Health vs wealth: The impact of mining on pregnancy outcomes

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Abstract

In 2011, the Supreme Court of India implemented restrictions that ultimately banned mining for over 150 iron ore mines due to environmental concerns. Using data on birth outcomes from two national surveys in a difference-in-differences approach, we find reduced stillbirths and low birth weight deliveries for births in regions subject to the restrictions relative to control regions. We do not find statistically significant effects on medically terminated pregnancies or maternal anemia. Our analysis reveals that these effects are driven by two primary mechanisms: improved air quality in treated districts and a change in the income composition of mothers. Despite overall declines in household consumption, the income quintiles of mothers in treated districts increased relative to controls, suggesting income-selected fertility. We also observe reduced household income, which may partially offset the positive effects. Our results indicate that the combined environmental benefits and changes in maternal demographics outweighed the local economic costs in terms of pregnancy outcomes. These findings have important implications for understanding the health-wealth trade-offs in resource extraction and policies related to India's energy transition and future mine closures.

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1 Introduction

In-utero environmental exposures to air pollution and water pollution have been shown to lead to a variety of adverse pregnancy outcomes. In 2021, India accounted for more stillbirths than any other country (Lindt et al., 2022) while also boasting nine of the ten most polluted cities in the world by PM2.5 concentration.[1] Improving pregnancy outcomes for mothers and infants is an important development goal.

In India, mining and resource extraction are significant sources of income but are also primary contributors to local pollution. India is the world's second-largest coal producer (Energy Institute, 2023), fourth-largest iron ore producer, and a major producer of many other minerals (US Geological Survey, 2024). Mining is a primary source of income for a large population but can result in significant externalities. Drilling and blasting create particulate matter pollution, mine tailings can leech into waterways, and other toxic chemicals and compounds are used or disturbed during mining. Until the 2010s, enforcement of regulations in the mining sector in India was notoriously lax, which culminated in a series of controversial rulings by the Supreme Court of India that resulted in significant multi-year bans on mining in several resource-rich areas (Banerjee, 2020).

This paper leverages exogenous variation in mining caused by a Supreme Court of India ban on iron ore mining in Karnataka to study the effects of mining on pregnancy outcomes. In 2010, the Supreme Court of India restricted iron ore exports from three districts in Karnataka, and in 2011-2013, iron ore mining was banned entirely in districts. Due to the ban, 150 mines were closed, which resulted in a decline in iron ore production in Karnataka, from a pre-ban level of 4.5 million tons per month to a low of less than 0.5 million tons in late 2011.

We exploit the Supreme Court restrictions on mining as a natural experiment that allows us to study the impacts of mining on pregnancy outcomes. We hypothesize that the mining restrictions may have affected pregnancy outcomes through income and pollution channels via the fetal origins hypothesis (Almond and Currie, 2011). Kamble and Brewer (2024) show that the restrictions depressed wages for unskilled laborers and consequently reduced household consumption levels by 20% in the affected districts. A decline in income may have reduced the ability to pay for medical care or reduced the quality of nutrition, leading to worse pregnancy outcomes. At the same time, cessation of mining activities may have improved air and water quality, improving pregnancy outcomes. Figure 1 displays a schematic of our hypothesized mechanisms linking the mining restrictions to changes in pregnancy outcomes. Because the theoretical effect of the mining restrictions on pregnancy outcomes is ambiguous,

[1] See https://www.iqair.com/world-most-polluted-cities, accessed May 2024.

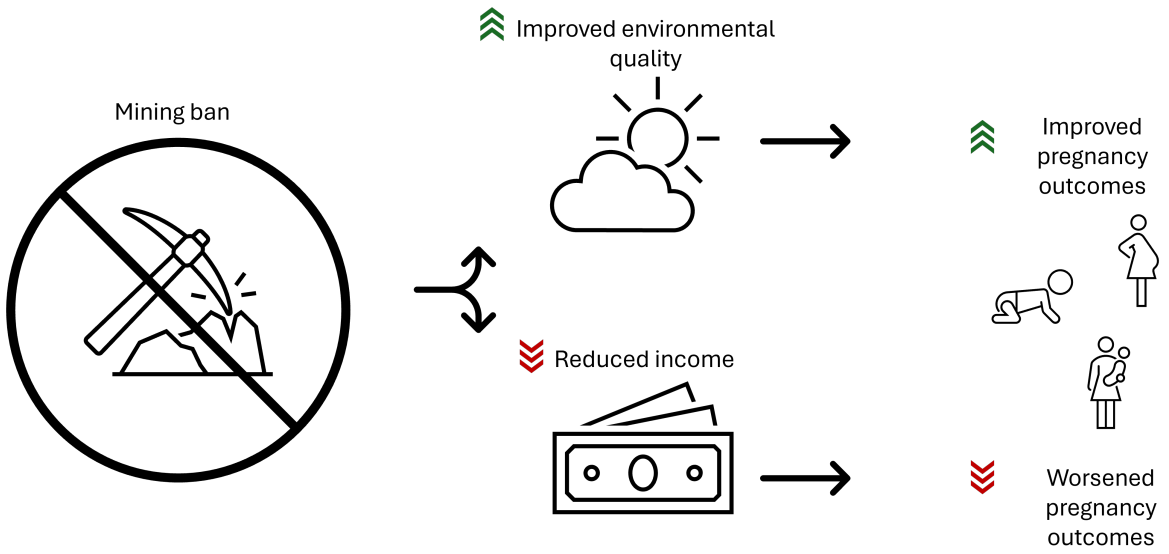


Figure 1: Hypothesized causal mechanisms linking the mining restrictions to changes in pregnancy outcomes. The mining restrictions reduce local incomes but improve environmental quality. Reduced incomes may have a negative impact on pregnancy outcomes, while improved environmental quality may reduce in-utero exposures to pollution and improve pregnancy outcomes. This research finds evidence for both channels (decreased income and improved environmental quality), and the overall effect is to improve pregnancy outcomes in districts where mining was banned.

we empirically evaluate the net effect of the restrictions on pregnancy outcomes against a null hypothesis of no effect.

Our empirical strategy compares pregnancy outcomes in districts subject to and adjacent to the mining restrictions with other districts in India in a difference-in-differences research design. We use data on pregnancy outcomes collected from the National Rural Health Mission (NRHM) and the Indian Human Development Survey (IHDS). The NRHM data collects information on district-level pregnancy-related variables in India from 2008 to 2015, while the IHDS surveyed women about their most recent pregnancy, allowing for the creation of a panel on pregnancy outcomes from 2001 to 2012. Treatment is defined as in-utero exposure to the mining restrictions, which could affect mothers' incomes and pollutant exposures. We estimate the impact of the mining restrictions on total births, stillbirths, medically terminated pregnancies, maternal anemia, and low birth weight.

Using a two-way fixed-effects model, we estimate that mining restrictions lead to a significant reduction in the number of stillbirths and low birth weight births for pregnant mothers in treated districts. We do not see statistically significant impacts on the number of medically terminated pregnancies or the likelihood of maternal anemia in treated districts. An event-study approach confirms that pre-treatment trends in outcomes for treated districts

were evolving similarly to those in control districts. We do not find evidence of improvements in any of our tested pregnancy outcomes for adjacent districts. In both treated and adjacent districts, we estimate that the mining restrictions significantly reduced total births, which is likely driven by decisions to delay fertility in response to income uncertainty.

These primary estimates suggest improvements in pregnancy outcomes, which could be driven by reductions in in-utero pollutant exposures or selective fertility if mothers whose incomes were affected by the mining restrictions decided not to have children. In the paper, we test whether these mechanisms were present by analyzing maternal incomes and air quality. First, we show using the National Sample Surveys that overall household consumption declined in districts subject to mining restrictions, consistent with a loss of mining income; however, we also show that the relative income quintiles of mothers *increased* in these districts, consistent with an income-selected fertility effect. In adjacent districts, we estimate a smaller negative impact on overall household incomes (not statistically significant) and a reduction in relative maternal income quintiles, potentially explaining the lack of impacts on pregnancy outcomes in adjacent districts.

Next, we analyze the impact of the mining restrictions on environmental quality using satellite-derived PM2.5 data. Iron ore is typically mined using open-pit methods that can result in additional air emissions from open drilling and blasting, as well as additional runoff into waterways. To test the environmental quality and consumption mechanism, we first estimate that the mining restrictions reduced PM2.5 concentrations by 0.93 $\mu g/m^3$ in the treated districts and 0.45 $\mu g/m^3$ in the adjacent districts. While particulate matter is only one dimension of environmental quality that may have improved, we see this estimate as useful in demonstrating the validity of our hypothesized channel of environmental quality improvement. Finally, we estimate the impact of the mining restrictions on reported fevers and coughs in the IHDS as a falsification test—we expect to see a reduction in coughs due to an improvement in air quality but not necessarily fevers. We find that during the restrictions, fewer coughs are reported relative to controls, while there is no effect on fevers.

The effects of resource extraction on health outcomes are of new interest given national commitments to net-zero carbon emissions pledges that are expected to reduce coal extraction in the coming decades. While India has pledged to achieve a 2070 net-zero carbon emissions goal (Birol and Kant, 2022), its state-operated coal mining company has recently expanded operations to meet increasing electricity demand (Varadhan, 2024). While not a perfect comparison, our paper sheds light on how declines in coal mining might influence local health outcomes even as miner's incomes decline. We discuss the implications of our findings for the energy transition at the conclusion of the paper.

This paper contributes to the economics literature that estimates the causal impacts of

economic activities and environmental exposures on health and pregnancy outcomes (e.g., Chay and Greenstone, 2003b; Currie and Neidell, 2005; Currie et al., 2009; Greenstone and Hanna, 2014). Our results complement the findings of prior work studying the impacts of mining on local incomes and pregnancy outcomes. Mining results in higher incomes in nearby communities (Aragón and Rud, 2013; Bazillier and Girard, 2020), but at a cost of increased local pollution that may result in worsened health outcomes and lower rent prices (Rivera, 2020). Income gains from mining have been shown to improve outcomes for women both in India (Guimbeau et al., 2023) and in developing nations in Africa (Benshaul-Tolonen, 2024). The three most closely related papers study the effects of mine openings and closings on health outcomes in developing countries. First, (Parker et al., 2016) find that Dodd-Frank Act restrictions on US imports of conflict minerals from the Democratic Republic of the Congo resulted in increased infant mortality due to reduced incomes. Von der Goltz and Barnwal (2019) find that active mines in developing countries increased local incomes but caused higher rates of anemia and stunted growth for children living nearby, outcomes which are consistent with heavy metals exposures. Benshaul-Tolonen (2019) estimates the impact of new gold mines on birth outcomes in Africa, finding that new mines improve local incomes and reduce infant mortality.

