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MEE232

THE IMPACT OF MINERAL EXPLORATION(DISCOVERIES) ON EDUCATIONAL OUTCOMES IN SUB-SAHARAN AFRICA

OFORI JUSTICE LIVINGSTONE
MASTER'S THESIS'

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Abstract

Mineral wealth is seen as a potential driver for economic growth, providing countries with the unique opportunity to increase their revenue, create employment, and strengthen their infrastructure. However, the long-term impacts of mineral discoveries on educational outcomes in Sub-Saharan Africa (SSA) remain contested in the literature. The study uses data from the DHS database and the USGS, combined with geospatial information about mineral exploration. An ordered probit model is used to estimate the relationship between mineral wealth and educational attainment, considering various control variables like local economic activity and infrastructure. The findings indicate that mineral wealth significantly reduces later-life educational outcomes of individuals while increasing household wealth creating a problem of private benefits vs social costs and misaligned incentives. The policy implications of these results are discussed, emphasizing the importance of reforming educational policies in order to increase its attractiveness to rival the incentives from mineral exploration activities.

KEYWORDS: Mineral exploration, Mineral wealth, Resource Curse Hypothesis, Educational Outcomes, Human Capital Development, Economic Growth

Contents

1 Introduction

The start of mineral exploration activities in any given region is often met by widespread optimism, excitement and expectations of prosperity. Minerals are seen as potential drivers for economic growth, providing countries with the unique opportunity to increase their revenue, create employment, and strengthen their infrastructure. The capital intensive nature of mineral exploration activities can lead to the multiplier effect [2]. At the heart of these developments lies the belief that such activities will ultimately elevate the living standards of the local population and contribute to long-term development. As a result, mineral exploration is frequently seen as a symbol of greater opportunities ahead.

However, this idealized narrative is frequently challenged by the complex realities faced by resource-rich regions, particularly in Sub-Saharan Africa (SSA). While the positive sides of mineral wealth are often highlighted and lauded, the negatives are often maligned and overlooked. In SSA, resource-rich countries like Ghana, Zambia, and South Africa have witnessed significant economic transformation as a result of the exploitation of their resources. Yet, the relationship between mineral exploration and broader socio-economic development still remains contested in the literature. Numerous studies suggest that the sudden influx of wealth can lead to economic imbalances, increased inequality, and the neglect of other critical sectors such as education (Ahlerup, Baskaran and Bigsten, 2019; Aragon and Rud, 2013). While the immediate effects of mineral exploration might seem positive, long-term consequences often diverge from the expectations, leading to what is commonly referred to as the "resource curse" (Sachs and Warner, 2001).

[2] The injection of capital from mineral exploration activities generates further spending on investment leading to an increase in employment, income and public services such as schools, roads and hospitals

Studies in several contexts have consistently highlighted the crucial role education plays in shaping the long-term socioeconomic outcomes of individuals. Higher levels of educational attainment have been shown to improve living standards (Kouladoum, 2023) and acts as a catalyst for breaking the vicious cycle of poverty [3]. Studies have also indicated that education serves as a key pathway to economic mobility, better health, and enhanced social welfare (Schultz, 2004; Heckman, 2006). In SSA, where educational disparities are prevalent, the promise of education as a tool for social and economic empowerment remains a focal point for policy and development. This makes education's relationship with regional economic alterations-such as those induced by mineral exploration-particularly significant.

In SSA, The complexities of mineral exploration and socio-economic development are more profound at the local level. Although this region is very rich in minerals such as gold, silver, diamonds, copper, and oil, the effects of these resources on local populations are more complex than they might appear at first glance. For individuals living in these resource-rich areas, the rise of mineral exploration activities can alter the opportunity cost of schooling [4]. As is often the case, the surge in mineral exploration activities can result in economic pressures on households making education less of a priority, especially for children. These pressures often change the expectation that mineral wealth will improve public services, including education (de la Brière et al., 2017).

[3] Poverty in Sub-Saharan Africa often results from a "poverty trap," characterized by low savings, limited capital investment, and insufficient education, creating a self-reinforcing cycle that hinders development (Tacoli et al., 2023)

[4] Opportunity cost of schooling refers to the trade-off between the direct benefits of education (such as future earnings) and the immediate economic benefits that families might gain from child labor in sectors like mining.

The main objective of this study is analyze how mineral resources impact the later-life educational outcomes of individuals within these regions. This study first conducts a district-level analysis to assess the educational attainment of individuals living in mining areas, choosing this level due to the relative uniformity of educational systems at the administrative unit level. This approach allows for a clear comparison of educational outcomes across mining and non-mining districts, providing an initial assessment of how mineral wealth may influence education at the regional scale. The findings of the district-level analysis suggest that, although the presence of minerals within a particular district may bolster the extensive margins by improving the educational attainment levels of people in these areas through improved access to education, these positive spillovers are offset by the negative externalities. In particular, the economic opportunities provided by mining can increase the opportunity cost of schooling, leading to higher rates of child labor and school dropout in certain contexts. For the individual-level study, the results show that the decision to forgo schooling in favor of mining activities is not as myopic as initially feared. It presents an interesting dilemma from the private and social perspectives. While the income gained from mining activities may bolster household income, it creates a significant reduction in the human capital accumulation of the society which is a critical driver for sustainable growth and development. This makes mineral's impact on education a more complex subject and decision making bodies in the region must factor all these intricacies in their targeted policy framework. Overall, the results suggest that mineral wealth in SSA is a double-edged sword for educational outcomes. In summary, this research advances the literature by demonstrating that the effects of mineral wealth on the later-life educational outcomes in SSA are complex, context-specific, and mediated by economic incentives.

The paper proceeds as follows: Chapter 2 reviews the literature on the resource curse and education's role in development. Chapter 3 describes the data and methodology, combining geospatial mineral data with the DHS surveys. Chapter 4 presents the empirical results, while Chapter 5 discusses their implications, Chapter 6 showcases some robustness tests and Chapter 7 concludes with policy recommendations.

2 Literature Review

2.1 Resource Curse Hypothesis

The main theoretical framework underpinning this study is the resource curse hypothesis. This hypothesis, first propounded by (Sachs and Warner, 1995), postulates that countries with a plethora of resources tend to experience stunted economic growth, poorer development of human capital, and greater inequality due to the misallocation of wealth generated by natural resources. This theory is more so relevant in the context of SSA due to the region's vast resource share. According to (Foundation, 2022), SSA holds 30% of the world's mineral reserves, many of which are critical to renewable and low-carbon technologies including solar, electric vehicles, battery storage, green hydrogen, and geothermal. To put the region's enormous resource wealth into further context, Ghana, as of October 2024 holds 28.1 tonnes of gold in its central bank reserves, ranking it fifth in Africa and 60th globally (GhanaWeb, 2024). The Democratic Republic of the Congo (DRC), another SSA country, also possesses approximately 3.4 million metric tons of cobalt reserves, accounting for nearly half of the world's supply. Given the extensive context provided, it is undeniable that SSA is a key player in the global mineral market, with its vast resource wealth holding the potential to drive significant economic growth and development—if managed effectively—yet also exposing the region to the risks of the resource curse, as discussed in the theoretical framework.

At the macro-economic level, the Dutch Disease phenomenon has been outlined as the main driving mechanism explaining the resource curse hypothesis. This theory, originally coined by (Corden and Neary, 1982), was used to explain the negative impacts of the discovery of natural gas reserves in the Netherlands in 1963. According to the model developed in the paper (Corden and Neary, 1982), Netherlands' natural gas discovery led to a substantial inflow of foreign currencies which resulted in the appreciation of the Dutch guilder [5]. However, this appreciation of the Dutch guilder led to other sectors such as agriculture and manufacturing becoming less competitive on the global market. This created a heavy resource dependence and subsequently led to a de-industrialization effect. This shift toward resource dependence and away from diversified sectors serves as a key mechanism to explain the resource curse hypothesis, where resource wealth can hinder long-term economic growth and diversification. A poignant example of the Dutch Disease manifesting in the SSA context can be seen in (Laguda, 2019) which found that Nigeria's oil-dependence has ultimately resulted in the decline of their agricultural sector productivity.

Studies by (Rahim, 2021) support the argument that, the abundance of resources may hinder investments in education, resulting in a reduction of skilled labour ultimately leading to a halt in economic diversification and growth. This idea is further reinforced by the findings of (Volchkova and Suslova, 2009) who argue that natural resource wealth in countries impede human capital development, particularly skilled labour. They further postulate that, this

[5] The Dutch guilder was the official currency of the Netherlands from the 17th century until it was replaced by the euro in 2002

reduction in countries' human capital due to inadequate investment in education ultimately hamper industrial growth, especially in capital-intensive industries that require sophisticated skills. Also, (Gylfason, 2002) discusses the broad pattern observed across resource-rich countries, showing how the dependence on resource extraction diverts resources from education. In the African context, further evidence can be inferred from the study of (Ahlerup, Baskaran and Bigsten, 2019) exploring the impact of gold mining on education in Africa. The study documents that gold mining ultimately reduced educational attainment of individuals living in mineral-rich areas and thus, affects the long-term development of human capital in these areas.

All these papers have provided vivid empirical evidence that highlight the negative impact of resources on education across several regions and context. This widespread evidence supports the notion that natural resource wealth, particularly in Sub-Saharan Africa, often exacerbates the challenges of economic diversification and human capital accumulation. However, it is important to note that the negative impacts observed are not inevitable at the individual level. While resource wealth at the macro level can detract from investments in education and human capital, at the micro level, the story may be more complex and dynamic which necessitates a granular analysis to explore a deeper impacts of minerals and the educational outcomes of individuals living within these regions.

