Mali, Senegal, Tanzania, illustrated in Figure 1—serves as a quasi-experiment to understand how the risk of infant mortality changes with local industrial development. Open pit gold mining—the most common form of large-scale gold mining in the region—is capital intensive and dominated by large multinational firms (see Table A11) previously not integrated into the local economy (Gajigo et al., 2012). I focus on large-scale gold mining because this part of the mining industry expanded rapidly during the sample period (Figure 1), has a dominant production technology—open pit mining—in the region making its effects plausibly comparable across localities. Moreover, large-scale gold mining is less reliant on infrastructure connectivity than other more bulky natural resources (Weng et al., 2013). For these reasons, I argue that the mine openings are plausibly exogenous to the local economies. Large gold mines often open up in relatively poor, rural areas: in our sample, the infant mortality rate is higher (with an average of 151 per 1000 live births) and the urbanization rate lower in the communities where the gold mines will eventually open.

I construct a dataset of 37,365 children born within 100 km of a mine by combining data on women's fertility records from Demographic and Health Survey (DHS) and large-scale gold mining data. Combining the two data sources using geographic information at the village/neighborhood (henceforth called DHS cluster) and mine level, I construct several measures of proximity to mines. I utilize the exogenous increase in large-scale gold mining to estimate the causal effect of local industrialization by defining treatment and control groups based on proximity measures. Outcomes in the treatment group—children born close to mines—are contrasted with children born further away in a before-after analysis. I show that pre-mining trends are similar across the treatment and control groups. Importantly, the method flexibly controls for unobservable differences between countries and districts—such as culture, religion and ethnicity—countrywide shocks—e.g., policy or government changes—and temporal trends within subnational districts.

Infant mortality rates decrease with more than 50% of baseline within a few years from the start of the industrial gold mining. The effects are concentrated within 10 km from the mine center point, corresponding to the area with the starkest changes in local economic growth and job creation. The analysis tries to choose between mechanisms, but acknowledges that the industrial development changes many relevant parameters concurrently, making it difficult to disentangle the separate effects of hypothesized channels. Moreover, the results are robust to different assumptions about trends, fixed effects and clustering. I find no significant changes in child health care access, but mothers have better access to fertility information on the radio. Women are also more likely to work in the service sector. These findings are supported by evidence showing that large-scale gold mining increases women's empowerment in Sub-Saharan Africa (Tolonen, 2018).

Importantly, the results are robust to the exclusion of children born to recent migrants. Excluding all mothers who migrated after the mine opening year, or in the four years prior to the mine opening year, reduces the treatment effect from 7.9 percentage points to 6.8 percentage points. This indicates that children born to mothers who have lived in the communities for a long time also benefit from the mine opening. This is in line with previous evidence from large-scale mining in Africa, confirming that both women born in the mining communities and migrant women benefit from the expansion in mining (Kotsadam and Tolonen, 2016; Tolonen, 2018).

The treatment effect of a new large-scale gold mine on local infant mortality is large compared with countrywide trends in infant mortality rates. The drop in the infant mortality rate occurring within one to two years from the first year of production is twice as large as the reduction in the infant mortality rate experienced in Singapore during two decades of high economic growth, and equivalent to total gains in infant survival rates in the African survey countries since 1970 to today. The results illustrate that industrial development can bring significant and rapid gains in infant survival rates in high mortality areas.

The paper discusses remainder of the paper is organized as follows. Section 1 presents the data and context of gold mining in Sub-Saharan Africa. Section 2 describes the empirical strategy. Section 3 presents the results and discusses potential mechanisms. Section 4 describes the robustness analysis. Section 5 provides a brief discussion of the magnitude of the results in relation to global trends in infant mortality and concludes.

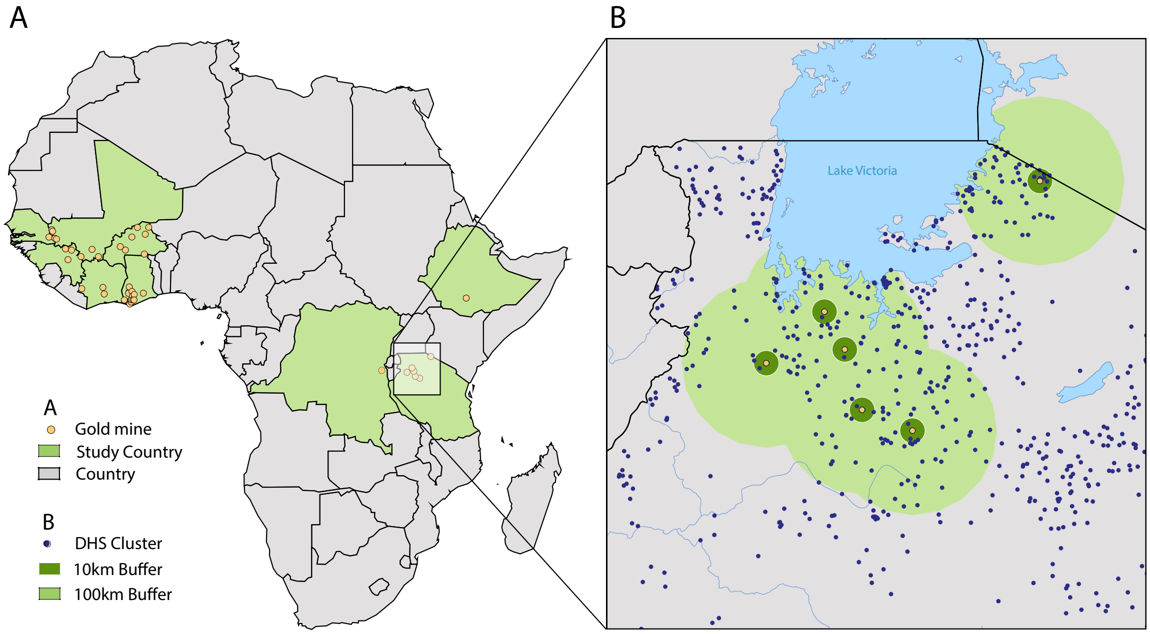


Figure 2: Map of Gold Mines and DHS Clusters in Northwestern Tanzania

1 Data and Context

The paper creates a unique record of births across mining areas in Africa and extractive industry data. Specifically, I combine demographic data from 30 individual nationally representative surveys conducted in 9 countries. The dataset contains 37,365 births from 1987 to 2012 recorded to mothers living within 100 km of an industrial gold mining site. Figure 2A shows the geographic location of the gold mines used in the analysis, and Figure 2B zooms in on Tanzania, highlighting mine locations (yellow dots), the survey area (the green circles) and villages (also called DHS clusters, indicated by blue dots).

1.1 *Demographic data*

The Demographic and Health Survey (DHS) collects data on health and fertility in developing countries (see Appendix for more detail). The final data set consists of 30 cross-sectional DHS datasets: four survey rounds each for Burkina Faso, Ghana, Guinea, Mali, and Tanzania, and three survey rounds for Cote d'Ivoire, Ethiopia, and Senegal, and one survey round for Democratic Republic of Congo. This corresponds to all the DHS survey rounds that have household location data for countries in which there is at least one large-scale gold mine that was ever active between 1987 and 2012. Appendix Figure A1 shows the sample years for each country (dashed line), and the years for which we have sampled births (shaded grey). All women aged 15-49 in the randomly selected households are selected for the sample, and the outcome of all pregnancies in the last five years are recorded. Descriptive statistics for children aged 0 to 5 as well as for their mothers are presented in Table 1. Variable descriptions can be found in appendix Table A1.

Table 1 illustrates that there are some pre-treatment differences among mothers in the control (column 2) and treatment group (column 3). In particular, mothers in the pre-treatment group are slightly less urban, 0.68 years younger and have half a year more education (which could be due to the age composition). Importantly, the infant mortality rates are significantly higher in the pre-treatment group compared to the control group in the pre-treatment period. This will not be a threat to the estimation strategy, which relies on the parallel trend assumption.

For certain outcomes such as women's employment and fertility, I use the women's recode instead of the child recode. Women who have given birth in the last five years prior to the survey year are included in the child recode, however, to understand for example the effect of industrial mining on fertility we need to analyse the full sample of women – also those who had no children. Mean values for outcomes used from the women's recode are reported in the relevant results tables.

1.2 *Mining data*

The large-scale gold mining data comes from IntierraRMG (see Appendix Text) and contains all African large-scale gold mines with geographic coordinates and historic production volumes. The data has previously been used in research on the effects of large-scale mining (Aragón and Rud, 2015; Kotsadam and Tolonen, 2016; von der Goltz and Barnwal, 2014). The geo-coordinates provided by the data have been updated to correspond to the mine center point (see Appendix for further details).

The data set contains only large-scale mining operations, most of them owned by foreign owned companies (see Table A11) from for example Canada, Australia and the UK. The context is highly relevant: extractive industries receive a large share of total foreign direct investment. In particular, large-scale gold mining has rapidly expanded across African countries: Africa currently produces 20% of the world production of gold and 34 countries in Africa have significant gold deposits that could be extracted in large-scale operations in the future (Gajigo et al., 2012).

The industrial mining database only contains information on large-scale gold operations. Artisanal and small-scale mining (ASM) may be a confounding factor but the lack of detailed, time-varying records of legal and illegal ASM activities makes it impossible to disentangle the two sectors. In some instances, artisanal and small-scale mining is part of the land use prior to the establishment of a large-scale mine. The establishment of a large mine may (1) crowd out small-scale activities through enforcing property rights, (2) not affect the ASM sector, especially if the small-scale mining is illegal and property rights are not enforced, (3) increase ASM activities if the latter uses the scrap material from the large-scale mine. It is, to my knowledge, unknown which one of these three scenarios is the most common. Small-scale gold mining is associated with mercury pollution—the mercury is used in the traditional amalgamation process to separate the gold from the ore—which can be a threat to fetal development and child health. It is possible that large-scale gold mining could improve local child health by crowding out the small-scale sector, if the latter is associated with more adverse health effects.

Table 1: *Extensive Summary Statistics*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Mean value					Min	Max
Sample	whole sample	control group	treatment group	control group	treatment group		
Time period		pre	pre	post	post		
Characteristics							
mother age	29.17	29.54	28.86*	28.73	28.27	15	49
mother education	1.88	1.333	1.876*	2.483	4.880	0	21
household is urban	0.187	0.194	0.044*	0.181	0.236	0	1
child is male	0.506	0.506	0.512	0.506	0.550	0	1
birth number	3.976	3.996	4.290*	3.96	3.676	1	17
birth year	2000	1999	1997*	2003	2003	1987	2012
Infant mortality							
1 month	0.038	0.042	0.066*	0.035	0.024	0	1
6 months	0.057	0.070	0.108*	0.057	0.030	0	1
12 months	0.097	0.106	0.151*	0.091	0.048	0	1
12 months boys	0.103	0.110	0.150*	0.097	0.063	0	1
12 months girls	0.093	0.102	0.154*	0.085	0.030	0	1
Treatment variables							
industrial*mine dep.	0.010					0	1
mine dep. (10km)	0.023					0	1
Observations	48,151	25,583	639	21,438	491		

Notes: Control group is within 10-100 km from a mine

Treatment group is 0-10 km from a mine

pre-treatment, control group has mine = 0, and no active mine within 100 km

pre-treatment, treatment group has mine = 1, but no active mine within 10 km

post-treatment, control group has mine = 0, and at least 1 active mine within 100 km

post-treatment group has mine = 1, and at least 1 active mine within 10 km

* $p < 0.05$ for t-test between control group (2) and treatment group (3), pre-treatment

The expansion of the large-scale mining industry, however, also causes concern about environmental safety and sustainability (Economic Commission for Africa, 2011). The pollution burden from gold mining is mainly cyanide used in the amalgamation process to separate the gold from the ore, as well as arsenic found naturally in the gold ore, and other heavy metals such as lead, cadmium, chromium and nickel. Cyanide and arsenic exposure *in utero*, both lethal at high doses, are associated with adverse birth outcomes (Milton et al., 2005), and lead exposure with increased risk of premature birth, low birth weight, and retarded growth (Iyengar and Nair, 2000).

Despite these concerns, estimated pollution levels in mining areas are generally within WHO thresholds, and the literature is inconclusive regarding the health effects below the WHO thresholds (ATSDR, 2007b; ATSDR, 2007a). However, arsenic levels above the WHO thresholds have been confirmed in mining areas in Tanzania and Ghana (Almås and Manoko, 2012; Serfor-Armah et al., 2006), for example after mining accidents. There is suggestive evidence that pollution from mining activities reduces health: lead pollution from mining activities has been linked to stunting in children (von der Goltz and Barnwal, 2014), and a cross-sectional study in Spain found higher incidences of cancer in the population within 5 km from mining sites (Fernández-Navarro et al., 2012). Because of the lack of reliable and comparable data on heavy metal pollution in large-scale mining areas in Africa, it is not possible to understand heterogeneity in pollution across different mining sites. However, the large-scale gold mines included in the study are comparable in terms of production methods (see appendix tables with mine characteristics), ownership and mineral content why there are no clear hypotheses regarding the differential pollution levels across sites. I encourage future studies, should environmental pollution data become available, to explore the dose-response effect of pollution from mining on infant mortality and other health outcomes.

This study does not expand much beyond exploring infant mortality rates. There are two reasons for this. First, the DHS data contains a limited number of reliable child health indicators, such as cough, diarrhea and fever, and they are only collected in the sample year. Second, because the analysis is conducted on countries with high infant mortality rates, I argue that exploring effects of industrial development on infant mortality is justifiable and of first-order importance. It remains possible and untested that more children survive their first birthday, but face poorer long run health.

2 Empirical Strategy

The strategy of the paper follows Kotsadam and Tolonen (2016)[3] who estimate local employment effects from industrial mining in Africa, and links to the field of economic geography measuring agglomeration economies, e.g., local multipliers (Moretti, 2010), and health near industrial sites (Currie et al., 2011; Currie et al., 2015), including fracking sites in the US (Currie et al., 2017). The empirical strategy is a difference-in-difference analysis, comparing outcomes before and after in a treatment and a control group.

Treatment is based on proximity to mining site interacted with activity measures of the mine. Previous literature on mining (Aragón and Rud, 2013; Aragón and Rud, 2015; Kotsadam and Tolonen, 2016; von der Goltz and Barnwal, 2014) and commuting behavior in Tanzania, Ghana and Cote d'Ivoire (Shafer, 2000; Amoh-Gyimah and Aidoo, 2013; Kung et al., 2014), indicate that mine treatment effects should be concentrated to communities within 5-20 km from the mine. Kotsadam and Tolonen (2016) find the strongest treatment effects within 10 km from the mine center point, but use a 20 km distance in their baseline specification. DHS household coordinates are displaced by 1 to 5 km, and up to 10 km in 1% of the cases to ensure that individuals cannot be identified, and DHS recommends using binned thresholds larger than 5 kilometers. The baseline minimum distance used in this paper is 10 km. A contribution of the present paper is its empirical approach to estimat-

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[3] With a trivial modification to the variable specification to facilitate the interpretation of the coefficients.

ing distance effects in spatial analyses where a radius of influence is not known a priori by carefully mapping the spatial decay function with binned distance thresholds (equation 2) to determine the treatment distance.