Our paper makes three key contributions relative to the existing literature studying the impacts of mining on birth outcomes in the developing context. First, Von der Goltz and Barnwal (2019) and Benshaul-Tolonen (2019) have relied on assumptions that a mine opening or closing is exogenous to local conditions and that there could not be anticipation of openings or closings. In our case, mining restrictions were assigned by surprise rulings by the Supreme Court of India, leaving little room for anticipation or endogeneity. The only other study we have identified that uses plausibly exogenous variation is Parker et al. (2016), which relies on mineral import restrictions in the US Dodd-Frank Act. Second, our paper is the first to provide evidence of income-selected fertility in response to a change in mining operations. While previous papers estimate a positive impact of mining on local incomes and Benshaul-Tolonen (2019) notes that fertility rates increased in response to new mines opening, our paper demonstrates both a reduction in fertility, a reduction in local incomes, and an increase in the average income quintile of mothers when mining was restricted. Third, our paper is the first to provide any evidence on the environmental exposure mechanism at play in the health versus wealth tradeoff. While the previous papers are motivated by the health versus wealth tradeoff, they assume that mining results in environmental exposures and do not provide evidence of these exposures.

The remainder of the paper is structured as follows. Section 2 provides background information on the mining restrictions, reviews relevant literature on the impacts of mining

activities on health outcomes, and introduces hypotheses based on the prior literature. Section 3 describes the datasets we use in our empirical analyses. In section 4 we estimate the impact of the mining restrictions on pregnancy outcomes. We explore evidence on the potential mechanisms of changes in incomes and pollution exposures in section 5. Finally, Section 6 concludes with a discussion of the policy implications of our results.

2 Background and Hypotheses

In this section, we describe the mining industry in Karnataka and the events leading to the iron ore mining ban. In addition, we lay out our hypothesized effects of the mining restrictions on incomes, environmental quality, and, ultimately, pregnancy outcomes, drawing on the existing literature on the impacts of mining on local outcomes. This section sets the stage for our empirical analyses of the effect of the mining restrictions on pollution levels and pregnancy outcomes in Karnataka.

2.1 Karnataka mining ban

One-third of India's iron ore reserves are found in Karnataka, according to the Indian Bureau of Mines.[2] The state produces export-oriented magnetite and hematite iron ore. These iron ore reserves are clustered in the Chitradurga, Bellary, and Tumkur districts of Karnataka. The iron ore mines in this area are open pit mines, and physical mining labor is done predominantly by men. Prior to the ban, there were 166 mining leases in the area—123 of which were later found to be in violation of mining regulations.[3] Following public interest litigation and concerns about illegal mining in 2010, the Karnataka government curtailed iron ore exports from the state. The following year, the Supreme Court of India heard arguments about the export restrictions and found evidence of substantial violations of mining lease terms and improper disposal of mine waste. Finally, in the summer of 2011, the court ordered a complete ban on the Chitradurga, Bellary, and Tumkur districts' iron ore mining operations, closing more than 150 mines.

Figure 2 shows the monthly level of iron ore production in Karnataka, demonstrating the impact of the mining restrictions on iron ore mining levels. The ban brought all mining activities in the region to an abrupt halt, displacing iron ore miners and substantially affecting the unskilled labor market (**?**). According to several surveys and estimates, more than 40,000-100,000 individuals employed directly and indirectly in the mining sector in

[2]Indian Minerals Yearbook published by IBM.

[3]Central Empowered Committee final report dated February 3, 2012.

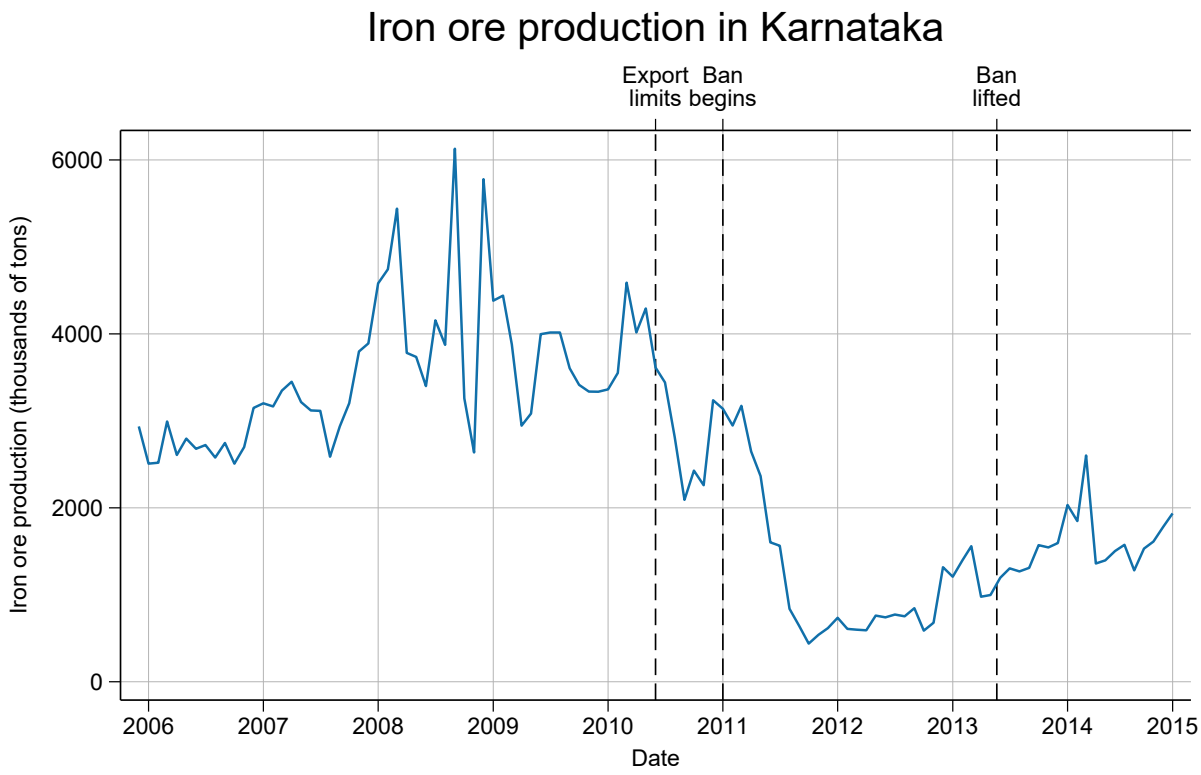


Figure 2: Monthly iron ore production in Karnataka, 2006-2015. Source: Indian Bureau of Mines

Karnataka found themselves out of work, exacerbating unemployment and economic distress in the region.[4]

In April 2013, the Supreme Court of India lifted the ban on iron ore mining in Karnataka with a production cap for each mine of 30 metric tons per annum. The ban on exports remained, and the level of iron ore production in Karnataka increased but remained low compared to the pre-ban period. In our study, we consider the 2010 export limits as the beginning of the restrictions on mining activities in Karnataka, as this was the first significant policy change that led to a reduction in iron ore production in the region.

2.2 Hypotheses and prior literature

Mining generates increases in incomes as well as worsened health outcomes due to increased environmental exposures. We hypothesize that the restrictions on mining may have impacted pregnancy outcomes for nearby mothers by reducing household income levels and by improving nearby environmental quality. Lower incomes may have worsened pregnancy

[4] https://pib.gov.in/newsite/PrintRelease.aspx?relid=78904

outcomes by reducing nutrition and access to prenatal care, while it is also possible that mothers whose incomes were affected decided to delay or avoid having children. Better environmental quality may have improved pregnancy outcomes by reducing in-utero exposures to pollutants linked to negative outcomes.

There is robust evidence in the existing literature that supports both the income and pollution mechanisms we hypothesize. The economic growth fueled by mining and natural resource extraction resulted in higher wages and standards of living for households living near mines. Expansion of a gold mine in Peru increased real wages and prices near the mine (Aragón and Rud, 2013). Higher gold prices lead to increased consumption for households living near artisanal gold mines in Africa (Bazillier and Girard, 2020). Kotsadam and Tolonen (2016) document that new mine openings in Africa lead men to take up higher-paying mining jobs while women shift from agricultural self-employment to the service sector. Rental prices were lower near mines in Chile, suggesting a compensating differential for pollution exposure (Rivera, 2020). In the case of the mining ban studied in this paper, **?** find that displaced mine workers shifted to agricultural labor and guaranteed government employment via the National Rural Employment Guarantee Act (NREGA), depressing agricultural labor wages by 25% for men. Overall, the restrictions led to a 20% decline in household consumption in the districts subject to restrictions and a 10% decline in household consumption in adjacent districts. We expect that these negative income shocks will work to worsen health outcomes in these districts.

At the same time, mining results in both reduced air and water quality in areas around mines. Waterways downstream of mines suffer from acidification with increased heavy metal content (Leblanc et al., 2000). While extracting minerals, a large amount of particulate matter, mist, and toxic gases such as SO_2 and NO_2 are generated in the mine pit (Zhang et al., 2013; Pandey et al., 2014). Mining workers and communities living around the mines are directly exposed to these pollutants. Exposure to certain chemicals and pollutants associated with mining, such as asbestos, arsenic, lead, and mercury, has been linked to an increased risk of lung cancer among miners (Donoghue, 2004; Wild et al., 2009). Rates of birth defects are higher for newborns with fathers employed in the mining industry Van Brusselen et al. (2020). Dumping of iron ore tailings, in particular, can result in loss of vegetation, soil erosion, water pollution, and air pollution (Thejas and Hossiney, 2022). Poor water quality caused by fracking has been shown to increase the prevalence of preterm birth and low birth weight (Hill and Ma, 2022).

The mining sector is one of the leading sources of air pollutants in the form of particulate matter (Juda-Rezler et al., 2011). Mining generates particulate matter that varies in size from less than 0.5 μM to greater than 500 μM (Ghose and Majee, 2007). Prolonged expo-

sure to these particulate matters can cause respiratory problems, gastrointestinal illnesses, kidney damage, neurological disorders, and death among mine workers (Hendryx and Ahern, 2008; Zanobetti and Schwartz, 2009; Huang et al., 2005). A growing economics literature has demonstrated causal links between particulate matter exposures and negative health outcomes. [5] Many of these studies have focused on infant and birth outcomes, finding that particulate matter exposures are linked to increased infant mortality (Chay and Greenstone, 2003a,b; Currie and Neidell, 2005; Greenstone and Hanna, 2014; Tanaka, 2015), lower birth weights (Currie et al., 2009), higher incidence of premature and high-risk births (DeCicca and Malak, 2020), and higher risk of stillbirth (Gehrsitz, 2017). Long-term exposure to air pollutants can be harmful to the body, resulting in stunted growth, and the effect can be irreversible (Balietti et al., 2022). Poor air quality has also been shown to lead to anemia for pregnant women due to its impacts on hemoglobin levels (Hwang and Kim, 2024; Datt et al., 2023; Chaudhary et al., 2022).