2.2 The Theory of Education as a Pathway to Development

As has been established in economic theory, human capital development, mainly through education, is one of the key drivers of economic growth. Human capital is an important input in the production process while also being an essential component shaping the long-term economic growth trajectories of countries, this according to the Endogenous Growth Theory. The theories propounded by (Romer, 1990; Lucas Jr, 1988) suggest that, education plays a crucial role in human capital development and it is seen as essential for enhancing labour productivity, fostering technological innovation, and driving sustainable economic growth. Their findings further suggest a positive relationship between education attainment and productivity. Thus, higher educational attainment levels causes an increase in skill levels which in turn enhances efficiency and raises individual and societal productivity. Their endogenous growth models further asserts that the knowledge accumulation gathered from education, is a critical component of growth. This offers a clear distinction from classical models that view technological progress and capital accumulation as exogenous. These theories thereby imply that education is not just an avenue for social mobility, but is also an essential driver of economic dynamism.

Empirical evidence support the notion that, beyond the macroeconomic benefits that education provide, education also instigates inter-generational mobility. Studies by (Heckman, 2006) further magnify the leading role early childhood education plays in breaking the vicious cycle of poverty, a theory which has significant implications of SSA, where child labor in mining regions often truncates educational trajectories (Bhalotra and Heady, 2003). Thus, it is clearly evident that education remains a pivotal pathway for SSA to harness its mineral wealth sustainably. The subsequent chapters empirically test these theoretical claims, examining how mineral wealth reshapes educational outcomes across districts and individuals.

2.3 Contributions to Literature

Although there has been extensive literature on the macroeconomic dynamics of the Dutch Disease and resource dependence and its impact on human capital development, its microeconomic implications still remain underexplored in the SSA context. Notable attempts by (Ahlerup, Baskaran and Bigsten, 2019) explored the dynamics between gold mining and education focusing on the district-level offering valuable insights to district-level dynamics using aggregated data. This study delves deeper into the individual-level impacts of resource wealth on educational attainment by utilizing pseudo-longitudinal data from the (Demographic and Health Surveys, DHS), geocoded data on mineral positions from (U.S. Geological Survey, 2025), and other relevant data sources, to examine how resource wealth influences educational attainment at the grassroots level and aims to identify the specific channels through which this relationship is formed. This study also introduces the concept of private benefits versus social costs which is novel dimension in resource curse hypothesis literature,particularly in the context of SSA and thereby highlights alternate ways through which resource wealth can inhibit human capital development at the individual level.

3 Data

3.1 Data Sources

3.1.1 Demographic and Health Surveys Data

Data on educational outcomes in SSA, which was the main dependent variable for this study, were sourced from (Demographic and Health Surveys, DHS) between the period of 2015 to 2023. This survey also provided individual-level data on indicators such as socioeconomic status, duration of residence, health status, and age of respondents. Additionally, it attached the required geo-referenced coordinates of respondents which allowed this study to perform a structured spatial analysis on the educational outcomes of individuals living in close proximity to mineral deposits and mines. DHS employed a stratified two-stage cluster sampling design to ensure nationally and sub-nationally representative data across all countries. For the first stage of the sampling procedure, clusters were selected using probability proportional to size (PPS) within urban and rural strata for each region, ensuring that clusters reflect the population distribution. For the second stage, within each selected cluster, a complete household listing was conducted, followed by systematic random sampling of households to be interviewed. This household listing and mapping were rigorously conducted using GPS technology and tablet-based data collection to ensure accuracy and completeness.

The stratified two-stage cluster design is explicitly intended to produce representative estimates at the national level, for urban and rural areas. The sample size and design allow for reliable estimates of key indicators, including education, at these geographic levels. Sampling errors and design effects are calculated using appropriate statistical methods (Taylor linearization and Jackknife repeated replication) to account for the complex survey design. Although DHS is generally structured to be representative at the regional-level rather than at lower administrative levels such as the district level, the DHS sampling strategy includes measures to enhance representativeness. The first is the use of probability proportional to size sampling ensuring that, larger population centers have proportionally more clusters, increasing the likelihood that the sample reflects the population distribution within districts. Also, household listing and GPS mapping within clusters improve the accuracy of household selection, reducing selection bias. Again, sample weights are provided and applied in analysis to adjust for differential probabilities of selection, non-response, and to align the sample with known population distributions from the census. Lastly, DHS provides manuals and guides such as (The Demographic and Health Surveys (DHS) Program, 2022) which serve as a good reference point for mapping and aggregating survey data to administrative units, improving the spatial accuracy of district-level estimates which proved invaluable in this study allowing me to aggregate key variables such as Educational Attainment and Educational Completeness.

This study utilizes pseudo-longitudinal data from DHS and gathers data across 32 SSA countries recording a total number of observations of 774,987. Refer to Table 8 for further details.

3.1.2 Other Data Sources

To complement the DHS data, this study utilized geo-referenced data from the United States Geological Survey (USGS), which provided detailed information on mineral deposits across SSA (U.S. Geological Survey, 2025). This dataset offers insights into the locations and sizes of key mineral reserves in the region, such as gold, cobalt, and petroleum. The geo-referencing of mineral deposits allowed me to link mineral wealth with educational outcomes, enabling the investigation of how proximity to and the extent of mineral deposits and mining sites in specific regions affect local educational attainment. At the district level, these data allowed for the segregation of mining and non-mining districts as shown in Figure 4. It also helped to develop a nuanced individual-level analysis of the phenomenon.

Data from the PRIO-GRID dataset were also utilized in this study as it provided essential geographical and socio-economic controls which I integrated into the analysis (PRIO-GRID, Various). This dataset offers high-resolution geographic data, including variables such as population density, climate factors, and land-use types, which are essential to understand the broader environmental and economic context of the districts under study. For the purpose of examining the role of mineral wealth at the district level, the PRIO-GRID dataset also provided data on gold reserves, which was particularly relevant for my subsequent individual-level analysis.

Finally,I incorporated data from (Berman et al., 2017)'s study which gave valuable insights on the economic impact of resource wealth in various SSA countries. This dataset added another solid contextual layer with regards to the economic dynamics of resource-rich regions, particularly in terms of how mining affects local communities. It provided essential controls for my study.

3.2 District-level Study

As shown in Figure 1, The first unit of observation used for this study was at the district level, specifically focusing on the admi2 administrative level, which is a standard geographical unit used in many datasets. The admi2 level, representing a district's second administrative level in most African countries, was seen as an ideal unit of observation as districts are more likely to have consistent local economic and educational policies, infrastructure, and resources compared to larger national units according to the study by (Diliberti, Woo and Kaufman, 2023). The impacts of mineral wealth, governmental policies and community-level socioeconomic factors are more directly observable at this level which allows for an in-depth analysis of mineral wealth's impact of educational outcomes.

Table 1: Top 10 Minerals in Africa Based on their Frequency of Occurrence

Mineral	Number of Deposits
Gold	446
Diamond	127
Copper	84
Uranium	70
Cobalt	50
Iron Ore	48
Graphite	37
Platinum-group elements (PGE)	30
Rare Earth elements (REE)	24
Nickel	21

Notes: The table lists the top 10 minerals based on the (U.S. Geological Survey, 2025) Mineral deposits dataset.

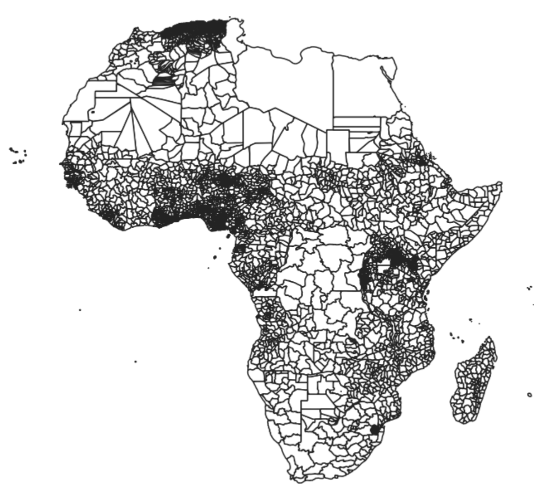

Figure 1: Administrative Level 2 Map of Africa

3.2.1 Main Outcome Variable(s): Education

Educational Attainment Level(mean) was used as the main outcome variable in the district-level analysis to measure the highest level of education obtained by individuals in each district utilizing (Demographic and Health Surveys, DHS) data[6]. This variable was initially categorized as 0 for 'No Education', 1 for 'Primary Education', 2 for 'Secondary Education', and 3 for 'Tertiary Education.' This categorical variable was then aggregated to each respondent's district to compute the mean educational attainment level within each district. Aggregating the educational attainment variable to the district level is necessary to capture district-wide educational patterns and to understand how local socioeconomic factors influence educational outcomes, particularly in relation to mineral wealth.

For the next district-level model specified, *Educational Completeness(mean)* was used to measure district-wide educational completeness levels. Following a similar data construction structure as the first outcome variable, this variable was first categorized as 0 for 'Incomplete Primary', 1 for 'Complete Primary', 2 for 'Incomplete Secondary', 3 for 'Complete Secondary' and 4 for 'Tertiary Education' before being aggregated to the district level. The main objective of the use of this variable was to serve as a proxy to measure school dropout rates in SSA districts. Similar approaches have been employed in educational economics literature to analyze dropout rates and educational completion. For instance, (Woldehanna, 2012) utilized a similar aggregation method to examine children's educational completion rates and dropout patterns in Ethiopia, highlighting the importance of district-level analysis in understanding educational

[6] See (Moscona, Nunn and Robinson, 2020; Depetris-Chauvin and Özak, 2020) which uses a similar data aggregation method to measure socioeconomic outcomes using the same data.

dynamics. This variable offers a more granular perspective of the challenges faced by resource-rich regions pertaining to educational outcomes.

