Natural resources and gender (in)equality in education in Africa

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Abstract

This research examines the effects of natural resource rents on gender educational (in)equality across a panel of 52 African countries from 2000 to 2022. We test the gendered Dutch Disease theory, which points to natural resource wealth as a potential explanation for the slow progress toward gender equality. We use Two-Stage Least Squares (TSLS), Limited Information Maximum Likelihood (LIML), and Instrumental Variable Quantile Regression (IVQR) estimates. We find four main results. First, natural resource rents reduce gender educational equality at the primary, secondary, and tertiary levels. Second, the reductive effect of natural resource rents on gender educational equality increases with the level of education. Third, this reductive effect is higher in countries with high levels of gender educational inequality. Fourth, public education spending moderates the negative effects of natural resource rents on gender educational equality. Therefore, natural resources are a curse in the educational sector. However, this curse can be mitigated or reversed by substantially increasing public spending on education. African governments should use revenues from the natural resources sector to invest in education and improve gender educational equality.

Keywords: natural resources, gender, educational (in)equality, public education spending, Africa

JEL codes: H52, I25, N57, O13, O15

1. Introduction

The role of natural resources in the development process is the subject of much debate in developing countries. The exploitation of natural resources can have a negative effect on gender educational equality. Indeed, the gender-based resource curse theory (Ross, 2008) argues that economies heavily dependent on natural resources (oil, gas, minerals, etc.) tend to under-invest in human capital, particularly education. Furthermore, this theory indicates that when there are few economic incentives to develop an educated workforce, girls, already in a disadvantaged position in certain cultural contexts, are often the first to be excluded from education systems. In addition, the extractive economy is a masculinized sector that requires few qualifications and offers attractive salaries. This can divert educational investment in favor of boys, who are perceived as more likely to benefit from local economic opportunities. When income can be generated without education, families may consider girls' education a lower priority, especially in contexts where they are destined for a domestic role. Ross (2008) shows that oil-rich countries often have lower levels of female participation in public life, including education.

The institutional context can also play an important role. The abundance of natural resources can weaken institutions (corruption, clientelism) or lead to the formation of extractive institutions (Acemoglu and Robinson, 2012). This affects the quality and equity of public services, including education. Girls may be more vulnerable to these institutional failures. Similarly, in rentier states, redistribution is often used to maintain social stability, but not necessarily to promote inclusive or gender-sensitive education policies. In societies with rigid gender norms, resource abundance can exacerbate gender inequalities. Conversely, in more egalitarian societies, income from natural resources can be mobilized and used to reduce these gaps.

Dependence on natural resources can also have a positive effect on gender equality in education through increased public revenues (Gylfason, 2001), women's economic empowerment, and poverty reduction. Natural resources can generate substantial public revenues to fund educational programs, including policies targeting gender inequalities, such as scholarships for girls, school infrastructure, and awareness-raising campaigns. In some cases, resource-driven economic growth can free up time for girls by reducing domestic chores and improving their health, thereby facilitating their access to school. Economic growth generated by natural resources can reduce the financial barriers to education for girls, including school fees and opportunity costs.

If the effect of natural resources on gender educational inequality is controversial on a theoretical level, the same is true on an empirical or factual level. Empirically, the Dutch disease has been demonstrated in several developing countries. For example, Amini (2018) points out that resource-rich African countries (Angola, Sudan, Nigeria, and Congo) perform worse in terms of quality of life than resource-poor East Asian economies (Japan, South Korea, Taiwan, Singapore, and Hong Kong), which have achieved high standards of living equivalent to those in the West. In Africa, the curse of natural resources has been particularly documented in Burkina Faso (Bazillier and Girard, 2020; Ouoba, 2017, 2018; Pokorny et al., 2019), in Democratic Republic of Congo (DRC) and Equatorial Guinea (Blanco and Grier, 2012), in Mozambique (Almeida dos Santos, 2020) and Nigeria (Gelb, 1998; Lewis, 2009; Blanco and Grier, 2012; Sala-i-Martin and Subramanian, 2012).

