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The local health impacts of natural resource booms

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Abstract

This paper uses novel micro-data on natural resources and administrative health data in Brazil to study how economic booms in minerals affect health at birth. By implementing a reduced-form estimation of shift-share research designs, the identification strategy relies on the exogeneity of global commodity prices to municipality-specific health outcomes. I find that, following changes in international prices, municipalities with historically more endowments have a higher number of premature births and births with low Appearance, Pulse, Grimace, Activity, Respiration scores. The impacts are primarily driven by metallic minerals. Instead, industrial minerals do not appear to have any effect on birth outcomes. Even though booms in metallic minerals generate benefits through resource windfalls—by increasing wealth and generating economic opportunities—the investigation of mechanisms reveals that they also result in costs—due to pollution—which seem to prevail. Hence, some metallic minerals remain a curse more than a blessing.

KEYWORDS
birth outcomes, economic booms, minerals

1 | INTRODUCTION

Many low- and middle-income countries are endowed with a variety of natural resources, such as crops, minerals, and oil. Over the 2000s, the rise in commodity prices played an important role in driving the economic growth of these countries (McMahon & Moreira, 2014). Booms in production increased wealth and economic opportunities (Aragon et al., 2015), but the net impacts on population health are still under-studied. Do natural resource booms benefit or harm the health of local communities? This paper explores the relationship between natural resources and local economic development in the context of an emerging economy, namely Brazil. It focuses on the 2000–2010 decade, when the commodity price cycle and abundant capital inflows played a key role in improving the country's economic performance. By studying the trade-off between benefits and costs that economic booms in minerals generate, this paper provides evidence of the mechanisms through which different types of minerals affect birth outcomes.

There are different economic and biological channels behind the mechanisms through which booms in mineral resources can affect health at birth (Almond et al., 2018).

On the one hand, booms in natural resources can benefit local economies through *resource windfalls* and *economic opportunities*. Increased mining activities could lead to more governmental resources through royalties. If municipalities were to invest this wealth in public health goods local economies would benefit (Aragon & Rud, 2013; Asher & Novosad, 2016). Similarly, booms in natural resources might create job opportunities (Kotsadam & Tolonen, 2016), and the income could be used on health investments for mothers and children, or could be spent on nutritious food.[1] Through these mechanisms, and the economic and health channels behind them, the health of mothers and thus of their children are expected to ameliorate.

On the other hand, booms in mineral resources could deteriorate health at birth through two main mechanisms. The former mechanism is related to new job opportunities created locally. The first economic channel behind this mechanism concerns the *opportunity cost of time* that newly employed mothers face: More time spent at work could cause lower investment in children's health (Miller & Urdinola, 2010). A second biological channel concerns *maternal stress* due to her or her husband's job conditions. In fact, the biological literature provides evidence that maternal stress is associated with worse birth outcomes (Arnetz et al., 1991; Thompson, 2014; Van den Bergh et al., 2005; Weinstock, 2005).[2,3]

The latter mechanism is related to *pollution*: Water and air pollution, and soil contamination from industrial waste as a result of increased mining activities could pollute and degrade the environment, consequently producing adverse birth outcomes (Anshasy & Katsaiti, 2015; Currie & Schmieder, 2009; Currie et al., 2009; Currie, 2013; der Goltz & Barnwal, 2018; Jayachandran, 2009; Romero & Saavedra, 2016; Stieb et al., 2012). The biological literature shows that both prenatal and postnatal exposure of mothers to pollution can contribute to worse outcomes. Prenatal exposure affects fetal development through two biological mechanisms: Pregnant women are exposed to air pollutants and/or toxins and this interferes with their health, which in turn disrupts fetal nutrition and oxygen flow; or, some pollutants and/or toxins could directly cross the placenta.[4] Postnatal exposure to pollution contributes to infections for mothers, causing worse birth outcomes.[5]

By exploiting within-municipality variation over a long time period, this paper assesses whether and how changes in the global prices of minerals affect health disproportionately in municipalities with historically higher endowments of these natural resources.

The identification strategy relies on the reduced-form estimation of the shift-share approach inspired by the work on Bartik instruments (see Goldsmith-Pinkham et al., 2020 for a review). Specifically, my empirical approach fits well into the framework developed by Borusyak et al. (2022), which argues that shift-share designs provide causal estimates as long as the time-series shocks are exogenous to local economic conditions. In my context, I argue that global commodity prices are exogenous to municipality-specific health outcomes, as single municipalities have typically too-small endowments or production capacity to influence international market prices. I further ensure that the assumption of exogeneity of the shock holds by using as main specification one that excludes the few municipalities accounting for a significant share of global endowments in specific minerals of which Brazil is a top worldwide exporter. As also illustrated in Borusyak et al. (2022), this empirical approach is especially well-suited in panel-data settings like the one I study, characterized by several periods and a large number of shocks, in which it is possible to control for both location and time fixed effects.[6]

Using novel data on 40 types of minerals produced from 1996 to 2010, and by exploring the richness of health administrative data, I provide causal evidence of the net local impacts on indicators of population health: infant mortality, birth weight, gestational length, indicators of brain development, and anomalies at birth. The data availability in Brazil also allows me to investigate the mechanisms at play, studying the trade-off between benefits and costs that resources create, for different types of minerals (metallic and industrial).

The first part of the analysis describes the net impacts on health. Following an increase in international prices, municipalities with higher endowments of mineral resources experienced negative impacts on birth outcomes. The estimates show an increase in premature births and births with low Appearance, Pulse, Grimace, Activity, Respiration (APGAR) scores. The results are driven by metallic minerals, while industrial minerals do not appear to have any effect. Additional analysis across selected metallic minerals shows that the health effects are positive for economic booms in minerals that generate royalties through taxation and for which there is no consistent evidence of pollution, such as aluminum and iron ore. Instead, in line with past research, some untaxed polluting minerals such as lead, chromium, and cadmium remain more a curse than a blessing. More importantly, for other minerals such as manganese, copper and gold, for which the pollution channel is established in the literature but that also generate royalties, the impacts on health at birth remain negative on average. This suggests that, despite potential benefits from resource windfalls, the costs of pollution seem to prevail.

The second part of the analysis explores the mechanisms at play which help explain the health effects observed. First, economic booms in natural resources make municipalities richer through royalties. I find evidence that resources increase local Gross Domestic Product (GDP), government expenses, including health expenditures, and investment in public health goods. Second, economic booms in natural resources generate job opportunities which materialize in higher employment, wages, and household income. There is no evidence that the positive economic impacts from increased job opportunities are mitigated by a higher opportunity cost of mothers' time. Instead, estimates show a higher utilization of health services. Given the improved household conditions, I argue that lack of nutritious food or job-related maternal stress should not play a role in explaining the worse outcomes.

Instead, the results show that natural resource booms increase emissions of nitrous oxide (N_2O) and sulfur dioxide (SO_2), both of which are related to mining activities. In line with the pollution channel, there is also suggestive evidence that hospitalizations for children under 1 year old related to prenatal conditions increase. Altogether, the findings highlight how a trade-off exists at the municipality level between the benefits and the costs that economic booms in mineral resources create locally. Yet, most of the metallic minerals remain more a curse than a blessing for children's health.

This paper contributes to the following strands of the literature. First, it contributes to the studies on the effect of natural resources on economic development. This literature finds a negative relationship between natural resource abundance and GDP at the country level (Corden & Neary, 1982; Gylfason et al., 1999; Leite & Weidmann, 1999), the so-called "curse" for countries rich in resources (Sachs & Warner, 1995). However, more recent studies challenged the past empirical approaches used, and show that this relationship can disappear or be reversed (Brunnschweiler, 2008; van der Ploeg & Poelhekke, 2009). An emerging literature, which exploits intra-country rather than across-country variation, provides evidence of impacts of natural resources on local economic growth (Douglas & Walker, 2016; Papyrakis & Gerlagh, 2007) and living standards (Allcott & Keniston, 2018; Aragon & Rud, 2013; Bernstein et al., 2022; Black et al., 2005; Jacobsen and Parker, 2014; Kotsadam & Tolonen, 2016; Marchand, 2012; Michaels, 2011).[7] However, the studies focus on oil, and a paucity of those provide evidence from low- or middle-income countries. The data gathered from Brazil allows me to build on this empirical literature, by extending the analysis on 40 types of mineral resources. Furthermore, by exploiting the richness of administrative data, this study provides evidence on a broader range of indicators of health at birth, still under-investigated in the literature.

Second, this paper adds on a dearth of studies linking socio-economic impacts of mining on health, such as APGAR score at birth (Romero & Saavedra, 2016) for gold, and women's anemia (der Goltz & Barnwal, 2018) for lead. While these studies confirm the negative spillovers of pollution, another study (Benshaul-Tolonen, 2019) finds a decrease in infant mortality after the opening of gold mines. By not limiting the analysis to one specific mineral and/or to one specific health outcome, this paper draws a broader picture of the whole trade-off between positive and negative channels of impact, distinguishing between types of minerals (metallic and industrial) and exploring a wide range of outcomes. In addition, leveraging international price variation and the rich geographical heterogeneity, I estimate the effects on the local communities at the more aggregate level of a municipality, rather than comparing areas close and far from the mines (Aragon & Rud, 2013; Kotsadam & Tolonen, 2016; der Goltz & Barnwal, 2018; Benshaul-Tolonen, 2019).

Third, this study relates to the literature exploring the relationship between business cycles and health (Bellés-Obrero & Castello, 2018). Several studies investigate recessions and mortality outcomes, but a small set focuses on short-term economic expansions or other measures of health at birth. In line with evidence from developed (Aparicio & González Luna, 2013; Dehejia & Lleras-Muney, 2004) and developing (Baird et al., 2011; Bhalotra, 2010; Bozzoli & Quintana-Domeque, 2014; Paxson & Schady, 2005) countries, this study finds that the measures of health at birth explored are *countercyclical*, while health-care utilization is *procyclical*. As little is known about the precise mechanisms of this relationship (Bellés-Obrero & Castello, 2018), it is worth noting that the deterioration of health following natural resource booms is not due to the increase in the opportunity cost of time during the economic expansion, but it is primarily driven by pollution.

The remainder of the paper is organized as follows. Section 2 describes the background on mineral resources in Brazil and their potential health effects. Section 3 presents the data sources. Section 4 describes the identification strategy, sample, main results and robustness checks. Section 5 provides evidence of the different channels of impact. Section 6 concludes.

2 | BACKGROUND

2.1 | Natural resources in Brazil

Brazil is one of the most geographically diverse countries in the world. Not only is it approximately 8.5 million kilometers in size, making it the largest country in South America and the fifth largest in the world, but it also ranked seventh in the world for GDP at R$2.4 trillion in 2013. Gross Domestic Product per capita has grown since 1995, consolidating its position as a middle-income country (World Bank Group, 2013). Brazil has made outstanding progress in poverty reduction, with the proportion of the population living on less than USD 1.25 per day falling from 7.2% to 3.8% between 2005 and 2012. Nevertheless, over one-half of households live with per-capita income at or below the minimum wage, and, the income distribution remains one of the world's most uneven. The abundance of natural resources along with the rise in commodity prices in the 2000s, contributed to the country's recent growth.

During the early 21st century there was a rise in the price of many commodities, including oil, metals, fuels, food and chemicals, due to the increased demand from emerging markets such as Brazil, Russia, India, and China (BRIC), and to concerns over long-term supply availability (Erten & Ocampo, 2013).[8] The price of precious metals such as gold and silver increased since people were saving in stocks. Similarly, the prices of aluminum, copper and other metals increased due to the rise of electronics industries. This paper focuses on the 2000–2010 decade and the role that mineral resources played for the economic growth in Brazil.

Brazil's mineral sector includes industrial minerals, metals, and fossil fuels. The mining industry in Brazil not only contributes a significant part to the annual GDP (4.1% in 2013), but was also responsible for the trade surplus until a crisis in 2014–2016 (Caputi et al., 2019; KPMG Global Mining Institute, 2015). According to the Ministry of Mines and Energy, after reaching US$53 billion in 2011, the mining industry has been on a continuous decline. In 2014, the production was much lower at US$43 billion, with the share of the main minerals over the total value produced being: 60.7% for iron ore; 19.0% for construction aggregates; 5.2% for gold; 4.2% for copper; 2.0% for nickel and aluminum, while other minerals accounted for less than 2%. Brazil is one of the world's largest producers of iron ore, manganese, aluminum and tin, and one of the largest exporters of gold and producers of copper. It is self-sufficient for limestone, industrial diamonds, tungsten, and talc, while it imports or produces potassium, diatomite, zinc, and rare-earth minerals (KPMG Global Mining Institute, 2015; Ministry of Mines and Energy, 2013).

Mining activities receive the same tax treatment applied to other economic activities. Mining exploration and exploitation are subject to regular federal and state corporate tax regimes. The first source of income is the Financial Compensation for the Exploration of Mineral Resources (CFEM), which is a royalty for the economic exploration of mineral resources created by the Brazilian Constitution. The CFEM is collected by the federal government which is responsible for the distribution of the tax to states where the mineral was extracted (23%) and to municipalities where the production occurs (65%), keeping the remaining 12%. Section 6 of Law 7, 990/89 states that the CFEM can be charged at up to 3% of the net income arising from sales of minerals, obtained after the last stage of processing and before industrial transformation.[9] Until 2017, a 3% rate was applicable for aluminum, manganese, rock salt, and potassium; a 2% rate was applicable for iron ore, copper, fertilizer, mineral coal, and other mineral substances; a 0, 2% rate was applicable for gemstones, colored cuttable stones, carbonate, and precious metals; and a 1% rate for gold.[10]

In some states, a state tax is also present. The control, monitoring and supervision of research activities, mining, exploration and exploitation of mineral resources fee (TRFM) is a state tax applicable in Minas Gerais, Pará, Amapá, and Mato Grosso do Sul, which considers the tons of mineral mined, onto which is applied a fixed BRL amount, and set annually by the states. In practice, municipalities, which are the geographical level considered in the analysis, receive most of the revenues primarily from CFEM.

2.2 | Existing evidence on health impacts of minerals

I follow the standard classification of mineral resources as (1) metallic and (2) industrial minerals (Figure 1).

As summarized in Appendix Table A1, among *metallic minerals*, the existing medical and public health literature finds causal evidence of negative health effects of lead (der Goltz & Barnwal, 2018) on stunting, and of gold on low APGAR scores (Romero & Saavedra, 2016).[11] The literature also suggests that minerals such as cadmium, chromium, copper, manganese, and tin might have negative effects on newborns. Instead, research on other metallic minerals, such as aluminum, iron ore, tantalum, vanadium, and zinc, is limited, especially on birth outcomes. Present studies either focus on adults, suggesting negative health effects on the worker population, or they are still at the animal stage. Other research shows no effects on human health for tungsten, zirconium, and rare-earth minerals.