The main specification is the following:

$$\begin{aligned} Infantmortality_{icdt} = \beta_0 + \beta_1 industrial_{ct} \cdot minedeposit_c + \beta_2 minedeposit_c \\ + \alpha_d + \sigma_{dtrend} + \delta_{kt} + X_i + \varepsilon_{icdt} \end{aligned} \tag{1}$$

where the outcome, infant mortality in the first 12 months, is regressed on an indicator for if there is a known gold deposit (known by 2012) within 10 km (called *mine deposit*), and an interaction effect capturing if this mine deposit was in production in the year of the birth (*industrial*mine deposit*). The regression controls for sub-national district fixed effects α_d, district linear time trends σ_{dtrend}, and country-year fixed effects (birth year or survey year), δ_{kt}, and a vector of mother and birth controls, X_i. Subscript i indicates an individual birth, c DHS cluster, k country, and t year. Individual level controls include mother's age, age squared, education, if the household lives in an urban area, and child's birth order. In all regressions, I have limited the sample to within 100 km from a deposit, and I cluster the standard errors at the DHS cluster level (unless otherwise stated). In addition, I use a spatial lag model that allows for non-linear effects with distance from the mine. This method is further explained in the robustness section.

To estimate the causal effect of an industrial-scale gold mine opening on infant mortality, the timing and placement of the opening must be exogenous to local changes in infant mortality. The necessary condition for a gold mine is a gold deposit, which is a geological anomaly and random (Eggert, 2002). Moreover, multinational gold mining firms prefer to invest in regions with low corruption, and stable and transparent business environments (Tole and Koop, 2011). Such factors could vary at the national, province, or at most, district level and should pose no problem for the estimation strategy as it controls for unobserved differences between districts (by using district fixed effects), national-level policy changes or other unobserved factors changing annually (by using country-year fixed effects), and district-specific linear time trends.

Access to infrastructure is one factor that varies within administrative districts. High-volume, bulky resources such as coal and iron are heavily reliant on good infrastructure — railways, road networks and ports—but the high-value commodity gold is less dependent on regional infrastructure as it can be transported using air traffic (Weng et al., 2013). Suggestive evidence of a subset of mining sites having their own air fields are provided in Figure A8.

2.1 *Parallel Trends*

Both empirical strategies rely on the assumption that in absence of the mine opening, the treatment and the control communities would have been on similar trajectories. The validity of this assumption is examined using non-parametric techniques and event study graphs, and presented in Figures 3, 4, and appendix Figures A2, A3, A4, and A5. I discuss these results in more detail below. The data on births are divided into treatment communities, defined as those living within 10 km from a mine, and control communities, that are located 10-100 km away from a mine.[4] The horizontal axes represent mine lifetime, starting at 10 years before mine opening year.

The mining communities and non-mining communities are on similar trends in infant mortality in the years before the mine openings, which is confirmed using linear trend prediction in Figure 3A[5], and using local polynomial smooth in Figure 3B.

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[4] Because 0-10 km around a center point is a much smaller area than 10-100 km around a center point, the control group is larger in size. Moreover, at the extremes (-10 years, or + 10 years) the sample sizes are smaller than for the mine life years in the middle.

[5] The specification is a linear model with no control variables and no fixed effects, hence substantially different from the main regression specifications. It is regressing infant mortality as a function of mine life year independently for the treatment group (within 10 km) and the control group (10-100 km away). A t-test confirmed that the pre-mine opening slopes are not significantly different from each other. The data structure

Both specifications allow for a trend break at year -2—the start of the investment phase—of the mine lifetime, in contrast to Figure 3C which shows one smoothed trend (thus not allowing for a sharp break around the mine opening year). In the appendix I explore the robustness of these results. I redefine the investment period to one year, allowing for a break in year -1 (Figure A2B), or at year 0 (Figure A2C) which changes the slopes of the pre-trends in the linear specification (presented in the left side column) and the trends in the treatment and control groups appear non-parallel. However, imposing a linear structure is too strict since the pre-period now includes the investment period (which pulls down the trend).[6] I conclude that the mine starts affecting local infant mortality rates at year -2 of the mine lifetime, and that the empirical specification must allow for the investment period to differ from the earlier period. I will do this in the main empirical specification by (i) excluding the investment period from the sample, (ii) allowing for a different treatment effect during the investment period, or (iii) including the investment period into the treatment period. The results will be robust to all three specifications. However, the investment period is not associated with the same pollution risk as the production phase but may have significant economic effects leading to an underestimation of the pollution channel, why it's not the preferred specification.

There is seemingly an increase in mortality rates around mine life year 8 to 10 (Figure 3), which could be because of mine closure or because of a reversal of the positive health effects. However, removing mines that close does not significantly change the result. In this study, we will not be able to understand the effect of mine closure on infant mortality—the majority of gold mines opened during the study period, but few closed—leading to insufficient power to investigate this aspect in a regression framework at the moment. Hopefully future studies can investigate this aspect as more gold mines have closed down. Moreover, regression

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is similar in Figures B and C, but fitting a local polynomial smooth instead, with or without excluding the investment period.

[6] This is illustrated by the non-parametric investigation of trends in Figure A2, where the right side column shows fairly parallel trends from year -10 to year -2 for Figures A-C.

analysis do not confirm an increase in infant mortality rates around mine years 8 to 10.

Figure A3 explores the same pattern for a sample which excludes migrants. I exclude all migrants that moved to the community after the mine opening year, or in the four years prior to the mine opening year. I do this to exclude anticipatory migration that may lead to selection bias. The patterns observed when excluding migrants are similar to those in the full sample. Row A—which excludes the two year investment phase—provides the most suitable quasi-experimental setting. The linear trends are not perfectly parallel, but the local polynomial smoothing allows us to see that the two groups are tracking each other over time, especially in the last few years before mine opening.

The same figures are produced for boys (A4A), and girls (A4B) where the left column shows the result for the linear specification, and the right column for local polynomial smooth. Overall, the trends explored using the local polynomial smooth look fairly parallel in the pre-period for both groups. The linear specification is slightly less convincing - where treatment communities show a small increase in mortality for boys, and decrease for girls - probably due to some years deviating from the overall trend as observed in the non-parametric specification. Because sample sizes are now smaller, the data seems more sensitive to outliers, as expected. The non-parametric specification however shows that the pre-trends are very parallel in the last 5 years before mine opening, which is convincing for the analysis.

The trends for infant mortality in the first 6 months of life (A4C) are parallel for the treatment and control group, with a clear jump in the treatment group post-treatment. The evidence is less convincing for neonatal mortality (first month of life) using linear trends (A4D), possibly because of something happening in the treatment group in the years -10 to -8. The polynomial trends look, however, parallel in the five years before the mine opening.

An alternative investigation of the parallel trends assumption is using night lights (Figure 5). The graphs show a stark deviation from the trend in year -2 of the mine lifetime, both in the linear specification (A) and using local polynomial smooth (B).

2.1.1 *Exploring parallel trends using regression*

Moreover, I regress the same variable used on the X-axis, *years until mine opening*, in Figure 3A on the full sample using the control variables, time trends and fixed effects defined in the main specification. To allow for differential trends for areas close to mines and areas further away, I interact the variable *years until mine opening* with the indicator variable for close to mine. The interaction effect, which captures the difference in time trend of mining areas and non-mining areas, is 0.012 and insignificant at all conventional significance levels (p=0.107).

To further explore the parallel trends assumption in a regression framework, I predict and plot the residuals from the baseline model (Table 2, column 1) but excluding the main treatment variables (industrial*mine deposit, and deposit). The residuals are around zero for the control group throughout the period. The residuals for the treatment group mimic the control group up until year -2 of the mine lifetime, when they drop (Figure 4). Disaggregating by gender shows similar results (see Appendix Figure A5).

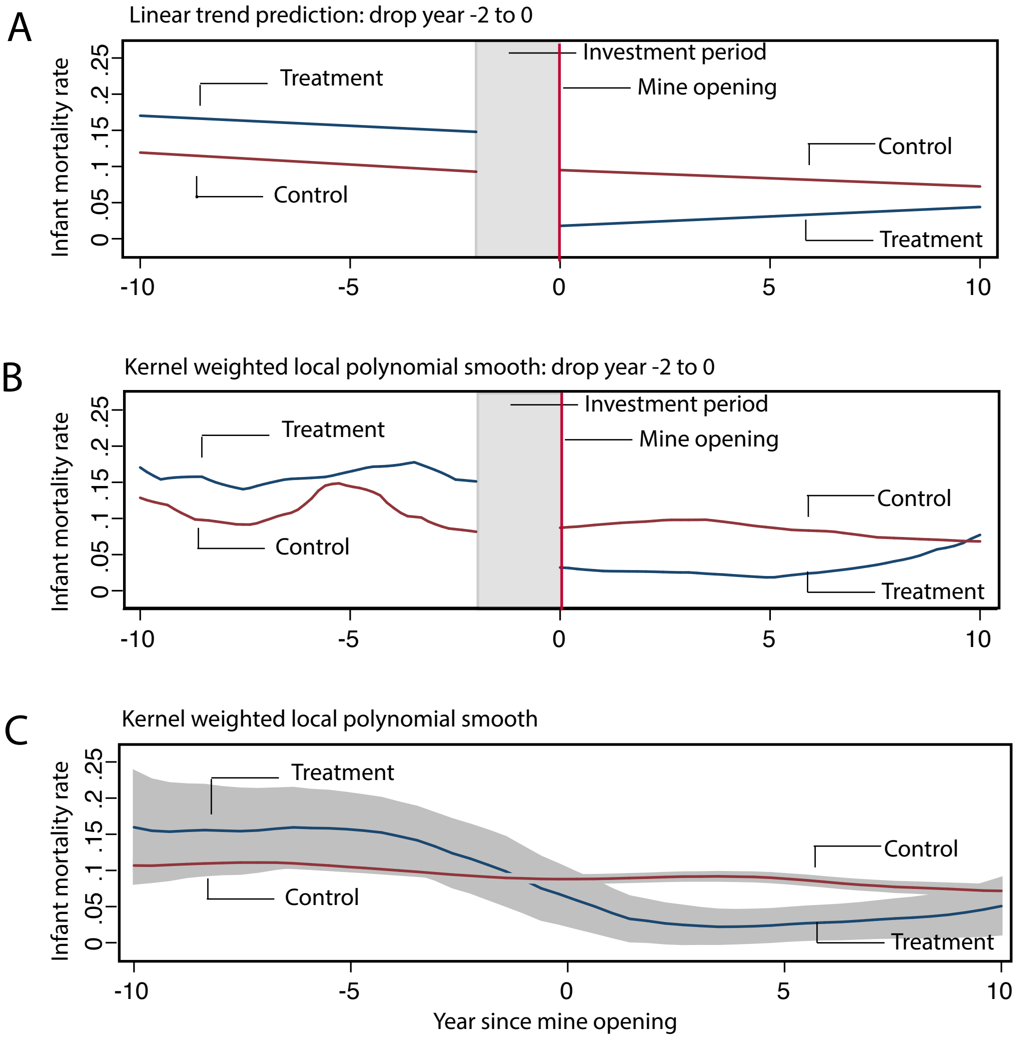

Figure 3: Linear trend (A), local polynomial smooth (B), and local polynomial smooth (C) for infant mortality in first 12 months

Notes: Years since mine opening is on the horizontal axis, ranging from ten years before mine opening to ten years after mine opening. The treatment group is drawn within 10 km from the closest mine, and the control group 10-100 km from the closest mine, excluding births with a second mine within 20 km. Figure A and B allow for a break at year -2. Figure C provides 95% confidence intervals. In contrast to the main specification there are no control variables or fixed effects, and only the opening year of the closest mine is considered. Mine closing year is not considered.

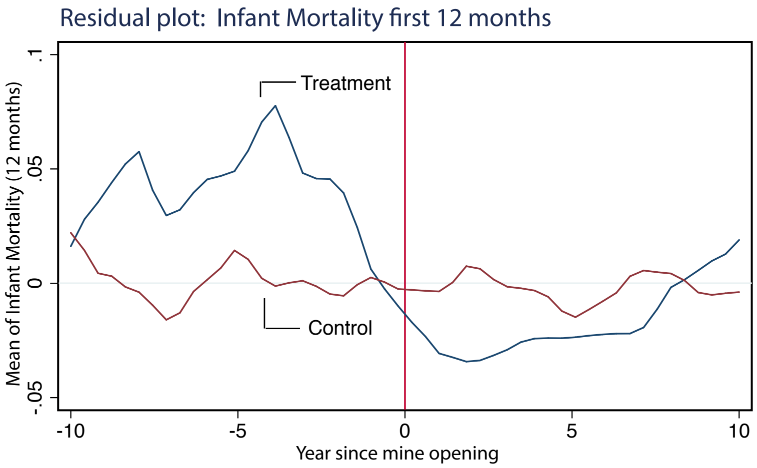

Figure 4: Event study graph plotting the residuals from the main estimation excluding the treatment variables: Infant mortality first 12 months

Notes: The graphs plot the residual by year for the model explored in Table 2 column 2 excluding the two treatment variables. The residuals are plotted for all births, excluding children who live near a second gold mine (43 births).

3 Results and Mechanisms

3.1 *Main Results*

Table 2 shows the regression results for infant mortality using a 10 km distance cutoff: mine opening is associated with a 5.5 percentage point decrease in mortality rates (column 1). Taking potential spillovers into account by excluding the 10-30 km area, and the investment phase (two years prior to mine opening), the coefficient is estimated at 7.9 percentage points (column 2). Infant mortality decreases for boys (6.3 percentage points), and girls (9.5 percentage points). The effects are economically significant: the 5.5 percentage point decrease in mortality is equivalent to 50% decrease in mortality rates, compared with the sample mean.

Table 2: *Main Results*

Dependent variable:	infant mortality first 12 months				total fertility	listen to radio family planning	service sector job	wealth
Sample:	children	children drop spillover	girls	boys	woman	woman	woman	woman
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
industrial*mine deposit (at birth)	-0.055***	-0.079***	-0.095***	-0.063**				
	(0.019)	(0.026)	(0.036)	(0.032)				
industrial*mine deposit (at survey)					-0.217	0.147***	0.064**	0.421**
					(0.141)	(0.046)	(0.024)	(0.191)
mine deposit (within 10 km)	0.034**	0.048**	0.064**	0.032	0.107	-0.070	-0.036	-0.121
	(0.017)	(0.024)	(0.029)	(0.028)	(0.105)	(0.046)	(0.024)	(0.100)
Country-birth year FE	Yes	Yes	Yes	Yes	No	No	No	No
Country-survey year FE	No	No	No	No	Yes	Yes	Yes	Yes
District linear trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Drop 10-30 km away	No	Yes	Yes	Yes	No	No	No	No
Drop investment phase	No	Yes	Yes	Yes	No	No	No	No
Mean of outcome	0.097	0.102	0.098	0.105	3.260	0.470	0.233	2.722
Mean (treatment, pre-treatment)	0.151	0.151	0.150	0.154	3.905	0.354	0.120	2.551
Observations	37,365	29,221	14,863	14,358	57,581	46,028	55,944	29,777
R-squared	0.101	0.104	0.119	0.123	0.673	0.204	0.183	0.427

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ Clustered standard errors clustered at DHS cluster level. Linear probability models. All regressions in column 1 to 5 control for mother's age, age square, mother's education, urban, child's birth number, and fixed effects for district, birth month, and country-birth year. Outcome is infant mortality in the first 12 months since birth. All regressions columns 5-7 control for woman's age, education, urban, and fixed effects for district and country-survey year, as well as district linear time trend. Mine deposit captures if there is a gold deposit within 10 km from the household. Industrial captures if the gold deposit was actively extracted in the child's birth year, or in the survey year. The investment phase is defined as the two years preceding the opening year and is dropped in columns 2-4. Mean (treatment, pre-treatment) is the sample mean for the treatment group before the mines were active.