The existing literature comes to mixed conclusions on the net impacts of mining on health outcomes in developing nations. Using data from over 800 mines in 44 developing countries, Von der Goltz and Barnwal (2019) finds that mining increases wealth but has negative impacts on health. Pregnant mothers were more likely to be anemic, while children with in-utero exposures to mining were more likely to have stunted growth—both patterns consistent with increased lead exposures. For children living near mines but not exposed in utero, there were positive impacts on height. In contrast, Benshaul-Tolonen (2019) finds that African gold mines result in large income gains that also reduce infant mortality by over 50%, suggesting that the income improvements outweigh the pollution costs.

3 Data

We seek to test our hypotheses that the mining restrictions affected pregnancy outcomes via the channels of decreased income and reduced environmental quality. To do so, we collect data on pregnancy and health outcomes, household consumption, and air quality and use an estimation strategy that compares outcomes in districts subject to the mining restrictions and adjacent to the banned districts to other unaffected districts in India. We describe each data source below.

For our main pregnancy outcomes of interest, we use National Rural Health Mission (NRHM) Management Information System data. These data are obtained from health care clinic records and include yearly information on district-level outcomes for pregnant women,

[5] For a recent review of the literature on causal inference studies linking air pollution exposures to health outcomes, see Brewer et al. (2023).

birth outcomes, and infant health from 2008-2015 in 552 rural districts in India. Our main outcomes of interest are the fraction of stillbirths and medically terminated pregnancies. Stillbirth is defined as a non-live birth occurring after 28 weeks, while a medically terminated pregnancy is a pregnancy terminated due to medical reasons and is distinct from an elective abortion. The Medical Termination of Pregnancy Act of 1971 dictates that abortion can be carried out up to 20 weeks of gestation period if the registered medical practitioner finds that there is a substantial risk for the pregnant woman or the child to be born.

The NRHM data also include information on the number of mothers who tested positive for anemia during pregnancy and the average measured birth weight of live births in hospitals. The measurements of anemia and birth weight likely suffer from selection bias due to the large number of births and prenatal care that take place outside of hospital institutions. Anemia during pregnancy is very common in India, about 50 percent of pregnant women were found anemic in India in 2019.[6]

In addition, we use data from two rounds of the Indian Human Development Survey (IHDS), a nationally representative survey of about 200,000 individuals in more than 40,000 households in India. The first round of the survey was conducted before the restrictions in 2005-06, and the second round was conducted during the ban in 2011-12. Women answer questions about their most recent pregnancy, which allows us to construct a yearly panel of pregnancy outcomes from 2001-2012. The survey includes detailed information on self-reported pregnancy and health outcomes, including birth weight, anemia during pregnancy, and short-term medical conditions such as fever and cough. Maternal anemia can be affected by environmental exposures to air pollution and heavy metals that reduce blood hemoglobin concentrations and so is a primary outcome of interest. Similarly, birth weights have been linked to particulate matter exposures in prior research (Currie and Neidell, 2005). Finally, we analyze the effect of the restrictions on reported cough and fever as a falsification test. We expect environmental exposures to air pollution to potentially increase the prevalence of respiratory symptoms such as coughing, but we do not expect to see any impact on fevers.

Our analysis of the mining restrictions' effect on income utilizes the National Sample Surveys Office (NSSO) from 2007 to 2012. The NSSO data is a repeated cross-section of individuals who are geographically identified at the district level. In these surveys, households report their income levels in the prior 30 and 365 days, giving us two measures of household income. The one-year recall metric is likely to less precise due to recall error, while the one-month recall metric may be more variable due to short-term fluctuations in income.

To study environmental quality, we use high-resolution satellite-based PM2.5 data produced by (Dey et al., 2020). These data are high-resolution (1-km) ambient PM2.5 pollutant

[6] https://databank.worldbank.org/source/health-nutrition-and-population-statistics

monthly averages derived from aerosol optical depth from Moderate Resolution Imaging Spectroradiometer (MODIS) data using an algorithm. We match PM2.5 levels to village centroids from the census of India for 2005-2014. Mining may affect more dimensions of environmental quality than PM2.5 levels, so any estimated impacts on PM2.5 should be seen as a lower-bound estimate of the environmental impacts of the restrictions. Our goal in examining PM2.5 is to show that the mining restrictions were large enough to impact environmental quality and, therefore, provide evidence for improved environmental quality as a mechanism for changes in pregnancy outcomes.

Table 1 displays pre-restriction summary statistics for the restricted and adjacent districts and control districts. We observed that there was no statistically significant difference in our important outcome variables, stillbirths, medically terminated pregnancies, and the effect of immunization on infants in those mining districts compared to the rest of India.

4 Pregnancy outcomes

4.1 NRHM data

We first estimate the impacts of the mining restrictions on pregnancy outcomes using the National Rural Health Mission data. We estimate the average treatment effect of the mining restrictions on the treated (ATT) units using a two-way fixed effects strategy. Our outcome variables include the district-level log of total births, the logged number of stillbirths, the logged number of medically terminated pregnancies, the logged number of mothers who tested positive for anemia during pregnancy, and the logged number of newborns born under 2500 grams.

Our empirical strategy compares outcomes in the restricted districts and adjacent districts to unaffected districts before and after the mining restrictions in a difference-in-differences design. Our preferred empirical approach estimates effects on outcome $Y_{d,t}$ in district d and time period t for treated and adjacent districts in the following fixed effects specification:

$$Y_{d,t} = \mu_d + \lambda_{r,t} + \beta^{closure} Closure_{d,t} + \beta^{neighbor} Neighbor_{d,t} + \varepsilon_{d,t}, \tag{1}$$

where μ_d is a district fixed effect that controls for time-invariant confounders, $\lambda_{s,t}$ are year-by-region r indicators that allow for differential trends in pregnancy outcomes by Indian administrative zones (regional groups of states),[7] $Closure_{d,t}$ is a binary variable that is one for the three districts subject to the mining ban after restrictions on iron ore mining begin,

[7]Alternative specifications using state-by-year indicators provide similar average treatment effect estimates but reduce the precision of the event-study estimates. These results are available upon request.

Table 1: Pre-treatment period summary statistics comparing treated and adjacent districts with control districts in the rest of India

	(1) Treated/Adjacent districts Mean/SD	(2) Controls Mean/SD	(3) Difference Diff./t-stat
NRHM data:			
Log of stillbirths	6.271	5.578	-0.693***
	(0.740)	(1.381)	(-5.632)
Log of total reported deliveries	10.331	9.922	-0.409***
	(0.607)	(1.242)	(-4.025)
Log of newborn under 2.5 kg	7.912	7.656	-0.257**
	(0.657)	(1.723)	(-2.274)
Log medically terminated pregnancy	5.744	5.658	-0.086
	(0.948)	(1.704)	(-0.545)
Log of anemia	6.938	5.612	-1.327***
	(0.868)	(1.884)	(-8.844)
Observations	39	1768	1807
IHDS data:			
Size of infant (small=1)	0.326	0.173	-0.153***
	(0.469)	(0.378)	(-6.002)
Anemia among mothers	0.149	0.217	0.068***
	(0.356)	(0.412)	(3.485)
Income quintile of mothers	2.619	3.137	0.518***
	(1.377)	(1.424)	(14.363)
Fever (Y=1)	0.911	0.869	-0.043***
	(0.285)	(0.338)	(-2.937)
Cough (Y=1)	0.792	0.695	-0.098***
	(0.406)	(0.460)	(-4.708)
Observations	1513	42988	44501
NSSO data:			
Household Consumption in last 30 days	11096.991	14808.305	3711.314***
	(6424.535)	(11505.395)	(27.302)
Household Consumption in last year	15214.227	24074.433	8860.206***
	(28174.762)	(46445.043)	(14.880)
Observations	2269	460294	462563
Pollution data:			
PM 2.5 (μg/m^3)	46.460	58.517	12.057***
	(22.355)	(31.666)	(7.202)
Observations	180	38040	38220

NRHM and Pollution data is aggregated at the district level, IHDS data is an individual level panel, and NSSO data is a repeated cross-section at the household level. *** p<0.01, ** p<0.05, * p<0.10.

$Neighbor_{d,t}$ is a binary variable that is one for districts sharing borders with the affected districts in the post period, and $\varepsilon_{d,t}$ is a conditional-mean-zero error term. Ordinary least squares estimation of equation 1 will lead to unbiased estimates of the average treatment effect on the treated (ATT) units under standard parallel trends and conditional exogeneity assumptions. We cluster standard errors at the district level in this and all other specifications as this is the level at which treatment is assigned (Abadie et al., 2022).

Our empirical approach allows for heterogeneous impacts to districts directly subject to the mining restrictions versus districts adjacent to directly affected districts.[8] Districts directly subject to the mining restrictions may have experienced stronger environmental and local economic impacts as a result of the restrictions, but it is possible that some mine workers live in adjacent districts and that some environmental spillovers may be seen in adjacent districts. Our specification allows for this heterogeneity and is akin to common empirical strategies studying the impacts of mining on local outcomes that allow for impacts to vary by distance to a mine (Von der Goltz and Barnwal, 2019; Benshaul-Tolonen, 2019). Ultimately, a majority of our estimated impacts for adjacent districts are close to zero and statistically insignificant, but this specification excludes them from being controls in case of treatment spillovers.

Because iron ore export restrictions began in 2010 and the ban began in 2011, we consider 2010 the first year of exposure. We expect pregnancy outcomes to be affected for births with in-utero exposure to the restrictions. Thus, we define exposed pregnancy outcomes are births with any potential in-utero exposure to the mining restrictions. Some pregnancies with deliveries in the first few months of 2010 may be coded as "treated" by the mining restrictions, which means our estimates are attenuated toward zero due to measurement error.

[8]The mining restrictions were placed on three districts in Karnataka: Tumkur, Bellary, and Chitradurga. These districts are bordered by districts in Karnataka and Andhra Pradesh: Koppal, Raichur, Kurnool, Anantapur, Haveri, Gadag, Mandya, Chikmagalur, Davanagere, and Bangalore Rural. A typical travel time from the center of a restricted district to the center of an adjacent district is about one hour by automobile on Google Maps.