In Nigeria, despite significant oil resources, oil-rich regions have low female enrolment rates, partly due to conflict, corruption, and under-investment in education. On the other hand, in recent decades, Botswana, a resource-rich country, has experienced rapid positive economic growth and significant human capital accumulation (Acemoglu et al., 2001; Gylfason, 2008a, 2008b). In Botswana, diamond revenues have provided stable funding for public education, reducing the gap between boys and girls, which is consistent with Davis (1995) and Stijns (2006, 2009), who argue that natural resources can generate significant additional revenues for financing the education sector for all.

Natural resources can lead to the reinforcement of patriarchal norms. Natural resources are controlled by male elites, leading to the marginalization of women. The existing legal system tends to favour men's interests, both in terms of access to natural resources and participation in decision-making processes (Nurlatifah et al., 2020). This creates deep-rooted inequalities, where women not only lose access to resources but also miss out on opportunities to defend the needs of their communities (Prasetyo, 2024). Natural resource rents can be captured by undemocratic groups, reducing equitable investment in public services. In Brazil, Brollo and Troiano (2016) show that the influx of natural revenues into municipalities can improve school enrolment rates, but that girls benefit less than boys if policies are not targeted. Gylfason and Zoega (2002) find that natural resource abundance significantly increases gender educational inequality, measured by the difference between male and female secondary education. Unequal distribution of natural resources rents can explain the unequal distribution of education.

Lederman and Maloney (2007), Brunnschweiler (2008), and Bulte and Damania (2008) assert that there is no natural resource curse. Lederman and Maloney (2007) see a "*curse of missing resources*". In addition, Brunnschweiler (2008) and Bulte and Damania (2008) state that the idea of a natural resource curse is a "*false problem*", an alibi that policymakers use to blame the economic problems they face. Bazilier and Girard (2020) find that the gold boom in Burkina Faso has not affected education.

Overall, natural resources can reduce or aggravate gender educational inequality or have no effect. However, based on the resource curse, which tends to prevail mostly in African countries (Auty, 1993; Corden and Neary, 1982; Sachs and Warner,1995, 2001; Gylfason and Zoega, 2002), we put forward the following hypothesis: *Natural resource rents reduce gender educational equality in Africa (Hypothesis 1)*. In addition, since inequality feeds on itself and countries have different levels of gender educational inequality, we also argue that *this reductive effect of natural resources on gender educational equality is higher in countries with high levels of gender educational inequality (Hypothesis 2).* In countries where gender inequalities in education are already high, revenues from natural resources tend to further exacerbate these inequalities.

The effects of natural resources on gender educational inequality may also be conditional on public spending on education, such that when the government increases education spending, natural resources promote gender educational equality. Public education spending can mitigate or even reverse the negative effects of natural resources on gender educational inequality. Using natural resource rents to invest in education can reduce gender educational inequality. In similar arguments, Bodea et al. (2016) indicated that public spending could mitigate civil conflicts related to oil wealth. Similarly, Debonheur et al. (2024) find that natural resource rents have a negative effect on human development in Africa, with this negative effect mitigated by food imports, which ensure food security in these countries. The negative effect of natural resource rents on gender educational equality can be mitigated or neutralized in countries with higher levels of public education spending. Therefore, based on previous research (Davis, 1995; Gylfason, 2001; Fargues, 2005; Stijns, 2006, 2009), we postulate the following hypothesis: *The natural resource curse can be mitigated by significantly increasing public spending on education in Africa (Hypothesis 3)*.

In Africa, while access to education is increasing, inequalities persist. Over the period 2000–2022, Africa has not achieved gender parity at all levels of education. At the primary, secondary,

and tertiary levels, the gender parity index of girls to boys is less than unity: it is 0.93 for primary, 0.88 for secondary, and 0.78 for tertiary education (World Bank, 2025). While Africa has reached the 2022 world average of 0.93 for primary education, for secondary and tertiary education—with world averages estimated at 0.92 and 0.93, respectively—there is still progress to be made. In addition, there are major disparities among African countries in terms of equal access to education. At the primary, secondary, and tertiary levels, respectively, only 30.77%, 28.85%, and 23% of African countries have achieved gender equality in education (World Bank, 2025). In other words, 69.23%, 71.15%, and 77% of countries in the region still experience gender inequality in education. Meanwhile, African countries are rich in natural resources. Over the period 2000–2022, rents from natural resources represent, on average, more than 11.53% of GDP. At least 38.46% of African countries have reached this average.