Among *industrial minerals*, studies find evidence of negative health effects, but they are limited to animals or adult workers in mining sites. Most of the industrial minerals, including asbestos, barite, beryllium, graphite, gypsum, feldspar, perlite, talc, and pyrophyllite, are associated to respiratory diseases, lung diseases, and breathing problems. However, I did not find studies on health at birth. For other industrial minerals, there is a lack of evidence on health effects.

3 | DATA

The empirical analysis combines different data sources.

3.1 | Health data

First, the study relies on data on health outcomes and access to health-care which are publicly available from the Brazilian Ministry of Health (DATASUS). Data on mortality are constructed from the Brazilian National System of Mortality Records (SIM), which gathers information on deaths officially registered in Brazil; infant mortality is defined as deaths that occurred

(1) METALLIC MINERALS
Aluminium, Cadmium, Chromium, Cobalt, Copper, Gold, Iron Ore, Lead, Lithium, Manganese, Nickel, Rare Earths, Silver, Tantalum, Tin, Tungsen, Vanadium, Zinc, Zirconium
(2) INDUSTRIAL MINERALS
Asbestos, Barite, Beryllium, Clays, Diamond, Diatomite, Graphite, Gypsum, Feldspar, Fluorspar, Kyanite, Lime, Mica, Perlite, Quartz, Rubber, Sand and Gravel, Stone-crushed, Stone-dimension, Sulfur, Talc and Pyrophyllite

FIGURE 1 Categorization of minerals. The figure describes the categorization of 40 minerals used in the analysis. The values of the mineral index (MI) were winsorized at 99th percentiles for aluminum, gemstones, lime, potassium chloride, quartz, stone dimensions and fertilizer. This resulted in the exclusion of gemstones, potassium chloride, and fertilizer since these minerals were only present in 21, 6 and 4 municipalities.

before the child turned 1 year old. Low-weight births (below 2.5 kg), premature births (less than 37 weeks), births with congenital anomalies, and indicators of low APGAR score at birth at 5 minutes are constructed from the System of Information on Life Births (SINACS).[12] I also used SINACS to define Crude Birth Rate (CBR) and births with antenatal care (ANC) visits. Data on the female population and births by mother's age are used to construct measures of the Total Fertility Rate (TFR). The variables are expressed in 1,000 births.

A potential concern with health administrative data is non-random measurement error since the registration of deaths or births could be incomplete. Yet, significant advances have been made since the 1990s and the data are commonly used by researchers investigating child health in Brazil (Bhalotra et al., 2016; Fujiwara, 2015; Gamper-Rabindran et al., 2010; Koppensteiner & Manacorda, 2016; Rangel and Vogl, 2019).[13] In addition, a robustness check includes state-by-year fixed effects to control for potential time trends in improvements in registration at the state level (Bhalotra et al., 2016), and I account for municipality-specific linear time trends to capture differential improvements by municipality in the measurement of health outcomes.

A related issue is potential measurement error in the number of low-weight births, since some literature (Blanc & Wardlaw, 2005; Boerma et al., 1996; Channon et al., 2011) suggests that birth weight is subject to heaping. Yet, this indicator is a well-validated measure that is often used in research, also in Brazil (Bhalotra et al., 2016; Fujiwara, 2015).

3.2 | Mineral endowments and prices

Data on metals and industrial minerals were manually collected from the "Anuario Mineral" paper reports of the Brazilian National Department of Mineral Production (DNPM). The reports describe reserves of minerals, dividing them into three categories in a decreasing level of confidence: measured, indicated and inferred.[14] This analysis uses the most accurate category, that is, measured endowments. Yearly data on total measured reserves were obtained for all municipalities with positive mineral endowments between 1996 and 1998 and then standardized to the same unit (tons). Zero values were assigned to those municipalities which did not have mineral endowments before the beginning of the panel data.

Data on international commodity prices were gathered from the World Bank Global Economic Monitor (GEM) commodities database. The prices for each natural resource were matched to the mineral endowments by the name of the commodity. However, since GEM data include a broad category of "minerals and metals", the prices for each category were supplemented using the U.S. Geological Survey Science Data Catalog (USGS) to have a specific price for each type of mineral. All units of measure are standardized to U.S. dollars per ton. The final dataset for analysis comprises 40 types of minerals with yearly reserves predating the study period (1996–1998) and price data over a decade (1999–2009).

3.3 | Other data

Several variables were constructed to explore the mechanisms from the following data sources: (i) the Brazilian Institute of Geography and Statistics (IBGE), which collects data on population, GDP, and value of exports; (ii) Brazil's National Treasury through the Ministry of Finance (FINBRA) database, which collects data on revenues, expenses and transfers from taxes; (iii) the National Register of Health Facilities (CNES), which gathers data on health facilities and personnel (Rocha et al., 2018); (iv) the Relacao Anual de Informacoes Sociais (RAIS), a survey of all formal establishments collected by the Ministry of

Labor, which provides information on employment and payroll; (v) the population Census in 2000 and 2010, which include employment, wages, and household income; (vi) Emission Dataset for Global Atmospheric Research, which uses nationally reported emissions combined with regional scientific inventories in the format of gridmaps at 0.1 × 0.1° resolution, and contains: (1) direct greenhouse gases, (2) ozone precursor gases, and (3) acidifying gases per geographic areas, as defined by the Kyoto Protocol in the two years of 2000 and 2008. The data were reconstructed to match each municipality and expressed in tons per year.[15] The analysis considers air pollutants potentially linked to activities such as Methane (CH_4) and N_2O as "greenhouse gases", Carbon Monoxide (CO) as "ozone precursor gases", SO_2 as "acidifying gases".

Appendix Table B1 presents descriptive statistics on the main outcome variables, while Appendix Table B2 describes mineral endowments and prices. In the 2000s, each municipality in the sample has an average population of 36,000. About 36% of people are employed, and 17% are reported employed in the formal sector, and their average monthly household income is BRL 1,031 ($248). As far as health is concerned, premature births (60.9/1000) and underweight births (73.2/1000) are frequent, while births with low APGAR scores (34.8/1000) and births with anomalies (5.76/1000) are less common. Infant mortality is 18 deaths per 1000 births. On average, each municipality has 85.5 health facilities and 743.3 health personnel per 100,000 people. Municipalities spend on average BRL 23 million each year, mostly for health (BRL 8.34 million) or education (BRL 8.74 million). They also receive BRL 23.8 million of transfers from the federal government. In terms of minerals, the average municipalities had about 303,600 tons of minerals between 1996 and 1998, and the average price change they experience year-to-year is a decrease of 5164 USD. However, there is variation among metals and industrial minerals: Over the study period, the price of industrial mineral declines, while the price of metals increases.[16]

4 | THE IMPACT OF MINERAL ABUNDANCE ON HEALTH

4.1 | Identification

The empirical strategy assesses whether changes in mineral prices affect health disproportionately in municipalities that historically have more endowments of these resources. Time variation comes from movements in annual prices. Cross-section variation comes from historical mineral endowments across different municipalities.

For each commodity in each municipality, I construct an annual mineral index (MI) that captures its natural resources endowment between 1996 and 1998 times the (yearly) current international price. Specifically, let $M_{km,96-98}$ be the average endowment of mineral k in municipality m between 1996 and 1998, and let P_{kt} be the international price at time t. Thus, the annual MI for mineral k in municipality m in year t is the local mineral endowments times international prices: $MI_{kmt} = M_{km,96-98} {*} P_{kt}$. Given the variety of minerals, I construct a measure of the index for each municipality, summing up each single MI for the minerals present in the municipality (MI_{mt}). The index is then standardized, subtracting the mean and dividing by the standard deviation to ease the comparison across different types of minerals. A change in the index is then represented by a change in 1 unit, that is, 1 standard deviation.[17]

To study the effects of natural resource booms on health, I estimated the following empirical model:

$$y_{mt} = \alpha_m + \delta_t + \beta MI_{mt-1} + \epsilon_{mt-1} \tag{1}$$

The unit of observation is at the municipality-year, where y_{mt} captures various measures of municipality health outcomes in municipality m and year t, and α_m and δ_t are municipality and year fixed effects, respectively. Standard errors are clustered at the level of the municipality to account for potential serial correlation within municipalities.[18]

I study how changes in the MI (at $t-1$) at the municipality level affect health outcomes 1 year later (at t). I investigate the impacts on health at birth for children that were conceived or were in utero at the time of the mineral price change. The changes in mineral price at $t-1$ potentially affect the production of minerals at t. Changes in the mineral production might then impact health at birth for newborn children at t. Equation (1) captures the differential effect of mineral prices on municipality health outcomes, approximately 1 year later.[19]

The identification strategy relies on the reduced-form estimation of the shift-share approach inspired by the work on Bartik instruments (Adao et al., 2019; Borusyak et al., 2022; Goldsmith-Pinkham et al., 2020; Jaeger et al., 2018), and builds on recent empirical studies which use similar indexes (Bernstein et al., 2022; Dube & Vargas, 2013; Rozo & Vargas, 2021). My approach closely resembles the setting studied by Borusyak et al. (2022), who argues that the exogeneity of the time-series shocks is a sufficient condition for identification, and particularly so in panel-data settings with several periods and a large number of shocks that allow for the inclusion of both location and time fixed effects. More specifically, in my context, mineral endowments measure the differential exposure to common shocks, that is, changes in international prices. The strategy in fact exploits within-municipality variation over time driven by exogenous fluctuation in global commodity prices to study how such shocks affect local birth outcomes.

The causal identification relies on the exogeneity of the shocks, as Borusyak et al. (2022) show that the Bartik estimator is numerically equivalent to a shock-level regression. I argue that global commodity prices are exogenous to municipality-specific health outcomes, since single municipalities have typically too-small endowments or production capacity to influence international market prices. We might be concerned that some municipalities do indeed drive fluctuations in global commodity prices, as Brazil is one of the top worldwide producers and exporters of few minerals such as iron ore, manganese, aluminum, tin, copper, and gold. To alleviate such a concern, I adopt a conservative approach where I exclude from my main specifications all municipalities that, in any given year, constitute a significant share (more than 1%) of the global mineral endowments.[20]

I further report robustness tests where I consider the plausibility of cross-sectional endowment shares being themselves exogenous. The exogeneity of shares is an attractive identifying assumption in standard Bartik contexts where the time-series variation (e.g., change in national industry employment) is likely endogenous to local conditions (Goldsmith-Pinkham et al., 2020). In my context, where I primarily rely on the exogeneity of shocks, such an assumption is not necessary. Nonetheless, I provide evidence strengthening the robustness of the findings, by only using average reserves of minerals at the beginning of the data sample (1996–1998) as cross-sectional exposure, under the assumption that historical endowments are determined by the exogenous spatial distribution of natural resources and are therefore unlikely to reflect endogenous discovery or extraction efforts that might be correlated with population health. I implement a few empirical tests in Section 4.4.1, as suggested by Goldsmith-Pinkham et al. (2020).

4.2 | Sample

Over the study period, the data contained 5,570 unique municipalities. However, some municipalities changed over the years either because of the borders being redefined, or municipalities being merged or divided. The primary analysis sample consists only of the 4,965 municipalities which remained the same over the period of interest (2000–2010). However, robustness checks with the full sample of municipalities are also presented.

In the analysis sample, each municipality in Brazil covers an area of about 1500 square kilometers. I define municipalities by type based on the total revenues from mineral reserves between 1996 and 1998. In 2000, about one third of the municipalities (1,047) have positive endowments (Figure 2) and this is pretty stable over time: 70% are endowed only with industrial minerals, about 20% only with metallic minerals, and about 10% with both. The main analysis is implemented using the sample of constant municipalities, assigning zero values to those municipalities which do not have endowments between 1996 and 1998.

4.3 | Main results

Table 1 describes the main effects of changes in international prices of minerals on health outcomes, for municipalities with different levels of reserves. I find that a 1 standard deviation increase in the MI increases premature births and births with low APGAR scores. The results are driven by metallic minerals, while there is no impact for industrial minerals. However, the estimates on industrial minerals are similar or bigger in magnitude than the ones for metallic minerals for most of the health outcomes (columns 1–4), but they are imprecize. This might be due to the fact that there is lower variation in international prices of industrial minerals (Appendix Figure C2) compared to metallic ones (Appendix Figure C1). Results are also robust correcting for multiple hypothesis testing (see adjusted p-values reported in Table 1).[21]

The use of the standardized MI allows the comparison of the estimates across different categories of minerals. However, it renders the interpretation of the magnitude of the coefficient less straightforward. Before normalization, the mean value of the MI is about USD 435.3 million, with a standard deviation of USD 2.37 billion (Table B2, Panel A). 1 standard deviation represents about 1.5 times the total of USD 1.57 billion, which is a price change of 5163$—the average year-to-year price change of minerals in the data (Table B2, Panel D)—for a municipality with an average mineral endowment of 303,600 tons (Table B2, Panel B). Taking as example premature births (Table 1, column 3), 1 standard deviation increase in the MI increases premature births by 0.887, representing a change of 1.5% over the mean of 60.91. Then, for a municipality with an average mineral endowment of 303,600 tons between 1996 and 1998, an average price change of 5163$ each year increases premature births by 0.66 times the coefficient, that is it increases premature births by 0.59, that is, about 1% over the mean. A similar interpretation could be drawn for the other coefficients in Table 1: The effects represent 1.4% over the mean for births with low APGAR score; 0.3% for infant mortality; 0.3% for low weight births; and 1.4% for births with anomalies.[22]

FIGURE 2 Geographical distribution of minerals. The figure describes the geographical distribution in mineral reserves in the year of 2000 for all municipalities in Brazil. [Colour figure can be viewed at wileyonlinelibrary.com]

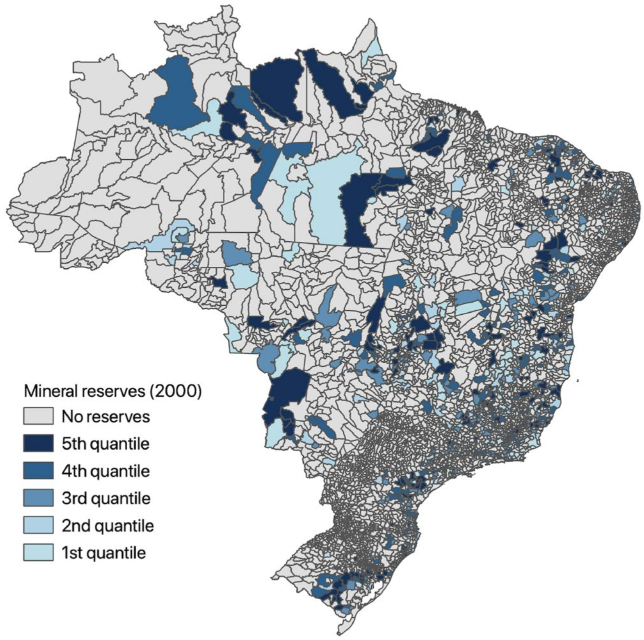

TABLE 1 The local health effects

	(1) Infant mortality	(2) Low weight births	(3) Premature (<37w) births	(4) Low APGAR score	(5) Births with anomalies
Mineral index	−0.084	−0.388	0.887***	0.741***	0.124
	(0.119)	(0.306)	(0.255)	(0.234)	(0.103)
Adj p value	[0.478]	[0.205]	[0.000]	[0.002]	[0.228]
Metallic minerals	−0.081	−0.274	0.683***	0.588***	0.104
	(0.096)	(0.244)	(0.201)	(0.160)	(0.083)
Adj p value	[0.397]	[0.261]	[0.001]	[0.000]	[0.210]
Industrial minerals	0.239	−1.009	1.070	0.537	−0.027
	(0.462)	(1.019)	(1.316)	(2.206)	(0.315)
Adj p value	[0.605]	[0.322]	[0.416]	[0.808]	[0.933]
Obs	54,499	54,505	54,504	54,505	54,505
Mean Dep Var	17.99	73.22	60.91	34.75	5.763

Note: The table presents the local effects of changes in prices of minerals on health outcomes at birth. Observations are at the year-municipality level. The sample contains about 4,955 municipalities constant over the period from 2000 to 2010. Mineral Index is defined as the interaction between the levels of reserves of minerals between 1996 and 1998 and the yearly average international price. The dependent variables are defined on 1,000 births. Infant mortality is defined as the death of an infant before his or her first birthday (column 1); births with low birth weight are defined as below 2.5 kg (column 2); premature births are defined as births which happened before 37 weeks of gestation (column 3); births with low APGAR are defined as with the score measured at 5 mins being lower than 7 (column 4); births with anomalies are defined as births with any type of anomalies (column 5). Adjusted pvalues are calculated to account for multiple hypothesis testing following Newson and Team (2003) and Newson (2011). Controls not shown include year and municipality fixed effects, and total population. Standard errors are clustered at the municipality level.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Sources: DATASUS—SINACS.