Table 2: Effect on pregnancy outcomes, NRHM data

	(1) Log Total births	(2) Log Stillbirths	(3) Log Medically Terminated Pregnancies	(4) Log Anemia	(5) Log Low Birth Weight
Post X Treated district	-0.134***	-0.652***	-0.261	-0.012	-0.129
	(0.027)	(0.221)	(0.169)	(0.292)	(0.227)
Post X Adjacent district	-0.230**	0.003	0.061	0.414*	0.050
	(0.099)	(0.143)	(0.249)	(0.230)	(0.107)
District FE	Yes	Yes	Yes	Yes	Yes
Year indicators	Yes	Yes	Yes	Yes	Yes
Region X Year	Yes	Yes	Yes	Yes	Yes
Obs.	4,871	4,836	4,593	4,302	4,871

Estimated on NRHM data where an observation is logged number of outcomes at the district and yearly level using equation 1. Coefficients can be interpreted as percentage changes after the transformation $100 \times (\exp(\beta) - 1)$. The number of observations varies due to unreported outcomes in some districts. Standard errors clustered at the district level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

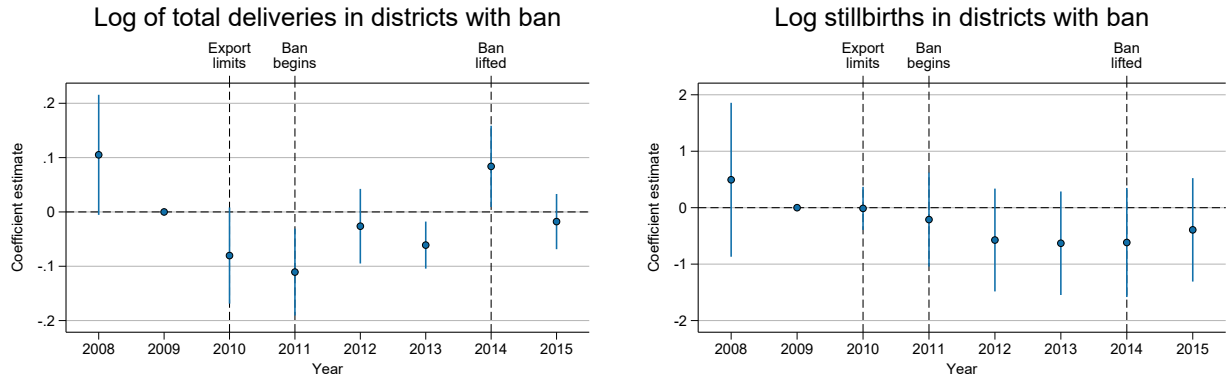
Table 2 presents our estimates of the ATT. We estimate that the restrictions resulted in a statistically significant reduction in logged total births and logged stillbirths in affected districts. Because we use logged outcomes, our estimates can be interpreted as approximate percentage changes, but using the transformation for the marginal effect, $\exp(\beta) - 1$, our estimates suggest that the restrictions reduced total births by 12.5% and stillbirths by 47.8% in treated districts. Our estimates for logged medically terminated pregnancies and logged low birth weight are large and negative but are not statistically significant, while our estimate for the logged number of anemic mothers is close to zero and not statistically different than zero. For adjacent districts, we see a reduction in logged total births of 20.5%, but no other statistically significant effects.

Given that we see a reduction in the number of total births, we considered the possibility that our estimated reductions in negative pregnancy outcomes are just an artifact of a reduced number of births. We do not find this to be the case. We consider an alternative specification that augments equation 1 with the logged number of births as an additional control variable, which would block the confounding backdoor channel of a change in the total number of births (Cinelli et al., 2022). We display the results of these regressions in table 8 in the appendix, but our coefficient estimates are similar to those in table 2 above.

We supplement our ATT estimates with an event-study approach that allows us to estimate dynamic treatment effects using the following baseline specification:

$$Y_{d,t} = \mu_d + \lambda_{r,t} + \sum_{\ell \neq 2010} \left[\beta_\ell^{closure} Closure_d \cdot 1(t = \ell) + \beta_\ell^{neighbor} Neighbor_d \cdot 1(t = \ell) \right] + \varepsilon_{d,t}, \tag{2}$$

where Ban_d is a binary variable that is one for the three districts subject to the mining ban, and $Adjacent_d$ is a binary variable that is one for districts sharing borders with the affected districts. These estimates will also allow us to examine the validity of the parallel trends assumption by looking at pre-treatment trends in outcomes in the treated and adjacent districts relative to the control districts.[9]



(a) **(b)**

Estimated on NRHM data where an observation is at the district and yearly level using equation 2 with 2009 as the omitted period. 95% confidence intervals derived from standard errors clustered at the district level.

Figure 3: Event-study estimates for (a) log of total deliveries and (b) log of stillbirths

Figure 3a and 3b display our event-study estimates for the logged total deliveries and logged stillbirths outcomes. Total deliveries decline when the ban begins but appear to recover by the final year of the ban with statistically significant reductions in 2011 and 2013. A reduction in total births could be caused by either fertility selection or by out-migration, but the dynamic pattern of these estimates is more consistent with fertility selection. An out-migration would result in a persistent decline in births, but we see an immediate short-lived reduction in births followed by a rebound increase after the mining ban was lifted. Stillbirths in districts with the ban show a decline from the baseline rate that increases in magnitude as the ban continues and decreases in magnitude as the ban ends, but none of the coefficients is precisely estimated. Given our lack of precise ATT estimates for medically terminated pregnancies, anemic mothers, and low birth weight infants, we relegate the event study estimates for these outcomes to the appendix along with our estimates for adjacent districts. For all outcomes in districts with mining restrictions, we do not see any evidence that suggests the parallel trends assumptions are likely to be violated.

[9]In addition, we plot the raw values of outcome variables that we observe in multiple time periods in appendix section A.

4.2 IHDS data

We supplement our analysis of the NRHM data using data from the IHDS. The IHDS includes self-reported health conditions from a broad sample of households surveyed in repeated cross sections in 2005-06 (pre-ban) and 2011-12 (during the ban), but mothers recall information about their last birth, which allows us to construct a panel of births for mothers who reported giving birth from 2001-2012. Our empirical strategy is similar to that used with the NRHM data, but we include a set of indicator variables for districts that interacted with the interview year to control for any effect of the mining restrictions on recall bias. Our estimating equation is:

$$Y_{i,d,t,y} = \mu_d + \lambda_{r,t} + \eta_{d,y} + \beta^{closure} Closure_{d,t} + \beta^{neighbor} Neighbor_{d,t} + \varepsilon_{d,t}, \tag{3}$$

where Y_i, d, t, y is the outcome of interest for mother i in district d who gave birth in year t and was interviewed in period y. $\eta_{d,y}$ are district-by-interview year fixed effects that control for any effects contemporaneous with the interview that might affect recall bias, and all other variables are as defined in equation 1. The outcomes we analyze are a survey question asking if the infant was small at birth, and a survey question asking if the mother was anemic during her last pregnancy.

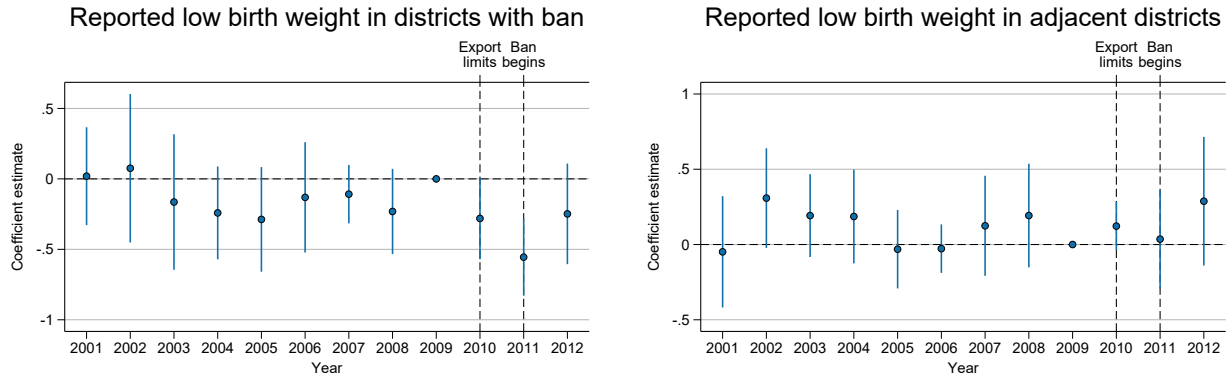
Table 3 displays our estimates of the ATT for the IHDS data. We find that the mining restrictions reduced the likelihood of an infant being small at birth by 21.2 percentage points, which is large considering that prior to the mining restrictions, 31 percent of births were reported as small in districts subject to the mining restrictions. We do not find any statistically significant effects on the likelihood of a mother being anemic during her last pregnancy.

We also estimate an event-study version of equation 2. We display our event-study estimates for the size of the infant in figure 4. We find statistically significant declines in reported birth weights in 2010 and 2011, and we see a negative coefficient in 2012 that is not statistically significant. For adjacent districts, we do not see the same patterns. In addition, we do not see any evidence that the parallel trends assumptions are likely to be violated. For anemia, we display our event-study estimates in figure 13 in the appendix, which are not statistically significant.

Table 3: Effect on pregnancy outcomes, IHDS data

	(1) Low birthweight	(2) Anemic mother
Post X Treated district	-0.212**	0.104
	(0.093)	(0.063)
Post X Adjacent district	0.054	0.301***
	(0.089)	(0.097)
District FE	Yes	Yes
Survey date X district	Yes	Yes
State X birth year	Yes	Yes
Obs.	12,987	12,999

Estimated on IHDS data where an observation is a reported birth by a mother in a given year. The outcome variable for low birth weight is an indicator equal to one if the mother reported that the baby had a small or very small birth weight while the outcome variable for anemia is an indicator equal to one if the mother reported she was anemic during her pregnancy. Standard errors clustered at the district level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.



(a) **(b)**

Estimated on IHDS data where an observation is a reported birth by a mother in a given year with 2009 as the omitted period. The outcome variable is an indicator equal to one if the mother reported the baby had a small or very small birth weight. 95% confidence intervals derived from standard errors clustered at the district level.

Figure 4: Event-study estimates for reported low birth weight births estimated on IHDS sample.

5 Mechanisms

Our findings in the previous section indicate a substantial reduction in unfavorable pregnancy outcomes for households in districts where iron ore mining was banned. We hypothesized that pregnancy outcomes could be influenced via the income and environmental quality

channels. In this section, we examine the effect of the mining restrictions on household consumption, the income quintile for mothers, and satellite-measured PM2.5 concentrations.