3.2 *Selective Fertility*

There is a noted association between fertility and infant mortality. On the one hand, a reduction in fertility can lead to higher investment per child, and improved child survival rates. On the other hand, high infant mortality rates can motivate high fertility, ensuring a minimum number of surviving children. The drop in fertility rate (-0.217 children per woman, see Table 2) is, however, insignificant and too small to explain the whole drop in the infant mortality rate: an accounting exercise shows that the counterfactual mortality rate would need to exceed 80% among the children that were not born post treatment to explain the whole reduction in mortality.[7] Results on the extensive and intensive margin are further explored in Table 3. With the exception of a significant increase in the likelihood of a woman being pregnant at the time of survey, there are no significant changes in the extensive or intensive margin of fertility, nor the likelihood that a woman experienced a miscarriage or had an abortion. Heterogeneous results by subgroups presented in Appendix Table A5 indicate that women in agriculture living in mining communities are more likely to ever had a child. However, Appendix Table A4 show that children born to women working in agriculture and living in mining communities experience a decrease in probability of mortality, compared to women working in agriculture elsewhere. Note that the occupational categories are also affected by the mining activities, so these effects should not be considered causal.

3.2.1 *Trivers-Willard hypothesis*

I explore the gender differential effects in more detail in Table A6. The main result is robust to inclusion of an indicator variable for the gender of the child. However, the gender composition could be an outcome of changes in the external conditions as stated by the Trivers-Willard hypothesis (see for example Almond and Edlund, 2007). In particular, it

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[7] There are 3.260 births per woman, so 30.7 women give birth to 100 children. The regression results show that 0.217*30.675 (6.656) fewer children will be born. The counterfactual mortality would need be 5.5 children per 6.656 children born, above 80%, for the drop in fertility to account for the whole drop in mortality rate.

Table 3: *Intensive and Extensive Margin Changes in Fertility*

Dependent variable:	(1) ever had a child	(2) total lifetime fertility	(3) ever had terminated pregnancy	(4) currently pregnant
industrial*mine deposit	-0.035	-0.217	-0.010	0.053***
	(0.022)	(0.141)	(0.028)	(0.018)
mine deposit	0.019	0.107	0.014	-0.031*
	(0.016)	(0.105)	(0.021)	(0.016)
Mean of outcome	0.759	3.259	0.165	0.103
Observations	57,581	57,581	40,442	55,246
R-squared	0.378	0.673	0.092	0.025

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ Standard errors clustered at DHS cluster level. Linear probability models. All regressions in control for woman's age, education, urban, and fixed effects for district, country-survey year, and district linear time trend. The outcome variables are: if the woman ever gave birth to a child, total children born , and ever experienced a terminated pregnancy because of miscarriage or abortion, and currently pregnant. The sample size is smaller for the variable for terminated pregnancy as it is not always collected by DHS. The sample is the DHS woman's sample, and thus include all women aged 15-49 regardless if they had a child in the last 5 years.

is found within the biological and demographic literature that an improvement in external condition is associated with more male births. In fact, columns 2 and 3 in Table A6 confirm that large-scale mining is associated with an insignificant and higher likelihood of the birth of a male child, which could be due to reduced incidence of miscarriages of male children (although no significant change is observed in the likelihood of miscarriages, a variable that is most likely measured with error). It is possible that the insignificant increase in the share of male births partially explain the gender difference observed for the main treatment effect (Table 2, columns 3 and 4). If less healthy male fetuses are now carried to term instead of miscarried, it could lead to more marginal deaths in infancy.

Accordingly, a dummy for wealth of household (column 3) is associated with a 1.7 percentage points increase in the likelihood of a male birth, significant at the 10% level. Note that wealth, which is defined to the household being in the top 40% of the wealth distribution in the country, is affected by the presence of large-scale mining. Wealth scores are 0.421 higher in active mining areas (Table 2, column 8). The interpretation of these results should thus be made with caution. The sample size is reduced when including wealth controls (columns 5-8) as not all surveys used collected wealth data. The wealth dummy and the wealth interaction effects with the treatment variables are all insignificant but in the expected directions. With a sample size of 17,701 (column 5-6), the main treatment effect remains negative but is now insignificant, which could be due to the (i) reduction in sample size, and (ii) that wealth is essentially an endogenous control through which mining affects mortality risks.

3.3 *Women's Employment*

Women's employment and access to information about family planning may be important determinants of infant health. Results in Table 2 confirm that women in mining communities are 14.7 percentage points more likely to listen to radio shows discussing family planning than their peers, and 6.4 percentage points more likely to work in the service sector. This result is supported by previous research on African mining (Kotsadam and Tolonen, 2016; Tolonen, 2018) finding that women gain jobs in service sectors in mining areas and are more empowered.

Using the sample of all women aged 15-49, we find that women in active mining communities are insignificantly more likely to live in urban areas, and have 0.3 years more of education (see Appendix Table A2). Moreover, we find no significant changes in the occupational composition of partners to the sampled women (columns 4-7). These results are for all women, and not the women who have given birth to children, and not limited to those who were young at the beginning of the mine lifetime. The effects should be stronger for younger, unmarried women at the time of the mine opening, which is confirmed in Tolonen (2018).

Appendix Table A4 explores heterogeneity for different occupational subgroups, although as occupation is also affected by the large-scale mining these effects should not be interpreted causally.

3.4 *Access to Health Care*

Corporate social responsibility programs from the mining companies and the change in local economic growth could change access to health care and early health-behavior. I consider this in Table 4, which shows that there are no significant changes in health care behavior, such as received any antenatal care (column 1), was ever vaccinated (column 4), has health card (column 5), nor were the children less likely to be very small at birth (column 2)—a proxy measure for inadequate *in utero* growth or preterm birth—or have cough, diarrhea or fever in the last 2 weeks before surveying. Nonetheless, there is an indication that knowledge and use of oral rehydration therapy — an efficient and cheap treatment of diarrhea — increases in the mining communities (column 6). This effect could indicate better access to health information, either from access to clinics or through media. Note that the samples differ across the different outcomes, with columns 1-7 using all births (given data availability), and columns 8-10, that record health at the time of the survey, using the sample of children under the age of 5 who were alive at the time of surveying. Sample sizes also vary across the columns as not all measures has been collected in all survey rounds.

Appendix Table A2 explores the effects of mining on an additional set of outcome variables, including if the community is urban, mother's age and education, and occupations of partners of women. Additionally, Table A3 includes some of the important child health determinants as controls. However, because such variables may be changing with mining, this analysis likely suffers from endogenous controls. Nonetheless, we note that the result is robust to the inclusion of most variables, although the full model (column 8) which includes wealth quintile controls yields an insignificant treatment effect.

3.5 *Local Economic Development*

The results on infant mortality are supported by similar non-parametric analysis of night light density (Figure 5), a proxy for economic development. Night lights have been used as a proxy for urbanization and economic performance in Africa —cf. Michalopoulos and Papaioannou (2013)— although caution is advisable as the proxy may be less reliable in areas with low level of economic development. Additionally, the mines may emit lights at night due to around the clock operations. The extent to which measures of economic growth from mining would suffer from this bias is not, to my knowledge, known. The figure illustrates that mining areas (within 10 km) are on a similar night light trend as areas further away (10-100 km from the mine location) in the pre-treatment period, although at a higher level. However, starting in the investment phase (mine year -2) there is a clear divergence with average light sharply increasing in mining areas and it stabilizes at a higher level. Divergence from the pre-trend is expected during the investment period, which is

Table 4: *Mechanisms: Health Behavior and Access*

Dependent variable:	received antenatal care	very small at birth	was breastfed months	ever received vaccine	has health card	knows ORS	share toilet	cough last 2 weeks	diarrhea last 2 weeks	fever last 2 weeks	birth order
Sample:	all births	all births	all births	all births	all births	all birth	all births	surviving children	surviving children	surviving children	all births
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
industrial*mine deposit	-0.041	-0.032	0.711	0.004	-0.002	0.144***	0.036	-0.034	-0.017	-0.009	-0.206
	(0.061)	(0.022)	(0.580)	(0.105)	(0.053)	(0.054)	(0.084)	(0.043)	(0.031)	(0.051)	(0.165)
mine deposit	0.037	0.012	-0.297	-0.120	-0.076	-0.148**	-0.009	-0.053	-0.024	-0.045	0.167
	(0.060)	(0.021)	(0.493)	(0.074)	(0.054)	(0.064)	(0.067)	(0.048)	(0.023)	(0.055)	(0.117)
Birth month FE	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	Yes
Survey month FE	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
District FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-birth year FE	Yes	Yes	Yes	Yes	No	No	No	No	No	No	Yes
Country-survey year FE	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
District time trend	Yes	Yes	Yes	Yes	No	No	No	No	No	No	Yes
District fixed effect	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Drop 10-30 km away	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Drop investment phase	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean value	0.212	0,055	15.487	0.682	0.808	0.699	0.562	0.191	0.167	0.292	3.950
Observations	30,339	35,510	32,542	12,695	32,613	35,850	13,543	30,475	31,331	33,595	38,414

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ Standard errors clustered at DHS cluster level. All regressions control for mother's age, age square, mother's education, urban, child's birth order (not column 11, where it is the outcome), and fixed effects for birth month, district, and country-birth year when treatment is measured in the birth year and linear district time trend (column 1-4, 11), and fixed effects for district, country-survey year, survey month (columns 5-10). Columns 1-7, and column 11 uses sample of all births in the last five years. Columns 8-10 uses sample of children alive at time of the survey. Outcome variables: (1) antenatal care received, (2) child was very small at birth, (3) breastfeeding (months, capped at 12) for children who survived until first birthday, (4) ever vaccinated, (5) mother has a health care card for the child, (6) the mother knows about Oral Rehydration Salts, (7) the household shares a toilet, (8) the child had cough, (9) diarrhea, (10) fever in the last two weeks, and the child's birth order (11).

capital intensive and is thought to generate local construction employment. There is a drop in night lights at year 7, possibly due to a change in the composition of mines. The night lights in the treatment group however remains well above that in the control group.

Because a local economic shock induced by mining changes many factors at once, it is hard to further assess what mechanisms drive the reduction in infant mortality rates. To summarize, several factors change alongside infant mortality with the mining boom: local economic growth, women's employment, access to health care information through media, and knowledge about an efficient strategy to treat child diarrhea. Women in active mining areas also live in households that are richer (Table 2, column 8).

There is a poverty gradient in infant mortality, as the biggest contributors to high mortality rates globally are maternal and infant malnutrition (Black et al., 2013a), and easily curable diseases such as diarrhea (Black et al., 2003; Dupas, 2011). Increases in local economic activity, household wealth, and better access to health information — effects that we have measured in active mining communities — could all have important roles in combatting high infant mortality rates. Previous research show that health information joint with cash transfers under the program PROSPERA significantly improved child health in Mexico (Gertler, 2004). Interventions that target undernutrition and micronutrient deficiency could reduce deaths in children under the age of 5 by 15%, if they reached 90% of the population in the most needing countries (Bhutta et al., 2013). Increases in women's earning potential and household wealth could help families reach more nutritious diet. In addition, women's empowerment is thought to be positively linked to child health and welfare (Duflo, 2012).

We explored other potential mechanisms that could drive the result. However, we do not identify changes in urbanization, migration status, women's age, education, fertility, breastfeeding behavior and access to sanitation. The sensitivity of the main results will be explored further in the next section.

Table 5: *Sensitivity Analysis*

Dependent variable:	infant mortality first 12 months							infant mortality 1 month	infant mortality 6 months
Specification:	no FE (1)	country-year FE (2)	district trend (3)	drop spillover (4)	distr. cluster. (5)	mine cluster. (6)	mine FE (7)	baseline (8)	baseline (9)
industrial*mine deposit	-0.060***	-0.060***	-0.055***	-0.079***	-0.079***	-0.079***	-0.084***	-0.028**	-0.062***
	(0.020)	(0.019)	(0.019)	(0.026)	(0.026)	(0.027)	(0.026)	(0.014)	(0.019)
mine deposit	0.039**	0.036**	0.034**	0.048**	0.048*	0.048	0.051**	0.015	0.034
	(0.016)	(0.016)	(0.017)	(0.024)	(0.029)	(0.029)	(0.024)	(0.014)	(0.018)
Birth month, year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-birth year FE	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District time trend	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Drop 10-30 km away	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Drop investment phase	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
District clustering	No	No	No	No	Yes	No	No	No	No
Mine clustering	No	No	No	No	No	Yes	No	No	No
Mine FE	No	No	No	No	No	No	Yes	No	No
Mean of outcome	0.097	0.097	0.097	0.102	0.102	0.102	0.102	0.038	0.057
Mean (treatment, pre-)	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.066	0.108
Observations	37,365	37,365	37,365	29,221	29,221	29,221	29,221	38,414	34,016
R-squared	0.038	0.099	0.101	0.104	0.104	0.104	0.105	0.025	0.046

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ Clustered standard errors clustered at DHS cluster level, except Columns 5 and 6 which clusters at the district and mine level respectively. All regressions control for mother's age, age square, mother's education, urban, child's birth number and birth month. Column 2 controls for country-birth year fixed effects. Column 3 adds district linear time trend. Column 4 drops investment phase and individuals living 10-30 km away. Column 7 adds mine fixed effect, which is a time-invariant mine-specific dummy variable for the closest mine to each birth. Outcomes are infant mortality in the first 12 months (columns 1 - 7), one month (column 8) or six months of life (column 9), conditional on live birth. The sample size is larger for neonatal mortality (Column 8), as more children had, at the time of surveying, lived to be older than 1 month. Children not yet 12 months at time of surveying were excluded from Columns 1-7. Mine deposit captures if there is a gold deposit within 10 km from the household. Industrial captures if the gold deposit was actively extracted in the child's birth year. The investment phase is defined as the 2 years preceding opening year. Mean (treatment, pre-) shows the mean value in the treatment group, before treatment.

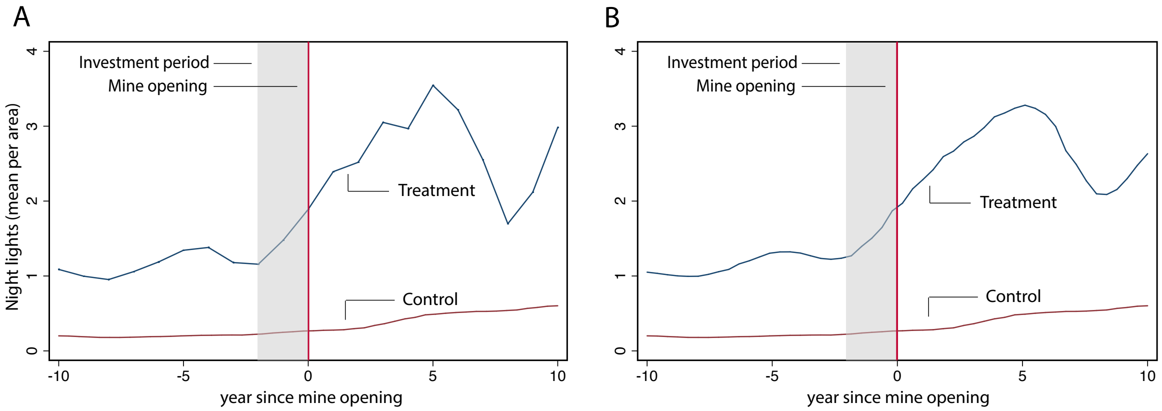

Figure 5: Night lights

Notes: The figure shows a twoway line plot (A) and kernel-weighted local polynomial smooth estimation (B) of night lights in mining areas (within 10 km from a mine) compared with the control area 10-100 km away from a large-scale gold mine. Mines that close within 10 years are excluded.