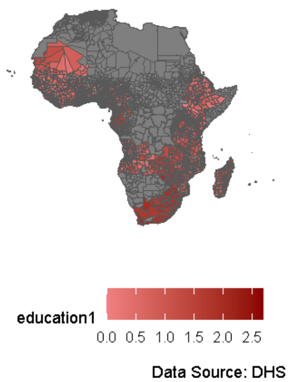

Figure 2: Aggregate District-Level Educational Attainment

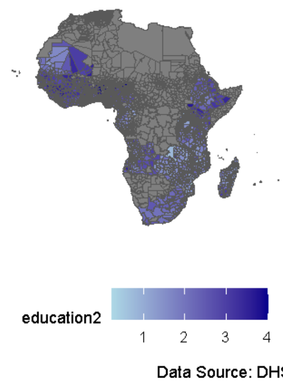

Figure 3: Aggregate Level of Completeness Across Districts

3.2.2 Main Explanatory Variable

The main explanatory variable this study uses for its district-level analysis is *Mineral Deposits*. To construct this variable, I utilized geospatial data on mineral deposits from the (U.S. Geological Survey, 2025), which provides detailed geocoded information on mineral resources. The process began by overlaying the district-level administrative boundaries of the study area on the geocoded mineral deposit data using QGIS, a tool for advanced geospatial analysis. After overlaying the administrative map with the mineral deposit data, I counted the number of mineral deposits present within each district. This step ensured that the geographic distribution of mineral resources was accurately captured at the district level. Based on this count, I created a dummy variable, Mineral Deposits, where a value of '1' indicates that a district contains one or more mineral deposits, and '0' indicates that no mineral deposits are present in the district. This construction method allows for a binary categorization of districts, distinguishing between those with access to mineral wealth and those without consistent with the estimation technique

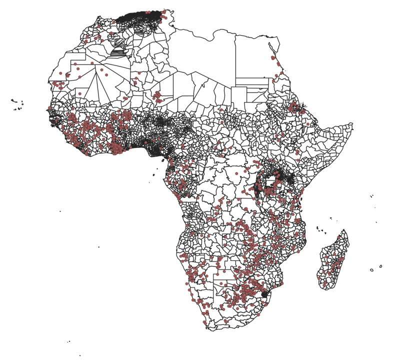

Figure 4: Map Showing the Placement of Mineral Deposits Across Districts in Africa

of (Berman et al., 2017). While the exploitation of these resources does not necessarily occur in all areas, the mere presence of mineral deposits can lead to economic growth, infrastructure development, and in-migration to these areas. As argued by (Adu Sarfo and Tweneboah, 2024), mineral deposits can create similar socio-economic dynamics as active mining, such as changes in local economic activities, migration patterns, and shifts in public infrastructure. These dynamics, even without actual resource extraction, can still affect local outcomes, such as educational attainment. This makes mineral deposits a valuable variable to assess the potential impact of resource wealth on education, since they account for direct and indirect influences of mineral wealth on local communities. The exogenous nature of this variable is critical for this study, as it is related to the presence of mineral resources to the geological presence of minerals and is by no means affected by human economic decisions that could be influenced by educational results or other local factors.

3.2.3 Confounders

Distance to the Capital, adopted from (Berman et al., 2017), is a critical co-variate used in this study as it helps to control for geographic isolation and infrastructure disparities that could confound the relationship between mineral wealth and education. This variable captures the average distance from each district to the country's capital, which can be a significant determinant of economic and social outcomes, including access to education. In areas farther from the capital, mining revenues may not be equally distributed, and such regions may face barriers in accessing the same quality of educational services available in more urbanized or centrally located districts as shown by (Bani et al., 2024). The inclusion of this variable thus, controls for any regional inequalities which are not as a direct consequence of mineral wealth but may influence educational outcomes in these regions.

The *Log Distance to the Nearest Border*, another variable adopted from the study of (Berman et al., 2017), is a key co-variate included in this study to account for the potential influence of cross-border trade, migration, and economic interaction on educational outcomes in mineral-rich districts. Theoretical frameworks in international economics and regional development suggest that proximity to international borders often plays a significant role in shaping local economic conditions. Studies by (Fujita, Krugman and Venables, 2001) suggest that regions near borders experience a higher level of economic activities due to trade flows, market integration, and migrant labor, which can create both opportunities and challenges. For example, border districts in resource-rich regions may benefit from smuggling, informal trade, and access to global markets, potentially boosting local economies and improving education funding. Also, it can be argued that, mining districts closer to the border are more likely to experience labor market competition as local inhabitants face stern competition for jobs from migrants and refugees from neighboring countries resulting in young people diverting their attention from schooling.

The *Urban* variable captures the level of urbanization in the district, which could influence the educational outcomes of individuals. Urbanization has long been considered a key factor affecting educational attainment, as urban areas tend to offer better access to educational resources, infrastructure, and services compared to rural areas. In the context of SSA, urban districts are often characterized by higher levels of economic activity, better roads, and more schools, which may contribute to higher educational enrollment and completion rates. This makes urban areas an important control variable when assessing the effects of mining operations on education, as resource wealth in these areas may interact with urbanization levels in complex ways. Prior studies, such as those by (Bani et al., 2024), have shown that urban areas tend to have more stable and better-funded education systems, which might explain the higher educational attainment levels observed in these regions compared to their rural counterparts. Thus, including the Urban variable allows for a clearer understanding of the impact of mineral wealth on education, while controlling for the confounding influence of urbanization. However, it is important to note that mining sites are more likely to be set up in rural areas rather than in urban areas. This is due to the fact that mineral deposits are typically found in more remote and less developed regions, where the costs of acquiring land for large-scale mining operations are lower. Rural areas, especially those that are rich in natural resources like gold or diamonds, often become the focal points for mineral exploration and extraction. As a result, individuals living in mining districts are more likely to reside in rural areas where the presence of mining operations can have a significant impact on educational outcomes.

This study also uses *Water Availability* as it serves as a proxy for the Agricultural Suitability of a district. One of the indicators that determine the agricultural suitability of an area is the availability of water. It is a widespread fact that the presence of water enhances agricultural productivity and ultimately, the economic outcomes of rural regions. This is due to the critical irrigation function that water serves in the agricultural production process. Increased agricultural productivity increases the revenue of local farmers and, in turn, increases the economic strength of an area. In SSA, where agriculture is a dominant economic activity, access to water can significantly impact the livelihoods of local households and their ability to invest in education. In areas where water is scarce, there is lower agricultural productivity and economic hardships with families in these areas likely to face economic pressures that hamper their investment in education. Studies by (Bhalotra and Heady, 2003) has shown that families in such regions are likely to use child labor to support household income which could have some telling repercussions on educational outcomes in such areas. The inclusion of this variable in our model thereby accounts for regional economic conditions that might otherwise confound the relationship between mineral resource deposits and educational outcomes. Water availability serves as an indirect indicator of economic development, which in itself is key to educational outcomes.

The last co-variate used in this study is the *Rule of Law*. This variable, represented as 'wbgi_rle_init' is part of the World Governance Indicators (WGI) and represents an initial measure of governance, specifically focusing on the Rule of Law or Government Effectiveness. This variable is constructed by aggregating data from multiple sources, including the Economist Intelligence Unit (EIU), Afrobarometer, and the World Bank Enterprise Surveys, which assess aspects such as judicial fairness, contract enforceability, and property rights protection. The data is then standardized on a scale from -2.5 to +2.5, where higher values indicate better governance. Individual source data are combined using principal component analysis (PCA) to create a composite governance score, which is normalized over time. Missing data is handled through interpolation or imputation to ensure that countries with sparse data are still included in the analysis, providing a comprehensive view of governance quality across countries. This study introduces this variable to cater for the influence of legal and institutional frameworks on educational outcomes in mining areas. It is well established in political economic literature that the rule of law plays a central role in resource allocation and the management of natural resources. As suggested by the resource allocation theory, countries with weak governance structures often misallocate resources wealth generated from mineral extraction. This has the tendency to exacerbate inequality and hinder long-term economic development. In SSA, the relationship between the Rule of Law and resource allocation is even more profound. Countries with a strong presence of the rule of law tend to have higher checks and balances, ensuring that sitting governments are legally obligated to allocate resources gathered from minerals efficiently, leading to significant investments in education (Gylfason, 2002). Using this variable as a control accounts for the institutional strength of each country, thereby capturing the potential moderating effect that governance quality may have on the educational outcomes of individuals living in mining areas.

3.2.4 Descriptive Statistics for District-Level

Table 2 shows the descriptive statistics of all the variables used in the district-level study and offers some key insights into the variables used in this study. Educational attainment has a mean of 1.26 which shows fairly moderate levels of educational attainment in districts. The Educational completeness variable has a mean of 2.26 which suggests that individuals across districts in the sample have completed secondary school on average. Mineral Deposit's mean is

0.080 meaning that, very few districts in SSA have mineral deposits present.

Table 2: Descriptive Statistics for District-Level Study

Variable	Obs	Mean	Std. dev.	Min	Max
Educational Attainment	3,739	1.259104	0.5409343	0	2.69697
Educational Completeness	3,739	2.264569	.6819226	0.25	4
Mineral Deposits	3,739	0.0798568	0.2710956	0	1
log Distance to Border	3,739	4.412233	1.161387	-3.00338	6.385683
Distance to Capital	3,739	594.9238	401.6693	3.702701	1809.641
Urban	3,739	0.202545	1.453118	0	51.74691
Rule of Law	3,739	-.7261846	.5735722	-1.719866	.8581458
Water	3,739	2.6511	8.736811	0	93.31481

Notes: Descriptive statistics include the mean, standard deviation, minimum, and maximum values for each of the key variables.

The mean of the Urban variable (0.2) means that most districts in the same are rural and underdeveloped which makes sense since the region of focus is SSA. Water Availability, a proxy for agricultural suitability, shows significant variations, with a mean of 2.65, which shows that many districts in SSA may have suitable conditions for agricultural production. The log Distance to Border and Distance to Capital both account for the geographical districts within districts with districts further away from these key areas likely to experience a deprivation and may face challenges in accessing education.