Girls' education is central to their economic empowerment and their ability to take advantage of opportunities generated by foreign direct investment and export businesses (Saad et al., 2021; Braunstein et al., 2015). Gender equality in education improves gender equality in wage employment in Africa (Oudanou et al., 2024) and fosters economic growth (Assoumou-Ella, 2019). Without education, girls are likely to remain in precarious, low-paid jobs, perpetuating gender inequalities. Investing in girls' education also reduces their fertility, poverty, and child mortality and improves their health (Claudio et al., 2018). The significant benefit of female education in both market and non-market outcomes underscores the importance of this research in Africa, a region with the highest gender educational inequality and poor female socioeconomic outcomes.

The contribution of this research is fivefold. Firstly, while most research analyzes the effects of natural resources on human capital in general (Stijns, 2006, 2009; Sun et al., 2018) or on income inequality (Fum and Hodler, 2010; Hartwell et al., 2019; Sawadogo and Ouoba, 2024a,b), this research focuses on gender inequality in human capital development, particularly in education. Education is an important dimension of human capital, and all citizens should have universal access to it, boys and girls alike (Sen, 1999; African Union Commission, 2015; United Nations, 2015). The role of natural resources in gender educational inequality is notably understudied (Oniyangi, 2013; Savoia and Sen, 2021) and therefore remains scant. In addition, previous research did not analyze, not only the direct and heterogeneous effects of natural resources on gender educational inequality, but also the conditional role of public education spending.

Secondly, this research analyses gender educational inequality at all levels of education: primary, secondary, and tertiary. The effect of natural resources can be potentially different from

one level of education to another. This is because the underlying economic and social mechanisms do not operate uniformly at the primary, secondary, and tertiary levels. As the costs and demands of education rise, households may increasingly prioritize boys' education. Consequently, natural resource wealth may intensify gender disparities more markedly at higher levels of education.

Thirdly, while girls in many developing countries have caught up with—and in some cases surpassed—men in terms of educational attainment (Grant and Behrman, 2010; Psaki et al., 2018; Bossavie and Kanninen, 2018), Africa stands out for having both the lowest levels of education globally and the highest degree of schooling inequality in favor of boys (Psaki et al., 2018; UNICEF, 2020). Compared to other developing regions, Africa made the least progress in closing the educational gender gap (Baten et al., 2021). Africa is the region with the lowest female empowerment and education rates. Girls receive less investment than boys do. In Africa, it is more common to invest in the education of sons than in daughters. Focusing on Africa means that more efforts should be made in this region to close the gender gap in education. In this perspective, this research is also an important contribution to educational public policies in this region, a region particulary rich in natural resources but with high educational gender inequality. As well as contributing to the literature on the resource curse, our paper fits into the broader research agenda on human capital inequality[1].

Fourthly, we use Two-Stage Least Squares (2SLS) and limited information maximum likelihood (LIML) to account for endogeneity. Finally, we use instrumental variable quantile regressions (IVQR) to account not only for endogeneity but also for the heterogeneity in the levels of gender educational inequality across African countries.

The remainder of this research is organized into three sections. The second section deals with methodology and data. The third section presents the results and discussion. The fourth section concludes and draws policy implications.

2. Methodology and Data

This section presents the theoretical and empirical models, the data and variables, and the estimation methods.

2.1. Theoretical and Empirical Models

[1] Particulary in Sustainable Development Goals (SDGs) 4 and 10. Goal 4 aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. This goal supports the reduction of disparities and inequities in education, both in terms of access and quality. SDG 10 aims to reduce inequalities within and among countries by promoting inclusive policies and ensuring equal opportunities for all.

This research tests the natural resource curse hypothesis in general (Corden and Neary, 1982; Auty, 1993; Sachs and Warner,1995, 2001) and the gendered Dutch disease hypothesis (Ross, 2008) in particular, in the field of education. The development of the natural resources sector may be accompanied by the relative decline of other sectors of the economy, including education, which is an important dimension of human capital and plays a leading role in the economic development process of countries. This risk applies to countries that generate substantial revenues from the exploitation of natural resources. However, these resources can be used to invest in education and reduce gender inequalities. These investments can take the form of building infrastructure, recruiting teachers, granting scholarships, and raising awareness of the importance of education for all, including girls. The theoretical model can be written as follows:

$$Gender\ Educational\ Inequality = f(Natural\ Resources, X) (1)$$

Model (1) means that gender educational inequalities are a function of natural resource rents and other factors (X). The effect of natural resources can be positive or negative. Following the natural resource curse hypothesis, we formulate our hypothesis according to which *natural resource rents increase gender inequalities in education in Africa (Hypothesis 1).* In other words, it reduces gender equality in education in the region.