Yet, it is possible that natural resource booms change the composition of the characteristics of households who live within the municipality, and thus of newborn children, due to the migration of mothers and/or their fertility choices. In terms of migration, we may worry about selective inward migration of women with better child survival (Loayza & Rigolini, 2016), and selective outward migration of women who have children with worse survival chances. Alternatively, there could be inward migration of low-skilled human capital attracted by new jobs and outward migration of more educated people concerned about the pollution created by mining activities. In terms of fertility choices, it is possible that only women with certain socio-demographic characteristics (e.g., low-skilled, low educated) decide to have children. Hence, we could observe changes in health at birth of children (of recently migrated or pre-existing women) that are due to changes in the composition of mothers, rather than direct impacts of natural resource booms.

Appendix Tables B4 and B5 explore these concerns.[23] Appendix Table B4 shows a small but statistically significant increase in population levels (column 1), mainly for metallic minerals, and similar changes in the working-age population, even if not statistically significant (column 2). When investigating these increases by gender and age groups, I find that the changes for metallic minerals are driven by several age groups (15–17, 40–49, 50+) and both male and female populations. Since fertility is higher among women in their 20s, this suggests that net inward migration could exist, but could be limited by the fact that either very young (15–17 years old) or older women (40+ years old) of less fertile ages migrate into the municipalities.

Appendix Table B5 explores the potential selection bias using CBR and TFR as proxies for fertility. While I do not find changes in CBR, there is a small increase in TFR (0.0049 children on 1.9 TFR), only for metallic minerals. However, this change is driven by women in the age groups 35–49 years old (not shown) who are not the primary age-group migrating inward (Appendix Table B4). I cannot fully exclude that selective fertility might play a role, but this should be limited due to the small magnitude of the change, which is not driven by the migrating female population.

To shed light on the plausibility of the mechanisms, I then investigate how the proportion of births, by mothers' characteristics (age, education, and race) changes (Appendix Table B6). There is no evidence of selection by race and mixed patterns for age and education.[24] Even though selection cannot be be fully dismissed as an alternative explanation, by controlling for these changes, the main estimates remain robust (Appendix Table B7 Panel H).

Next, I explore the heterogeneity of the health impacts by type of minerals. Recall that some metallic minerals such as aluminum, manganese, copper, iron ore and gold have the highest CFEM tax rates (3% for aluminum and manganese, 2% for copper and iron ore, 1% for gold), and thus they generate wealth at the municipality level. On the contrary, it is established in the literature and rigorously empirically tested (Appendix Table A1) that other minerals, such as lead, tin, chromium, cadmium generate high levels of pollution, in addition to gold and manganese. Finally note that a sub-sample of these minerals are both polluting and generating wealth at the municipality level (manganese, copper and gold), thus making the net impacts on population health ambiguous. In Table 2 I categorize selected metallic minerals into: (i) those who are not polluting but generate royalties (Panel A); (ii) those who are polluting and do not generate royalties (Panel B); and, (iii) those who are polluting and generate royalties (Panel C) to shed some initial light on the different channels at play.[25]

Estimates in Table 2 suggest that minerals that generate resource windfalls, and for which negative pollution impacts on birth outcomes are not established in the literature, mainly create positive health effects: a reduction in births with low weight for aluminum and a decrease in infant mortality for iron ore (Panel A). Instead, changes in international prices of most of the untaxed polluting minerals generate negative impacts on health, with the exception of tin that, however, is present only in 27 municipalities (Panel B). More interestingly, when there is a trade-off at play between the benefits of resource windfalls and the costs of pollution, the impacts remain on average negative (Panel C), suggesting that the costs of pollution seem to prevail.

4.4 | Robustness checks

4.4.1 | Pre-shock differences between municipalities

Following the shift-share literature, I provide additional tests to support the identification strategy.

First, in some settings, the exogeneity of the shares might be implausible because they can be co-determined with level of outcome of interest (Goldsmith-Pinkham et al., 2020). I then test the correlation between levels of mineral reserves and health outcomes at the beginning of the panel (Appendix Table B8). Even if this is not necessary for the empirical strategy to be valid, it is an additional helpful test that, combined with the plausible exogeneity of the time-series shocks, further strengthen the identification argument behind my strategy.

Second, Goldsmith-Pinkham et al. (2020) further suggests to check whether differential exposure to common shocks leads to differential changes in the outcomes of interest. I therefore explore whether variables related to population and socio-demographic characteristics, expenditures, employment, income, inequality, pollution, CBR and TFR at the beginning of the panel (2000) predict ex-ante levels of reserves (1996–1998).[26] I use a least absolute shrinkage and selection operator (LASSO) to select the most important predictors (male working age population, adult employment rate), and I show that results are robust to the inclusion of these controls (Appendix Table B9, Panel A). This is reassuring because movements in point estimates when conditioning on observable confounders suggest the potential importance of unobserved confounders.

TABLE 2 The local health effects - Selected minerals

	(1) Infant mortality	(2) Low weight births	(3) Premature (<37w) births	(4) Low APGAR score	(5) Births with anomalies
Panel A: Resource windfalls and no pollution					
Aluminum (3%)	−0.993	−4.093***	2.882	−2.884	1.260
	(0.887)	(1.495)	(2.800)	(6.656)	(3.786)
Iron ore (2%)	−0.264**	−0.257	−0.124	0.483	0.092
	(0.128)	(0.383)	(0.322)	(0.410)	(0.122)
Panel B: No resource windfalls and pollution					
Lead	−0.075	0.228**	0.334*	0.111	−0.069
	(0.145)	(0.113)	(0.177)	(0.136)	(0.071)
Tin	0.399	1.148	−0.128	0.819	−0.237
	(0.285)	(1.294)	(1.200)	(0.527)	(0.178)
Chromium	−0.024	−0.028	−0.745	0.369***	0.063*
	(0.070)	(0.121)	(0.681)	(0.136)	(0.035)
Cadmium	0.073***	0.161**	0.024	−0.054	0.005
	(0.025)	(0.073)	(0.065)	(0.058)	(0.027)
Panel C: Resource windfalls and pollution					
Manganese (3%)	−0.112	0.214	0.100	0.618*	−0.157
	(0.197)	(0.398)	(0.468)	(0.360)	(0.173)
Copper (2%)	0.016	0.119	0.484***	2.457***	−0.101
	(0.201)	(0.112)	(0.114)	(0.452)	(0.062)
Gold (1%)	0.100	0.171	0.913**	0.300	0.171*
	(0.114)	(0.456)	(0.425)	(0.876)	(0.098)
Obs	54,499	54,505	54,504	54,505	54,505
Mean Dep Var	17.99	73.22	60.91	34.75	5.763

Note: The table presents the local effects of changes in price of selected metallic minerals on health outcomes at birth. Observations are at the year-municipality level. The sample contains about 4,955 municipalities constant over the period from 2000 to 2010. Mineral Index is defined as the interaction between the levels of reserves of each mineral between 1996 and 1998 and the yearly average international price. The dependent variables are defined on 1,000 births. Infant mortality is defined as the death of an infant before his or her first birthday (column 1); births with low birth weight are defined as below 2.5 kg (column 2); premature births are defined as births which happened before 37 weeks of gestation (column 3); births with low APGAR are defined as with the score measured at 5 minutes being lower than 7 (column 4); births with anomalies are defined as births with any type of anomalies (column 5). CFEM taxation is reported between parenthesis. Controls not shown include year and municipality fixed effects, total population, and the total mineral index to account for the potential production of other minerals in the municipality. Standard errors are clustered at the municipality level.

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Sources: DATASUS—SINACS.

Finally, I control for differential municipal trends by interacting pre-shock municipal characteristics with the year fixed effects to flexibly account for this threat to the identification strategy. The main health effects remain similar when adding interaction terms between predictors of endowments and time (Appendix Table B9, Panel B).[27]

4.4.2 | Alternative mineral indexes

Municipalities with no endowments could be included or not in the standardization process of the MI MI_{mt-1}. Appendix Table B3 provides evidence that estimates are robust when using alternative standardized indexes or an unstandardized measure. The MI used in the main specification is standardized so that has mean 0 and standard deviation 1 on the full sample of municipalities. Yet, the index takes negative values for those municipalities with no endowments. Alternatively, I construct a standardized index only on municipalities with positive reserves, including municipalities with no endowments with a 0 index value (Panel A). I also construct a similar standardized index only on municipalities with positive reserves, but excluding municipalities with no endowments (Panel B). Finally, I show estimates using an unstandardized MI (Panel C).

4.4.3 | Additional tests

As shown in Appendix Table B7, the estimates are robust when restricting the analysis to the sample of municipalities matched based on ex-ante health outcomes by using a propensity score matching without replacement (caliper 0.001). I estimate a logit regression where being treated is defined as having zero versus any mineral reserves (Panel A) or as having mineral reserves below or above the median level at the beginning of the panel (Panel B). This suggests that the impacts are not driven by ex-ante levels of health differentiating municipalities with lower or higher mineral endowments. I also account for municipality-specific linear time trends to capture differential linear trends in the health outcomes that might predate the price changes occurring in mid-2000s, and differential improvements by municipality in the measurement of health outcomes, and estimates remain similar (Panel C). Furthermore, Appendix Table B7 confirms that the main effects are robust to considering the sample of the entire set of municipalities (Panel D); adding state-per-year fixed effects (Panel E); changing the initial mineral reserves to other years (Panel F); restricting the sample of municipalities to those with positive mineral endowment at the beginning of the panel (Panel G). Estimates are also robust to controlling for changes in the percentage of births by mother characteristics (Panel H). Finally, Appendix Table B10 shows that the estimates are also similar if the indexes for metallic and industrial minerals are included in the same empirical model.

5 | MECHANISMS

There are many mechanisms through which natural resource booms, due to changes in international prices, can impact birth outcomes.

5.1 | Resource windfalls

Natural resources, and especially metals, are linked to expropriation taxes that directly increase income at the municipality level. If these resources are used by politicians for investment in public health goods, we might expect a positive health effect on newborn children.[28]

Table 3 shows that booms in metallic minerals increase municipality GDP per capita (column 1). While I do not find any change in the value of exports (column 2), estimates provide evidence that municipalities receive higher transfers because of royalties (column 3), and more of these resources are spent (column 4), also on health (column 5). Instead, there is no evidence of resource windfalls for industrial minerals. This is consistent with the fact that 65% of royalties (CFEM) are mainly collected and transferred to municipalities for metals. Results on resource windfalls are robust to a battery of robustness checks (Appendix Table B11).

Despite not finding changes in health expenditures (Table 3, column 5), I document an increase in the total amount of health personnel, especially doctors (Table 4, column 2 and 3). For industrial minerals, however, the changes appear to be driven by health personnel working in private health facilities, rather than as part of the public health system (not shown).

5.2 | Economic opportunities

On the one hand, higher employment could increase household income and this could be invested in mothers' and children's health, and/or on more quantity and better quality of food. On the other hand, higher female employment could reduce the time spent on health investments (Miller & Urdinola, 2010).

Table 5 presents evidence of the effects of price changes on economic activities, using RAIS (columns 1 and 2) or Census data from 2000 to 2010 (columns 3–5). I find a statistically significant but small increase in the proportion of the population working (columns 1 and 3).[29] Monthly wage (column 4) also increases, and this translates into a 2.5% increase over the mean in household income. Overall, mining activities generate more economic opportunities, but only following economic booms in metallic minerals. Instead, there are no statistically significant effects for industrial minerals. These results are also robust to a battery of robustness checks (Appendix Table B12).

I also find evidence that new local employment opportunities for women do not take away time from child health investments. I find a higher utilization of ANC services and vaccinations, as well as increased hospitalizations (Table 6, columns

TABLE 3 Resource windfalls

	(1) GDP per capita	(2) Log (tot exports, USD)	(3) Log (transfers *received*)	(4) Log (transfers *spent*)	(5) Log (health expenditures)
Mineral index	0.492**	−0.023	0.036***	0.040***	0.021*
	(0.218)	(0.088)	(0.013)	(0.015)	(0.013)
Metallic minerals	0.395**	−0.025	0.029***	0.033***	0.017**
	(0.178)	(0.072)	(0.009)	(0.011)	(0.008)
Industrial minerals	0.253	0.142	0.008	−0.000	0.011
	(0.311)	(0.245)	(0.134)	(0.126)	(0.130)
Obs	54,505	39,640	54,505	54,505	54,505
Mean Dep Var	7.936	5.171	15.51	14.35	14

Note: The table presents the local effects of changes in prices of minerals on wealth outcomes. Observations are at the year-municipality level. The sample contains about 4955 municipalities constant over the period from 2000 to 2010. Mineral Index is defined as the interaction between the levels of reserves of minerals between 1996 and 1998 and the yearly average international price. The dependent variables are defined as GDP per capita (column 1); log of total value of exports in USD (column 2); log of total transfers received by the municipality because of oil or mining (column 3); log of total transfers used by the municipality (column 4); log of total governmental health expenditures (column 5). Controls not shown include year and municipality fixed effects and total population. Standard errors are clustered at the municipality level.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Sources: IBGE, FINBRA, SIOPS.