3.3 Individual-Level Study

The second unit of observation for this study was conducted on individuals within a $0.5° \times 0.5°$ longitude and latitude which corresponds to approximately 55 $\times$ 55 km at the equator. The main aim behind this was to analyze the later life educational outcomes of individuals living in mining areas. Using PRIO-GRID 55x55km grid cells, I overlayed data on mineral extraction sites from PRIO-GRID with individual respondent data from the DHS to conduct my spatial analysis.[7] This approach allowed me to examine the proximity of individual respondents within a 55km grid cell to active mining operations and assess how this proximity influences their school completion rates. Integrating spatial data on mining activities with geo-coded educational data, I was able to perform a novel and granular analysis on the later-life educational attainment levels of people living in mining areas.

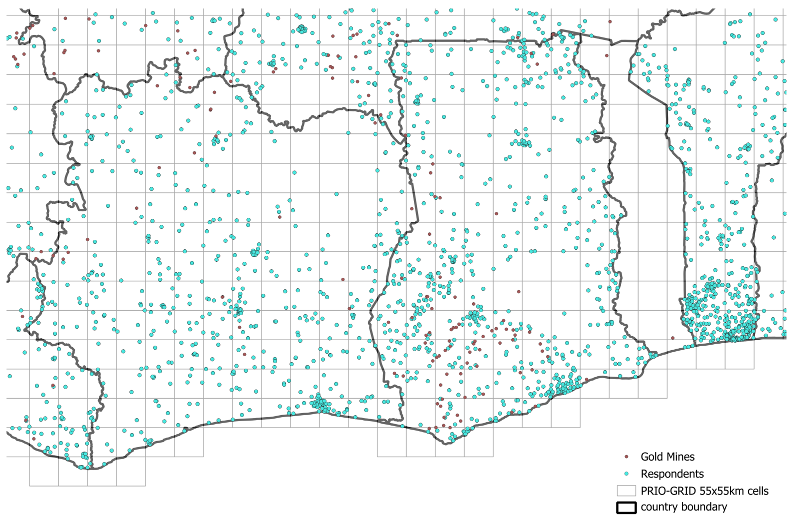

Figure 5: PRIO-GRID 55x55km Cells Showing Respondents Within 55km of Gold Mines

3.3.1 Main Outcome Variable

The main outcome variable used for the Individual-level analysis was *Educational Completeness*. This variable, which is identified as v149 and mv149 in the DHS dataset, was then structured into four categories. '0' for 'Incomplete Primary Education', 1 for 'Primary Education', 2 for

[7] It is important to note that, due to data privacy concerns, the geocoded DHS data is displaced by 5km from the village the respondent's data was taken and by 2km if the respondent's data was taken in a city. This does not significantly impact the results of this study because the study uses the standardized PRIO-GRID 55x55km grid cells which is a wide enough range to capture any displacement.

’Incomplete Secondary’, and 3 for ’Complete Secondary’ and 4 for ’Tertiary’. This variable captures the intensive margins of educational participation specifically measuring whether or not individuals have completed any educational milestones in any given grid cell. This categorization sheds more light on how mining impacts individual decisions to participate in education at various stages.

The inclusion of *Socio-Economics Status (SES)* as another outcome variable for my individual-level study helps to account for the probable impacts of mineral exploration activities on the economic status of individual households. It is well documented in the literature that mining can significantly alter the economic landscape of an area which ultimately affects the socio-economic status of individuals within these areas (an important factor in an individual’s access to education and educational decisions). The increased economic opportunities that come with mining activities can severely influence the decision to stay in school or move to work in mines. Hence, the SES of an individual can either promote educational participation or severely hamper any progress due to the increased opportunity cost of schooling. The findings from (Lee, Kim and Rhee, 2021) suggest that, wealthier households are less likely to have high rates of school dropouts and are likely to also have better educational resources as compared to poorer households who have a high propensity to engage in child labor in a bid to ease off the financial pressures on the family at the expense of education. To estimate this variable, I redefined the v190 and mv190 variables from the DHS dataset and classified them as; 1 for the poorest, 2 for poorer households, 3 for middle SES, 4 for richer households, and 5 for the wealthiest. Including this variable in my study allows me to make an accurate assessment of the relationship between mining exposure and the later-life educational outcomes by accounting for the financial factors that control the educational trajectories of individuals and households.

3.3.2 Main Explanatory Variable

Gold Mine was used as the main explanatory variable for this individual-level study. This variable was sourced from (PRIO-GRID, Various)'s Gold database. As can be inferred from Table 1, gold is the most prevalent mineral across Africa making it suitable to use for my granular analysis. It was coded as a dummy variable indicating '1' for grid cells with gold mines present and '0' for grid cells with no gold mines. Despite utilizing the (U.S. Geological Survey, 2025) data on the geopositions of mineral deposits throughout Africa as the main explanatory variable for my district-level study, the decision to narrow the focus to *gold placer* or *gold mines* is justified given gold's dominance in the mineral landscape of the SSA region. The PRIO-GRID Golddata also proved to be far more suitable for the individual-level study as it offers specific temporal information. Unlike the USGS data, which does not include the start year of exploration of these minerals, the new dataset captures the production start year and current status of the mine which was instrumental in estimating my main treatment variable termed *Early Exposure*. Relying on the mineral deposits data from USGS would have required me to make a significant assumption that, mineral deposits are permanent and as such, individuals native to these mineral-rich areas are automatically exposed to the dynamics associated with mineral exploration and mining activities. Although this is not so far-fetched, this assumption does not account for the actual timing of the mineral exploration activities, and therefore, may overlook essential temporal dynamics of exposure. In contrast, the PRIO-GRID Golddata provides specific time periods that allowed me to track exact time periods of individual exposure.

3.3.3 Main Confounding Variable

Early Exposure, which is the most important variable in my individual-level study, estimates the exposure of individuals to mineral exploration activities during their adolescence. Prior studies have shown that, the period between 12 and 15 years are vital for educational attainment for people in SSA as it typically marks the transition from primary to secondary education. At this stage, many adolescents are vulnerable to dropping out of school due to various socio-economic factors. According to (UNESCO Institute for Statistics, 2021)'s study on SSA, one-third of adolescents between the ages of 12 to 13 years are out of school, and nearly 60% of youth between 14 to 15 years are school dropouts further highlighting the fragility of adolescents between these age groups to educational exclusion. In order for me to estimate early exposure to mineral exploration activities, particularly gold mining, I used the PRIO-GRID Golddata, which provides specific temporal information on the start year and current status of mining operations. Combining this information with respondent's birth years, I created a time frame during which individuals were between the ages of 12 to 15 years old. Studies such as (African Development Bank, 2009; World Bank, 2014) have all estimated the average lifespan of mines in Africa to be 22 years which was an assumption adopted for this study since data on the end year of mines were not provided and the year the PRIO-GRID data was taken remains unclear. Additionally, I accounted for individual's native status using the v104 and mv104 variables in the DHS dataset. This variable allows my study to determine the later-life educational outcomes of individuals in resource-rich regions and also isolates the potential effects of living in mining areas during an individual's formative years. I then modeled it as a dummy variable where '1' indicates early exposure to gold mining and '0' representing no early exposure. This variable helps in understanding the causal relationship between exposure to mineral exploration activities and educational attainment, as the experience of growing up near mining operations can alter educational trajectories.

3.3.4 Other Confounders

An important control variable employed in this study *Gender*. Due to the patriarchal structure of SSA households, gender is important in determining access to education and child labor. Traditional gender roles have a significant impact on educational outcomes in SSA. For instance, as explained by (De Lange, 2009), male children are more likely to engage in child labor due to not only economic pressures but also the traditional gender roles assigned to males in SSA at the expense of education. Conversely, female children often attain lower education levels due to society placing lesser emphasis on on female education. Females are more frequently expected to contribute to household chores and family welfare, roles that may limit their access to formal education. This variable helps to control for gender-based disparities in both labor market participation and education.

The last control variable this study employs is the *Residence* status of an individual. This variable captures whether an individual lives in an urban or rural area. The argument here is, that people living in urban areas have better access to quality education as opposed to people living in rural areas. The inhabitants of urban centers have access to better-equipped schools, qualified teachers, and greater educational resources. Furthermore, these areas benefit from high educational investments making them likely to have higher educational attainment and completion rates as compared to people living in rural areas. Accounting for this variable ensures that the observed effects on educational attainment are not confounded by geographic location.

3.3.5 Descriptive Statistics for Individual-Level Study

Table 3: Descriptive Statistics for Individual-level Study

Variable	Obs	Mean	Std. Dev.	Min	Max
Educational Completeness	754,987	2.233118	1.531678	0	4
Gold Mine	763,875	0.0838946	0.2772299	0	1
Early Exposure	763,875	0.0673528	0.1945643	0	1
Socio-Economic Status	763,772	3.019231	1.426656	1	5
Residence	763,772	0.391901	0.4881751	0	1
Gender	763,772	0.6958713	0.4600377	0	1

Notes: Descriptive statistics include the mean, standard deviation, minimum, and maximum values for each of the key variables.

The descriptive statistics for the individual-level study is presented in the Table 3. The *Educational Completeness* level has a mean of (2.23) with a standard deviation of (1.53) signifying that, most respondents in the sample have completed at least secondary education but there is still a considerable level of variation amongst respondents. The Gold Placer variable, indicating whether there are mining operations occurring within a grid cell, has a mean of (0.084) reflecting the relatively low amount of gold mines within the sample.

The *Early Exposure* variable which captures whether respondents were exposed to mining activities during their adolescence has a mean of (0.07) which shows that, relatively fewer people were exposed to gold mining activities in any given grid cell when they were between the ages of 12 to 15 years old. *SES*, as measured by the redefined wealth variable from the DHS data, has a mean of (3.02), with a standard deviation of (1.43), implying moderately high socioeconomic status on average in the sample, with some variation between individuals. This variable is crucial for controlling the confounding effects of economic factors on educational outcomes, particularly in resource-rich areas where mining can significantly alter local economic conditions.