4 Sensitivity Analysis

Model sensitivity tests are found in Table 5. From a parsimonious specification, the model is modified sequentially to allow for country-birth year fixed effects (column 2), district-linear time trends (column 3), spillover effects (column 4), as well as clustering of standard errors at the district level (column 5), and mine level (column 6), and time invariant closest-mine fixed effects (column 7). A limitation of the specifications using mine fixed effects is that if a birth happened near several gold mines, the fixed effect will only control for the nearest gold mine. The regression results are stable both in magnitudes and significance levels across the specifications.

Table 6 shows the results from 5 different specification that vary the definition of the treatment and control group. Model 1 allows for differential effects for the investment period, by specifying an indicator variable for the last two years preceding the first year of production of the closest mine, and interacts this variable with an indicator for whether the mine is within 10 km from the household location. Model 2 combines the investment period and the productive phase into one variable and interacts it with the proximity measure. The results from the model are in line with the main results in the paper, and are statistically significant. The somewhat smaller treatment effect observed could be because the economic effects seem to take up over time (as seen in the night light graphs), thus by including years -2 to 0 the overall treatment effect is somewhat reduced. This model is not the preferred specification as it, in the presence of environmental pollution from the extractive activities, it would risk to overestimate the positive economic impacts and underestimate the environmental pollution.

Model 3 uses the baseline specification of the treatment variables but excludes the investment phase, whereas model 4 excludes the households that are located within 10 to 30 km away from a mine, and model 5 repeats the preferred specification that drops spillovers for reference. Appendix Table A7 shows that the results are robust varying the spatial definition of the control group, drawing it from 10-40 km, 10-50 km, 30-40 km, or 30-50 km away from a mine. The treatment effect is robust across specifications (columns 1-4, varying from 4.9 pp to 5.6 pp), also to the exclusion of the investment phase (columns 5-6). Despite some differences in the effect sizes depending on the exact definition of treatment, the results point toward robust and negative effects of proximity to large-scale gold mining on local infant mortality rates.

4.1 *Neonatal Mortality*

Table 5 columns 8 and 9 provide estimates for infant mortality measures in the first month, and first 6 months using the baseline econometric specification. The sample sizes differ across the regressions for 12, 6, and 1 month. This is because a birth is only kept in the sample if the child was at least 12, 6, or 1 month (respectively) at the time of the interview. A birth that happened 8 months before the interview will be included in the sample for *infant mortality 1 month* and *infant mortality 6 months*, but not for *infant mortality 12 months*. The sample sizes are 38,414 for neonatal mortality (1 month), 34,016 (for 6 months), and 29,221 (12 months). Note that this sample size is smaller than the sample sizes columns 1 to 3 that

Table 6: *Alternative specification of treatment, control and spillovers*

Dependent variable:	infant mortality first 12 months				
Specification:	model 1 (1)	model 2 (2)	model 3 (3)	model 4 (4)	model 5 (5)
industrial*mine deposit	-0.056***		-0.060***	-0.077***	-0.079***
	(0.021)		(0.020)	(0.026)	(0.026)
mine deposit	0.035*	0.036**	0.038**	0.047**	0.048**
	(0.018)	(0.017)	(0.017)	(0.023)	(0.024)
investment*mine deposit	-0.007				
	(0.038)				
investment period	-0.002				
	(0.006)				
(inv+ind)*mine deposit		-0.053***			
		(0.019)			
birth month FE	Yes	Yes	Yes	Yes	Yes
birth year FE	Yes	Yes	Yes	Yes	Yes
drop 10-30				Yes	Yes
drop 2 years			Yes		Yes
Observations	37,365	37,365	33,127	32,898	29,221

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Clustered standard errors clustered at DHS cluster level. All regressions include baseline controls and fixed effects. Model 1 to 5 tries different specifications of treatment and control. The models include additional treatment variables: *investment period* is an indicator variable for the investment phase of the closest mine, defined as the two years before production starts; *investment*mine deposit* interacts an indicator for close to a deposit (within 10 km) with the investment phase for the closest mine, where the investment phase is defined as the two years before production starts; *(inv+ind)*mine deposit* is an interaction variable for being close to a mine that was either in the investment phase or productive phase at the time of birth.

does not use the spillover specification introduced in column 4.

The mean values are also different:[8] average infant mortality rate in the first month is 6.6%, in the first 6 months it has increased to 10.8% of all births, and in the first year it increases to 15.1% of births (for the treatment group, pre-treatment). The mean values indicate that the neonatal period — just after birth up to the first month — is a crucial time for a child. The result (column 8) indicates that mine opening reduces neonatal mortality by 2.8 percentage points, or 42%. The mortality risk decreases also at later stages, indicated by the 6.2 percentage points (or 57%) reduction in mortality in the first 6 months (column 9).

4.2 *Selective Migration*

Selective inward migration of women with better child survival is a potential concern. Removing women who migrated during the investment phase (defined as the two years preceding the mine opening year) or later from the sample marginally reduces the estimated effect to 7.3 percentage points (Table 7 column 3, compared with the main result in Table 2 column 2 of 7.9 percentage points). The effect is still economically and statistically significant. However, it is unclear from what year women may start moving to a mining area in anticipation of it opening, so Table 7 I also drop early migrants from the sample. Excluding all women who ever migrated is overly conservative: the majority of women migrants in developing countries migrate for marriage (Rosenzweig and Stark, 1989). Excluding late migrants, however, reduces the concern that selective inward migration of women drives the result. In this table I only drop women who live within the mining community (within 10 km from the mine), where the mine was going to start producing within 1-5 years after her migration decision, or if it had already started. Excluding women who migrated one year be-

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[8] The proportion of child deaths that happen in the neonatal period varies with economic development. Using demographic and health survey data from 44 countries, Black et al. (2003) show that in the highest mortality areas ca 20% of child deaths are neonatal. In lower mortality areas, the proportion is higher at 50%. This indicates that child mortality rates past the neonatal period respond better to development improvements.

Table 7: *Anticipatory Migration*

Dependent variable:	Infant mortality (12 months)					
	(1)	(2)	(3)	(4)	(5)	(6)
industrial*mine deposit (at birth)	-0.079***	-0.077**	-0.073**	-0.070**	-0.068*	-0.053
	(0.026)	(0.033)	(0.034)	(0.035)	(0.037)	(0.035)
mine deposit (within 10 km)	0.048**	0.043	0.043	0.043	0.045*	0.039
	(0.024)	(0.027)	(0.027)	(0.027)	(0.027)	(0.025)
Sample limit: migrated [...] years before mine opening	-	1	2	3	4	5
Birth month FE	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-birth year FE	Yes	Yes	Yes	Yes	Yes	Yes
District time trend	Yes	Yes	Yes	Yes	Yes	Yes
Drop 10-30 km away	Yes	Yes	Yes	Yes	Yes	Yes
Drop investment phase	Yes	Yes	Yes	Yes	Yes	Yes
Mean value	0.1018	0.1126	0.1126	0.1126	0.1127	0.1126
Observations	29,221	20,630	20,623	20,613	20,605	20,590
R-squared	0.104	0.104	0.104	0.104	0.104	0.103

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Clustered standard errors clustered at DHS cluster level. All regressions control for mother's age, age square, mother's education, urban, child's birth number and birth month and fixed effects for country-birth year and district linear time trend. The regressions exclude migrants. Column 2 exclude migrants who migrated one year before the mine's first active year or later. Column 6 exclude migrants who migrated 5 years before the first mine opening year or later.

fore the first year of production of the mine, or later, reduces the coefficient size marginally (7.7 percentage points, Table 7 column 2). Reducing the sample size by dropping earlier migrants (columns 3-6) reduces the coefficient size further, although the magnitudes are still large (5.3 to 7.3 percentage points) and significant (except for column 6). Women who are born in the mining communities, or who moved to the communities several years before the mine opening year thus also experience a drop in infant mortality risk.

The analysis, however, does not solve a potential issue of selective outward migration. Women who have children with worse survival chances could move out from mining areas as a response to the start of gold mining, which would reduce the incidence of infant mortality. DHS does not collect data on place of origin, so it is not possible to test this hypothesis. However, no negative change in infant health is observed in the control communities, which continue along the same trend (Figure 3A-C). Such an hypothesis is also contradicted by regression results in Figure 7A, which detects no deterioration in the distance bins further away from the mines.

4.3 *Mother Fixed Effects*

Mother fixed effects—previously used by Kudamatsu (2012)—can reduce the concern that the effect is driven by selective inward migration. I use mother fixed effects in appendix Table A8. The mother fixed effect sharply reduces the sample size (to 29,234 births for the regression on infant mortality in the first 12 months) by imposing that a woman has more than two births in the last five years before surveying, and that at least one birth happens on either side of the mine opening year. In total, there are 94 women in the sample who who live near a mine and fulfill these criteria. 368 women living within 10 km from a mine deposit have more than one birth recorded in the sample, but do not necessarily experience the mine opening during the time period. In total, there are fifteen thousand women who have more than one birth captured in the data. The magnitude of the results using mother fixed effects are comparable to the main results, although statistically insignificant. However, a power calculation indicated that this sample size is insufficient to detect changes in an event as rare as infant mortality.

4.4 *Timing of Effects*

The economic effects and pollution effects need not coincide: the pollution burden might build up over time mitigating the positive effects on infant mortality stemming from economic growth. We find no evidence for this hypothesis. The coefficients for infant mortality are negative for all years subsequent to mine opening (years 1-2, 3-4, 5-6, and so on up to year 11-12) (see Figure 6A), although some coefficients are not significant. The results are supportive of the pattern seen in Figure 3C that indicate less statistical precision further away from the mine opening year, but a reversal of the negative effect on infant mortality.

Figure 6B allows for the effect on lifetime fertility to change over time. If a new mine opens, it might take a few years to adjust fertility preferences and outcomes. However, there is little evidence of clear changes in fertility over time. The coefficients vary across the years and are for the most part insignificant, with the exception of years 5-6 and 11-12 where the effect on fertility is estimated to be negative and significant.

As an alternative specification to explore timing of the reduction in infant mortality, the sample is limited by the number of active mine years (Table 8). In this strategy, I compare the control group to children born within 2 years of mine opening (column 1), or to children born within the first 10 years since mine opening (column 6). There are only slight changes in coefficient size and it peaks with specification 4, which allows for the effect to happen during the five years after mine opening. The exercise illustrates that the drop in infant mortality occurs alongside economic growth from the mine opening, and remains lower during the mine's productive phase. We can reject the hypothesis that the reduction in infant mortality is offset during the mine lifetime as the pollution levels build up.

Table 8: *Timing of Effects*

Dependent variable:	infant mortality first 12 months					
	(1)	(2)	(3)	(4)	(5)	(6)
industrial*mine	-0.061**	-0.067***	-0.070***	-0.093***	-0.061*	-0.068***
	(0.030)	(0.024)	(0.024)	(0.026)	(0.035)	(0.024)
mine deposit	0.036	0.044**	0.046**	0.068***	0.038	0.047**
	(0.027)	(0.021)	(0.021)	(0.024)	(0.035)	(0.022)
Sample limit:						
years after mine opening	2	3	4	5	6	10
Birth month FE	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-birth year FE	Yes	Yes	Yes	Yes	Yes	Yes
District time trend	Yes	Yes	Yes	Yes	Yes	Yes
Drop 10-30 km away	Yes	Yes	Yes	Yes	Yes	Yes
Drop investment phase	Yes	Yes	Yes	Yes	Yes	Yes
Observations	22,197	23,722	24,702	25,420	26,517	31,601
R-squared	0.112	0.110	0.109	0.118	0.120	0.108

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Clustered standard errors clustered at DHS cluster level. All regressions control for mother's age, age square, mother's education, urban, child's birth number and birth month and fixed effects for country-birth year and district linear time trend. The different regressions limit the treatment years to first 2 years, 3, 4, 5, 6, or 10 years after the first mine opening year. It imposes no restriction on the pre-opening time period.

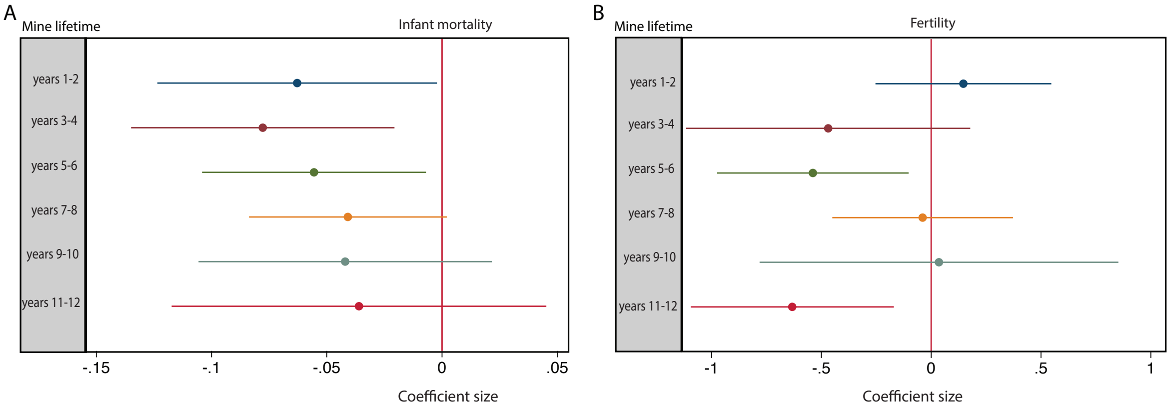


Figure 6: Infant Mortality and Fertility by Mine Lifetime

Notes: Each graph shows results from 6 different regressions, separate for infant mortality in the first 12 months (A) and women's lifetime fertility (B). The specification in A is the baseline specification which does not exclude spillovers. The vertical axis shows the sample used in the treatment group: births happening within the first two years after mine opening (1-2), in year 3 and 4 (3-4), in year 5 and 6 and so on up to mine life year 11-12. The horizontal axis shows the coefficient estimate and 95% confidence intervals. The control group remains the same in all regressions. Figure B shows the regression results using the same specification but for the women's sample and with lifetime fertility as the outcome variable.

4.5 *Geographic Distribution of Effects*

An alternative hypothesis is that the estimated treatment effect comes from an increase in infant mortality in the control group. The reasons could be because of displacement of artisanal mining from the large-scale mining site to nearby communities, or relocation of households with worse health outcomes. However, Figure 3A shows that while the treatment group sees a large reduction in infant mortality, the control group remains on a weakly negatively sloping trend.

To allow for non-linear effects with distance and better understand the geographic distribution of effects, I implement a spatial lag model. This specification will map the geographical distribution of effects across a 100 km plane from the mine center point. This strategy will inform about the usefulness of the chosen threshold distance in the baseline strategy (10 km). I allow for two sets of non-linear spatial structures:

$$\begin{aligned} Y_{icdt} = \beta_0 + \sum_s \beta_d\, industrial_{ct} \cdot minedeposit_c + \sum_s \beta_d\, minedeposit_c \\ + \alpha_d + \sigma_{dtrend} + \delta_{kt} + X_i + \varepsilon_{icdt} \end{aligned} \tag{2}$$

for $s \in \{0-10,\, 10-20, \ldots, 60-70, 70-100\}$

This spatial lag model allows for non-linear effects with distance from the mine. Each birth is recorded to a distance bin—0-10 km, 10-20 km, etc.—and compared with the reference category 70-100 km away. The specification controls for the same fixed effects, trends and individual level controls as the baseline specification. The results from this alternative model can be seen in Figure 7A. Mortality rates decrease sharply in the closest bin (0-10 km), but there is no significant effect beyond 10 km. We can thus exclude the possibility that the estimated treatment effect stems from a deterioration of health in the control group.

Next we explore the stability of the treatment effects of large-scale mining on infant mortality when excluding one country at the time (appendix Figure A6) and one mine at the time (appendix Figure A7). The effect sizes remain negative and significant.