5.1 Household consumption

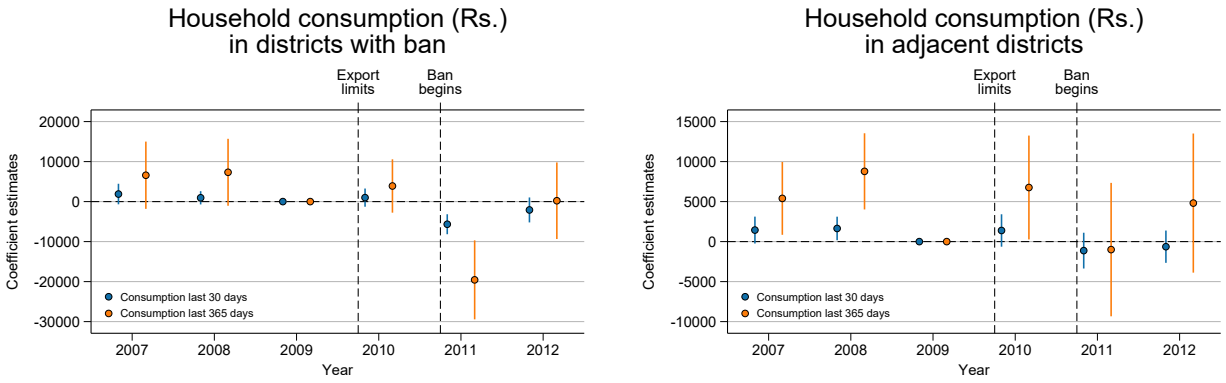
We use the National Sample Surveys from 2007 to 2012 to find the effect of the mining restrictions on household consumption. Given that many people in the region were directly employed in the mining sector or were employed in related sectors, we expect to see a reduction in household incomes and, therefore, consumption. We estimate the ATT for household consumption using equation 1 and the dynamic treatment effects using equation 2. There are two measures of household consumption in the data. One question asks about household expenditures in the last 30 days and the other question asks about household expenditures in the last 365 days. The National Sample Surveys are conducted in January-June in even-numbered years and July-December in odd-numbered years, so the observations in 2010 are just prior to the restrictions in mining and serve as our omitted category.

We present our average treatment effect estimates in table 4. We find that based on 30 days recall, the household consumption for districts subject to mining restrictions reduced by about Rs. 5000, and the household consumption in neighboring districts declined by about Rs. 2000. The estimates for 365 days recall are not as precise, but we find similar trends that overall household consumption declined. We display our estimates of the dynamic treatment effects in figure 5, which demonstrate parallel trends prior to the mining restrictions and a decline in reported consumption after the ban, particularly in the 30-day estimates.

Table 4: Effect on household consumption, NSSO data

	(1) Consumption last 30 days	(2) Consumption last 365 days
Post X Treated district	-3481.067***	-10662.060**
	(979.058)	(4341.337)
Post X Adjacent district	-1155.179	-1130.553
	(725.657)	(2274.439)
District FE	Yes	Yes
State X Month	Yes	Yes
Obs.	864,976	864,976

Estimated on NSSO data where an observation is a household consumption level in Rupees reported by a survey respondent in a given month. The two outcome variables ask the value of what the household consumed in the last 30 days and the last 365 days. Standard errors clustered at the district level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.



(a) **(b)**

Estimated on NSSO data where an observation is a household consumption level in Rupees reported by a survey respondent in a given month. The two outcome variables ask the value of what the household consumed in the last 30 days and the last 365 days. 95% confidence intervals derived from standard errors clustered at the district level.

Figure 5: Two-way fixed effects Event-study estimates (equation 2) for household consumption in Rupees.

5.2 Income quintile of mothers

A family can adjust fertility decisions in response to realized or expected income changes. While we show that the mining restrictions reduced incomes on average, we hypothesize that families who experienced income reductions may have decided to forego or postpone fertility. This self-selection into fertility could mean that incomes for mothers were not affected in the same way as average incomes. If low-income mothers whose incomes were affected by the ban delayed fertility, we would expect to see the incomes of mothers increase relative to prior years.

To test our hypothesis, we estimate the effect of the mining restrictions on the income quintile of mothers $= \{1, 2, ...5\}$ using the IHDS dataset. We use the same empirical specification we used to estimate the impact of the mining restrictions on self-reported birth weights and anemia in our earlier analysis of the IHDS data (equation 3). We do not observe mothers' incomes in the year of their last birth, so our outcome variable is the income quintile of mothers during the year they responded to the IHDS survey. Our fixed effects strategy includes survey-year-by-district indicators as controls, so any contemporaneous effect of the mining restrictions is absorbed into this set of indicator variables. In addition to the linear regression estimates, we report estimates from a Poisson pseudo-maximum likelihood regression to account for the fact that the income quintile takes on a finite number of values.

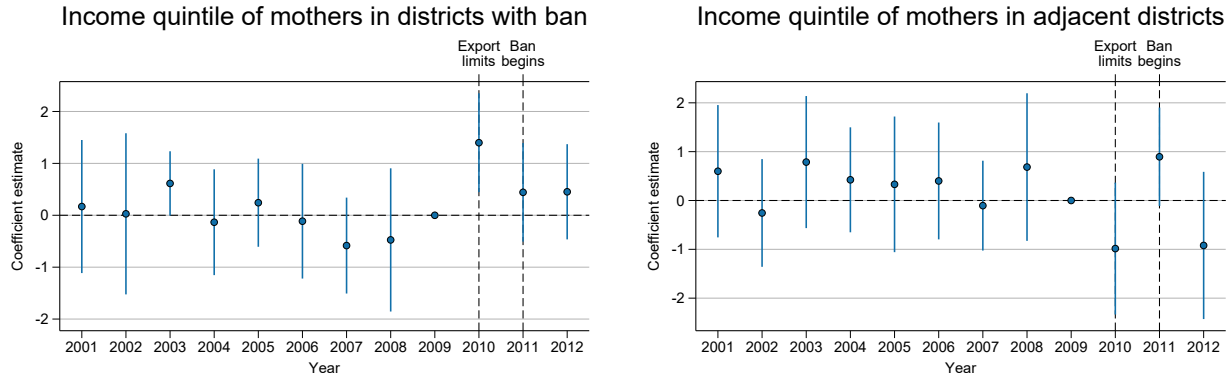
Table 5 displays our estimates, which suggest that mothers in treated districts had incomes that were 0.56 quintiles higher after the mining restrictions relative to control districts. For adjacent districts, we estimate that the income quintiles of mothers were 0.61 quintiles

Table 5: Effect on mother's income quintile, IHDS data

	(1) Income quintile of mothers OLS	(2) Income quintile of mothers Poisson
Post X Treated district	0.566***	0.169***
	(0.161)	(0.045)
Post X Adjacent district	-0.612**	-0.191**
	(0.237)	(0.078)
District FE	Yes	Yes
Survey date X district	Yes	Yes
State X birth year	Yes	Yes
Obs.	19,055	19,055

Estimated on IHDS data where an observation is a reported birth by a mother in a given year. The outcome variable is the mother's income quintile = $\{1, 2, ...5\}$ at the time of the survey. Column 2 reports Poisson coefficients, which have marginal effects of 0.50 for treated districts and -0.56 for adjacent districts. Standard errors clustered at the district level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

lower after the mining restrictions relative to control districts. The Poisson regression estimates are similar: districts subject to restrictions saw a 0.50 quintile increase while adjacent districts saw a 0.56 quintile decrease.



(a) **(b)**

Estimated on IHDS data where an observation is a reported birth by a mother in a given year with 2009 as the omitted period. The outcome variable is the mother's income quintile = $\{1, 2, ...5\}$ at the time of the survey. 95% confidence intervals derived from standard errors clustered at the district level.

Figure 6: Event-study estimates for mothers' income quintiles estimated on IHDS sample

Next, we estimate an event study regression to evaluate the parallel trends assumption and test for temporal heterogeneity. Figure 6 displays our estimates for treated and adjacent districts. For districts with mining restrictions, we see a large statistically significant increase in income quintile for mothers in the year the export limits began, but this effect gets smaller

in the subsequent two years and is not statistically significant. This pattern is consistent with low-income mothers delaying fertility in expectation of reduced household incomes. For adjacent districts, the pattern is less clear. We see a large decrease in the average quintile of mothers in 2010, followed by a similar magnitude increase in 2011 and a decrease again in 2012. Given the inconsistent pattern and wider confidence intervals, we recommend caution in interpreting the adjacent district estimates.

If the relative income quintile of mothers increased, it is possible that other characteristics of mothers changed due to endogenous fertility decisions based on education or age. We also estimated the impact of the ban on the age of mothers, education of mothers, and education of spouses. We find no statistically significant impact of the ban on the composition of mothers along these dimensions in the districts where mining was restricted. We display these estimates in appendix section D.

We hypothesize that these compositional changes in mothers' incomes could have also lead to changes in prenatal care utilization.[10] We estimate the effect of the ban on a binary variable for whether a mother received prenatal care and the number of prenatal care visits. Our estimates are close to zero and not statistically significant, so we cannot reject the null hypothesis that prenatal care consumption was the same for mothers in treated districts during the mining restrictions relative to the controls. These estimates are displayed in appendix section E.

5.3 Environmental quality

In this section, our goal is to estimate some of the environmental quality improvements caused by the mining restrictions by examining satellite data on PM2.5 concentrations. While this will not be a complete characterization of all of the potential environmental improvements, we see this as an important demonstration that the mining restrictions had a large enough impact on environmental quality to influence pregnancy outcomes. Thus, our estimated impacts on PM2.5 should be thought of as a lower-bound estimate of the impact of the mining restrictions on environmental quality.

To identify the impact of the mining restrictions on air quality in affected and adjacent districts, we estimate the ATT and dynamic treatment effects using similar two-way fixed effects regression specifications to those outlined in equations 1 and 2, but replacing region-by-year trends with state-by-month trends to control for state-specific trends in particulate matter concentrations. As controls in these regressions, we include logged maximum

[10] A reduction in prenatal care utilization is the main mechanism identified by Parker et al. (2016) who found that reduced US imports of conflict minerals resulted in higher infant mortality in communities near affected mines.

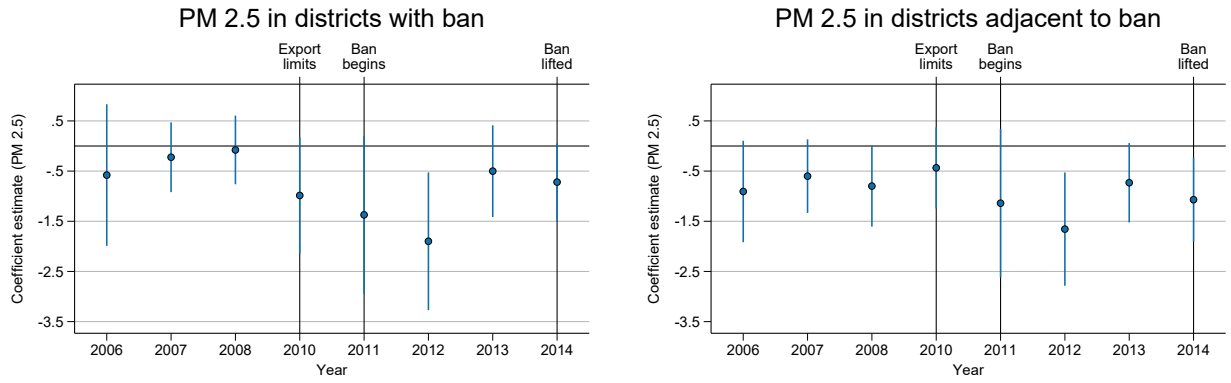
temperature and precipitation.