The *Residence* variable distinguishes between respondents living in urban or rural areas. It has a mean of (0.39) which indicates that approximately 39% of the total respondents live in urban areas. The rural-urban dynamic is very essential to this study as urban areas usually have access to infrastructure and infrastructure compared to rural areas. The variable *Gender*, has a mean of 0.70 indicating that most of the respondents in the sample are male.

These descriptive statistics essentially provide additional context to the study by explaining the distribution of key variables in the individual-level study.

4 Empirical Strategy and Main Results

This section presents the empirical analysis on the relationship between minerals and educational outcomes in SSA. The initial unit of observation was taken at the district level, where aggregated district-level data was used to estimate the extent to which mineral wealth influences educational outcomes at the admi2 level across SSA. Different measurements of education were used at the district level to estimate both the extensive and intensive margins of education in resource-rich districts. This study subsequently shifted its focus to the individual level, focusing on how early exposure to mineral exploration activities impacts the later life educational outcomes of individuals in mining areas. The findings presented in this section highlight the role of resource wealth in shaping educational trajectories, highlighting both the positive and negative spillovers associated with mineral exploration activities.

4.1 Baseline Results

The first aim of this study was to understand how the presence of mineral deposits in a district affects the educational attainment levels of these mineral-rich regions. As suggested by (Adu Sarfo and Tweneboah, 2024), the mere presence of mineral deposits in these regions can drive socioeconomic dynamics similar to that of active mining. The presence of mineral deposits has the potential to drive economic activity and increase investments which can also boost the local economy and infrastructure including educational facilities. Simultaneously, the presence of mineral deposits has the tendency to also have adverse effects on the aggregate educational levels of districts by increasing the opportunity costs of schooling due to the increased demand for labor particularly from artisanal mining activities. Given this context, Mineral Deposits was used as the primary treatment variable, allowing this study to analyze the variations between mineral-rich regions and non-mineral regions. The exogenous nature of mineral deposits can be assumed due its geographic and historical nature. The data on mineral deposits, compiled by USGS, considered mainly geographic and historical factors which are outside the control of local populace or policy decisions. Consequently, the presence of mineral deposits in any given district can not be influenced by factors that simultaneously affect educational outcomes. Therefore, I argue that the presence of mineral deposits serves as an exogenous treatment, allowing this study to draw causal inferences regarding their effects on educational attainment in a district. In order to empirically test my research objective with the cross-sectional survey data my study employs, I used an Ordinary Least Squares (OLS) model with the following specification;

$$\text{EdAt}_d = \alpha + \beta_1 \text{MinDep}_d + \beta_2 \text{logDistB}_d + \beta_3 \text{DisCap}_d + \beta_4 \text{Urban}_d + \beta_5 \text{ROE}_d + \beta_6 \text{Water}_d + \gamma_c + \epsilon_d \quad (1)$$

where EdAt_d is the average Educational Attainment level at district d, MinDep_d is a dummy variable categorized as 0 if there are no mineral deposits in district d and 1 if mineral deposits are present, logDistB_d is the mean of the logarithmic distance of district d to the country's border, DisCap_d represents the mean distance of district d to a their country's capital, Urban_d is a dummy variable indicating whether district d is an urban or rural settlement, ROE_d indicates the presence of the Rule of Law within a district d, Water_d represents the Water Availability of district d which is a proxy for agricultural suitability of a district, γ represents the Country-level fixed effects, ϵ represents the error term. It is important to mention that this model controlled for country-level fixed effects which accounts for unobserved heterogeneity between countries that could influence educational attainment levels in mineral-rich regions. This study additionally clusters results at the district level to account for potential correlation of standard errors within districts.

Column (1) of Table 4 presents the OLS regression results for the relationship between mineral deposits and educational attainment at the district level. Mineral deposits' coefficient (0.042) is statistically significant at the 10% level which indicates a strong positive relationship between the presence of mineral deposits and educational attainment in districts with mineral endowment. This finding is consistent with studies of (Aragon and Rud, 2013; Bani et al., 2024) and several other resource boom literature which suggest that the presence mineral resources in an area triggers positive spillovers on the local economy, including improvements in education. The point is, mineral deposits is a driver of economic activity in an area, thereby fostering local development. Local development here is characterized by the construction of roads, schools and hospitals, which are considered as critical infrastructure facilities essential to the living conditions of the local populace. These developments catapult the area's access to education

Table 4: Educational Attainment in Mineral-Rich Districts

Educational Attainment	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	OLS	OLS	OLS	OLS
Mineral Deposits	0.042*	0.052*	0.055*	0.074**	0.066**	0.065*
	(0.023)	(0.023)	(0.023)	(0.024)	(0.026)	(0.026)
Urban		0.019	0.018	0.017*	0.016*	0.016*
		(0.010)	(0.0096)	(0.0079)	(0.0076)	(0.0077)
Water Availability (mean)			0.0048***	0.0025**	0.0026**	0.0028**
			(0.00096)	(0.00084)	(0.00085)	(0.00087)
Distance to Capital (mean)				−0.00072***	−0.00070***	−0.00070***
				(0.000046)	(0.000048)	(0.000048)
log Distance to Border (mean)					0.027**	0.028**
					(0.010)	(0.010)
Rule of Law (mean)						0.0011
						(0.00072)
Observations	3,739	3,739	3,739	3,739	3,739	3,739
Country-level FE	x	x	x	x	x	x
R^2	0.3025	0.4007	0.4067	0.5045	0.5207	0.5216
Adjusted R^2	0.2957	0.3895	0.3952	0.4945	0.5104	0.5110
Clusters	District-level	District-level	District-level	District-level	District-level	District-level

Notes: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. This model utilizes cross-district variations in mineral deposits to segregate mineral-rich regions from non-mineral rich regions. The results absorbs 27 country-level fixed effects accounting for unobservable country-level factors that might confound the relationship between mineral discovery and educational outcomes. The results presented in this table are clustered by districts to cater for unobserved heterogeneity.

and provides better educational opportunities for individuals within these districts.

In Column (2), I introduced the control variable, *Urban*, accounting for the effects of urbanization. Mineral deposits' coefficient (0.052) still remained positive and statistically significant at the 10% significance level. This indicates that, mineral deposits independently influences educational attainment levels even after partialing out the potential confounding influence of urbanization rate (proxied by an urban indicator).

The results presented in Column (3) introduced *Water Availability*, a proxy used to measure the agricultural suitability of a district, as an additional control for distinct environmental characteristics that could impact educational attainment outcomes. Mineral deposits' coefficient is still statistically significant at the 10% level and increases slightly in magnitude to (0.055), further strengthening the strong positive relationship between mineral resource endowment and educational attainment. Even in agriculturally suitable districts that may have higher economic development trajectories, mineral deposits continues to influence educational attainment levels positively.

The mean distance to a country's capital, was introduced as a control in Column (4) to cater for the proximity of a district to the capital city. The coefficient of mineral deposits still remains positive (0.074) and even more statistically significant (5%) showing that even after controlling for a district's access to the capital city, mineral wealth endowment in a district continues to positively impact educational attainment. The negative coefficient of the *Distance to Capital* variable indicates that, the farther a district is from the country's capital, the lesser their educational attainment levels which is consistent with the findings of (Bani et al., 2024).

Column (5) controls for the logarithmic distance of a district to a country's border in order to account for any potential cross-border influences. Mineral Deposit's coefficient still remains positive at (0.066) and statistically significant at 5% which supports the robustness of my results. This evidently indicates that despite cross-border dynamics, the impact of mineral deposits on education attainment does not diminish.

Finally, Column (6) introduces a country-level control called Rule of Law which assesses the strength of a country's checks and balances that inadvertently affects revenue allocation from resource wealth. The coefficient of Mineral Deposits still remains significantly robust at the 5% level with a value of (0.065).

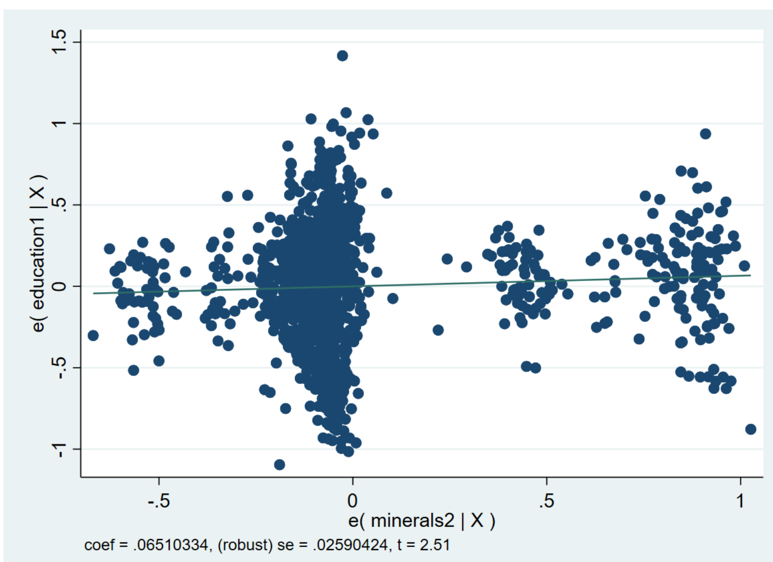

Figure 6: A scatter plot indicating the relationship between the presence of mineral deposits and educational attainment levels from Column (6)

The results show that the presence of mineral deposits in Sub-Saharan positively impacts educational attainment levels across districts in the region, as visually represented by Figure 6. Every model specification showed a positive correlation between mineral deposits and educational attainment contributes positively to improving educational attainment outcomes, thereby aligning seamlessly with the literature on natural resource boom.