4.6 *Spatial Randomization Test*

A spatial randomization inference test is used to show that the main results are not spurious because of a mis-specified model. All mine locations are simultaneously offset between 0 and 50 km in any direction while the mines keep their *de facto* opening year. The exercise shows that the results attenuate toward zero when doing so. Figure 7B shows the distribution of treatment effects (*industrial*minedeposit*) when the mine location was randomized 1,500 times. The dashed line shows the initial treatment effect using the baseline model. A distribution centered at zero is not expected as the random mine placement (offset up to 50 km) will partially overlap with the 10 km treatment area. The exact p-value is presented in

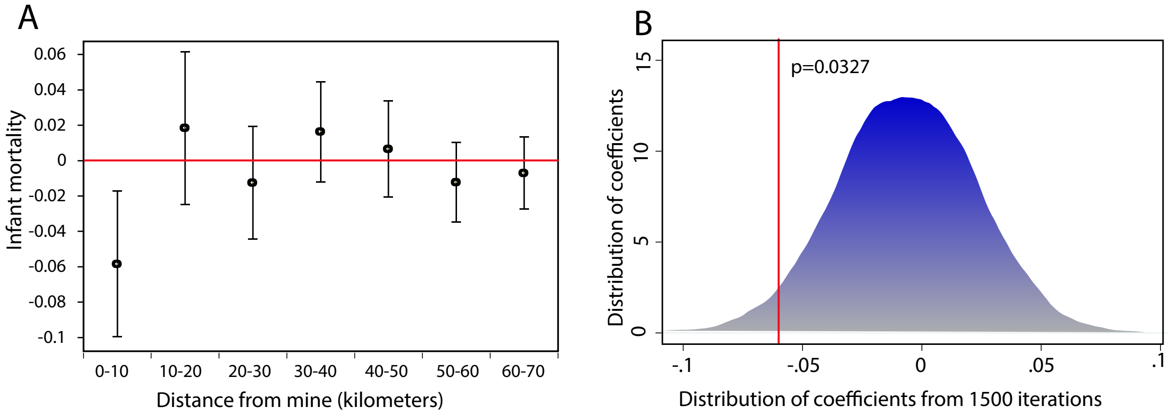


Figure 7: Spatial lag model (A) and Spatial randomization test (B)

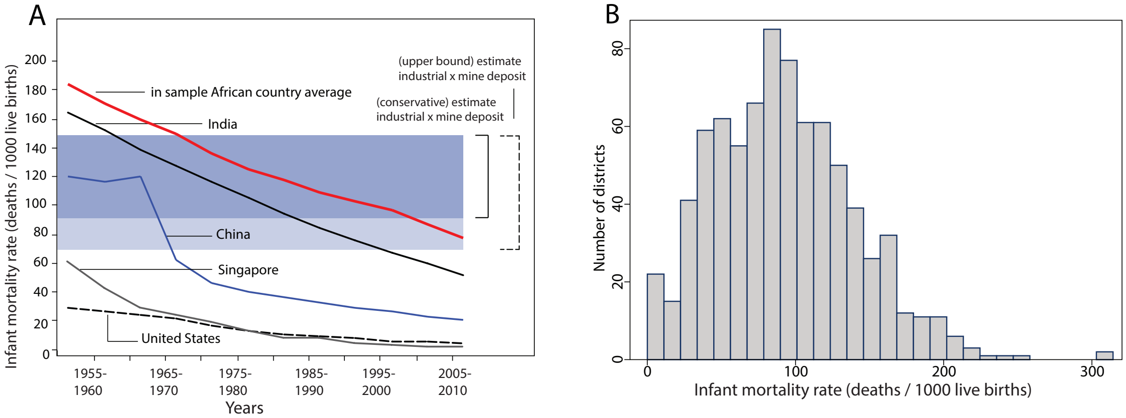
Notes: Figure A shows the results from a spatial lag model with 10 km distance bins using the baseline set of control variables and 95% confidence intervals. Figure B shows the distribution of 1,500 coefficients from a spatial randomization test. The true mine locations were simultaneously offset by 0-50 km, and the main estimation model was re-estimated. The red line is the baseline estimate and the exact p-value shows the likelihood of the original estimate being drawn from this distribution.

the figure and shows that it is unlikely that a misspecification of the model (Equation 1) is driving the results for infant mortality.

5 Discussion

The large-scale gold mining industry is rapidly expanding in Africa, yet we have limited understanding of how large-scale mining operations affect local communities. In this analysis, I have attempted to fill the knowledge gap regarding infant mortality in the wake of the mining boom. The analysis contributes to the understanding of a more general question: whether local industrial shocks can reduce infant mortality despite pollution risks. Infant mortality is an important parameter in the study context: the sample used in this study has an average rate of infant mortality of 9.7%, with most districts recording average rates of 80-90 deaths per 1000 births (Figure 8).

When a gold mine opens, the infant mortality rate decreases by more than 50% among



Data from UN Population Division. Calculations author's own.

Data from DHS. Calculations author's own.

Figure 8: Global trends in infant mortality compared with treatment effect (A), District distribution of infant mortality (B)

Notes: The data in Figure A comes from UN Population Division and the calculations are the author's own. The data are provided with 5 years averages. The data in Figure B comes from DHS and shows the distribution of infant mortality by district within the sample.

children who live within 10 kilometers.[9] The effects are geographically concentrated to the vicinity of the mine: at 20 km distance, there is no longer a detectable change in survival rates (Figure 7A). Importantly, selective migration of mothers with better child survival skills does not explain the whole effect: children born to never or early migrants, who migrated the latest 4 years before the mine opening year experience a drop in mortality risk comparative to that of the full sample.

The large, significant and almost instant drops in infant mortality experienced by mining communities around the time of mine opening may come from increases in local welfare. The mining spurs local economic growth—proxied by night-lights—and women living close to mines are 27% more likely to work in the service sector. Moreover, other potential channels change concurrently with the economic growth: households are wealthier, local women also have better access to media discussing matters of reproductive health, and have better

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[9] 50% is the less conservative measure using the main treatment effect (-0.055) and the mean in the overall sample (0.097). The most conservative measure using the treatment group, pre-treatment mean (0.151) results in a 36.4% change. The least conservative estimate is using the preferred specification (Table 2, column 2) of 7.9 percentage points and the mean of the treatment group, resulting in a 77.4% decrease in mortality.

knowledge of the use of oral rehydration salts, and important remedy for diarrheal diseases. One limitation of the study is that it cannot choose between potential channels that change concurrently with the local industrial growth. However, effects of large-scale gold mining on women's empowerment is further discussed in Tolonen (2018). I exclude the possibility that the effects are driven by a decrease in fertility among women in the local communities or an increase in health seeking behavior.

The trend break in mortality happens in the years immediately preceding the first production year, which corresponds to the capital investment period. The investment period is known to generate local employment. Sensitivity analysis shows that infant mortality drops around the time of mine opening and remains persistently lower during the mine's productive phase. The results are robust to the inclusion of mine fixed effects, the exclusion of district linear time trends and birth-year fixed effects, and to different levels for clustering of the standard errors. Furthermore, a spatial randomization test shows that artificially offsetting true mine location by 0 to 50 km creates null-results. The study explores an industrial sector during a period of expansion. The settings does not allow us to analyse the long run health changes of an industry in the process of contraction, nor can the study inform us about the effects of the expansion of large-scale gold mining on broader health outcomes, such as cognitive development and cancers. I encourage future studies to focus help shed light on these issues.

The estimated effects are economically important. The average morality rate in the mining communities before the mines open is 151 deaths per 1000 births. The infant mortality rates drop by around 55 to 79 deaths per 1000 live births with the onset of large-scale gold mining. The drop in mortality is comparable to historic reductions in infant mortality: China's infant mortality rate dropped by 58 deaths per 1000 births between 1960 and 1970, or by 79 deaths between 1960 and 1980, from an average of 121 deaths per 1000 births (see Figure 8B). During the peak of its development phase, the decades of 1950 and 1960, Singapore decreased its mortality rate by 32 deaths per 1000 births. In contrast, in the United States during the same period, mortality rates dropped from 25 to 14 deaths per 1000 births, but from a lower level. The magnitude of the effect estimated in this paper corresponds to the total gains in infant survivals achieved in Sub-Saharan Africa since the 1970s to today. This illustrates that the reductions in infant mortality rates spurred by large-scale gold mining in Africa are comparatively large and important.

The data used in this project comes from 1987-2012. A glance at the UN statistics for infant mortality shows that infant mortality was a relevant factor also in the last recorded time period (2005-2010). All study countries report high levels of mortality: 79 deaths (per 1000 live births) in Burkina Faso, 77 in Cote d'Ivoire, 116 in Democratic Republic of Congo, 72 in Ethiopia, 50 in Ghana, 93 in Guinea, 101 in Mali, 55 in Senegal and 64 in Tanzania (Table A9). If a treatment effect such as the one estimated in this paper occurred today, countrywide, in Ghana, Senegal or Tanzania, the target rate of infant mortality specified by the sustainable development goals would be reached. This study using the boom in large-scale gold mining in Africa shows that that local industrial development spurred by mining reduces infant mortality rates by 50% within two to four years. The research highlights that industrial development from natural resources has an important role to play in the achievement of the sustainable development goals for infant mortality in Sub-Saharan Africa. However, future research should explore the long run effects of the sector, including in the post-production phase, and later life health outcomes.

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Appendices

A Data

A.1 Demographic and Health Survey

The Demographic and Health Survey collects data on health and fertility in developing countries and is funded by USAID (see www.dhsprogram.com for more information). The dataset used in this paper consists of 30 cross-sectional datasets joined as a repeated cross-section. The paper uses two sets of data: child recode and women's recode. The women's recode samples women aged 15-49 in eligible households. The women's recode provides information of her marital status, occupation and fertility. For example, the women's recode is used to estimate changes in local fertility levels. The main analysis on infant mortality is done on the child recode. The child recode provides an entry for each birth to a woman surveyed in the women's recode, limited to births in the last five years prior to the interview. The subset of women are therefore different in the two recodes: only women who have given birth in the last five years will figure in the child recode. Extensive summary statistics are available in Table 1, and variable definitions in Table A1 in the Appendix.

A.2 Gold Mining Data

The gold mine data comes from IntierraRMG. The data is licensed and obtained by subscription. The subscription was obtained in 2013 from Oxford Center for Research Rich Economies (OxCarre) where the author is an affiliated researcher. More information about IntierraRMG can be found at http://www.intierrarmg.com. The dataset contains all large-scale gold mines globally, with geographic coordinates and historic production volumes. Due to missing information and potential misreporting of the data provided by IntierraRMG, all gold mining entries in the study countries were double checked against Mining Atlas - Explore the World of Mining (www.mining-atlas.com). Using Mining Atlas and Google Earth, the true geographic location was extracted and updated to reduce measurement bias from misreporting of the geographic coordinates. The coordinates were chosen to represent the center point of the mining locations on Google Earth. These coordinates were then matched with the coordinates at the village or neighborhood level provided by DHS.

A.3 Night lights

The raw night lights data come from NOAA (see http://ngdc.noaa.gov/eog) and uses Version 4 DSMP-OLS Nighttime Lights. The night light measures are stable lights by calendar year. The data come at 20 arc second grids and were used to create area weighted average annulus by distance from a gold mine.

A.4 UN Population Division

The country level statistics on infant mortality used to compare the estimates from the analysis with the global trends in infant mortality, comes from UN Population Division, Department of Economic and Social Affairs. The data are taken from World Population Prospects: The 2015 Revision, File MORT/1-1: Infant mortality rate (both sexes combined) by major area, region and country, 1950-2100 (infant deaths per 1,000 live births). The data were used to calculate the average infant mortality rate among the countries analysed in the paper. The raw data for selected countries are presented in Table A9.

A.5 GADM database of Global Administrative Areas

The DHS data provides region (subnational level 1) information. However, in this project we have used district level information. The district data comes from GADM database of Global Administrative Areas which provides the polygons for administrative areas globally.

The name and size of subdivisions vary across countries. Subnational level 2 was chosen for this project, regardless of the nationally specific name for this level and the average geographic size of such a subdivision. The data were accessed from DivaGIS in August 2013 (www.diva-gis.org/datadown). The subdivision level 2 data were then extracted for each DHS cluster, which is a village or a neighborhood in a city, by overlaying the DHS cluster data and the GADM data using ArcGIS. The DHS clusters are offset with 1 to 10 km to ensure privacy of respondents. This will introduce some random error in the assignment of districts to individual observations as individuals living close to a district border may have been assigned the neighboring district instead.

B Figures and Tables

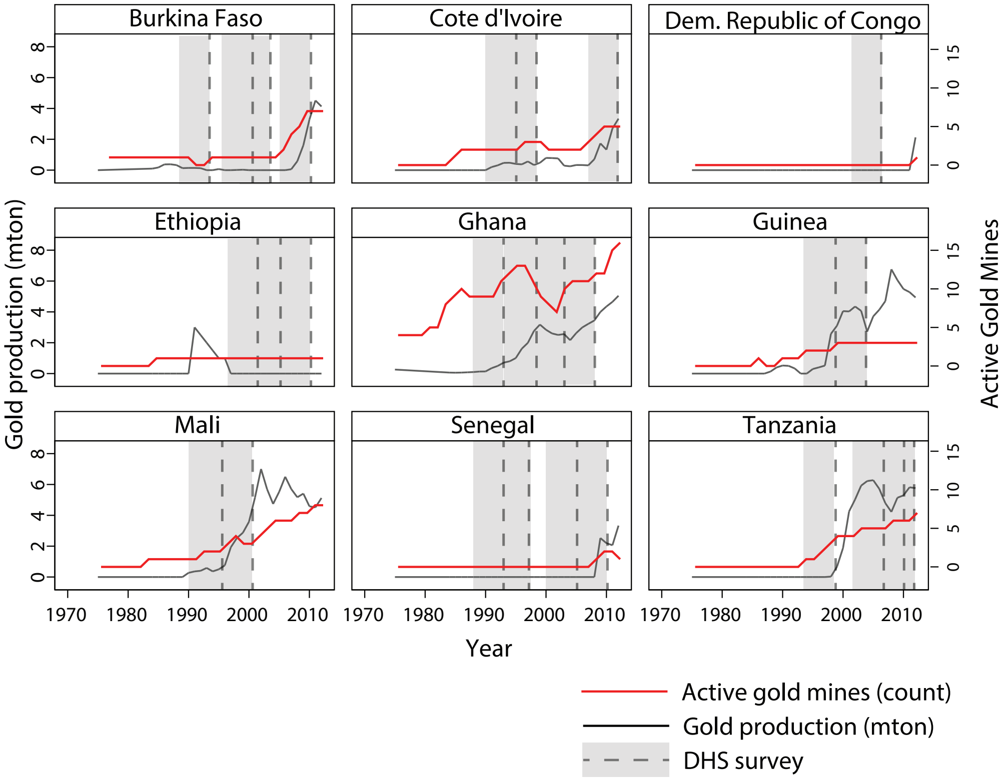

Figure A1: The Evolution of the Production of Gold and the Demographic and Health Surveys and Sample Years by Country