Table 6: Effect on PM2.5 concentration

	(1)	(2)	(3)
Post X Treated district	-2.74***	-2.67***	-0.91***
	(0.12)	(0.25)	(0.26)
Post X Adjacent district	-2.50***	-1.95***	-0.53**
	(0.13)	(0.30)	(0.21)
District FE	Yes	Yes	Yes
Time indicators	Yes	Yes	
State X Time indicators			Yes
Weather controls		Yes	Yes
Obs.	76,440	72,283	72,063

Outcome variable is monthly PM2.5 concentration (μg/m^3) in a district, so estimates are changes in PM2.5 concentration caused by the mining restrictions in treated and adjacent districts. Weather controls include logged maximum temperature and precipitation. Robust standard errors clustered at the district level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 6 displays our estimates of the effect of the mining restrictions on PM2.5 levels in the treated and adjacent districts using several different fixed effects control strategies. Our preferred approach is column 3, which includes both weather controls and state-by-time indicators, which allows for different PM2.5 seasonality by state. We estimate that the mining restrictions reduced PM2.5 concentrations by 0.91 μg/m^3 in the treated districts and 0.53 μg/m^3 in the adjacent districts. This is a substantial effect with sizeable implications for pregnancy outcomes. To put this into perspective, a 0.91 μg/m^3 decline would result in a 0.82% reduction in infant mortality, using the dose-response relationship for developing nations estimated by Heft-Neal et al. (2018).



(a) **(b)**

Notes: Two-way fixed effects (equation 2) event-study estimates with 95% confidence intervals accounting for clustering at the district level.

Figure 7: Estimated dynamic treatment effect on air pollution (PM2.5)

Figure 7 displays the event-study estimates of the impact of the mining restrictions on particulate matter concentrations. These figures show no violation of the parallel trends assumption for either affected or adjacent districts. Moreover, both sets of results show declines in PM2.5 concentrations that peak at a 1.6 μg/m^3 reduction in 2012. We see that even in 2014, after the ban was lifted, estimated PM2.5 levels were lower relative to controls. This is likely due to the lower level of mining even after the ban was lifted (see figure 2) and the fact that mines that were permitted to resume mining were those following mining regulations.

5.4 Other health outcomes consistent with environmental quality channel

As a falsification test, we evaluate the impact of the mining restrictions on the self-reported incidence of fever and cough in the past 30 days using the IHDS survey. We expect an improvement in environmental quality (such as a reduction in PM2.5 concentration) to have an effect on upper respiratory conditions such as a cough, but we do not expect the restriction to affect the prevalence of fevers. At the same time, it is possible that an improvement in general health or healthcare services in these districts may have been spuriously correlated with the mining restrictions, which would result in reductions in both reported fevers and coughs. Thus, we expect to observe a statistically significant decrease in coughs alone as consistent with an environmental quality improvement, while there should be no change in the prevalence of fever.[11]

[11] A similar falsification test with reported fevers is conducted by Von der Goltz and Barnwal (2019).

We estimate the impact of the mining restrictions on reported cough and fever using the full IHDS sample in the pre-mining-restrictions survey round (2005) and during-mining-restrictions round (2012) in a similar specification to that in equation 1. We present results from a regression without additional controls as well as a regression that includes a control for household income. Table 7 presents the ATT estimates for both outcomes. We estimate a statistically significant decrease in the prevalence of reported coughs but not reported fevers. The addition of income as a control does not affect our estimates substantially, suggesting that income changes from the mining restrictions are not driving the results. This finding is consistent with our hypothesized mechanism of an improvement in environmental quality.

Table 7: Effect on fever and cough

	Fever	Fever	Cough	Cough
Post X Treated district	0.01	0.01	-0.14**	-0.14**
	(0.07)	(0.07)	(0.06)	(0.06)
Post X Adjacent district	0.06*	0.06*	-0.01	-0.01
	(0.03)	(0.03)	(0.06)	(0.06)
District FE	Yes	Yes	Yes	Yes
Survey date X State	Yes	Yes	Yes	Yes
Income control		Yes		Yes
Obs.	168,899	168,899	168,899	168,899

Estimated on full IHDS sample with one pre-ban and one during the ban period. Outcomes are individual-reported fever and coughs in the past 30 days. Standard errors clustered at the district level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

6 Conclusion and Discussion

This paper studied the effects of mining on nearby pregnancy outcomes by analyzing the 2010-2013 restrictions on iron ore mining in Karnataka, India that resulted in over 150 iron ore mines shutting down. We hypothesize that mining restrictions might either improve pregnancy outcomes by reducing exposure to pollution from mining or worsen pregnancy outcomes by reducing incomes for mothers. We collect data on pregnancy outcomes from the National Rural Health Mission and Indian Human Development Survey to estimate the impact of the mining restrictions on pregnancy outcomes directly. We supplement these datasets with income data from the National Sample Survey and satellite-derived particulate matter to find evidence for our hypothesized mechanisms.

Our estimates suggest that these restrictions resulted in large reductions in stillbirths (47.8%) and the fraction of births with low birth weight (21.2%) in the districts where mining

was restricted. We do not observe statistically significant impacts on medically terminated pregnancies or maternal anemia. Our event study estimates suggest that the reductions in negative pregnancy outcomes were generally largest during the period when most mining was fully banned in the districts.

As mechanisms for these effects, we find evidence for income-selected fertility but this does not appear to be the main driver of the improvement in pregnancy outcomes. First, we estimate a 12.5% reduction in total births during the restriction period, which suggests that some portion of our estimated reduction in negative pregnancy outcomes may have been due to choices to delay or forego fertility decisions or by out-migration after the mining restrictions. Out-migration would result in a persistent decline in births, but instead, we see an immediate short-lived reduction in births followed by a rebound increase after the mining ban was lifted, a pattern more consistent with fertility selection. In addition, although we show that average household incomes decreased during the mining restrictions, the average income quintiles of mothers increased at the same time. This suggests that women with lower household incomes who were affected by the mining restrictions may have decided not to have children. Our event-study estimates suggest that both the reduction in fertility and the income selection are strongest at the beginning of the restriction period, while the improvements in pregnancy outcomes only occur later after the ban begins. Ultimately, the magnitude of the reduction in fertility and temporal mismatch between estimated selection effects and health improvements suggests that this mechanism cannot fully account for the improvement in pregnancy outcomes.

We also find evidence of an improvement in air quality concentrated in districts where mining was restricted. Our estimated impact of the mining restrictions suggests that PM2.5 concentrations declined by 0.91 $\mu g/m^3$ in the treated districts and 0.53 $\mu g/m^3$ in the adjacent districts. Furthermore, our event-study estimates show that the peak improvements in air quality coincided with the improvements in pregnancy outcomes. A 0.91 $\mu g/m^3$ reduction in PM2.5 concentration is sizable, but may not be nearly large enough to account for the large improvements in pregnancy outcomes during the restrictions alone; however, particulate matter concentration is only one dimension of the environment that is affected by mining. Mining can result in releases of SO_2, NO_2, and other harmful gases. Mining can also affect water quality, resulting in heavy metal exposure. Thus, we see our PM2.5 estimates as suggestive evidence for a number of other changes in environmental exposures that may have improved pregnancy outcomes.

These findings contrast with previous research on the impacts of mining on birth and health outcomes in developing countries. While our results are consistent with the general findings of Von der Goltz and Barnwal (2019) that mines negatively affect local health

outcomes, our results differ in that we do not see any impact on anemia. Our findings differ more from those of Parker et al. (2016) and Benshaul-Tolonen (2019) whose findings suggest that mining improves birth outcomes. Parker et al. (2016) find that US mineral import restrictions increased infant mortality in communities near affected mines in the Democratic Republic of the Congo by 143%, which they attribute to income losses and reduced consumption of health care services by affected mothers. In our case, we do not see evidence that mining restrictions reduced prenatal care utilization (appendix section E). Similarly, Benshaul-Tolonen (2019) shows that the opening of gold mines in Africa resulted in a 50% reduction in infant mortality due to large increases in incomes—a similar magnitude finding to ours, but in the opposite direction. One potential explanation for this is that mine closures may affect outcomes differently than openings. Given that the infant mortality reduction estimates in Benshaul-Tolonen (2019) diminish over time, new mines may affect the environment less than old mines. It is possible that it takes time for contaminants to seep from mines or accumulate to dangerous levels in the downstream, so negative effects through environmental channels may occur later.[12] More generally, mine openings and closings are unlikely to have symmetric effects. Another reasonable explanation is that the exposures from the gold mines in her study were cleaner relative to the iron mines in this study. While both gold and iron mining in these contexts are open-pit, the mines in India were being shut down due to environmental concerns in the first place as the mining operators violated ore extraction, dumping, and storage norms. These considerations suggest that the balance of health versus wealth impacts of resource extraction likely vary depending on the local context and institutional settings as suggested by Greenstone and Hanna (2014).

Our findings have important implications for India's energy transition and the potential closure of coal mines in the coming decades. As India pursues its 2070 net-zero carbon emissions goal, a significant reduction in coal mining is expected. While the closure of coal mines may lead to economic challenges similar to those observed in our study of iron ore mining restrictions, our results suggest that there could be substantial health benefits, particularly for pregnant women and infants in mining regions. The improvements in air quality and subsequent positive impacts on pregnancy outcomes that we observed in Karnataka could potentially be replicated in coal mining regions.

[12]Over time, the contaminants slowly infiltrate into the groundwater or soil through surface runoff and leachate caused by tailings (Gleekia et al., 2016).