TABLE 4 Investment in public health goods

	(1) No. health facilities (100,000)	(2) No. total staff (100,000)	(3) No. doctors (100,000)	(4) No. nurses (100,000)
Mineral index	0.400	3.668**	0.975**	−0.040
	(0.467)	(1.677)	(0.411)	(0.194)
Metallic minerals	0.261	2.481**	0.615**	−0.042
	(0.383)	(1.238)	(0.295)	(0.153)
Industrial minerals	1.695	15.369**	5.479**	0.319
	(1.507)	(7.100)	(2.358)	(0.934)
Obs	29,730	19,820	19,820	19,820
Mean Dep Var	85.47	743.3	110.3	48.41

Note: The table presents the local effects of changes in prices of minerals on investment in health goods. Observations are at the year-municipality level. The sample contains about 4955 municipalities constant over the period from 2000 to 2010. Mineral Index is defined as the interaction between the levels of reserves of minerals between 1996 and 1998 and the yearly average international price. The dependent variables are defined as number of health facilities (column 1); number of total staff (column 2); number of doctors (column 3); number of nurses (column 4), per 100,000 people. These indicators are constructed as the mean over 12 months in each year. Controls not shown include year and municipality fixed effects and total population. Standard errors are clustered at the municipality level.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Sources: CNES.

1–3) for metallic minerals, while there are no statistically significant effects for industrial minerals, despite the coefficient on hospitalizations being of a meaningful magnitude.[30]

5.3 | Pollution

There are many environmental factors that can affect maternal and child health. Traditional risks include drinking-water contamination and indoor air pollution, while newer environmental risks are urban air pollution and exposure to toxic chemicals. As far

TABLE 5 Economic opportunities

	(1)	(2)	(3)	(4)	(5)
	RAIS		Census		
Data source:	Formal employment (%)	Monthly payroll (BRL)	Any employment (%)	Monthly wage (BRL)	Household income (BRL)
Mineral index	0.002***	1.259	0.002***	20.456**	26.095*
	(0.001)	(2.078)	(0.001)	(9.465)	(15.745)
Metallic minerals	0.002***	1.378	0.003***	21.833***	29.699**
	(0.001)	(1.581)	(0.000)	(8.158)	(13.802)
Industrial minerals	−0.000	−7.175	−0.001	−7.357	−16.335
	(0.002)	(11.862)	(0.002)	(14.180)	(18.589)
Obs	54,488	54,306	9908	9908	9908
Men Dep Var	0.17	554.6	0.36	630.6	1031

Note: The table presents the local effects of changes in prices of minerals on economic activities. Observations are at the year-municipality level. The sample contains about 4955 municipalities constant over the period from 2000 to 2010. Mineral Index is defined as the interaction between the levels of reserves of minerals between 1996 and 1998 and the yearly average international price. The dependent variables are defined as total formal employment rate as percentage of the working population (column 1); monthly payroll (column 2); any formal or informal employment rate as percentage of the population (column 3); monthly wage (column 4); household income (column 5). Columns 1–2 use RAIS dataset, columns 3–5 use Census data in 2000 and 2010. Controls not shown include year and municipality fixed effects and total population. Standard errors are clustered at the municipality level.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Sources: RAIS.

TABLE 6 Health services utilization

	(1)	(2)	(3)
	7+ ANC visits (1,000)	Vaccine doses (1,000)	Tot hospitalizations U1 (1000)
Mineral index	5.364**	1.041	43.657**
	(2.406)	(4.708)	(17.712)
Metallic minerals	3.938**	0.855	30.232**
	(1.975)	(3.860)	(12.939)
Industrial minerals	11.874	−3.673	187.963
	(8.742)	(9.962)	(116.073)
Obs	54,504	54,505	14,865
Mean Dep Var	509.1	918.8	1033

Note: The table presents the local effects of changes in prices of minerals on proxies for the utilization of health services. Observations are at the year-municipality level. The sample contains about 4,955 municipalities constant over the period from 2000 to 2010. Mineral Index is defined as the interaction between the levels of reserves of minerals between 1996 and 1998 and the yearly average international price. The dependent variables are defined as total number of births per 1,000 with more than 7 Antenatal Care Visits (column 1); total number of vaccine doses per 1,000 births (column 2); total number of hospitalizations per 1000 children under one year old (column 3). Controls not shown include year and municipality fixed effects and total population. Standard errors are clustered at the municipality level.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Sources: DATASUS - SINACS, SIH, RAIS, Census.

as mineral production is concerned, local communities can be exposed to pollution in several ways, such as dust and emissions from industrial processing, mine wasting into water and soil, and direct exposures to mine tailings.[31]

There is evidence from lower and middle-income countries that mineral activities could negatively affect health outcomes at birth through both air and water pollution. Metals are found to be negatively associated with psycho-motor and mental development and behavioral problems (Asmus et al., 2016). Hospital admissions for respiratory causes and emergency visits are also found to be higher in areas with high concentrations of air pollutants from industrial mining (Appendix Table A1).

Other studies find evidence of negative effects of gold mining on general health among adults in Peru (Aragon & Rud, 2013), on child malnutrition and acute respiratory diseases in Ghana (Aragon & Rud, 2016), on APGAR scores in Colombia (Romero & Saavedra, 2016), and on women's anemia and children's stunting in 44 developing countries (der Goltz & Barnwal, 2018).

Table 7 shows increased hospitalizations for infectious diseases, anomalies, and perinatal conditions which includes abortive outcomes and complications of labor and delivery, as well as any problem incurred during the 6-week period after birth. This is in line with the negative effects found on health at birth (Table 1), and it is primarily driven by metallic minerals. More interestingly, I find an increased number of hospitalizations for respiratory diseases (column 1) linked to industrial minerals, suggesting a potential cost of pollution also for certain industrial minerals, as confirmed by (Asmus et al., 2016).

Unfortunately, no nationwide data exists in Brazil on water pollution, so the analysis is limited to air pollution. Table 8 shows that there is a statistically significant increase in emissions of N_2O and of SO_2 (columns 2 and 4), and the changes are primarily driven by metallic minerals. Nitrous oxide is a gas usually emitted during industrial activities, as well as during the combustion of fossil fuels and solid waste. Similarly, SO_2 is a gas primarily emitted from fossil fuel combustion at power plants and other industrial facilities. These results, especially on SO_2, remain robust to alternative specifications (Appendix Table B13).

Instead, the majority of CH_4 emissions in Brazil are from agricultural processes (70%), waste (16%), energy (4%) and land-use change (6%) (Tunnicliffe et al., 2020), so it is not surprising that there are no changes. A decrease is reported in emissions of carbon monoxide (CO), which is generated during a spontaneous heating event in a coal mine and is not part of the analysis. However, the results are not robust to alternatives specifications (Appendix Table B13).

6 | CONCLUSION

Natural resources often receive media and political attention, both in developing and developed countries. Evidence on their economic impacts, however, has been mixed. Some studies show local economic benefits from increased wealth, such as for oil, while others primarily tackle the costs of certain polluting minerals for the health of communities surrounding the mines, such as for gold and lead. This paper investigates the whole trade-off between the benefits and costs which economic booms in natural resources create, focusing on 40 types of minerals produced in Brazil in the 2000s. Exploiting exogenous changes in global commodity prices and the pre-existing spatial variation in mineral endowments, this study draws a broad picture on the net effects of booms in metallic and industrial minerals on health at birth. It also documents the potential channels at play, to shed further light on which benefits or costs of mineral resources prevail.

TABLE 7 Hospitalizations (1,000 people), by type

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Respiratory	**Perinatal**	**Infectious**	**Digestive**	**Anomalies**	**Nervous system**	**Genital and urinary**
Mineral index	7.880	28.736**	3.885*	1.425	1.009*	0.389	0.203
	(5.252)	(13.088)	(2.218)	(0.900)	(0.574)	(0.325)	(0.523)
Metallic minerals	5.050	20.133**	3.137*	0.977	0.662	0.121	0.115
	(3.848)	(9.833)	(1.758)	(0.659)	(0.431)	(0.149)	(0.410)
Industrial minerals	46.706***	105.072	−1.613	6.037	5.398	7.199	1.757
	(17.771)	(89.935)	(12.820)	(5.353)	(6.711)	(8.666)	(2.332)
Obs	14,865	14,865	14,865	14,865	14,865	14,865	14,865
Mean Dep Var	388.9	385.4	158.9	22.87	20.78	9.667	8.344

Note: The table presents the local effects of changes in prices of minerals on types of hospitalizations of children under 1 year old. Observations are at the year-municipality level. The sample contains about 4,955 municipalities constant over the period from 2000 to 2010. However, hospitalization data are available only between 2008 and 2010 (see Table A1, Panel C). Mineral Index is defined as the interaction between the levels of reserves of minerals between 1996 and 1998 and the yearly average international price. The dependent variables are defined as the total number of hospitalizations per 1000 children under one year, by type: respiratory diseases (column 1); perinatal complications (column 2); infectious diseases (column 3); digestive diseases (column 4); anomalies (column 5); nervous system (column 6); genitourinary diseases (column 7). These are the main categories of hospitalizations (per number of hospitalizations over 1,000 children) as defined by CID 10 chapters. Controls not shown include year and municipality fixed effects and total population. Standard errors are clustered at the municipality level.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Sources: DATASUS—SIH.

TABLE 8 Air pollution

	(1) CH_4	(2) N_2O	(3) CO	(4) SO_2
Mineral index	0.142	0.008**	−1.638*	0.073***
	(0.139)	(0.004)	(0.985)	(0.025)
Metallic minerals	0.136	0.006**	−1.141	0.051***
	(0.104)	(0.003)	(0.761)	(0.016)
Industrial minerals	−0.846	0.013	−6.995	0.322
	(1.003)	(0.027)	(8.210)	(0.361)
Obs	10,936	10,936	10,936	10,936
Mean Dep. Var	12.90	0.415	24.21	1.204

Note: The table presents the local effects of changes in prices of minerals on air pollutants. Observations are at the year-municipality level. The sample contains about 4955 municipalities for the years 2000 and 2010, when air pollution data are available (EDGAR). Mineral Index is defined as the interaction between the levels of reserves of minerals between 1996 and 1998 and the yearly average international price. The dependent variables are defined as CH_4, Methane (column 1); N_2O, Nitrous Oxide (column 2); CO, Carbon Monoxide (column 3); SO_2, Sulfur Dioxide (column 4). All variables are defined in tons per year (in 100,000). Controls not shown include year and municipality fixed effects and total population. Standard errors are clustered at the municipality level.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Sources DATASUS—SIH.

Following an increase in international prices, municipalities with higher historical endowments of mineral resources experience an increase in premature births and births with low APGAR scores. These results are primarily driven by *metallic minerals*, while there is a lack of statistically significant effects for *industrial minerals*. On the one hand, the results suggest that natural resource booms generate benefits through resource windfalls—at the municipality level—and increased employment opportunities and income—at the household level—along with higher utilization of health services. On the other hand, costs of (air) pollution exist and seem to prevail, contributing to the worse birth outcomes.

Identifying the mechanisms at play is pivotal for policymakers, because the impact of any policy depends on the costs and benefits that each natural resource creates locally. This study finds that the health effects are positive for economic booms in minerals that generate royalties through taxation and for which there is no consistent evidence of pollution, such as aluminum and iron ore. Instead, some untaxed polluting minerals such as lead, chromium, and cadmium remain more a curse than a blessing. More importantly, for other minerals such as manganese, copper and gold, for which pollution has been established in the literature but also generate royalties, the impacts on health at birth remain on average negative. This suggests that, despite potential benefits from resource windfalls, the costs of pollution seem to prevail.

The study presents some limitations. First, because data on prices and health outcomes are lacking before the beginning of the panel, I cannot provide further evidence on parallel pretrends as suggested in Goldsmith-Pinkham et al. (2020). Yet, the identification strategy primarily relies on the exogeneity of global commodity prices (Borusyak et al., 2022). While not necessary for the identification to be valid, I also consider the plausible exogenous cross-sectional variation in endowments and, following Goldsmith-Pinkham et al. (2020), I provide several tests suggesting that this variation is also not subject to relevant endogeneity concern. Second, non-random measurement error in the registration of deaths or births remains a concern, mainly in remote areas. I control for potential time trends in improvements in registration at the state level since the surveillance is implemented by state-level functionaries. However, any residual bias might lead to biased estimates of the effects. Finally, I cannot fully dismiss that selective migration and/or selection into fertility play a contributing role in explaining worse health outcomes.

Despite these limitations, the study provides evidence that pollution appears to overcome the benefits from resource windfalls and economic opportunities. Thus, stakeholders should improve corporate social responsibility as well as transparency standards, at least in the regulation of some metallic minerals. They also need to establish better ways to protect the local population, especially pregnant women and newborns, from the negative spillovers of pollution. Much more needs to be done, at least in Brazil, to make sure that all metallic minerals become a blessing more than a curse.

CONFLICT OF INTEREST

The author declares that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

DATA AVAILABILITY STATEMENT

Data derived from public domain resources Raw data are publicly available. The cleaned dataset is available upon request.

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ENDNOTES

[1] See Almond et al., 2011; Lindo, 2011; Hoynes et al., 2015; Rocha & Soares, 2015 for examples on the *income* channel, and Almond & Mazumder, 2011; Rossin-Slater, 2013 for examples on the *nutrition* channel, and their effects on infant health.

[2] This happens through mechanisms which involve neuroendocrine processes, immune-inflammatory activity, behavior and infections (Wadhwa, Culhane, Rauh, & Shirish Barve, 2001; Wadhwa, Culhane, Rauh, 2001; Wadhwa, 2005; Goldenberg et al., 2008; Dunkel Schetter, 2011).

[3] See Dole et al., 2003; Rondó et al., 2003; Carlson, 2015; Persson and Rossin-Slater 2018; Menclova & Stillman, 2020 for examples of *maternal stress* due to income or economic shocks and its effects on infant health. See Rook et al., 1991; Vinokur et al., 1996; Westman et al., 2001 for evidence on maternal stress related to husband's job troubles. A specific literature focuses on terrorist attacks, conflict and disasters (Brown, 2020; Camacho, 2008; Mansour & Rees, 2012; Quintana-Domeque & Ródenas-Serrano, 2017; Simeonova, 2011).

[4] For example, air pollutants may decrease fetal-placental exchange of oxygen and nutrients, and may increase pulmonary and placental inflammation in the mother, potentially resulting in premature contractions and membrane rupture. Blood viscosity and coagulability may also change, slowing fetal growth and increasing the risk of maternal cardiovascular events, pre-eclampsia, and preterm delivery (Rangel and Vogl, 2019).