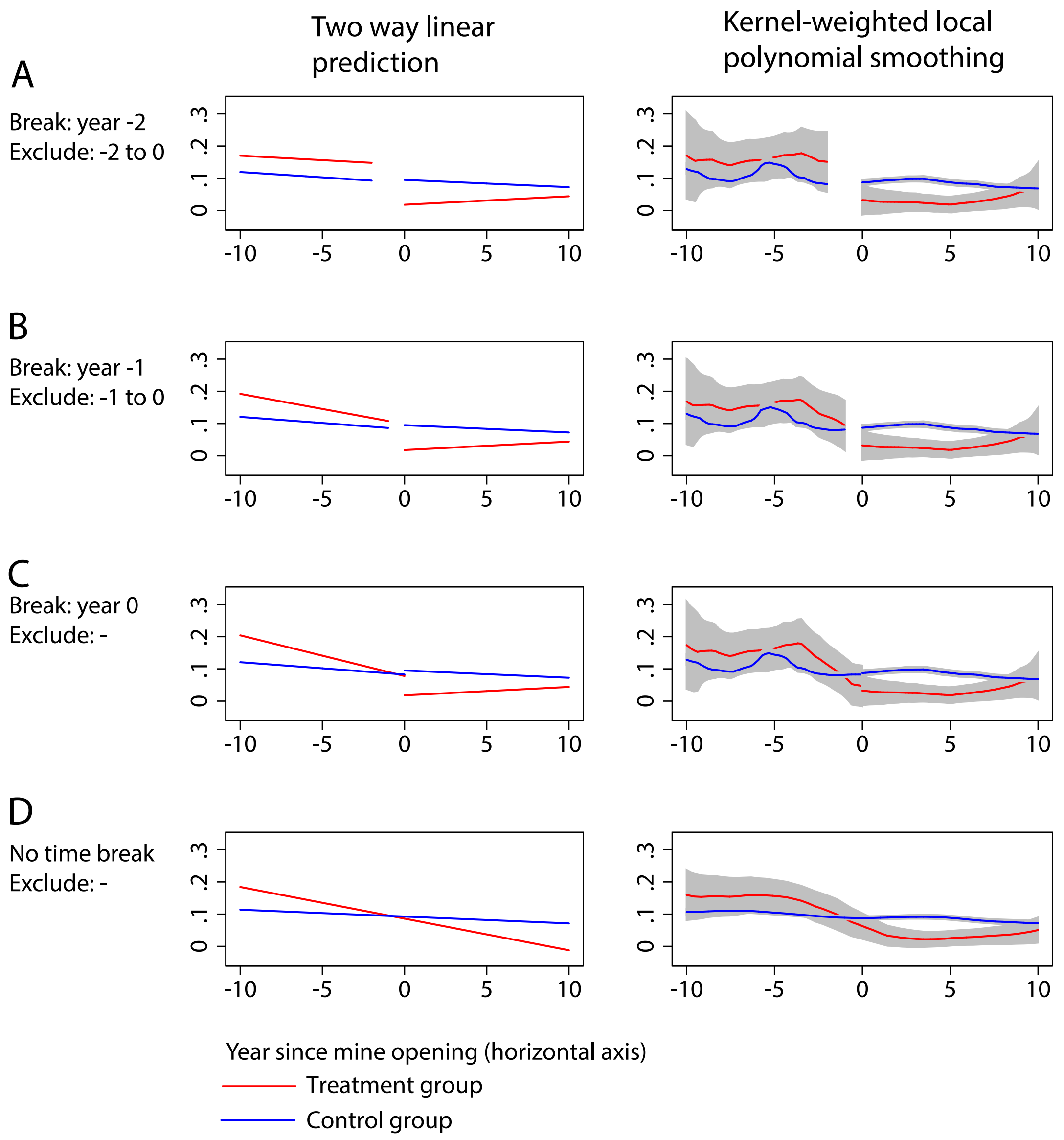

Figure A2: Parametric and non-parametric estimation of trends for infant mortality

Notes: The graphs show results for two-way linear prediction (column 1) and kernel-weighted polynomial smoothing (column 2) across four specifications (rows 1-4). The mine opening year is the first year of production for the mine that is closest to the individual. The treatment group (red line) is drawn from within 10 km for the closest mine. The control group (blue line) is drawn 10-100 km away, but excludes births with the second closest mine within 20 km. Row 1 uses the preferred specification and allows for a break at year -2, and excludes children born year -2 to year 0. Row 2 allows for a break at year -1, row 3 at year 0, and row 4 does not allow for a break.

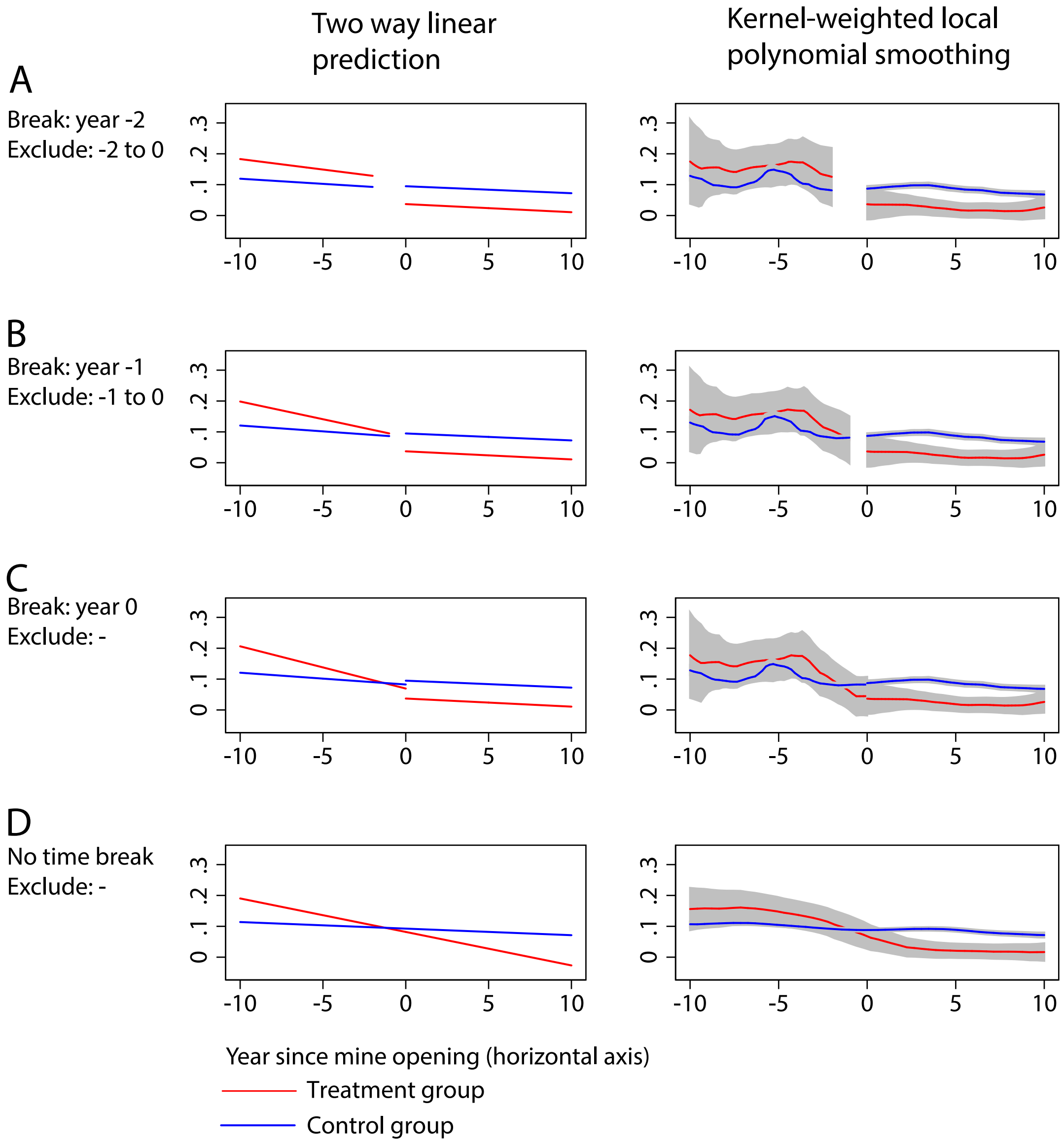

Figure A3: Parametric and non-parametric estimation of trends for infant mortality. Excluding migrants who moved 4 years prior to mine opening or later

Notes: The graphs show results for two-way linear prediction (column 1) and kernel-weighted polynomial smoothing (column 2) across four specifications (rows 1-4). The mine opening year is the first year of production for the mine that is closest to the individual. The treatment group (red line) is drawn from within 10 km for the closest mine. The control group (blue line) is drawn 10-100 km away, but excludes births with the second closest mine within 20 km. Row 1 uses the preferred specification and allows for a break at year -2, and excludes children born year -2 to year 0. Row 2 allows for a break at year -1, row 3 at year 0, and row 4 does not allow for a break. All births from mothers who migrated 4 years before the mine opening year, or later, are excluded.

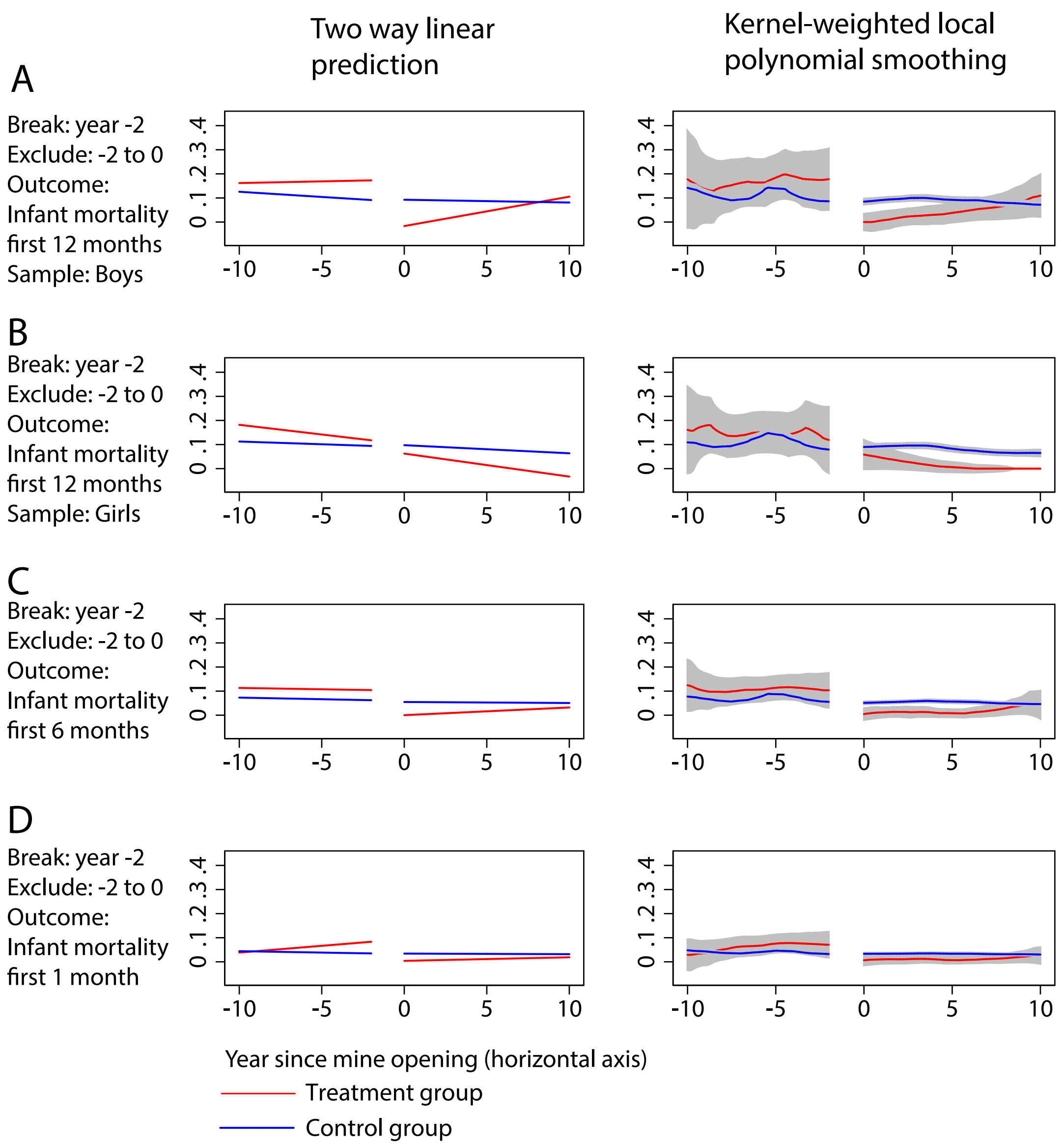

Figure A4: Parametric and non-parametric estimation of trends for infant mortality for boys (A), girls (B), mortality first 6 months (C), and neonatal mortality (D)

Notes: The graphs show results for two-way linear prediction (column 1) and kernel-weighted polynomial smoothing (column 2) across four samples (rows 1-4). The mine opening year is the first year of production for the mine that is closest to the individual. The treatment group (red line) is drawn from within 10 km for the closest mine. The control group (blue line) is drawn 10-100 km away, but excludes births with the second closest mine within 20 km. All rows (1-4) use the preferred specification and allows for a break at year -2. Row 1: infant mortality first 12 months, boys only. Row 2: infant mortality first 12 months, girls only. Row 3: infant mortality first 6 months. Row 4: infant mortality first 1 month.

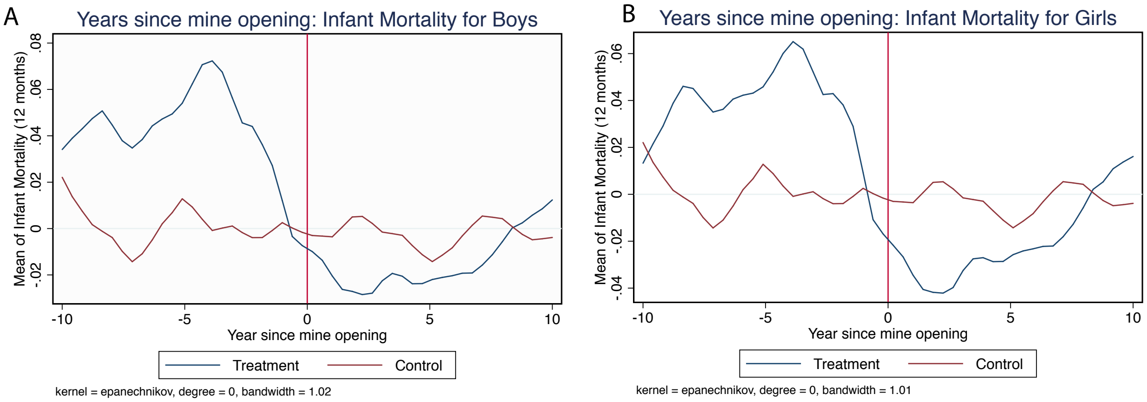

Figure A5: Event study graph plotting the residuals from the main estimation excluding the treatment variables: Infant mortality for boys (A), girls (B)

Notes: The graphs plot the residual by year for the model explored in Table 2 column 2 excluding the two treatment variables. The residuals are plotted for boys (A) and girls (B), excluding children who live near a second gold mine (43 births).