4.1.1 Educational Completeness and Minerals

The results from the baseline model suggest strong positive spillovers from mineral deposits on educational attainment which is in line with a wide range of resource-boom papers. The baseline model, however, only captures the extensive margins of educational outcomes, with its primary focus on district-level educational attendance without necessarily showing the completion rates across educational levels. To address this limitation, the second district-level model uses *Educational Completeness*, a variable which specifically aggregates district-level educational completeness at various levels, as the main outcome variable. This model opens a new dimension to my analysis as it provides a deeper understanding on how mineral deposits not only affects the access to education, as shown in the previous model, but also the ability of individuals in these regions to actually stay and complete educational milestones. This model maintains all other co-variates from the baseline model and also performs country-level fixed effects coupled with clustering results at the district-level to cater for heterogeneity.

Similar to the previous section, Column (1) of Table 5 presents the OLS regression results for the relationship between *Mineral Deposits* and *Educational Completeness* at the district-level. The results start off strong with the coefficient of *Mineral Deposits* at (-0.17), statistically significant at the 1% confidence level suggesting a negative relationship between mineral endowment and educational completeness. These results directly contradict the findings of the results obtained

Table 5: Educational Completeness in Mining Districts

Educational Completeness	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS
Mineral Deposits	−0.17***	−0.081*	−0.067*	−0.074	−0.078	−0.082*
	(0.038)	(0.048)	(0.045)	(0.045)	(0.045)	(0.045)
log Distance to Nearest Border (mean)		−0.049**	−0.071***	−0.072***	−0.068***	−0.076***
		(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
Distance to Capital (mean)			−0.00035***	−0.00034***	−0.00034***	−0.00036***
			(0.000057)	(0.000057)	(0.000057)	(0.000056)
Urban (mean)				0.010*	0.011*	0.013*
				(0.0043)	(0.0045)	(0.0056)
Rule of Law (mean)					0.0033**	0.0023*
					(0.0010)	(0.0010)
Water (mean)						−0.015***
						(0.0018)
Observation	3,739	3,739	3,739	3,739	3,739	3,739
Country-Level FE	X	X	X	X	X	X
R^2	0.0055	0.0075	0.0318	0.0324	0.0384	0.0660
Clusters	District-level	District-level	District-level	District-level	District-level	District-level

Notes: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. This model utilizes cross-district variations in mineral deposits to segregate mineral-rich regions from non-mineral rich regions. The results absorbs 27 country-level fixed effects accounting for unobservable country-level factors that might confound the relationship between mineral discovery and educational completeness levels. The results presented in this table are clustered by districts to cater for unobserved heterogeneity.

in Table 4, however, they are not entirely surprising given that *Educational Completeness* is a more in-depth measure of educational outcomes capturing educational milestones and school dropout rates. This is consistent with the findings of (Adam et al., 2004; Berman et al., 2017) with the economic intuition being that, despite the potential positive spillovers of mineral-wealth endowment, districts may face significant challenges in achieving educational completeness. Once the economic dynamics associated with mineral extraction begin to unfold, the opportunity cost of schooling in the area increases. Inhabitants of these districts, faced with severe economic pressures, may dropout of school to seek employment in mines which likely explains the negative relationship.

Column (2) introduces the log Distance to Border, accounting for the potential cross-border economic dynamics that may exist in districts closer to the country's border. The observed negative relationship remained unchanged with the coefficient of *Mineral Deposits* at (0.081) although the statistical significance dropped to the 10% confidence interval.

In Column (3), I controlled for the distance of a district to their respective country's capital and still found the results to coefficient of Mineral Deposits to be negative at (-0.067) and significant at the 10% confidence interval.

Column (4) further introduces the variable, Urban, to control for the influence of urbanization. The coefficient of Mineral Deposits is -0.074 and statistically insignificant. The insignificance of the results suggests that, while the sheer presence of mineral deposits positively affects educational attainment levels in mineral-rich- urban districts, this relationship may not be entirely the case for educational completeness levels.

Column (5) introduces Rule of Law, controlling for the legal environment and its potential impact on educational outcomes. The mineral deposits coefficient remains negative at (0.078) however it is not statistically significant. The inclusion of Rule of Law also signifies that, even regions with stronger legal institutions may still influence the negative impacts of mineral wealth on education completeness, pointing to the influence of economic incentives driving children away from school in favour of employment in the mining sector.

Finally, Column (6) adds Water Availability, as a control for agricultural suitability of a district. The coefficient for mineral deposits continues to be negative at (-0.082) and statistically significant at 10% confidence interval. This suggests that, even when accounting for the agricultural suitability of a district, the presence of mineral deposits still continues to exert a negative influence on educational completeness levels.

This section's results presents a contrasting perspective to the previous section, documenting a negative relationship between mineral deposits and educational completeness. These conflicting perspectives suggests that, while mineral deposits may improve the access to education in districts, they can simultaneously increase the opportunity costs of schooling which discourages school completion stemming from the economic pressures associated with mineral exploration activities. The resulting positive and negative spillovers that have been documented at the district level highlight the complexities of mineral wealth's relationship with education hence necessitating the need for a more granular individual-level analysis to understand how these dynamics play out in terms of school dropout rates and long-term educational outcomes which are duly explored in the next scope of our analysis.

4.2 Later-Life Educational Outcomes of Individuals Living in Mining Areas

The results of the district level study provided some conflicting but rather interesting findings which made it very important for me shift my focus to the later-life educational outcomes of individuals living in close proximity to mineral exploration sites, specifically within a $0.5° \times 0.5°$ longitude and latitude which corresponds to approximately 55 $\times$ 55 km at the equator, of gold mines. While previous sections focused on how the presence of mineral deposits can affect district-level educational outcomes, this section delves deeper into this phenomenon by focusing on how gold mining activities affect individual decisions to stay in school, complete their education, and pursue higher educational levels.

The individual-level study allows us to assess the long-term consequence of living in gold mining areas as it allows to capture the direct impact of early exposure to mining activities on later-life educational outcomes. As discussed in previous sections, studies by (Woldehanna, 2012; UNESCO Institute for Statistics, 2021) have emphasized on how critical the adolescent stage is in shaping the later-life educational outcomes of people. They argue that, the age period between 12 to 15 years old is a crucial period in the life of an individual as it marks the transition from primary to secondary education. If not exposed to the right conditions, adolescents between these age groups are susceptible to taking short-sighted and myopic decisions to drop out of school in pursuit of other opportunities, with the prospect of earning salaries from working in mines ever so attractive.

This individual-level study adopts the PRIO-GRID Golddata on Gold Placer's for two main reasons. Firstly, as shown in Figure 1, gold is the most prevalent mineral in SSA, making it a logical focus for examining how mineral wealth affects educational outcomes. Aside this, the PRIO-GRID Golddata provides some important temporal data on the production start year and current status of mines which was very crucial in estimating a time-frame to identify individuals who were exposed to mining activities during their adolescence. Using gold mining provides a concise assessment of how exposure to mineral exploration activities affects the individual's ability to achieve educational milestones.

To conduct this study, I specified the following Ordered Probit regression model;

$$y^* = \beta_0 + \beta_1 \text{GoldMine}_c + \beta_2 \text{Exp}_{ic} + \beta_3(\text{GoldMine}_c \times \text{Exp}_{ic}) + \Gamma \mathbf{X}_{ic} + \gamma_c + \gamma_r + \epsilon$$

where $\epsilon \sim N(0,1)$. The observed outcome y (EduComp) is determined by threshold parameters (cut1, cut2, etc.):

$$y = \begin{cases} 1 & \text{if } y^* \leq \text{cut1} \\ 2 & \text{if cut1} < y^* \leq \text{cut2} \\ \vdots & \\ k & \text{if } y^* > \text{cutk-1} \end{cases}$$

where EduComp_{ic} represents the level of Education Completed by individual i in grid cell c, GoldMine_c is the number of gold mines present in grid cell c, Exp_{ic} represents individuals i in grid cell c who were exposed to gold mining activities between the ages of 12 to 15 years old, ΓX_{ic} are the set of individual level control variables used in this model, γ_c represents the country-level fixed effects γ_r are the regional-level fixed effects conducted for this study. The results were clustered at the grid-cell level to cater for spatial heterogeneity across observations.

For a nuanced and multifaceted study, I introduced the Socioeconomic status of individuals within gold mining grid cells to capture the argument on private and social costs associated with education. All other variables in the previous model specification were maintained.

The results presented in Table 6 tells an interesting and multidimensional tale. From Column (1) to (4) it is evident that, early exposure to gold mining significantly reduces educational completeness, with the negative effect amplified in active mining areas. The interaction term in Column (1) reports a coefficient of (-0.0454) and has statistical significance at the 1% confidence level controlling for all other regional level fixed effects. The second model, which introduces the residence status of an individual (whether they reside in an urban or rural area) reports the same impact with the coefficient of the interaction term being (-0.0453) and also significant at 1% significance level. Column (3) introduces the gender of individuals in any given grid cell as an additional control variable and presents the same negative relationship which is statistically significant at the 1% significance level indicating that a unit increase in the interaction term reduces the probability of educational completeness by (-0.0457) units. Column (4) introduces the socio-economic status of individuals as an additional control variable, nonetheless, the impact of the interaction term still remains negative (-0.0459) with a statistical significance at the 1% level. These results are consistent with the findings of (Ahlerup, Baskaran and Bigsten, 2019) and confirms that, individuals within 50km of a gold mine tend to face a strong disincentive for school completion ending up becoming school dropouts at their educational transition stage likely through increased opportunity costs of schooling as children enter the mining labor force. It is now clearer than ever that the later-life educational outcomes of people living in mineral-rich areas are severely hampered. Now, to fully understand the ramifications of these results, I shift my attention to the later-life socioeconomic status of individuals within these regions.

The results presented in Column (5) to (7) also give very interesting insights and indications. The results from Column (5) indicates that, the mere presence of gold mines in any given 50 $\times$ 50 km grid cell tends to positively affect their respective SES, ranging between very poor to wealthy, with a coefficient of (0.2731) and statistically significant at the 1% level even after accounting for several controls and fixed effects. The coefficient of the interaction term in the SES model is insignificant which suggests that, early mining exposure does not statistically diminish these private wealth gains.