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A Parallel Trends

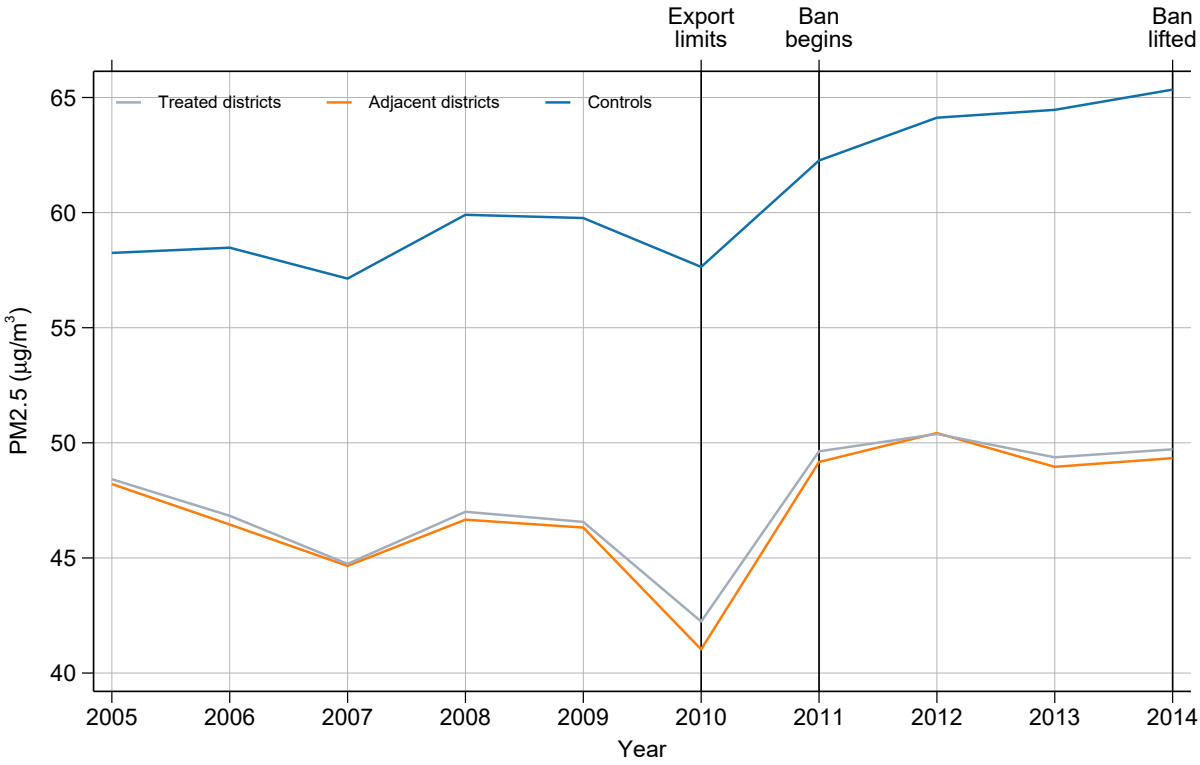


Figure 8: PM2.5 levels in restricted and adjacent districts relative to control districts, 2005-2014.

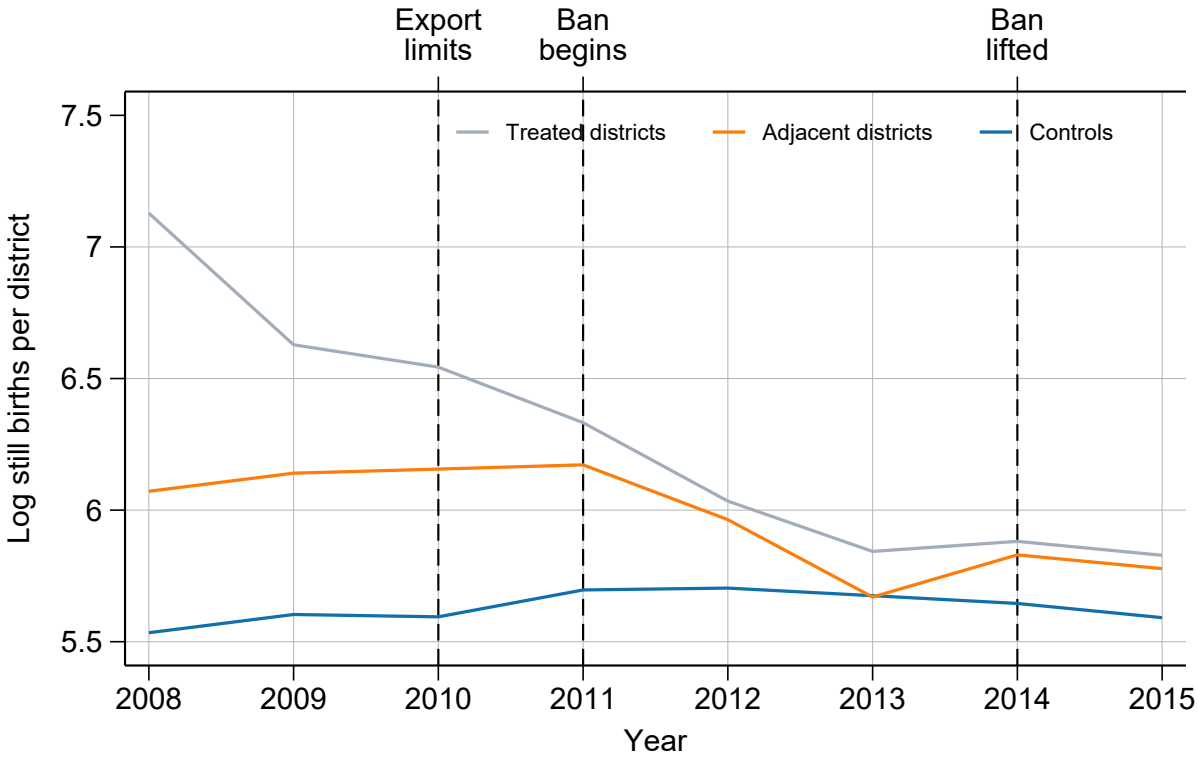


Figure 9: Percentage stillbirths in restricted and adjacent districts relative to control districts, 2008-2015.

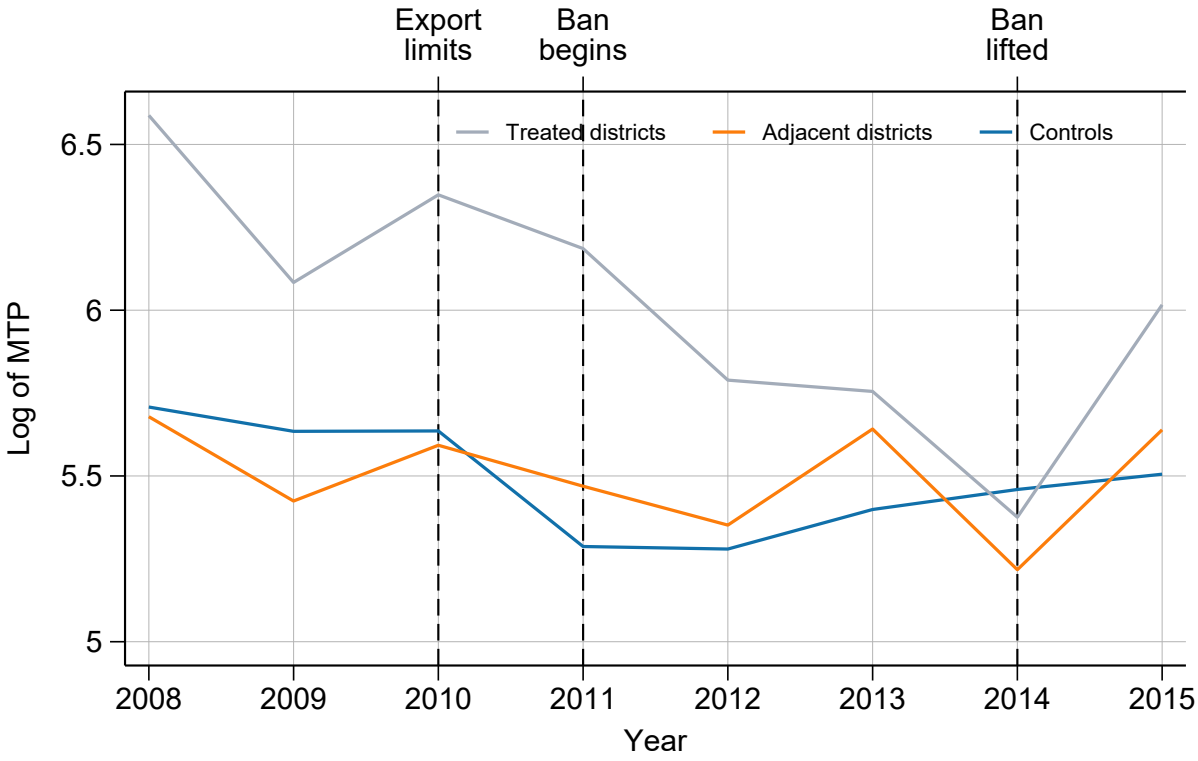


Figure 10: Log of medically terminated pregnancies (MTP) in restricted and adjacent districts relative to control districts, 2008-2015.

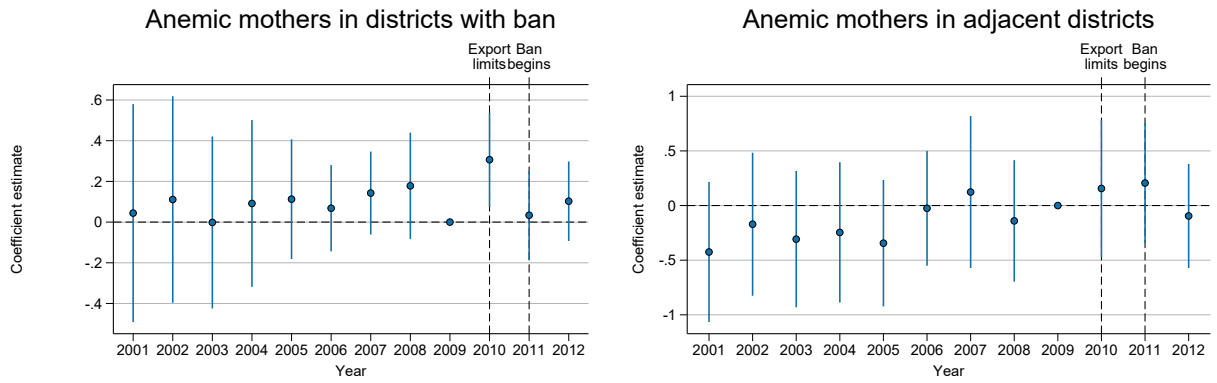
B Robustness checks

Table 8: Effect on pregnancy outcomes, controlling for total births

	(1) Log Total births	(2) Log Stillbirths	(3) Log Medically Terminated Pregnancies	(4) Log Anemia	(5) Log Low Birth Weight
Post X Treated district	-0.134***	-0.606***	-0.260	-0.020	-0.093
	(0.027)	(0.208)	(0.165)	(0.276)	(0.224)
Post X Adjacent district	-0.230**	0.102	0.086	0.482**	0.126
	(0.099)	(0.154)	(0.255)	(0.237)	(0.113)
Log of total reported delivery		0.551***	0.244***	0.713***	0.414***
		(0.066)	(0.094)	(0.136)	(0.069)
District FE	Yes	Yes	Yes	Yes	Yes
Year indicators	Yes	Yes	Yes	Yes	Yes
Region X Year	Yes	Yes	Yes	Yes	Yes
Obs.	4,871	4,836	4,593	4,302	4,871