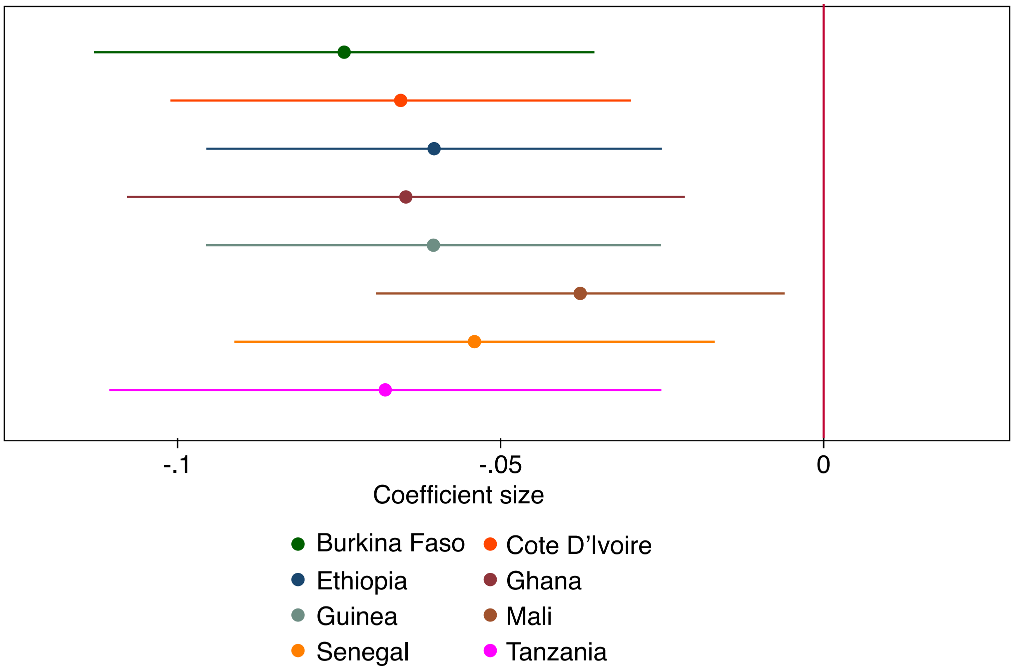

Figure A6: Drop one country at the time

Notes: The graphs show coefficient estimate for *industrial*mine deposit* for infant mortality in the first 12 months for 8 independent regressions using the baseline model. Each regression excludes the sample from one country as indicated by the country name.

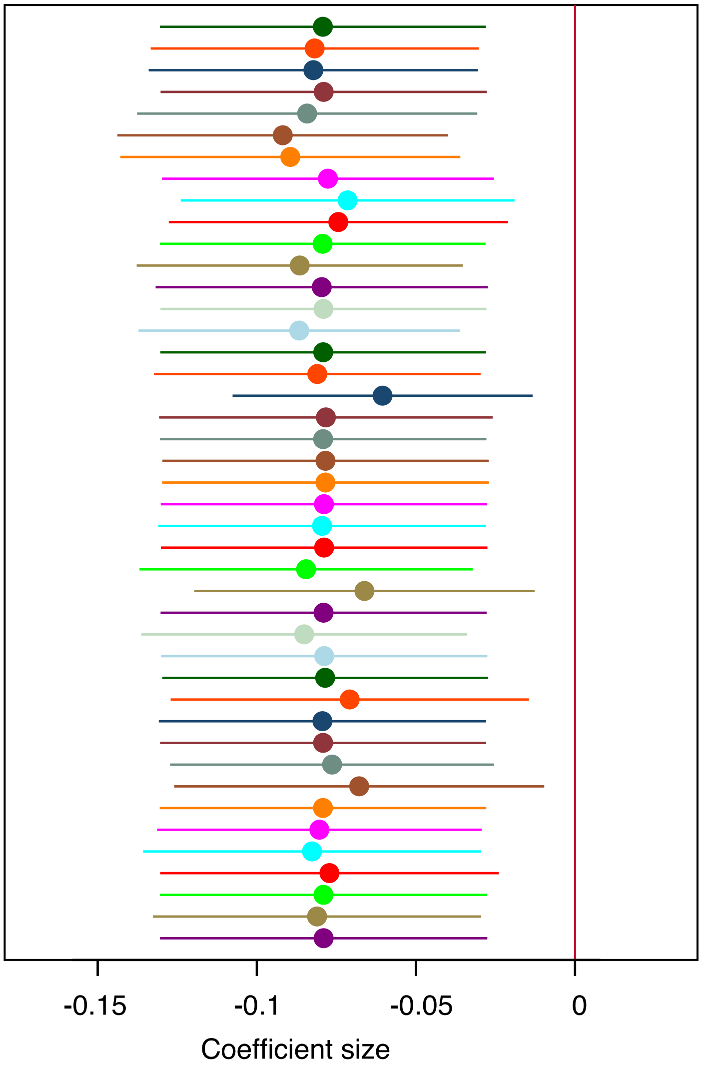

Figure A7: Drop one mine at the time

Notes: The graphs show coefficient estimate for *industrial*mine deposit* for infant mortality in the first 12 months for 43 independent regressions using the baseline model. Each regression excludes the sample from one mine.

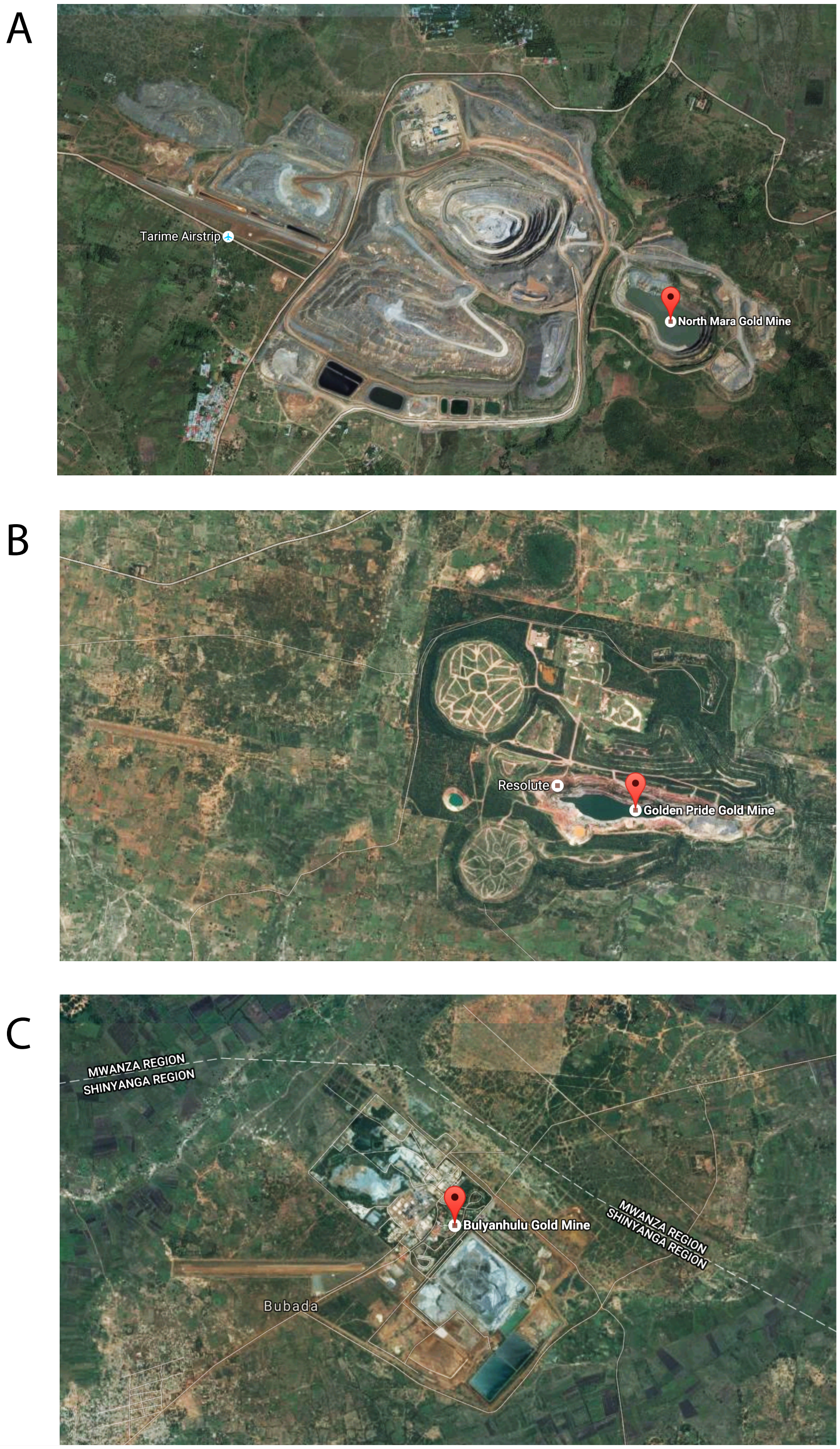

Figure A8: Google maps photos of three Tanzanian gold mines with airfields

Notes: An airstrip can be seen to the left of each mine site. Note that these mines are only a subset of the mines included in the analysis.

Table A1: Variable Definition

Variable	(1) Definition	(2) Data source
infant mortality	Child died within first 12 months of life	DHS child recode
infant mortality (1 month)	Child died within first months of life	DHS child recode
infant mortality (6 months)	Child died within first 6 months of life	DHS child recode
mother’s age	Age of mother in the child recode	DHS child recode
mother’s education	Number of years of schooling	DHS child recode
urban household	Household lives in an urban dwelling	DHS child recode
birth number	Child number in the birth order of mother	DHS child recode
birth year of child	Calendar birth year of child	DHS child recode
antenatal care	At least one antenatal care visit during pregnancy	DHS child recode
has health card	Mother can show child’s health card to interviewer	DHS child recode
very small at birth	Child very small size at birth, mother estimation	DHS child recode
ever vaccinated	Child ever received vaccination	DHS child recode
cough	Child had cough in the 2 weeks prior to surveying	DHS child recode
fever	Child had fever in the 2 weeks prior to surveying	DHS child recode
diarrhea	Child had diarrhea in the 2 weeks prior to surveying	DHS child recode
migrant (2 years)	If mother moved location 2 years prior to, or after closest mine opening	DHS child recode
migrant (5 years)	If mother moved location 5 years prior to, or after closest mine opening	DHS child recode
total fertility	Lifetime births, women	DHS woman recode
total fertility under 22	Lifetime births, women aged less than 22 at time of interview	DHS woman recode
listen to radio FP	Heard radio family planning message in last few months prior to interview	DHS woman recode
service job	Main occupation if worked in last 12 months, service sector	DHS woman recode
earns cash	Woman earns cash or cash and in kind for work	DHS woman recode
polygamous marriage	Is in a polygamous marriage currently	DHS woman recode
barrier health access	Index ranging 0-1, where 1 is is least access to health care for self due to money, permission or distance	DHS woman recode
industrial*mine deposit (at birth)	1 if an actively producing mine within 10 km from dwelling in the year of the child’s birth, 0 otherwise	Own construct
industrial*mine deposit (at survey)	1 if an actively producing mine within 10 km from dwelling in the year of the interview, 0 otherwise	Own construct
mine deposit	1 if a gold mine within 10 km, regardless of production status, 0 otherwise	Own construct

Table A2: Potential Mechanisms

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
				partner's occupation			
Dependent variable:	urban	age	education	agriculture	manual	service	professional
industrial*mine deposit	0.047	0.073	0.336	-0.064	0.049	0.018	0.010
	(0.060)	(0.075)	(0.328)	(0.047)	(0.035)	(0.029)	(0.023)
mine deposit	-0.067	-0.053	-0.093	0.036	-0.020	-0.007	-0.009
	(0.044)	(0.061)	(0.163)	(0.031)	(0.024)	(0.018)	(0.011)
Observations	38,428	38,428	38,414	41,359	41,359	41,359	41,359
R-squared	0.439	0.984	0.427	0.448	0.136	0.104	0.176

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Clustered standard errors clustered at DHS cluster level. Columns 4-7 use a woman's partner's occupation as outcome variable. The sample is the woman's recode. Service includes service and sales jobs, professional also includes clerical jobs.

Table A3: Adding extra controls

Dependent variable:	infant mortality first 12 months							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
industrial*mine	-0.080***	-0.079***	-0.080***	-0.080***	-0.085***	-0.086***	-0.094***	-0.083
	(0.026)	(0.026)	(0.027)	(0.027)	(0.027)	(0.027)	(0.035)	(0.060)
mine deposit	0.049**	0.048**	0.049*	0.050**	0.048*	0.048*	0.062**	0.060
	(0.024)	(0.024)	(0.025)	(0.025)	(0.025)	(0.025)	(0.026)	(0.058)
urban location		-0.010*	-0.010*	-0.007	-0.008	-0.009	-0.007	0.000
		(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)
mother ever migrated					0.009*	0.008	0.008	0.016**
					(0.005)	(0.005)	(0.005)	(0.007)
household wealth quintile 1								0.013*
								(0.008)
household wealth quintile 2								0.001
								(0.007)
household wealth quintile 3								0.001
								(0.007)
service employment			0.008			0.003	0.007	-0.021
			(0.014)			(0.014)	(0.015)	(0.016)
non agriculture empl.				-0.010*				
				(0.005)				
not working (last 12 months)				0.011*				
				(0.006)				
knows ORS							-0.018***	-0.007
							(0.005)	(0.006)
mother age	-0.019***	-0.019***	-0.019***	-0.019***	-0.019***	-0.019***	-0.018***	-0.014***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
mother education	-0.002***	-0.001**	-0.001**	-0.001**	-0.001**	-0.001**	-0.001*	-0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Observations	29,221	29,221	28,297	28,297	28,739	27,834	25,899	15,683
R-squared	0.104	0.104	0.106	0.106	0.104	0.105	0.105	0.113

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Clustered standard errors clustered at DHS cluster level. All regressions control for mother's age, age square, mother's education, urban, child's birth number and birth month and fixed effects for country-birth year and district linear time trend.

Table A4: Infant mortality allowing for heterogeneity by subgroups

	(1)	(2)	(3)	(4)
Dependent variable:	Infant mortality in first 12 months			
industrial*mine deposit*service	-0.053*		-0.066**	
	(0.032)		(0.032)	
industrial*mine deposit*agriculture		-0.039**	-0.043**	
		(0.017)	(0.017)	
industrial*mine deposit*partner in ag				-0.067**
				(0.030)
industrial*mine deposit	-0.055***	-0.040*	-0.036*	-0.069**
	(0.020)	(0.021)	(0.022)	(0.034)
mine deposit	0.035**	0.035**	0.035**	0.065***
	(0.017)	(0.017)	(0.017)	(0.024)
service	0.016		0.018	
	(0.013)		(0.013)	
agriculture		0.008*	0.008*	
		(0.004)	(0.004)	
partner in agriculture				0.006
				(0.006)
Observations	36,320	36,320	36,320	25,343
R-squared	0.103	0.103	0.103	0.099

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ Standard errors clustered at DHS cluster level. Linear probability models. All regressions in control for mother's age, age square, mother's education, urban, child's birth number, and fixed effects for district, birth month, and country-birth year, and district linear time trend. Outcome is infant mortality in the first 12 months since birth. The treatment effects are interacted with occupational categories, service or sales employment (*service*) and agricultural occupation (*agriculture*), or an indicator variable for partner working in agriculture (*partner in ag)*.