Table 6: Later-Life Outcomes of Individuals within 50km of a Gold Mine

	Educational completeness				*SES*		
	(1) Ordered Probit	(2) Ordered Probit	(3) Ordered Probit	(4) Ordered Probit	(5) Ordered Probit	(6) Ordered Probit	(7) Ordered Probit
GoldMine	-0.1362	-0.1179	-0.1071	-0.1564	0.2731***	1.8291***	1.8237***
	(0.1021)	(0.1021)	(0.1019)	(0.1005)	(0.0319)	(0.2125)	(0.2121)
Early Exposure	-0.0519***	-0.0498***	-0.0429***	-0.0382***	-0.2759***	-0.1869***	-0.1898***
	(0.0040)	(0.0042)	(0.0041)	(0.0040)	(0.0078)	(0.0069)	(0.0069)
GoldMine x Early Exposure	-0.0454***	-0.0453***	-0.0457***	-0.0459***	0.0021	0.0157	0.0161
	(0.0129)	(0.0129)	(0.0129)	(0.0128)	(0.0246)	(0.0208)	(0.0208)
Residence		0.2340***	0.0215***	-0.0189*		1.4834***	1.4834***
		(0.123)	(0.0074)	(0.0077)		(0.0157)	(0.0157)
Gender			0.0753***	0.076***			-.02963***
			(0.0034)	(0.0034)			(0.0032)
SES				0.0271***			
				(0.0025)			
cut1	-0.5929***	-0.5745***	-0.5180***	-0.4656***	-0.8661***	-0.8661***	-0.8661***
	(0.0465)	(0.0465)	(0.0467)	(0.0462)	(0.1368)	(0.1368)	(0.1368)
cut2	-0.2367***	-0.2180***	-0.1615***	-0.1081***	-.2093***	-0.6506***	-0.6506***
	(0.0465)	(0.0465)	(0.0465)	(0.0462)	(0.1369)	(0.0851)	(0.0851)
cut3	0.5054***	0.5243***	0.5894***	0.5243***	0.3901***	0.5243***	1.3694***
	(0.0463)	(0.0463)	(0.0463)	(0.0463)	(0.1369)	(0.0463)	(0.0849)
cut4	0.7394***	0.7582***	0.8151***	0.7616***	1.0859***	0.7394***	2.2613***
	(0.0463)	(0.0463)	(0.0463)	(0.0463)	(0.1371)	(0.0463)	(0.0855)
Observations	754,987	754,987	754,987	754,987	754,987	754,987	754,987
Country-Level Fixed Effects	x	x	x	x	x	x	x
Regional Level Fixed Effects	x	x	x	x	x	x	x
R^2	0.1467	0.1470	0.1478	0.2544	0.4630	0.4631	0.4633

Notes: The analysis controls for 333 regional-level fixed effects as well as 136 country-level fixed effects and clusters standard errors at the grid-cell level (3,020 clusters) to account for heteroskedasticity and intra-cluster correlation. All specifications include the full set of controls where applicable. Standard errors are reported in parentheses. Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Column (6),which introduces *Residence* as a control variable, and (6), which accounts for the gender of respondents, all give the same results. They both confirm that the presence of gold mines in a given vicinity increases the probability of attaining higher wealth gains with a coefficient of (1.8291) and (1.8237) respectively, reporting a statistical significance at the 1% level across both model specifications taking into account regional-level fixed effects. Both models, just like in Column (4), indicate that early exposure to mining activities does not significantly diminish the wealth status of individuals within these grid cells. This creates an interesting paradox that, the decline in educational milestones or an increase in school dropout does not affect the later-life household economic status which have been shown to significantly increase. Quite contrary to the widespread opinion, these findings suggest that, an individual's decision to drop out of school to seek job opportunities in local mines might not be as myopic as initially feared and in fact, may improve their livelihoods which raises multiple arguments.

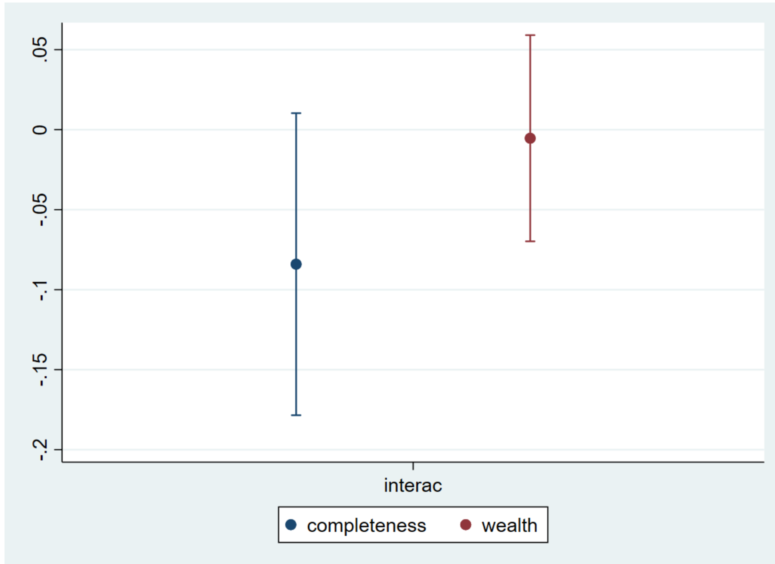

Figure 7: Interaction Effects of Mining Exposure on Socioeconomic Status and Educational Outcomes

The results from this individual-level study unveils some dual lens perspectives and insightful dynamics between private incentives and social welfare when analyzing the impact of minerals on education in SSA. From the individual or household perspective, the decision to dropout of school in pursuit of job opportunities may represent a rational economic choice. The statistical insignificance of the interaction term implies that, adolescents who leave school for mining work do not experience long-term wealth deprivation—at least in the medium term. This suggests that, for many households, the private benefits of mining labor outweigh the opportunity cost of forgone education. Thus, while dropping out may limit future earnings potential, families in mining regions face immediate economic pressures that make schooling a less attractive investment. This is consistent with the behavioral theory on poverty from studies by (Ndugwa et al., 2011), where short-term gains takes central importance over long-term human capital accumulation.

On the other hand, from a macroeconomic and societal perspective, the same behaviors generate substantial negative externalities. The significant drop in educational completeness represents a loss of human capital at the societal level. As has been established in macroeconomic literature, specifically the endogenous growth theory, education is a catalyst for productivity, innovation and economic diversification (Romer, 1990; Lucas Jr, 1988). When mineral exploration activities dis-incentivizes schooling, it undermines the very foundations of sustainable development. Consistent with the findings of (Papyrakis and Gerlagh, 2004), these results empirically validate the microeconomic channel of the resource curse hypothesis because, mineral exploration activities crowd out skill acquisition, trapping individuals in these areas into low-value-added extractive work. Also, the inter-generational effects are evident in the sense that, adolescents in mineral-rich regions are likely to inherit fewer opportunities for upward mobility, perpetuating cycles of resource dependence (Gylfason, 2002).

In summary, while the income earned from engaging in mineral exploration may benefit individual households, the social returns to education(such as the reduction of inequality, better health outcomes and institutional strengthening) are systematically sacrificed creating a collective action problem[8]

5 Discussion

The findings from this study offers some critical insight into the complex nature of the relationship between mineral exploration activities and educational outcomes in SSA. The central mechanism

[8] While individual households rationally prioritize mining income over education (private benefit), the aggregate result—a less-educated workforce—harms long-term economic growth and diversification (social cost), creating a dilemma where no single actor has an incentive to change behavior despite the shared detriment.

adopted by this study was the impacts of early mining exposure on education. As shown in the individual-level analysis, private benefits of mining, including immediate economic gains from engaging in mining activities, appear to counterbalance the long-term social costs of diminished educational outcomes. The findings also highlight an important aspect of the resource curse hypothesis by suggesting that, although mineral wealth may provide short-term economic opportunities, it may hinder sustainable development, particularly in education.

5.1 The Duality of Private vs Social Costs

The use of the SES variable in this study provided a critical counterpoint to educational outcomes, providing valuable insight into why households in mining regions often prioritize immediate mining income over long-term educational investment. At the micro-level, the findings of this study suggests that mining exposure does not make individuals worse off economically in the short-to-medium run. Rather, individuals in mining areas appear to adapt to local opportunity structures, where the immediate economic returns from mining outweigh the opportunity costs of education. This finding underscores the economic rationality of individuals in mining regions, who choose immediate economic returns over long-term educational benefits, given the limited perceived returns to education in these resource-dependent communities. This makes it erroneous to suggest that, the individual decision to engage in mining labor at the expense of completing educational milestones is myopic and shortsighted, at least from the individual perspective.

The private gains, however, in the form of increased household income due to mining labor simultaneously create social losses in terms of reduced human capital development. There is a rather substantial social cost of mining-induced educational attrition. As suggested by this study's findings, mining exposure leads to lower educational completion, which deprives SSA of the skilled labor force necessary to transition away from a resource-dependent economy. This is consistent with the Dutch-Disease hypothesis which postulates that, resource booms can crowd out other productive sectors including education (Corden and Neary, 1982). The short-term economic benefits of mining, while boosting household wealth, undermine long-term economic diversification and growth, which are dependent on a skilled workforce. The private gains from mining, though substantial in the short term, do not translate into lasting economic benefits for society as a whole.

This creates a collective action problem where no single household has the incentive to prioritize schooling, even though education has the tendency to yield more sustained development which has broader social benefits.

5.2 The Resource Curse and the Misalignment of Incentives

As supported by the results of this study, the resource curse is not an inevitable outcome of mineral wealth, but rather stems from the misalignment of incentives between individuals and society. As discussed in the previous section, individuals may rationally choose to prioritize the economic benefits associated with mining activities which seem to have both and short and middle-term private gains at the expense of long-term social costs (reduced human capital development). This misalignment of incentives, where individual benefits do not align with broader societal goals, is the key mechanism that drives the resource curse.

