Extended Abstract for the 64th ERSA Congress

Title: Dark Waters. The effect of mine openings on water quality in Sub-Saharan Africa

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Extended Abstract

Motivation

This study investigates the impact of mine openings in the Sub-Saharan Africa, following the mining boom experience since the Nighties, on the social conditions of local communities near extraction sites. Using satellite imagery and a difference-in-differences approach, we analyse how mineral extraction affects water quality, mainly proxied by turbidity. This research contributes to the existing literature on the environmental consequences of mining, offering new insights into the socio-economic outcomes associated with technological development in a region with immense mineral wealth but lagging improvements in living standards.
Moreover, we hypothesize that changes in water turbidity can serve as an indicator of broader environmental degradation caused by mining activities, providing a valuable tool for environmental monitoring.

Background

The technological advancements of the last two decades have led to an increase in the production of certain minerals, with some countries such as the Democratic Republic of Congo (DRC) being among the most important suppliers worldwide of certain critical raw material (IRENA, 2023; Li et al. 2024). For instance, in DRC, the rise was a direct consequence of the new demand for materials for efficient batteries in electric vehicles due to the Chinese boom in car markets (Marysse & Geenen, 2009; Byamungu, 2022) and, subsequently, the global spread of lithium-ion batteries (Malpede, 2021), which require cobalt, nickel, aluminium, and lithium. To briefly quantify this rise, cobalt production increased from 28,400 to 104,000 metric tons, copper from 150,000 to 1,230,000 metric tons, coal from 1,000 to 8,000 metric tons, gold from 10,000 to 46,000 kilograms, zinc from 7,500 to 12,337 metric tons, columbite-tantalite from 52 to 2,267 metric tons, and tin from 5,878 to 16,273 metric tons (USGS Mineral Yearbook).
Mines must be located very close to water sources. Lottermoser et al. (2003) technically explained that mines require water for various purposes including dust control, mineral processing, washing coal, and extracting metals through hydrometallurgical processes. This water is obtained from surface water bodies and underground aquifers, or as a by-product from the process of draining mines. Mining activities, whether in open pits or underground, often penetrate below the regional water table, necessitating the removal of water to prevent flooding. Specifically, mines that tap into significant underground water sources or are situated

in areas with high rainfall might need to pump out over 100,000 litres of water per minute to keep the mine dry. During certain phases of mining activities, water becomes a surplus by-product with no useful purpose. Indeed, this excess or previously used water must be continuously disposed of throughout the mining, processing, and metal extraction phases.

The social conditions of people living near extraction sites remain a contentious issue in academic discussions, while the importance of water quality is a topic of growing concern. The World Health Organization (2021) reports that 2 billion people lack safe drinking water. According to UNICEF data, only a small percentage of the population had access to safely managed water and less than half of the population can use water free of contamination. The quality of potable water from rivers and ponds become so a lifeline that directly impacts work, education, and economic stability. The availability of clean water in those areas profoundly influences displacement and migration due to its vital importance in agriculture and farming (Cuba et al., 2014), and health (Strunz et al., 2014; Prüss-Ustün et al., 2019; Nguyen et al. 2021). Ochieng et al. (2010) find that the water quality in mining areas of South Africa is below standard due to acid mine drainage from the gold and coal industries. Muimba-Kankolongo et al. (2021), who evaluated the contamination of water in six mining areas between the DRC and Zambia, discovered that in the drinking water obtained close to mining sites, the median concentrations of trace elements (Mn, Co, Ni, Cu, As, Cd, Pb, U) were substantially higher than in the control areas. This brings us to ask how mining extraction, driven by high-income countries demand, impact on water quality close to mines compared to what happens further away from mine sites.

Methodology and expected results

We used Google Earth Engine to create images from Landsat-7 and Landsat-8 satellites to calculate the water turbidity index (Lacaux et al., 2007) in the Sub-Saharan Africa between 1990s and late 2010s.

As first step, water bodies were isolated by land using the Normalized Difference Water Index (NDWI), defined as $NDWI = (Green - Nir)/(Green + Nir)$. Then, we calculate turbidity in wetland areas using the Normalised Difference Turbidity Index (NDTI), defined as $NDTI = (Red - Green)/(Red + Green)$ and clean of clouds presence. To do so, we create a geopolygon and geodataframe of the area of interest.

Turbidity, which refers to the optical clarity of the water, is often used alongside these parameters to provide a more holistic analysis of water quality (Davies-Colley & Smith, 2001; Damo & Icka, 2013). Data were processed at a resolution of less than 1 km. By leveraging mines and deposits geolocalized data from the U.S. Geological Survey, we employed a difference-in-difference approach to assess changes in water turbidity following the opening of a mine. Areas of the Sub-Saharan Africa are so categorized into two groups: a treatment group comprising those close to mine and a control group, which includes areas located further away from a mine. The distance will be chosen based on existing literature (Aragon and Rud, 2013 and 2016; Kung et al., 2014; Kotsadam and Tolonen, 2016). The aim is to assess whether the Turbidity Index of these two groups changes differently after the opening of a mine. The empirical specification is presented as follows:

$$y_{it} = \alpha_1 T_i + \alpha_2 P_t + \alpha_3 (T_i \times P_t) + \alpha_4 X_{it} + \gamma_i + \tau_t + \varepsilon_{it}$$

Where T_i represent the treated cells i and P represent the post dummy period; our coefficient of interest is α_3 and the regression also include a set of control variables X_{it} and a cell (γ_i) and time (τ_t) fixed effects, plus an independent and identically distributed error term ε_{it}.

We expect that areas surrounding newly opened mines will experience a significant deterioration in water quality due to mining waste and land degradation. Furthermore, to ensure the robustness of our results, we conducted a sensitivity analysis across multiple model specifications to account for potential confounding variables.

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