Table A5: Fertility changes by subgroups

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent variable:		Ever had child			Total fertility			Ever terminated pregnancy	
industrial*mine deposit*service	0.027		0.055	-0.058		-0.037	-0.006		-0.006
	(0.030)		(0.035)	(0.129)		(0.129)	(0.033)		(0.038)
industrial*mine deposit*agriculture		0.089***	0.102***		0.120	0.110		0.009	0.007
		(0.031)	(0.033)		(0.146)	(0.148)		(0.041)	(0.046)
industrial*mine deposit	-0.041*	-0.074***	-0.093***	-0.179	-0.242*	-0.229	-0.018	-0.022	-0.022
	(0.022)	(0.028)	(0.031)	(0.150)	(0.140)	(0.147)	(0.029)	(0.032)	(0.037)
mine deposit	0.020	0.017	0.019	0.105	0.103	0.102	0.019	0.019	0.020
	(0.015)	(0.016)	(0.017)	(0.106)	(0.109)	(0.109)	(0.021)	(0.021)	(0.020)
service	0.056***		0.099***	-0.114***		-0.038*	0.025***		0.034***
	(0.004)		(0.005)	(0.020)		(0.022)	(0.005)		(0.005)
agriculture		0.058***	0.101***		0.196***	0.179***		0.005	0.021***
		(0.004)	(0.005)		(0.022)	(0.024)		(0.005)	(0.006)
Observations	55,944	55,944	55,944	55,944	55,944	55,944	38,924	38,924	38,924
R-squared	0.377	0.378	0.384	0.672	0.672	0.672	0.093	0.092	0.093

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ Standard errors clustered at DHS cluster level. Linear probability models. All regressions in control for woman's age, education, urban, and fixed effects for district, country-survey year, and district linear time trend. The treatment effects are interacted with occupational categories, service or sales employment (*service*) and agricultural occupation (*agriculture*). The outcome variables are: if the woman ever gave birth to a child (columns 1-3), total children born (columns 4-6), and ever experienced a terminated pregnancy because of miscarriage or abortion (columns 7-9). The sample size is smaller for the last variable as it is not always collected by DHS. The sample is the DHS woman's sample, and thus include all women aged 15-49 regardless if they had a child in the last 5 years.

Table A6: Trivers-Willard Hypothesis

Dependent variable:	Infant Mortality	Male	Male	Male	Infant mortality in first 12 months			
Sample:	all	all	all	all	all	all	boys	girls
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
industrial*mine deposit	-0.079***	0.051	0.086	0.082	-0.087	-0.091	-0.082	-0.096
	(0.026)	(0.036)	(0.076)	(0.078)	(0.056)	(0.057)	(0.078)	(0.080)
mine deposit	0.048**	-0.033	-0.062	-0.068	0.051	0.056	0.052	0.060
	(0.024)	(0.027)	(0.074)	(0.073)	(0.056)	(0.057)	(0.077)	(0.077)
wealthy*industrial*mine deposit				0.020		0.020	-0.047	0.106
				(0.073)		(0.050)	(0.088)	(0.123)
wealthy*mine deposit				0.026		-0.022	0.009	-0.038
				(0.064)		(0.048)	(0.078)	(0.108)
wealthy			0.017*	0.016*	-0.005	-0.005	0.000	-0.013
			(0.009)	(0.009)	(0.006)	(0.006)	(0.008)	(0.008)
male	0.008**							
	(0.003)							
Observations	29,221	38,414	23,111	23,111	17,701	17,701	9,009	8,692
R-squared	0.104	0.015	0.022	0.022	0.111	0.111	0.138	0.131

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ Standard errors clustered at DHS cluster level. Linear probability models. All regressions in control for mother's age, age square, mother's education, urban, child's birth number, and fixed effects for district, birth month, and country-birth year, and district linear time trend. Outcomes for columns 1 and 5-8 are infant mortality in the first 12 months since birth, and the child is male in columns 2-4. The treatment effects are interacted with household wealth indicator, which takes a value of one of the household is among the 40% richest households compared with a national average.

Table A7: Varying the control group

Dependent variable:	Infant mortality in first 12 months					
	(1)	(2)	(3)	(4)	(5)	(6)
industrial*mine deposit	-0.050***	-0.049***	-0.057***	-0.056***	-0.069**	-0.071***
	(0.018)	(0.018)	(0.018)	(0.018)	(0.029)	(0.024)
mine deposit	0.026*	0.031**	0.030**	0.037**	0.024	0.054***
	(0.013)	(0.014)	(0.015)	(0.015)	(0.025)	(0.020)
Control group	10-40 km	10-50 km	10-40 km	10-50 km	30-40 km	30-50 km
Drop investment phase	No	No	Yes	Yes	Yes	Yes
Observations	8,338	12,697	7,410	11,276	3,504	7,370
R-squared	0.152	0.131	0.163	0.139	0.193	0.141
birth month FE	YES	YES	YES	YES	YES	YES
birth year FE	YES	YES	YES	YES	YES	YES

Table A8: Mother fixed effects

Dependent variable:	infant mortality 12 months (1)	infant mortality 6 months (2)	neonatal mortality 1 month (3)
industrial*mine deposit	-0.121	-0.093	-0.089
	(0.181)	(0.125)	(0.101)
birth order	-0.020*	-0.014	-0.011
	(0.012)	(0.009)	(0.007)
Mother FE	Yes	Yes	Yes
Country-birth year FE	Yes	Yes	Yes
District time trend	Yes	Yes	Yes
Birth month FE	Yes	Yes	Yes
Drop 10-30km away	Yes	Yes	Yes
Drop investment phase	Yes	Yes	Yes
Sample sizes			
Treated mothers before-after birth	94	94	94
Treated mothers with >1 birth	368	368	368
Treated children with >1 sibling	730	730	730
Mothers with >1 birth	15,093	15,093	15,093
Observations (# births)	29,234	34,030	38,428
R-squared	0.755	0.703	0.646

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Clustered standard errors clustered at DHS cluster level. All regressions control for mother fixed effect, child's birth number and birth month, and fixed effects for country-birth year and district linear time trend. Mine deposit captures if there is a gold deposit within 10 km from the household. Industrial captures if the gold deposit was actively extracted in the child's birth year. The sample size is larger when exploring neonatal mortality, as more children in the sample had, at the time of surveying, lived to be older than 1 month. Children not yet 12 months of age, at the time of surveying, were excluded from Column 1.

Table A9: Global Trends in Infant Mortality

	1950-1955	1955-1960	1960-1965	1965-1970	1970-1975	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000	2000-2005	2005-2010
Angola	230.49	214.76	199.91	185.99	172.85	160.8	156.97	152.99	150.47	137.9	115.98	104.3
Benin	209.89	194.93	183.78	172.54	151.97	136.41	126.42	119.6	108.19	97.8	90.62	85.11
Botswana	135.09	123.67	113.29	103.99	90.27	74.66	63.49	54.02	51.45	61.21	58.77	40.69
Burkina Faso	307.92	258.4	217.13	183.5	156.73	135.83	120.75	110.55	101.42	93.25	85.86	78.9
Burundi	166.5	157.3	148.5	140	137	127	118.4	116.3	126.13	116.93	107.09	101.14
Cameroon	169.43	157.72	144.86	133.01	119.93	107.51	97.94	93.05	93.54	96.1	96.67	94.05
Cape Verde	138.79	131.99	124.75	116.89	95.61	78.44	64.66	53.56	44.42	36.57	28.03	20.63
CAR	203.88	189.37	175.66	159.6	138.31	119.09	109.71	109.24	112.9	115.91	113.71	105.38
Chad	191.37	181.49	171.81	162.66	153.63	145.54	135.61	129.07	128.63	131.28	133.35	131.17
Congo	142.06	122.72	106.94	96.6	88.81	83.02	78.25	73.43	73.58	75.05	75.3	72.43
DRC	166.6	157.54	151.19	143.46	133.7	129.13	124.86	121.13	118.58	128.47	119.9	115.81
Cote d'Ivoire	167.48	160.39	154.7	147.37	126.85	108.54	96.16	93.37	94.67	91.93	84.7	77.17
Djibouti	222.47	202.65	185.25	168.86	153.88	140.59	125.1	116.95	109.17	99.98	91.08	82.08
Equatorial Guinea	196.38	186.02	176.11	166.62	157.36	148.6	138.12	127.61	118.14	113.65	110.66	102.45
Eritrea	176	162.8	150.5	139.1	133	127	115.8	104.48	89.79	73.21	61.75	53.88
Ethiopia	199.27	181.43	159.98	147.91	140.03	134.62	140.15	126.95	114.54	101.04	87.12	72.46
Gabon	179.34	166.6	157.54	134.28	113.54	94.99	77.66	63.15	58.88	58.28	57.72	51.15
Gambia	220.86	210.08	199.15	184.71	164.3	139.59	117.31	101.48	92.87	86.41	79.98	73.84
Ghana	150.09	132.63	122.87	117.21	107.5	97.5	90.48	83.93	72.88	70.63	61.85	49.61
Guinea	217.77	213.63	209.62	205.61	190.69	174	158.77	144.67	130.9	119.15	104.17	93.17
Guinea-Bissau	210.77	200.97	191.37	182.28	173.55	165.37	152.96	145.17	140.51	134.1	125.64	118.7
Kenya	147.01	133.67	116.96	104.39	91.5	80.44	70.11	66.73	66.48	69.14	69.54	64.72
Lesotho	169.27	150.35	134.28	130.26	123.09	109.72	93.95	83.83	69.65	81.29	86.15	76.86
Liberia	223.72	208.36	194.27	181.17	168.67	158.48	159.34	163.67	167.72	154.93	115.75	88.62
Madagascar	180.85	166.88	154.88	143.2	132.49	122.01	110.98	109.85	95.63	76.29	58.3	44.78
Malawi	197.89	192.49	185.86	180.04	168.43	159.27	150.95	143.42	133.1	120.78	107.41	95.23
Mali	175.4	172.61	168.15	162.36	155.75	148.7	140.78	134.62	127.14	119.08	110.51	101.35
Mauritania	151.09	149.33	147.02	142.71	133.32	113.26	93.07	80.94	76.71	75.7	76.51	77.33
Mauritius	103.09	73.84	60.63	67.24	60.76	37.67	26	23.11	18.47	19.69	13.35	12.76
Mozambique	220.12	201.39	184.79	172.06	158.4	145.79	143.06	142.84	133.95	114.6	99.09	88.03
Namibia	171.61	148.95	130.4	114.99	100.67	87.64	75.49	68.54	61.7	54.55	48.21	37.76
Niger	174.04	170.73	167.3	164.28	162.15	160.79	159.18	155.1	145.73	130.67	112.72	95.92
Nigeria	188.93	175.99	164	152.87	140.95	131.73	126.99	126.58	126.48	122.19	107.23	96.14
Rwanda	160.28	151.56	143.04	137	134.29	132.3	124.14	119.97	127.92	117.68	107.9	100.15
Sao Tome & Principe	124.13	112.13	98.83	88.01	79.67	69.59	66.41	63.47	60.62	57.92	55.35	51.71
Senegal	131.4	128.44	123.4	116.56	108.34	98.72	88.54	79.95	72.39	65.82	60.16	55.24
Sierra Leone	242.37	234.76	226.71	214.14	194.7	164.18	135.32	153.53	165.6	156.76	133.27	113.68
Somalia	207.23	192.88	179.34	166.59	154.55	148.76	137.77	127.16	141.3	122.58	110.58	106.67
South Africa	96.1	91.3	86.5	83.59	77.13	70.6	60.73	52.57	50.6	55.85	59.21	54.81
Swaziland	173.74	160.31	150.39	140.53	124.04	107.77	90.44	77.34	69.29	80.18	86.64	75.87
Tanzania	153.22	143.12	136.12	128.06	118.62	108.07	103.79	100.65	99.7	90.38	77.35	64.45
Togo	191.38	171.94	154.31	138.36	123.58	113.23	104.79	97.17	90.52	83.76	76.69	73.96
Uganda	160.43	145.29	130.17	116.46	102.76	105.98	107.64	108.45	110.43	104.63	91.03	79.16
Zambia	148.29	136.93	126.59	117.88	106.94	100.19	98.52	102.98	107.18	105.46	102.7	94.91
Zimbabwe	114.51	105.13	96.67	89.56	82.63	74.26	63.77	56.33	55.5	64.58	68.45	59.28
SSA average	177.97	165.01	153.46	143.21	131.18	119.50	109.81	103.99	100.12	95.19	87.20	78.52
Study country average	185.46	172.02	160.35	150.23	137.58	126.12	118.25	110.65	103.58	97.75	87.96	78.68
India	165.00	153.08	140.12	128.46	117.99	106.45	95.02	85.07	76.45	68.86	60.7	52.91
China	121.64	117.92	121.17	63.15	46.93	41.96	37.59	33.75	30.34	27.3	24.6	21.99
Singapore	60.69	43.18	28.6	23.78	19.34	12.85	8.7	7.79	4.49	3.33	2.55	1.92
United States	30.46	27.33	25.38	22.67	18.39	14.34	11.6	10.37	8.81	7.49	6.92	5.40

Notes: Data comes from UN Population Division and presents trends in infant mortality for selected countries from 1950 to 2010. Averages presented are based on author's own calculations.

Table A10: Mining sector by country

Country	Total Mines	First Year	Total Production (t)	Average Production (t)	Open Pit	Underground	Open Pit/ Underground
Burkina Faso	7	1984	113.25	16.18	6	1	0
Cote d'Ivoire	5	1991	68.46	13.69	5	0	0
Ethiopia	1	1991	11.00	11.00	0	0	1
Ghana	18	1975	1008.03	56.00	16	1	1
Guinea	3	1995	207.28	69.09	3	0	0
Mali	8	1990	633.76	79.22	5	1	2
Niger	1	2004	15.98	15.98	1	0	0
Senegal	1	2009	20.19	20.19	1	0	0
Tanzania	7	1998	469.32	67.05	5	1	1

Table A11: Mining companies

Company name	Country origin	Mines (in dataset)	Countries active
Akrokeri-Ashanti Gold Mines, Inc.	Canada	2	Ghana
Al-Amoudi Family	Saudi Arabia	1	Ethiopia
Amara Mining PLC	UK	2	Burkina Faso, Cote d'Ivoire
Anglogold Ashanti Ltd.	South Africa	12	Ghana, Guinea, Mali, Tanzania
Avnel Gold Mining Ltd.	UK	1	Mali
Avocet	UK	1	Burkina Faso
Banro Corp.	Canada	1	Congo (Dem Rep)
Barrick Gold Corp.	Canada	4	Tanzania
Bassari	Australia	1	Senegal
Eden Roc Mineral Corp.	Canada	1	Cote d'Ivoire
Endeavour Mining Corp.	Canada	3	Burkina Faso, Ghana, Mali
Ghana National Petroleum Corp.	Ghana	1	Ghana
Gold Fields Ltd.	South Africa	2	Ghana
Golden Star Resources Ltd.	USA	2	Ghana
Iamgold Corp.	Canada	3	Burkina Faso, Mali
Kinross Gold Corp.	Canada	1	Ghana
LionGold Corp.	Singapore	1	Ghana
MDN Inc.	Canada	1	Tanzania
Newcrest	Australia	1	Cote d'Ivoire
Newmont Mining Corp.	USA	1	Ghana
Noble Mineral Resources Ltd.	Australia	1	Ghana
Perseus Mining Ltd.	Australia	1	Ghana
Prestea Resource	Ghana	1	Ghana
PMI Gold Corp.	Canada	1	Ghana
Randgold Resources Limited	South Africa	4	Cote d'Ivoire, Mali
Resolute Mining Ltd.	Australia	2	Mali, Tanzania
Semafo Inc.	Canada	2	Burkina Faso, Guinea
Severstal	Russia	2	Burkina Faso, Guinea
Shanta Gold Ltd.	UK	1	Tanzania
State of Cote d'Ivoire	Cote d'Ivoire	2	Cote d' Ivoire
State of Mali	Mali	6	Mali
Teranga Gold Corp.	Canada	1	Senegal
Weather II	Egypt	1	Cote d'Ivoire

Notes: Some mines are double counted if the ownership is shared. This is true for operations by State of Cote d'Ivoire, State of Mali, Ghana Petroleum, Iamgold, Anglogold, Barrick, MDN, Eden Roc, Randgold Res, Resolute and Weather II. Missing company information for Esasse and Dunkwa mines in Ghana and Poura in Burkina Faso.