[5] In terms of prenatal exposure, several studies find a link between air pollution and fetal growth retardation or shorter gestation period, both of which are associated with low birth-weight (Dejmek et al., 1999; Wang et al., 1997). Postnatal exposure contributes to acute respiratory infection, a leading cause of infant death (Jayachandran, 2009). These mechanisms are related to the release in the air of poly-cyclic aromatic hydrocarbons (PAHs) (Hatch et al., 1990; Perera et al., 1998, 1999).

[6] In the context of shift-share research designs, Goldsmith-Pinkham et al. (2020) argues how the exogeneity of the shares would also be a sufficient condition for identification, in cases where time-series variation is unlikely to be exogenous. While not necessary in this context, where shocks are indeed plausibly exogenous, I follow Goldsmith-Pinkham et al. (2020) to provide several tests suggesting that cross-sectional variation in endowments is also not subject to relevant endogeneity concern.

[7] A smaller set of research studies describes the effects on corruption and conflict (Angrist & Kugler, 2008; Brollo et al., 2013; Caselli & Michaels, 2013; Dube & Vargas, 2013; Vicente, 2003).

[8] In the 2000s, Brazil was one of the world's fastest-growing economies, justifying it as being named the "B" in the BRIC countries by the economist Jim O'Neill. However, globally, there was a sharp down-turn in prices in mid-2008 to 2009 due to the financial crisis, when most commodity prices plummeted as the global growth slowed down and the consumer demand weakened in most major economies. While commodity prices rebounded after the crisis, and by the end of 2010 prices of many commodities were close to or above pre-crisis peaks (Gruss, 2014), Brazil entered a crisis in 2014–2016 (Caputi et al., 2019).

[9] Section 2 of Law 8001/90 defines net income for the purpose of calculating the CFEM as the gross income from sales, deduced by transactional taxes (ICMS, PIS, and COFINS) levied upon mineral sales, as well as freight and insurance expenses. CFEM is also due when the mineral had been used by the mining companies in their production process instead of being sold.

[10] The federal government enacted law No. 13,540/2017 which recently increased the CFEM tax basis as well as the rates. The taxable base is now the gross revenue, excluding only taxes over the sale. Taxation is the following: rocks, sands, gravel, clay, and other mineral products used directly in civil construction (also called construction aggregates), ornamental rocks, as well as mineral and thermal water are levied on a 1% rate; gold has a 1.5% rate; diamonds and other mineral products are now levied on a 2% rate, while aluminum, manganese, niobium, and rock salt have a 3% rate. The rate for iron ore is fixed at 3.5%.

[11] Another study (Benshaul-Tolonen, 2019) finds instead that gold mining leads to a reduction in infant mortality.

[12] APGAR is a widely used summary measure of health of newborn children which captures the presence of possible brain damage. It is found to be a significant predictor of health, cognitive ability, and behavioral problems later in life (Douglas et al., 2005). The measure is constructed as the number of births with APGAR scores below 7 out of 10.

[13] In the last decades, the quality of mortality information in Brazil has shown significant advances (Paes, 2005), reaching 100% coverage by 2010 in all states in the south and southeast regions, as well as some in the northeast and midwest. Advances were also made for the poorest states in the northeast and north of Brazil, especially for those that had the worst quality of records in previous periods (Queiroz et al., 2017). The degree of

completeness for death registration was estimated to be on average 90% in 2000–2010 (Lima and Queiroz, 2014). Similarly, birth registration has improved steadily from about 80% of registration in the 1990s to over 95% in the most recent years (Hunter & Sugiyama, 2018; Lima et al., 2018).

[14] Unfortunately, I do not have access to mineral production at the municipality level, so I cannot use international prices as instrumental variable for production.

[15] See https://edgar.jrc.ec.europa.eu/dataset%5Fhtap%5Fv2%5C%23intro for more information.

[16] Appendix Figures C1 and C2 describe the variation present in the data for each type of metallic and industrial mineral that is exploited in the empirical strategy.

[17] Municipalities with no endowments could be included or not in the standardization process. See Appendix Table B3 for definitions (in notes) and alternative estimates.

[18] Note that, unfortunately, data on health outcomes at the month level do not exist nationally for the period analyzed, so this prevents me from exploring whether the results on health at birth vary by exposure to minerals at different stages in pregnancy.

[19] Consider that most of the outcomes in the analysis (preterm births, births with low weight, with low APGAR scores or anomalies) are evaluated at birth: These newborn children were potentially exposed to booms in mineral resources while in utero during the 9 months of gestation. Instead, infant mortality is measured in older children, from birth to the child turning 1 year old. These children might then be exposed to booms in natural resources for less time while in utero or could have been born before changes in the production of minerals.

[20] Notice that only 10 municipalities produce more than 1% of global production of specific minerals over the study period.

[21] I followed Newson and Team (2003) and Newson (2011) and report frequentist q–values (or adjusted *p*-values) for multiple-test procedures, by defining the discovery set to control either the familywise error rate (FWER) or the false discovery rate (FDR). For each input *p*–value, the corresponding q–value is the lowest input uncorrected critical *p*–value (FWER or FDR) which would cause the input *p*–value to be included in the discovery set, if the specified multiple–test procedure was applied to the full vector of *p*–values. To be conservative, I use a step-up method where the q-value for each *p*-value is equal to the cumulative minimum of all the r-values corresponding to *p*-values of rank equal to or greater than that *p*-value.

[22] As a reference, over the same period, the average change year to year, from 2000 to 2010, in premature births at the municipality level was a decrease of 0.39. The estimated increase of 0.59 premature births caused by mineral resource booms, then completely overcame the yearly decrease in premature births at the municipality level.

[23] There are no data available on yearly migration rates at the municipality level. The best proxy measures I could use to understand whether the population changed after changes in international mineral prices are population levels, by age and gender, specifically focusing on working-age population.

[24] On the one hand, I find an increase in adolescent births and in older women's births, who might be more likely to have riskier pregnancies. Similarly, I also find an increase in births by women with no education, who might be less likely to attend ANC and more likely to have pregnancy complications. This could contribute to explain worse birth outcomes. On the other hand, I find an increase of births for mothers with more than 8 years of education who could counterbalance the negative impacts on health at birth.

[25] Note that most of the industrial minerals are (iv) not polluting and do not generate royalties, so please refer to the results in Table 1 for this remaining category. The impacts of all minerals in the data are reported in Appendix Figures C3 and C4 for each metallic (Figure C3) or industrial (Figure C4) mineral.

[26] Note that due to data availability, covariates are defined as early as possible in the panel, but reserves precede the covariates.

[27] Results are robust to using a larger set of covariates rather than the ones selected by LASSO. See Appendix Table B9, Panels C and D.

[28] Previous studies in Brazil which studied the impact of oil windfalls on local economy (Caselli & Michaels, 2013) and political behavior (Monteiro & Ferraz, 2012), however, found that revenues from oil increase the chance of re-election of the incumbent politicians and expenditures on public goods and services, but they do not directly materialize into an increase in good provision and infrastructure. Instead, oil revenues disappear before turning into the real goods and services.

[29] The analysis shows that the effects on formal and total employment are identical. Yet, note the two measures are coming from different data sources at different points in time. Given the lack of public available data, I cannot directly test that also informal employment proportionally increases due to better economic opportunities.

[30] Because of a lack of data, I could not test whether maternal stress levels change after economic booms. However, following changes in international prices, households become wealthier due to new job opportunities. Pregnant women are expected to worry less about their economic situation or their husband's job, thus potentially reducing their levels of stress.

[31] Most of the past literature studying the impacts of pollution on health mainly focuses on developed countries and analyzes the effects on infant health. The shorter time between exposure to pollution and health outcomes at birth (compared to adult outcomes) allows researchers to narrow down channels of impact. Additionally, studying health at birth is easier because of the availability of national registries in many countries. Moreover, health at birth predicts adult outcomes such as education or earnings well (Almond et al., 2011; Currie & Vogl, 2013). While most of the past studies focused on air pollution related to urbanization and traffic (Chay & Greenstone, 2003a; 2003b, Currie & Schmieder, 2009; Currie & Walker, 2011), very few studies investigated the effects of water pollution (Currie et al., 2013). Evidence in the fields of public health and epidemiology on health impacts of mining-related pollution is mainly based on correlations, while rigorous empirical identification is still lacking in economics.

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APPENDIX A: LITERATURE REVIEW

TABLE A1 Literature review

Type	Health outcome effects	References
Metallic minerals		
Aluminum	Negative health effects on respiratory diseases due to dust, especially for children	Petrela et al. (2001)
	Brain and bone diseases in children with high levels. No clear effects on birth defects	CDC (2021)
Cadmium*	Low growth of newborn baby; low IQ level; cardiac abnormalities; cranio-facial abnormalities such as small eyes of newborn baby, nasal bridge is poorly formed; lead to renal abnormalities	Neeti et al. (2013)
	DNA damage in neonates	Ni et al. (2014)
	Maternal exposure during pregnancy induced fetal growth restriction, fetal death and birth defects, sudden infant death, and preterm birth	Türker (2015)
Chromium*	Frequent spontaneous abortions, stillbirths, premature births, and neonatal deaths	Blankenship et al. (1994); Costa (1997); Ajayi et al. (2012); Amadi et al. (2017)
	DNA damage in neonates	Ni et al. (2014)
	High risk from drinking water contaminated, but no health effects	Naz et al. (2016)
	Kidney and lung damage for adults; no effects on child development, behavior or birth defects	CDC (2021)
Cobalt	Respiratory problems for adults; no clear effects on birth defects, but cobalt can be transferred from mother to child through breastmilk	CDC (2021)
	Hematological effects, sometime hearing loss, cardiomyopathy (mainly animal studies)	Paustenbach (2013)
	Urine contains metal residuals for both adults and children in DRC, but no investigation of health effects	Banza (2009)

TABLE A1 (Continued)

Type	Health outcome effects	References
Copper*	Nausea, vomiting, diarrhea, stomach cramps, liver and kidney damage. No evidence on cancer; No clear effects on birth defects of development of children. In animals can decrease fetal growth	CDC (2021)
	Increases chances of miscarriage, complication during delivery, low birth weight, muscular weakness in newborn baby, it leads neurological problems in growing children	Neeti et al. (2013)
	Children living in villages considered impacted by copper mining have better health outcomes for malaria infection, anemia and stunting than children from comparison sites	Knoblauch (2017)
Iron Ore	Higher rates of waterborne disease, fever, typhus, respiratory diseases for adult workers	Phraden (2014)
Lead*	Higher rates of stunting	von der Goltz and Barnwal (2018)
	Evidence of intellectual deficits (IQ) if blood level high	Bruce et al. (2005)
	Review paper which includes lead: miscarriage, premature births, low birth weight, and negative effects on brain and growth of children	Neeti et al. (2013); Türker (2015)
	Frequent spontaneous abortions, stillbirths, premature births, and neonatal deaths	Amadi et al. (2017)
	Higher risk of premature birth, low birth weight and retarded growth	Iyengar & Nair (2000)
Lithium	Used to treat bipolar disorders, can have negative effects on fetus, but no definite evidence	Cohen (1994)
	Small concentrations of lithium are beneficial to strengthen the cell wall and improve disease resistance	Vetrimurugan (2017)
Manganese*	Intrauterine growth retardation (IUGR) and lower birth weight	Wood (2009)
	Negative effects on brain development; no clear effects on birth defects	CDC (2021)
Nickel	Chronic toxicity (100 days): Respiratory disorders, pulmonary and nasal cavity cancers for male workers. No evidence on female and children	Das et al. (2008)
	Higher mortality in adult working males. Increased ischemic heart disease, diabetes, and lung cancer	Pasanen et al. (2012)
	DNA damage in neonates	Ni et al. (2014)
Rare earths	Higher risk heart attacks and lung diseases for adult workers; low IQ for children, leukemia	US EPA (2012)
	Increased risk of hypertension rates for adults	Wang et al. (2017)
	Unclear evidence, but several newspaper articles suggest potential negative effects	Rim (2016)
Tantalum	Can cause eye and skin irritation and respiratory problems. No evidence on workers, mostly animal studies	CDC (2021)
Tin*	Low neurodevelopment of newborns in a tin mining region, especially among boys	Marques et al. (2014)
Tungsten	No main health effects; if high exposure breathing problems; only animal studies	CDC (2021)
	Long-term contamination in soil. Health risk assessment, not health effects	Guo et al. (2017)
	Vanadium Nausea, mild diarrhea, and stomach cramps; breathing problems and cough in adults; no evidence on children; some other evidence on animals	CDC (2021)
Vanadium	May act as a carcinogen among both adults and children. Risk assessment not evidence of health effects	Yu and Yang (2019)
Zinc	Need the right amount for mothers and kids. High levels effects can be same as too low zinc: not proper growth or development. Adults: Nausea, vomiting, anemia, etc. No effects on cancer	CDC (2021)

(Continues)

TABLE A1 (Continued)

Type	Health outcome effects	References
Zirconium	Studies on animals, no studies in humans	
Gold*	Lower infant mortality, but also lower AGPAR.	Benshaul-Tolonen (2019); Romero and Saavedra (2016)
Silver		No specific studies
Industrial minerals		
Asbestos	Lung and other cancer, problems breathing in adults. Expected similar results on children. No effects on health at birth	Pira et al. (2011); CDC (2021)
Barite	Barium carbonate can cause slightly raised rates of amniotic fluid of fetuses with congenital malformation	Barosova et al. (2014)
	Limited evidence on adults. Cardiovascular and kidney diseases, metabolic, neurological, and mental disorders	Kravchenko et al. (2014)
	Silicosis in adults, evidence of cancer in animals	CDC (2021)
Beryllium	Negative effects on respiratory tract on adults (cause the Chronic Beryllium disease, i.e., fatal lung disease). Gastrointestinal lesions on animals. No clear effects on development and children	CDC (2021)
Graphite	Graphite pneumoconiosis (respiratory disease) in adults (similar to asbestos effects from dust)	Uragoda (1997), Lido (2008)
Gypsum	Damage to lungs from repeated or extended exposure	CDC (2021), Integrated Laboratory systems, Inc. (2006)
	Air pollution due to cement plants affect pre-term delivery	Yang et al. (2003)
Feldspar	Can contain Uranium, exposure to radiation.	Silveira et al. (1992), Cavariani (2016)
Fluorspar	Linked to osteochondral conditions (prolapsed intervertebral disks), mental disorders, endocrine disorders (goiter) in adults.	Davies (1994)
Perlite	Increase in allergic rhinitis, pneumonia, and COPD. Irritant to eyes, skin, and respiratory diseases	Schundler Company (2010); Maxim et al. (2014)
Talc and Pyrophyllite	Decreased lung function and increase radiological opacities in adult workers. No studies on children	Wild et al. (2008)
		Mandel et al. (2016)
Clays, diamond, diatomite, Kyanite, lime, mica, rubber, sand and gravel, stone-crushed, stone-dimension, sulfur		No studies found

Note: * indicates the studies that describe negative health effects of minerals on birth outcomes; References are cited next.