The misaligned incentives prevent the natural transition to a diversified economy thereby protracting the resource dependence. The economy fails to diversify and ends up becoming solely dependent of its resources as was the case in Netherlands in the 20th century. Thus, the resource curse, specifically in the context of educational outcomes in SSA, is not an inherent consequence of resource wealth but a result of the failure to align individual economic incentives with the long-term needs of society.

5.3 Policy Recommendations

The findings of this study highlight the need to address the misalignment of incentives in resource-rich areas to mitigate the negative impacts of mineral wealth on education. I suggest two main policy reforms that could help address this problem and help SSA to fully exploit the potential of mineral resource endowment and ensure a sustained and balanced growth trajectory.

The first key policy recommendation I propose is the introduction of conditional cash transfers for families living in mining districts. These transfers could be conditional on keeping children in school and ensure reduce the temptation for families to rely on children's labor in the mines. Making education financial competitive with short-term income from mining would reduce school dropout rates and ensure that, human capital development in the society is still high in order to promote a balanced and sustainable growth dynamic among mineral-rich countries in SSA. Also, another viable solution could be the initiation vocational training programs that integrate mining-related skills (such as engineering, environmental management, and mining safety) with formal education. These programs would allow children and adolescents to acquire skills that are both valuable for the mining sector and applicable to other economic sectors, thereby reducing the trade-off between education and employment in the mines.

6 Robustness Checks

In order to ensure the robustness and further validate the strength of the individual-level findings of this study, I performed a subsample analysis across the main regional blocs within Sub-Saharan Africa (SSA): Central, West, Eastern, and Southern Africa. The logic behind these robustness checks is embedded in the fact that institutional quality, economic structure, mining intensity, and educational infrastructure vary substantially across these regions, potentially leading to differential impacts of mineral exposure on educational and socioeconomic outcomes. This also helps to cater for impact of unobserved spatial heterogeneity across samples. Table 6 presents the results for the ordered probit model for two outcome variable: Educational Completeness (Columns 1-4) and SES (Columns 5-8). Each column represents different regional sub-samples to better understand how later-life outcomes are influenced by exposure to gold mining.

The results across Central, West and East Africa for the first model specification are fairly consistent as represented in Columns (1) to (3), with their respective coefficients recorded at (0.18), (0.048) and (0.076) coupled with statistical significance at 10%,10% and 1% respectively. Indeed, these sub-samples confirm that exposure to gold mining activities negatively and significantly reduces the probability of educational completeness reaffirming the results in Table 6. However, Column (4) documents opposing results with its coefficient (0.087) suggesting a positive relationship between early exposure to gold mining activities and later-life educational outcomes for countries situated in Southern Africa which contradicts the main findings of the

Table 7: Sub-Sample Analysis of Later-Life Outcomes Across SSA

	Educational completeness				*SES*			
	Central Africa (1)	West Africa (2)	Eastern Africa (3)	Southern Africa (4)	Central Africa (5)	West Africa (6)	Eastern Africa (7)	Southern Africa (8)
GoldMine	0.035	−0.032	−0.33*	−0.34***	0.13	2.16***	0.19***	0.30***
	(0.11)	(0.027)	(0.16)	(0.061)	(0.22)	(0.40)	(0.045)	(0.064)
Early Exposure	−0.090***	0.019**	−0.067***	−0.19***	−0.23***	−0.20***	−0.35***	−0.34***
	(0.013)	(0.0067)	(0.0074)	(0.0097)	(0.019)	(0.013)	(0.014)	(0.014)
Gold Mine x Early Exposure	−0.18*	−0.048*	−0.076***	0.087**	0.018	0.13**	−0.045	0.15***
	(0.095)	(0.025)	(0.020)	(0.028)	(0.20)	(0.045)	(0.034)	(0.044)
cut1	-0.9522***	-0.9675***	-0.316	-0.5078***	-0.9343***	-0.784*	-1.6037***	-1.3873***
	(0.0249)	(0.098)	(0.1432)	(0.1916)	(0.1484)	(0.1498)	(0.1286)	(0.1282)
cut2	-0.58***	-0.7557***	0.1916	-0.1791	-0.1983	-0.0869	-0.9982*	-0.7566
	(0.0232)	(0.098)	(0.1431)	(0.1917)	(0.1483)	(0.1502)	(0.1286)	(0.1285)
cut3	0.5445***	-.0147***	0.7265	0.7892*	0.4935	0.5679	-0.4591*	-0.1937
	(0.022)	(0.098)	(0.1432)	(0.1915)	(0.1470)	(0.1507)	(0.1287)	(.1285)
cut4	0.7262***	0.1802***	0.9838*	1.1681***	1.198***	1.3263***	0.1951	0.4793
	(0.0222)	(0.098)	(0.1434)	(0.1912)	(0.1471)	(0.1512)	(0.1286)	(0.1283)
Observation	59,108	340,851	237,003	115,871	59,108	340,851	237,003	115,871
Regional-level FE	x	x	x	x	x	x	x	x
Country-level FE	x	x	x	x	x	x	x	x
Base model controls	x	x	x	x	x	x	x	x
Clusters	Grid-cell level	Grid-cell level	Grid-cell level	Grid-cell level	Grid-cell level	Grid-cell level	Grid-cell level	Grid-cell level
Number of clusters	626	1394	1692	850	626	1394	1692	850
R^2	0.0013	0.026	0.028	0.029	0.13	0.11	0.092	0.075

Notes: Standard errors are reported in parentheses. Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

individual-level study.

For the second model specification, again, results are fairly consistent with Table 6 with all regional blocs documenting a positive effect of gold mining on the SES of households as shown from Column (5) to (8) with corresponding coefficients of (0.13), (2.16), (0.19) and (0.30) respectively although Central Africa's coefficient was documented as statistically insignificant.

The sub-sample analysis ultimately affirms the duality of private and social costs emphasized throughout the study. Even though mineral exploration activities increase household-level income, the depletion of educational completeness in SSA due to early exposure threatens long-term human capital development. This robustness test strengthens the empirical claim that the relationship between resource wealth and education is not monolithic but rather influenced by misaligned incentives as elaborated earlier.

7 Conclusion

This study has explored the dynamic, complex and multi-dimensional relationship between mineral exploration and educational outcomes in SSA using both districts and individual levels as units of observation. The results uncover some positive spillovers associated with mineral exploration as well as some unintented negative consequences. District-level results reveal contrasting findings, suggesting that, while mineral endowment may improve access to education in a district, it also has the tendency to increase school dropout rates due to the increased opportunity costs of schooling. At the individual-level, early exposure to mineral exploration significantly hampered later-life educational outcomes of individuals however, households within these areas saw short-to-medium-term economic gains, which highlighted the issue of misalignment between private incentives and long-term societal welfare.

These results align with the resource curse hypothesis explaining how mineral endowment can inadvertently stall human capital development by shifting the focus from education to immediate economic gains creating a collective action problem where individual rationality (prioritizing income from mineral exploration activities over schooling) conflicts with broader societal demands for a skilled workforce to foster sustainable development.

To curb these challenges, educational reform policies such as conditional cash transfers for families in mineral-rich districts and vocational training programmes integrating mining skills with formal education are recommended. These measures may potentially reduce school dropout rates by further incentivizing education and equipping the youth with adaptable skills fostering both immediate livelihoods and long-term economic diversification.

This study has a few limitations which can be further addressed in future studies. Firstly, migration patterns or selective settlement (e.g., more ambitious individuals moving toward mining regions) may bias the results. The inability of this study to fully control for this endogenous selection is a limitation. Also, The pseudo-longitudinal design (relying on retrospective matching of mining timelines and individuals' adolescence) is not as strong as true panel data. This limits causal inference over time and may miss dynamic effects that evolve beyond adolescence. Lastly, the lack of data on the closure dates of mines as well as the production volumes limits the ability to fully capture the duration and intensity of exposure, which could influence the magnitude of effects on education and SES. Future studies should address these concerns to capture a more accurate empirical framework of this phenomenon.

In conclusion, the relationship between mineral exploration is not inherently negative but is shaped by economic incentives. Addressing these incentives through thoughtful policy design can help transform mineral resources from a potential curse into a catalyst for inclusive and sustainable development.

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8 Appendix

Table 8: Description of DHS Sample

Country Name	DHS Country Code	Year of Survey	Weighted Sample
Angola	AO	2015-16	19,904
Burkina Faso	BF	2017-2018; 2021	25,379
Benin	BJ	2017-18	22,894
Burundi	BU	2016-17	24,649
Botswana	BO	2016-17	73
Cote d'Ivoire	CI	2021	22,267
Cameroon	CM	2018; 2022	21,547
Chad	TD	2018	108
Ethiopia	ET	2016; 2019; 2021-2022	36,494
Equatorial Guinea	EG	2016	35
Gabon	GA	2019-21	17,549
Ghana	GH	2016; 2017; 2019; 2022	22,090
Gambia	GM	2019-20	15,277
Guinea	GN	2018; 2021	14,878
Kenya	KE	2015; 2020; 2022	44,808
Liberia	LB	2016; 2019-20; 2022	11,879
Lesotho	LS	2023-24	9,628
Madagascar	MD	2016; 2021	27,619
Mali	ML	2015; 2018; 2021	14,325
Mauritania	MR	2019-21	21,357
Malawi	MW	2015-16; 2017	32,040
Mozambique	MZ	2015; 2018; 2022-23	18,804
Nigeria	NG	2015; 2018; 2021	54,554
Rwanda	RW	2014-15; 2017; 2019-20	40,949
Sierra Leone	SL	2016; 2019	21,899
Senegal	SN	2015; 2016; 2017; 2018; 2019; 2023	116,171
Tanzania	TZ	2015-16; 2017; 2022	37,482
Uganda	UG	2016; 2018-19	25,002
South Africa	ZA	2016	12,093
Zambia	ZM	2018	25,339
Zimbabwe	ZW	2015; 2018	17,894