Estimated on NRHM data where an observation is at the district and yearly level using equation 1. Coefficients can be interpreted as percentage changes after the transformation $100 \times (\exp(\beta) - 1)$. The number of observations varies due to unreported outcomes in some districts. Standard errors clustered at the district level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

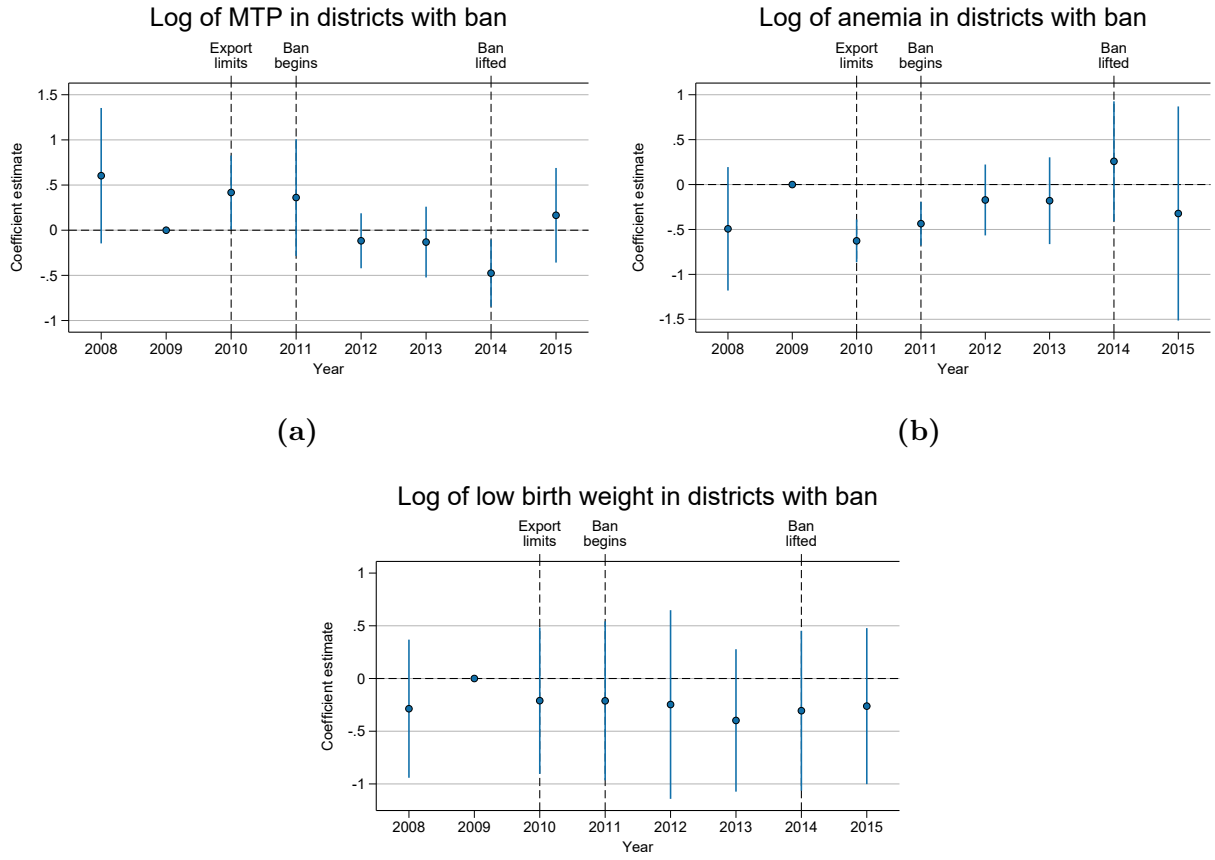
C Additional event study figures



(a) **(b)**

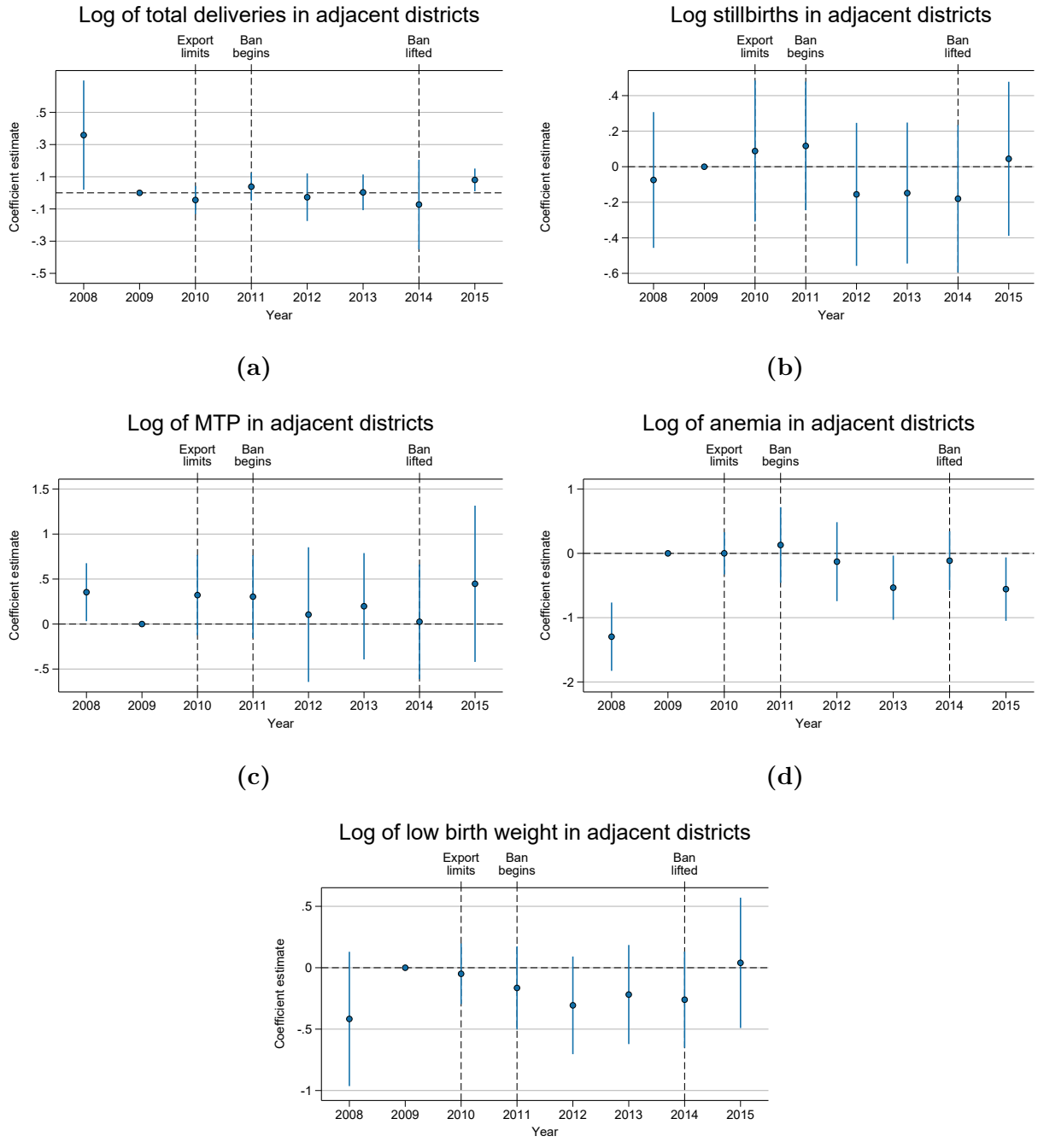
Estimated on IHDS data where an observation is a reported birth by a mother in a given year with 2009 as the omitted period. 95% confidence intervals derived from standard errors clustered at the district level.

Figure 13: Event-study estimates for reported anemia during pregnancy estimated on IHDS sample.



Estimated on NRHM data where an observation is at the district and yearly level using equation 2 with 2009 as the omitted period. 95% confidence intervals derived from standard errors clustered at the district level.

Figure 11: Event-study estimates for (a) log of medically terminated pregnancies, (b) log of anemic mothers, and (c) log of low birth weight infants



Treated districts are adjacent to those where mining was restricted. Estimated on NRHM data where an observation is at the district and yearly level using equation 2 with 2009 as the omitted period. 95% confidence intervals derived from standard errors clustered at the district level.

Figure 12: Adjacent district event-study estimates for (a) log of total deliveries, (b) log of stillbirths, (c) log of medically terminated pregnancies, (d) log of anemic mothers, and (e) log of low birth weight infants

D Composition of mothers: Age and education

Table 9: Age at birth and education of mothers and spouses

	(1) Mother's age	(2) Mother's years educ	(3) Mother's literacy	(4) Spouse's years educ	(5) Spouse's literacy
Post X Treated district	2.530	-0.830	-0.195	1.238	-0.045
	(2.364)	(1.786)	(0.176)	(1.408)	(0.138)
Post X Adjacent district	-2.051	1.577**	0.228**	0.573	-0.073
	(2.826)	(0.748)	(0.094)	(0.732)	(0.097)
District FE	Yes	Yes	Yes	Yes	Yes
Survey date X district	Yes	Yes	Yes	Yes	Yes
State X birth year	Yes	Yes	Yes	Yes	Yes
Obs.	19,311	19,270	19,290	18,647	17,749

Estimated on IHDS data where an observation is a reported birth by a mother in a given year. Outcomes are the age of the mother at birth and years of education and literacy rate for mothers and spouses. Standard errors clustered at the district level.

E Prenatal care

Table 10: Effect on prenatal care

	(1) 1(Prenatal care)	(2) # Prenatal visits
Post X Treated district	0.010	-0.172
	(0.037)	(1.205)
Post X Adjacent district	0.247*	-0.141
	(0.147)	(0.653)
District FE	Yes	Yes
Survey date X district	Yes	Yes
State X birth year	Yes	Yes
Obs.	13,008	12,220

Estimated on IHDS data where an observation is a reported birth by a mother in a given year. Outcomes are a binary indicator for whether the mother had prenatal care and a variable equal to the total number of prenatal visits. Standard errors clustered at the district level.