APPENDIX B: ADDITIONAL TABLES

TABLE B1 Summary statistics on health outcomes and covariates (2000–2010)

	(1) Mean	(2) SD	(3) Min	(4) Max	(5) Obs	(6) Data availability
Panel A: Health outcomes (1000 births)						
Infant mortality rate	18.0	16.0	0	1000	54,499	2000–2010
Births underweight (2.5 kg)	73.2	32.3	0	1000	54,505	2000–2010
Births premature (37 weeks)	60.9	50.3	0	976.9	54,504	2000–2010
Births with anomaly	5.76	8.53	0	166.7	54,505	2000–2010
Births with low (less than 7) APGAR 5 min	34.8	47.3	0	967.7	54,505	2000–2010
Crude death rate (CDR)	5.49	1.78	0.071	23.9	54,308	2000–2010
Crude birth rate (CBR)	15.6	4.78	0.22	80.4	54,314	2000–2010
Total fertility rate (TFR)	1.90	0.59	0.032	12.6	54,505	2000–2010
Panel B: Economic activities and government expenditures						
Population	35,726.8	206,897.6	690	11,253,503	54,505	2000–2010
Working age population	23,503.2	142,623.4	459	8,001,784	54,505	2000–2010
GDP (BRL)	446,980.1	4,964,763.3	1775	443,517,625	54,505	2000–2010
Total formal employment (%)	0.17	0.14	0	4.84	54,488	2000–2010
Number of formal firms	448.1	3568.9	1	234,035	54,316	2000–2010
Monthly payroll per employee (BRL)	554.6	682.8	2.83	70,256.3	54,306	2000–2010
Total employment (%)	0.36	0.10	0.074	0.73	9908	2000 and 2010
Monthly wage (BRL)	630.6	345.0	85.8	3157.7	9908	2000 and 2010
Household income (BRL)	1030.8	594.8	151.9	5179.3	9908	2000 and 2010
Exports (million USD)	27.6	222.6	0	10,203.7	39,640	2003–2010
Transfers received (million BRL)	23.8	132.1	0	11,310.9	54,505	2000–2010
Total expenditures (million BRL)	22.9	162.7	0	13,013.7	54,505	2000–2010
Health expenditures (million BRL)	8.34	64.6	0	5558.2	54,505	2000–2010
Hospitals (100,000 people)	85.5	53.3	0	682.2	29,730	2007–2010
Human resources (100,000 people)	743.3	276.8	0	7723.0	19,820	2007–2010
Doctors (100,000 people)	110.3	67.3	0	773.9	19,820	2007–2010
Nurses (100,000 people)	48.4	23.8	0	399.5	19,820	2007–2010
Panel C: Children outcomes (1000 people)						
Vaccine doses	918.8	319.6	260.2	8725.7	54,505	2000–2010
Births with more than 7 ANC visits	509.1	248.6	0	1000	54,504	2000–2010
Hospitalization any illness (U1)	1033.0	2998.3	0	67,202.1	14,865	2008–2010
Hospitalization respiratory	388.9	632.0	0	10,365.7	14,865	2008–2010
Hospitalization perinatal	385.4	2048.5	0	50,432.9	14,865	2008–2010
Hospitalization infectious diseases	158.9	389.0	0	12,706.7	14,865	2008–2010
Hospitalization digestive	22.9	120.6	0	3985.3	14,865	2008–2010
Hospitalization anomalies	20.8	221.4	0	12,252.9	14,865	2008–2010
Hospitalization nutrition	9.67	68.2	0	2176.7	14,865	2008–2010
Hospitalization nervous system	8.34	22.2	0	665.1	14,865	2008–2010
Hospitalization genital	11.4	32.6	0	993.6	14,865	2008–2010
Hospitalization circulatory	8.18	69.7	0	5268.0	14,865	2008–2010
Hospitalization skin infections	3.13	14.9	0	965.2	14,865	2008–2010
Hospitalization tumors	2.84	29.1	0	1771.8	14,865	2008–2010

(Continues)

TABLE B1 (Continued)

	(1) Mean	(2) SD	(3) Min	(4) Max	(5) Obs	(6) Data availability
Panel D: % of births by mothers' characteristics						
Age						
10–14 years old	0.011	0.011	0	0.33	54,505	2000–2010
15–19 years old	0.23	0.066	0	0.67	54,505	2000–2010
20–24 years old	0.31	0.060	0	0.80	54,505	2000–2010
25–29 years old	0.23	0.052	0	1	54,505	2000–2010
30–34 years old	0.14	0.051	0	0.64	54,505	2000–2010
35–39 years old	0.068	0.037	0	1	54,505	2000–2010
40–44 years old	0.020	0.017	0	0.38	54,505	2000–2010
Years of education						
None	0.036	0.053	0	0.76	54,505	2000–2010
1–3 years	0.14	0.10	0	0.93	54,505	2000–2010
4–7 years	0.37	0.10	0	1	54,505	2000–2010
8–11 years	0.31	0.14	0	0.92	54,505	2000–2010
12 or more years	0.10	0.074	0	0.89	54,505	2000–2010
Race						
White	0.54	0.35	0	1	54,505	2000–2010
Black	0.022	0.033	0	0.50	54,505	2000–2010
Yellow	0.0045	0.016	0	0.56	54,505	2000–2010
Brown	0.38	0.32	0	1	54,505	2000–2010
Indigena	0.0075	0.045	0	0.94	54,505	2000–2010
Panel E: Pollution						
Methane (CH_4, tons/year)	13.7	32.6	0.00075	1450.5	9862	2000 and 2008
Nitrous Oxide (N_2O, tons/year)	0.44	1.07	0.000063	73.3	9862	2000 and 2008
Carbon monoxide (CO, tons/year)	25.5	85.7	0.0027	2919.7	9862	2000 and 2008
Sulfur dioxide (SO_2, tons/year)	1.30	8.20	0.0043	339.6	9862	2000 and 2008

Note: The table presents summary statistics for the main variables used in the analysis. Observations are at the year-municipality level over the years defined in data availability column 6. The sample contains about 4955 municipalities constant over the period from 2000 to 2010.

Sources: DATASUS - SINACS, SINAN, SIH; IBGE; FINBRA; SIOPS; CNES; RAIS; Census (2000,2010); EDGAR.

TABLE B2 Summary statistics on mineral endowments and prices (1999–2009)

	(1) Mean	(2) SD	(3) Min	(4) Max	(5) Obs
Panel A: Natural resources index (USD million)					
All mineral index	435.3	2369.2	0	113,106.9	54,505
Metallic mineral index	89.8	1630.6	0	107,009.9	54,505
Industrial minerals index	345.4	1641.9	0	52,354.5	54,505
Panel B: Endowments in 1996–1998 (1000 tons)					
Reserves of minerals	303.6	3263.2	0	183,744.5	14,895
Reserves of metallic minerals	62.2	1294.9	0	68,971.0	14,895
Reserves of industrial minerals	523.1	6114.4	0	350,785	14,895
Panel C: Price (1000 USD)					
Price of minerals	62.6	16.7	41.6	97.9	54,505
Price of metallic minerals	14.2	7.53	7.56	35.4	54,505
Price of industrial minerals	104.4	28.6	66.2	165.9	54,505
Panel D: Average year-to-year price change (USD)					
Price change of minerals	−5163.6	14,854.8	−42603.0	10,246.0	49,550
Price change of metallic minerals	411.5	12,092.6	−26498.8	26,340.1	49,550
Price change of industrial minerals	−9978.4	20,923.3	−56511.1	20,294.6	49,550

Note: The table presents summary statistics for the main variables used in the analysis. Observations are at the year-municipality level between 1999 and 2009. The sample contains about 4955 municipalities constant over the period from 2000 to 2010.

Sources: DNPM; GEM; USGS.

TABLE B3 Mineral index (MI) standardization—Robustness checks

	(1) Infant mortality	(2) Low weight births	(3) Premature (<37w) births	(4) Low APGAR score	(5) Births with anomalies
Panel A: Standardization on positive reserves (full sample)					
Mineral index	−0.175	−0.827	1.743***	1.425***	0.265
	(0.241)	(0.624)	(0.522)	(0.484)	(0.208)
Obs	54,499	54,505	54,504	54,505	54,505
Panel B: Standardization on positive reserves (sub-sample)					
Mineral index	−0.289	−0.724	1.156**	0.787	0.284
	(0.248)	(0.621)	(0.558)	(0.515)	(0.210)
Obs	15,861	15,862	15,861	15,862	15,862
Panel C: Unstandardized reserves (USD billions) (full sample)					
Mineral index	−0.032	−0.153	0.322***	0.263***	0.049
	(0.045)	(0.115)	(0.097)	(0.090)	(0.039)
Obs	54,499	54,505	54,504	54,505	54,505
Mean Dep Var	17.99	73.22	60.91	34.75	5.763

Note: The table presents the local effects of changes in price of selected metallic minerals on health outcomes at birth. Observations are at the year-municipality level. The dependent variables are defined on 1000 births. Infant mortality is defined as the death of an infant before his or her first birthday (column 1); births with low birth weight are defined as below 2.5 kg (column 2); premature births are defined as births which happened before 37 weeks of gestation (column 3); births with low APGAR are defined as with the score measured at 5 minutes being lower than 7 (column 4); births with anomalies are defined as births with any type of anomalies (column 5). Panel A shows a standardized index only on municipalities with positive reserves, municipalities with no endowments are included and assigned value 0; Panel B shows a standardized index only on municipalities with positive reserves, municipalities with no endowments are excluded; Panel C shows an unstandardized index, in USD billions. As a reference the analysis uses a standardized index constructed on all municipalities in the sample, with positive or no endowments. Controls not shown include year and municipality fixed effects, and total population. Standard errors are clustered at the municipality level.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Sources: DATASUS - SINACS.

TABLE B4 Selective migration, by age and gender

	(1) Log (pop)	(2) Log (working age pop)	(3) Log (15–17 pop) - male	(4) Log (15–17 pop) - female	(5) Log (18–29 pop) - male	(6) Log (18–29 pop) - female	(7) Log (30–39 pop) - male	(8) Log (30–39 pop) - female	(9) Log (40–49 pop) - male	(10) Log (40–49 pop) - female	(11) Log (50+ pop) - male	(12) Log (50+ pop) - female
Mineral index	0.002	0.002	0.005**	0.004**	0.000	−0.001	0.001	0.002	0.000	0.003**	0.006***	0.007***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Metallic minerals	0.002*	0.002	0.004**	0.003**	0.001	0.000	0.001	0.002	0.001	0.003**	0.005***	0.006***
	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Industrial minerals	−0.008	−0.008	−0.001	−0.005	−0.015**	−0.016**	−0.001	−0.002	−0.006	−0.001	−0.004	0.001
	(0.008)	(0.008)	(0.012)	(0.010)	(0.007)	(0.007)	(0.011)	(0.009)	(0.007)	(0.009)	(0.009)	(0.011)
Obs	54,505	54,505	54,505	54,505	54,505	54,505	54,505	54,505	54,505	54,505	54,505	54,505
Mean Dep Var	9.480	9.021	6.019	5.964	7.233	7.179	6.813	6.793	6.593	6.571	6.577	6.575

Note: The table presents the local effects of changes in prices of minerals on selective migration. Observations are at the year-municipality level. The sample contains about 4955 municipalities constant over the period from 2000 to 2010. Mineral Index is defined as the interaction between the levels of reserves of minerals between 1996 and 1998 and the yearly average international price. The dependent variables are defined as total population in logs (column 1); total working age population in logs (column 2); total 15–17 years old male population in logs (column 3); total 15–17 years old female population in logs (column 4); total 18–29 years old male population in logs (column 5); total 18–29 years old female population in logs (column 6); total 30–39 years old male population in logs (column 7); total 30–39 years old female population in logs (column 8); total 40–49 years old male population in logs (column 9); total 40–49 years old female population in logs (column 10); total 50+ yrs old male population in logs (column 10); total 50+ yrs old female population in logs (column 11); Working age population is defined as 15–64 years old. Controls not shown include year and municipality fixed effects and total population. Standard errors are clustered at the municipality level.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Sources: IBGE.

TABLE B5 Fertility

	(1) TFR	(2) CBR
Mineral index	5.400	0.012
	(3.518)	(0.028)
Metallic minerals	4.904*	0.019
	(2.793)	(0.023)
Industrial minerals	−9.286	−0.192
	(21.015)	(0.166)
Obs	54,505	54,314
Mean Dep Var	1904	15.57

Note: The table presents the local effects of changes in prices of minerals on proxies for selective fertility. Observations are at the year-municipality level. The sample contains about 4955 municipalities constant over the period from 2000 to 2010. Mineral Index is defined as the interaction between the levels of reserves of minerals between 1996 and 1998 and the yearly average international price. The dependent variables are defined as: total fertility rate as total number of live births per 1000 female residents in the municipality in a year (TFR, column 1); crude birth rate as total number of live births per 1000 of the population in the municipality in a year (column 2). Controls not shown include year and municipality fixed effects and total population. Standard errors are clustered at the municipality level.

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Sources: DATASUS.

TABLE B6 Composition of mothers due to selective migration and fertility (% of births), by age, education and race of mothers

	(1) 10–19 years old	(2) 20–29 years old	(3) 30–44 years old	(4) No educ	(5) 1–7 years educ	(6) 8+ yrs educ	(7) White	(8) African	(9) Asian	(10) Mixed	(11) Indigenous
Mineral index	0.001***	−0.001***	0.001***	0.002***	−0.002	0.003*	−0.000	0.000	−0.000	0.005	−0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	(0.002)	(0.003)	(0.000)	(0.000)	(0.005)	(0.000)
Metallic minerals	0.000***	−0.001***	0.001***	0.001***	−0.001	0.002*	−0.000	0.000	−0.000	0.004	−0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	(0.001)	(0.002)	(0.000)	(0.000)	(0.004)	(0.000)
Industrial minerals	0.002	−0.002	−0.000	0.001	0.003	0.003	0.000	0.001	0.000	0.002	−0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)	(0.003)	(0.005)	(0.001)	(0.001)	(0.006)	(0.000)
Obs	54,505	54,505	54,505	54,505	54,505	54,505	54,505	54,505	54,505	54,505	54,505
Mean Dep Var	0.236	0.536	0.224	0.0362	0.516	0.415	0.536	0.0222	0.00451	0.384	0.00748

Note: The table presents the local effects of changes in prices of minerals on the proportion of births by type of mothers. Observations are at the year-municipality level. The sample contains about 4955 municipalities constant over the period from 2000 to 2010. Mineral Index is defined as the interaction between the levels of reserves of minerals between 1996 and 1998 and the yearly average international price. The dependent variables are defined as percentage of births by mothers of a certain age: 10–19 years old (column 1); 20–29 years old (column 2); 30–44 years old (column 3); of a certain education level (in years): no years of education (column 4): 1–7 years of education (column 5); 8+ years of education (column 6); of a certain race: White (column 7); African (column 8); Asian (column 9); Indigenous (column 10). Controls not shown include year and municipality fixed effects and total population. Standard errors are clustered at the municipality level.

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Sources: DATASUS.

TABLE B7 The local health effects—Robustness checks

	(1) Infant mortality	(2) Low weight births	(3) Premature (<37w) births	(4) Low APGAR score	(5) Births with anomalies
A. Matching (No vs. any reserves)					
Mineral index	−0.085	−0.389	0.918***	0.737***	0.123
	(0.119)	(0.307)	(0.251)	(0.233)	(0.103)
Obs	54,356	54,360	54,359	54,360	54,360
Mean Dep. Var.	17.99	73.22	60.91	34.75	5.763
B. Matching (Low vs. high reserves)					
Mineral index	−0.146	−0.149	1.061***	0.446*	0.118
	(0.136)	(0.319)	(0.339)	(0.238)	(0.112)
Obs	4327	4327	4326	4327	4327
Mean Dep. Var.	17.81	78.71	63.36	33.63	6.096
C. Controlling for municipality-specific time trends					
Mineral index	0.012	−0.153	0.603**	0.122	0.039
	(0.144)	(0.274)	(0.268)	(0.212)	(0.121)
Obs	54,499	54,505	54,504	54,505	54,505
Mean Dep. Var.	17.99	73.22	60.91	34.75	5.763
D. Full sample of municipalities					
Mineral index	−0.072	−0.396	0.949***	0.810***	0.123
	(0.119)	(0.307)	(0.254)	(0.233)	(0.103)
Obs	60,990	61,008	61,007	61,008	61,008
Mean Dep Var	18.06	72.80	60.95	35.07	5.674
E. Controlling for stateXyear FE					
Mineral index	−0.138	−0.328	1.104***	0.420*	0.142
	(0.125)	(0.307)	(0.283)	(0.229)	(0.104)
Obs	54,488	54,494	54,494	54,494	54,494
Mean Dep Var	17.99	73.22	60.91	34.75	5.763
F. Reserves in 1997–1999					
Mineral index	−0.057	−0.578	0.972***	0.641***	0.142
	(0.125)	(0.357)	(0.294)	(0.246)	(0.107)
Obs	54,499	54,505	54,504	54,505	54,505
Mean Dep Var	17.99	73.22	60.91	34.75	5.763
G. Sample of municipalities with positive reserves					
Mineral index	−0.146	−0.149	1.061***	0.446*	0.118
	(0.136)	(0.319)	(0.339)	(0.238)	(0.112)
Obs	4881	4881	4880	4881	4881
Mean Dep Var	17.64	78.77	63.64	33.12	6.149
H. Controlling for births by type of mothers					
Mineral index	−0.095	−0.442	0.825***	0.617**	0.104
	(0.130)	(0.326)	(0.248)	(0.250)	(0.108)

TABLE B7 (Continued)

	(1) Infant mortality	(2) Low weight births	(3) Premature (<37w) births	(4) Low APGAR score	(5) Births with anomalies
Obs	54,499	54,505	54,504	54,505	54,505
Mean Dep Var	17.99	73.22	60.91	34.75	5.763

Note: The table presents robustness checks for the local effects of changes in prices of minerals on health outcomes at birth. Observations are at the year-municipality level. Panel A includes only municipalities matched on pre-existing health outcomes (2000) where being treated is defined as having zero versus any mineral reserves. Panel B includes only municipalities matched on pre-existing health outcomes (2000) where being treated is defined as having mineral reserves below or above the median level at the beginning of the panel. Panel C controls for municipality-specific linear time trends. Panel D includes the full sample of 5570 municipalities in Brazil; Panel E includes state per year fixed effects. Panel F uses minerals' reserves in 1997–1999 for the mineral index. Panel G includes only municipalities with positive mineral reserves at the beginning of the panel data; Panel H includes controls for the percentage of births by mothers characteristics (age, education, race). Controls not shown include year and municipality fixed effects and total population. Standard errors are clustered at the municipality level.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Sources: DATASUS - SINACS.

TABLE B8 Lack of correlation between ex-ante mineral reserves and health outcomes (2000)

	(1) Infant mortality	(2) Low weight births	(3) Premature (<37w) births	(4) Low APGAR score	(5) Births with anomalies
Level of reserves	−0.004	0.046	0.005	−0.034	−0.001
	(0.007)	(0.029)	(0.049)	(0.038)	(0.003)
Obs	54,483	54,505	54,505	54,505	54,505
Mean Dep Var	17.99	73.22	60.91	34.75	5.763

Note: The table presents estimates for the (lack of) correlation between mineral reserves and health outcomes at the beginning of the panel, in 2000. Observations are at the year-municipality level. The dependent variables are defined on 1000 births. Infant mortality is defined as the death of an infant before his or her first birthday (column 1); births with low birth weight are defined as below 2.5 kg (column 2); premature births are defined as births which happened before 37 weeks of gestation (column 3); births with low APGAR are defined as with the score measured at 5 minutes being lower than 7 (column 4); births with anomalies are defined as births with any type of anomalies (column 5). Controls not shown include year and municipality fixed effects and total population. Standard errors are clustered at the municipality level.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Sources: DATASUS - SINACS.

TABLE B9 The local health effects—Robustness checks (adding controls)

	(1) Infant mortality	(2) Low weight births	(3) Premature (<37w) births	(4) Low APGAR score	(5) Births with anomalies
A. With selected controls (2000)					
Mineral index	−0.084	−0.394	0.930***	0.772***	0.139
	(0.119)	(0.306)	(0.254)	(0.233)	(0.102)
Metallic minerals	−0.081	−0.275	0.693***	0.593***	0.104
	(0.096)	(0.244)	(0.200)	(0.159)	(0.083)
Industrial minerals	0.232	−1.087	1.638	0.975	0.236
	(0.451)	(0.961)	(1.242)	(2.190)	(0.253)
B. With selected controls (2000) and time trends					
Mineral index	−0.054	−0.262	0.885***	0.737***	0.119
	(0.118)	(0.299)	(0.257)	(0.233)	(0.102)
Metallic minerals	−0.062	−0.192	0.662***	0.574***	0.092
	(0.095)	(0.240)	(0.203)	(0.159)	(0.083)
Industrial minerals	0.372	−0.521	1.479	0.737	0.139
	(0.463)	(0.964)	(1.269)	(2.204)	(0.252)

(Continues)

TABLE B9 (Continued)

	(1) Infant mortality	(2) Low weight births	(3) Premature (<37w) births	(4) Low APGAR score	(5) Births with anomalies
C. With all controls (2000)					
Mineral index	−0.085	−0.399	0.922***	0.767***	0.140
	(0.119)	(0.307)	(0.254)	(0.233)	(0.102)
Metallic minerals	−0.081	−0.278	0.688***	0.592***	0.105
	(0.096)	(0.244)	(0.200)	(0.159)	(0.083)
Industrial minerals	0.238	−1.125	1.592	0.924	0.240
	(0.452)	(0.964)	(1.237)	(2.188)	(0.253)
D. With all controls (2000) and time trends					
Mineral index	−0.116	−0.257	0.797***	0.605***	0.138
	(0.119)	(0.296)	(0.291)	(0.225)	(0.102)
Metallic minerals	−0.107	−0.190	0.609***	0.475***	0.105
	(0.096)	(0.238)	(0.230)	(0.155)	(0.083)
Industrial minerals	0.231	−0.489	1.056	0.516	0.201
	(0.446)	(0.931)	(1.308)	(2.146)	(0.258)
Obs	54,499	54,505	54,504	54,505	54,505
Mean Dep Var	17.99	73.22	60.91	34.75	5.763

Note: The table presents the local effects of changes in prices of minerals on health outcomes at birth. Observations are at the year-municipality level. The sample contains about 4,955 municipalities constant over the period from 2000 to 2010. Mineral Index is defined as the interaction between the levels of reserves of minerals between 1996 and 1998 and the yearly average international price. The dependent variables are defined on 1,000 births. Infant mortality is defined as the death of an infant before his or her first birthday (column 1); births with low birth weight are defined as below 2.5 kg (column 2); premature births are defined as births which happened before 37 weeks of gestation (column 3); births with low APGAR are defined as with the score measured at 5 minutes being lower than 7 (column 4); births with anomalies are defined as births with any type of anomalies (column 5). Panel A includes the predictors of endowments as selected by the least absolute shrinkage and selection operator (LASSO), that is, male working age population, adult and child unemployment rate. Panel B includes several covariates which include population, working age population, employment rates, proportion of mothers by age, education and race, gini coefficient, GDP per capita, size of the municipalities, total expenses and health expenses, transfers received and spent, population, CBR and TFR. Panel C includes interaction terms between selected covariates and time. Panel D includes interaction terms between all covariates and time. Controls not shown include year and municipality fixed effects. Standard errors are clustered at the municipality level.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Sources: DATASUS - SINACS.

TABLE B10 The local health effects—Robustness check (metallic and industrial minerals)

	(1) Infant mortality	(2) Low weight births	(3) Premature (<37w) births	(4) Low APGAR score	(5) Births with anomalies
Metallic minerals	−0.085	−0.261	0.671***	0.582***	0.105
	(0.096)	(0.244)	(0.202)	(0.162)	(0.083)
Industrial minerals	0.258	−0.952	0.924	0.409	−0.049
	(0.465)	(1.016)	(1.296)	(2.198)	(0.316)
Obs	54,499	54,505	54,504	54,505	54,505
Mean Dep Var	17.99	73.22	60.91	34.75	5.763

Note: The table presents robustness checks for the local effects of changes in prices of minerals on health outcomes at birth. The empirical model includes both the indexes of metallic and industrial minerals in the same regression. Observations are at the year-municipality level. The dependent variables are defined on 1,000 births. Infant mortality is defined as the death of an infant before his or her first birthday (column 1); births with low birth weight are defined as below 2.5 kg (column 2); premature births are defined as births which happened before 37 weeks of gestation (column 3); births with low APGAR are defined as with the score measured at 5 minutes being lower than 7 (column 4); births with anomalies are defined as births with any type of anomalies (column 5). Controls not shown include year and municipality fixed effects and total population. Standard errors are clustered at the municipality level.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Sources: DATASUS—SINACS.

TABLE B11 Resource windfalls—Robustness checks

	(1) GDP per capita	(2) Log (tot exports, USD)	(3) Log (transfers received)	(4) Log (transfers spent)	(5) Log (health expenditures)
A. Full sample of municipalities					
Mineral index	0.491**	−0.023	0.036***	0.040***	0.022*
	(0.218)	(0.088)	(0.013)	(0.015)	(0.013)
Obs	61,023	44,426	61,023	61,023	61,023
Mean Dep. Var	7.885	4.816	15.37	14.21	13.86
B. Controlling for stateXyear FE					
Mineral index	0.524**	−0.040	0.052***	0.057***	0.037**
	(0.220)	(0.088)	(0.017)	(0.019)	(0.016)
Obs	54,494	39,632	54,494	54,494	54,494
Mean Dep. Var	7.936	5.171	15.51	14.35	14
C. Reserves in 1997–1999					
Mineral index	0.496**	−0.047	0.038***	0.043***	0.022
	(0.214)	(0.113)	(0.013)	(0.015)	(0.014)
Obs	54,505	39,640	54,505	54,505	54,505
Mean Dep. Var	7.936	5.171	15.51	14.35	14
D. Sample of municipalities with positive reserves					
Mineral index	0.472**	−0.037	0.023*	0.028**	0.007
	(0.213)	(0.089)	(0.013)	(0.014)	(0.013)
Obs	4881	3582	4881	4881	4881
Mean Dep. Var	9.350	9.164	16.18	15.09	14.73

Note: The table presents robustness checks for the local effects of changes in prices of minerals on wealth outcomes. Observations are at the year-municipality level. Panel A includes the full sample of 5570 municipalities in Brazil; Panel B includes state per year fixed effects. Panel C uses minerals' reserves in 1997–1999 for the mineral index; Panel D includes only municipalities with positive mineral reserves at the beginning of the panel data. Mineral Index is defined as the interaction between the levels of reserves of minerals between 1996 and 1998 (1997–1999 for Panel D) and the yearly average international price. The dependent variables are defined as GDP per capita (column 1); log of total value of exports in USD (column 2); log of total transfers received by the municipality because of oil or mining (column 3); log of total transfers used by the municipality (column 4); log of total governmental health expenditures (column 5). Controls not shown include year and municipality fixed effects and total population. Standard errors are clustered at the municipality level.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Sources: IBGE, FINBRA, SIOPS.

TABLE B12 Economic activities—Robustness checks

	(1)	(2)	(3)	(4)	(5)
	RAIS		Census		
Data source	Formal employment (%)	Monthly payroll (BRL)	Any employment (%)	Monthly wage (BRL)	Household income (BRL)
A. Full sample of municipalities					
Mineral index	0.002***	1.113	0.004***	31.954***	43.081***
	(0.001)	(2.091)	(0.001)	(9.082)	(14.788)
Obs	60,942	60,714	10,992	10,992	10,992
Mean Dep. Var.	0.163	549.5	0.351	620.1	1010
B. Controlling for stateXyear FE					
Mineral index	0.002***	1.262	0.004***	31.800***	45.478***
	(0.001)	(2.456)	(0.001)	(8.715)	(14.551)
Obs	54,477	54,295	9906	9906	9906
Mean Dep. Var	0.169	554.6	0.356	630.6	1031
C. Reserves in 1997–1999					
Mineral index	0.002**	1.088	0.003***	30.459***	38.131**
	(0.001)	(2.170)	(0.001)	(8.840)	(15.031)
Obs	9908	9908	9908	54,488	54,306
Mean Dep. Var. 0.356	630.6	1031	0.169	554.6	
D. Sample of municipalities with positive reserves					
Mineral index	0.002**	1.321	0.002***	25.868***	34.740**
	(0.001)	(1.938)	(0.001)	(8.829)	(14.950)
Obs	4881	4873	868	868	868
Mean Dep. Var	0.209	611	0.371	712	1176

Note: The table presents robustness checks for the local effects of changes in prices of minerals on economic activities. Observations are at the year-municipality level. Panel A includes the full sample of 5570 municipalities in Brazil; Panel B includes state per year fixed effects. Panel C uses minerals' reserves in 1997–1999 for the mineral index. Panel D includes only municipalities with positive mineral reserves at the beginning of the panel data. Mineral Index is defined as the interaction between the levels of reserves of minerals between 1996 and 1998 and the yearly average international price. The dependent variables are defined as total formal employment rate as percentage of the working population (column 1); monthly payroll (column 2); any formal or informal employment rate as percentage of the population (column 3); monthly wage (column 4); household income (column 5). Columns 1–2 use RAIS dataset, columns 3–5 use Census data in 2000 and 2010. Controls not shown include year and municipality fixed effects and total population. Standard errors are clustered at the municipality level.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Sources: RAIS.

TABLE B13 Pollution—Robustness checks

	(1) CH_4	(2) N_2O	(3) CO	(4) SO_2
A. Full sample of municipalities				
Mineral index	0.152	0.008**	−1.661*	0.072***
	(0.138)	(0.004)	(0.985)	(0.026)
Obs	10,936	10,936	10,936	10,936
Mean Dep. Var.	12.90	0.415	24.21	1.204
B. Controlling for stateXyear FE				
Mineral index	0.072	0.005	−1.917**	0.063**
	(0.150)	(0.004)	(0.937)	(0.026)
Obs	9860	9860	9860	9860
Mean Dep. Var.	13.69	0.437	25.53	1.299
C. Reserves in 1997–1999				
Mineral index	0.123	0.007*	−1.619	0.071***
	(0.141)	(0.004)	(0.999)	(0.026)
Obs	9862	9862	9862	9862
Mean Dep. Var.	13.69	0.437	25.53	1.299
D. Sample of municipalities with positive reserves				
Mineral index	0.054	0.004	−1.396	0.071***
	(0.152)	(0.004)	(1.032)	(0.027)
Obs	860	860	860	860
Mean Dep. Var.	26.45	0.660	53.74	4.678

Note: The table presents robustness checks for the local effects of changes in prices of minerals on air pollutants. Observations are at the year-municipality level. The sample contains about 4955 municipalities for the years 2000 and 2010, when air pollution data are available (EDGAR) if not otherwise specified. Panel A includes the full sample of 5570 municipalities in Brazil; Panel B includes state per year fixed effects. Panel C uses minerals' reserves in 1997–1999 for the mineral index; Panel D includes only municipalities with positive mineral reserves at the beginning of the panel data. Mineral Index is defined as the interaction between the levels of reserves of minerals between 1996 and 1998 and the yearly average international price. The dependent variables are defined as CH_4, Methane (column 1); N_2O, Nitrous Oxide (column 2); CO, Carbon Monoxide (column 3); SO_2, Sulfur Dioxide (column 4). All variables are defined in tons per year (in 100,000). Controls not shown include year and municipality fixed effects and total population. Standard errors are clustered at the municipality level.

***$p < 0.01$, ** $p < 0.05$, *$p < 0.1$.

Sources: DATASUS—SIH.

APPENDIX C: ADDITIONAL FIGURES

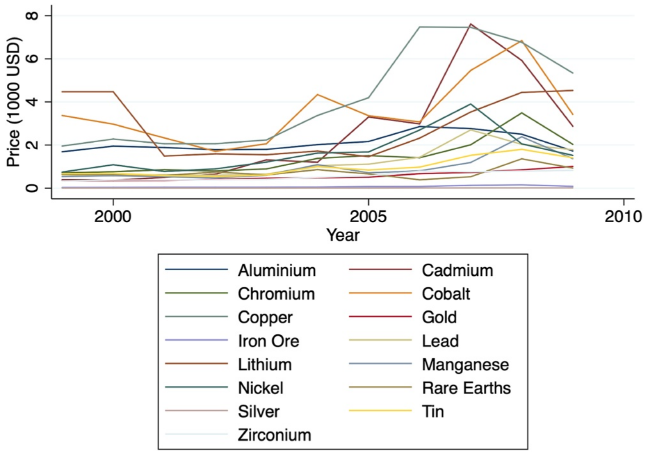


FIGURE C1 Average price levels for metallic minerals between 1999 and 2009. The figure describes the average price (USD, in 1,000), for metallic minerals, between 1999 and 2009 for all municipalities in Brazil. The prices of cobalt, nickel, rare earths, and tin are on 10,000 scale. The price of talc and pyrophillite is on 100,000 scale. The prices of tantalum, tungsten, vanadium, zinc are excluded because of low number of municipalities with these minerals and limited space. [Colour figure can be viewed at wileyonlinelibrary.com]

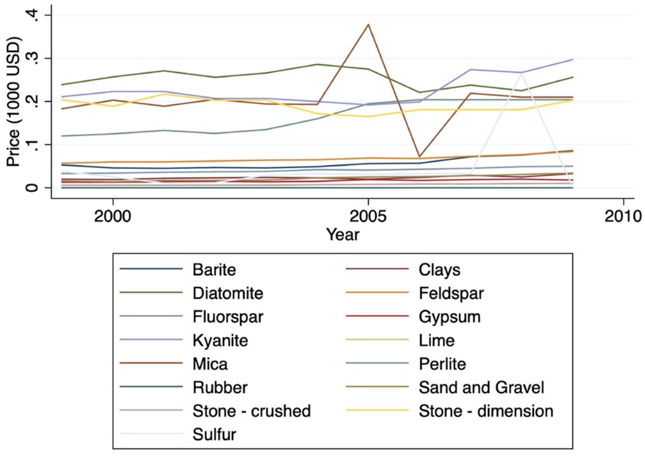
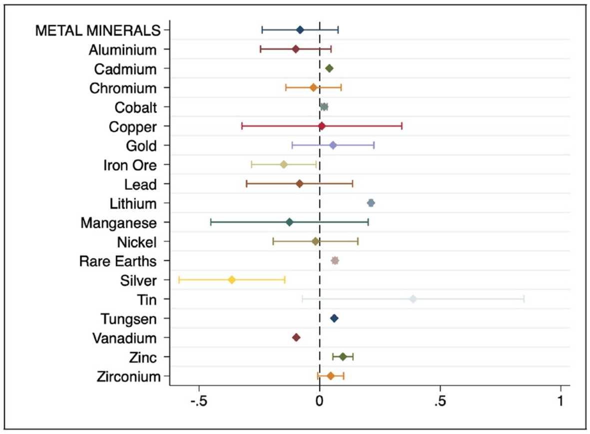
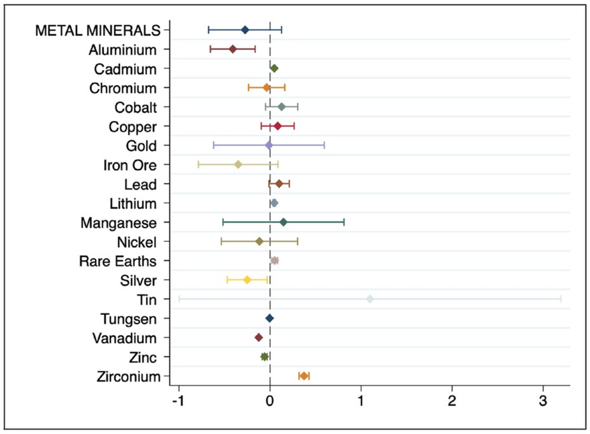


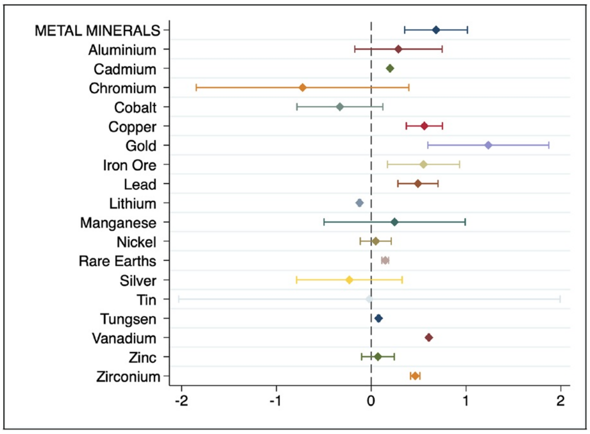
FIGURE C2 Average price levels for industrial minerals between 1999 and 2009. The figure describes the average price (USD, in 1,000), for industrial minerals, between 1999 and 2009 for all municipalities in Brazil. The prices of lime, mica and rubbers are on 10,000 scale. Prices of asbestos, beryllium and graphite are excluded because of low number of municipalities with these minerals and limited space. [Colour figure can be viewed at wileyonlinelibrary.com]



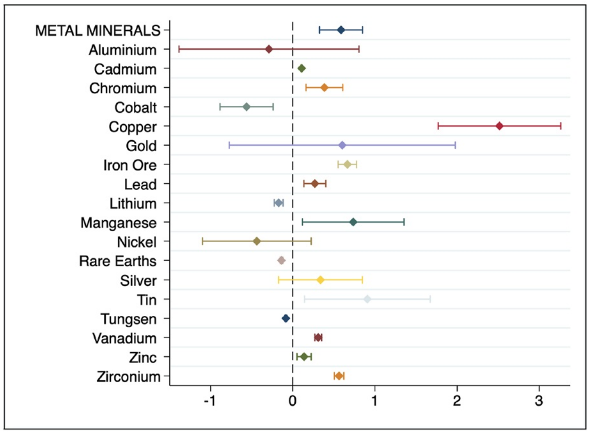
a. Infant Mortality



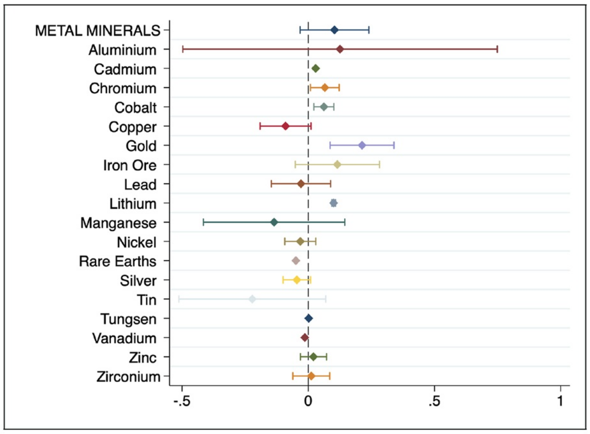
b. Low-weight births



c. Premature births

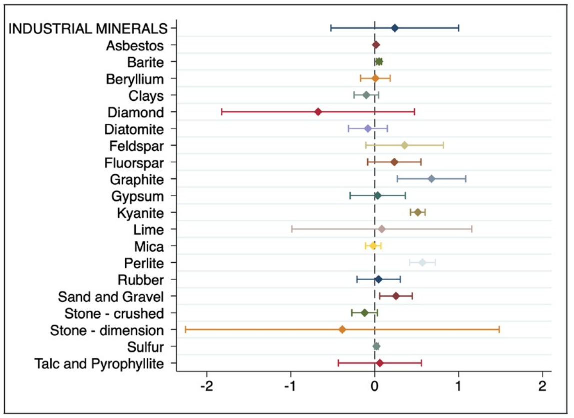


d. Births with low APGAR score

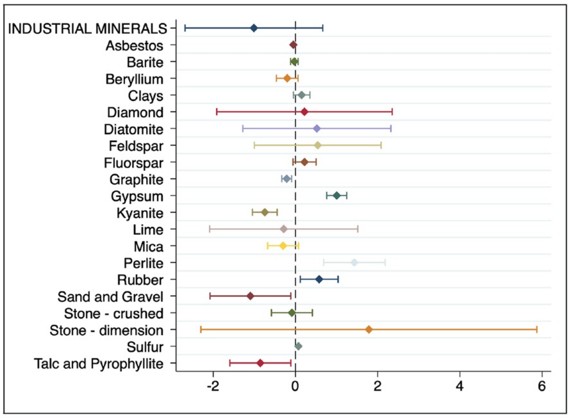


e. Births with anomalies

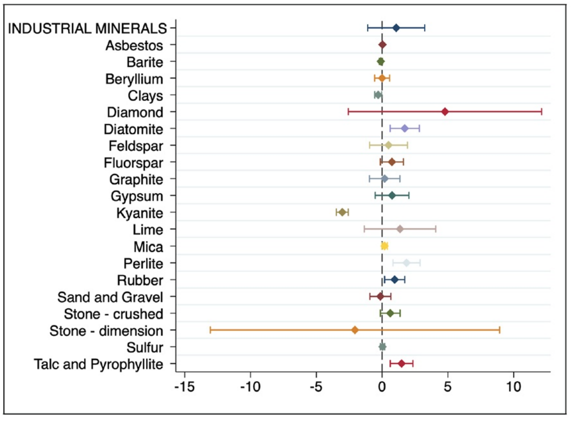
FIGURE C3 The local health impacts—(1) Metallic minerals. The figure plots the estimated coefficients of the local effects of changes in prices of minerals on health outcomes at birth, for metallic minerals. [Colour figure can be viewed at wileyonlinelibrary.com]



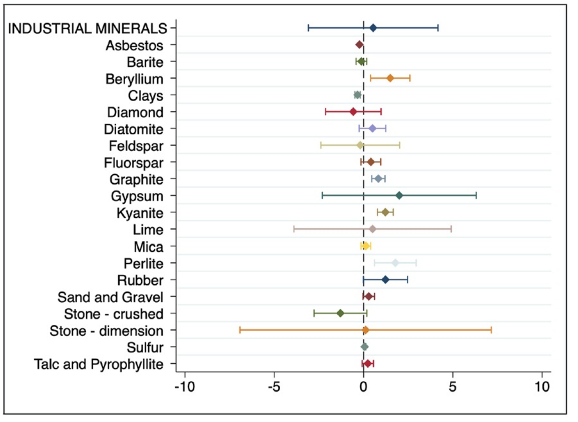
a. Infant Mortality



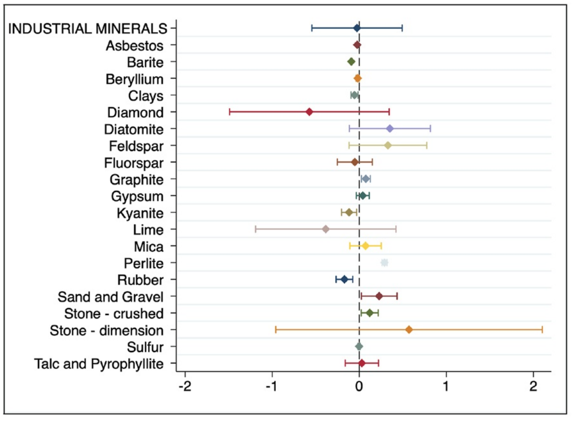
b. Low-weight births



c. Premature births



d. Births with low APGAR score



d. Births with anomalies

FIGURE C4 The local health impacts—(2) Industrial minerals. The figure plots the estimated coefficients of the local effects of changes in prices of minerals on health outcomes at birth, for industrial minerals. [Colour figure can be viewed at wileyonlinelibrary.com]