Empirically, the model is inspired by Gylfason (2001), Ross (2008), and Sun et al. (2018). We examine the effects of natural resources on gender educational inequality across primary, secondary, and tertiary levels in Africa. The empirical model can be formulated as follows:

$$Educineq_{it} = \beta_0 + \beta_1 NRR_{it} + \alpha_j X_{it} + \varepsilon_{it} (2)$$

Where i is in the country, t is the year; Educineq is a measure of gender educational inequality at the primary, secondary, or tertiary levels; NRR is the rents from natural resources; X is a vector of control variables; ε is the error term.

Following the literature on the determinants of gender educational inequality, the control variables used are public education spending (Geduce), GDP per capita growth rate (Gdpg), and women's political empowerment (wpe). By including these variables in the model, equation (2) can be rewritten as follows:

$$Educineq_{it} = \beta_0 + \beta_1 NRR_{it} + \alpha_1 Geduce_{it} + \alpha_2 Gdpg_{it} + \alpha_3 Wpe_{it} + \varepsilon_{it} (3)$$

The effect of natural resources on gender educational inequality can also be greater in more unequal African countries (Hypothesis 2). This means that natural resources reinforce pre-existing inequalities rather than correcting them. In countries where gender inequalities in education are already high, extractive rents are often associated with low incentives to invest in female human capital, economic specialization in male-intensive sectors (mining, oil), and social or institutional norms that discourage girls from attending school. These factors accentuate the relative dropout of girls, especially at the secondary and tertiary levels.

To this end, we analyse the heterogeneous effects of natural resources on gender inequalities using quantile regressions. The quantile estimator is obtained by solving the following optimization problem for the θ^{th} quantile, ($0 <\theta<1$):

$$\min_{\beta \in R^k} \left[\sum_{i \in \{i: y_i \geq x_i' \beta\}} \theta |y_i - x_i' \beta| + \sum_{i \in \{i: y_i < x_i' \beta\}} (1-\theta) |y_i - x_i' \beta| \right] \quad (4)$$

In equation (4) y_i is the dependent variable, and x_i a vector k by 1 of explanatory variables. Quantile regressions minimize the weighted sum of the absolute deviations, obtaining for example, the 10th or 90th quantiles by weighting the residuals appropriately. The conditional quantile of y_i given x_i is given by equation 2 below:

$$Q_y(\theta | x_i) = x_i' \beta_0 \qquad (5)$$

Finally, the effect of natural resources on gender educational inequality in Africa can also depend on the size of public education spending. *The natural resource curse can be mitigated by significantly raising public spending on education (H3).* We therefore investigate the conditional effects of public education spending on the effects of natural resources rents on gender educational inequality. Following Brambor et al. (2006), we formulate equation (5) as follows:

$$Educineq_{it} = \beta_0 + \beta_1 NRR_{it} + \alpha_1 Geduce_{it} + \gamma_{it}(NRR_{it} * Geduce_{it}) + \alpha_2 Gdpg_{it} + \alpha_3 Wpe_{it} + \varepsilon_{it} \quad (6)$$

With NNR*Geduce the interaction between natural resource rents and public education spending.

2.2. Data and Variables

The data used are annual. They cover a panel of 52 African countries over the period from 2000 to 2022. The list of countries in the sample is presented in Table A1 (in the appendix). The

choice of the study period and the sample size in Africa is explained by the availability of data. The dependent variables used are gender inequality in primary, secondary, and tertiary education. They are measured using the gross primary, secondary, and tertiary school enrollment Gender Parity Index (GPI), defined as the ratio of girls to boys enrolled at the primary, secondary, or tertiary levels in both public and private schools. An increase in these indicators indicates an improvement in gender equality in access to education, whereas a decline reflects a rise in gender disparities in education.

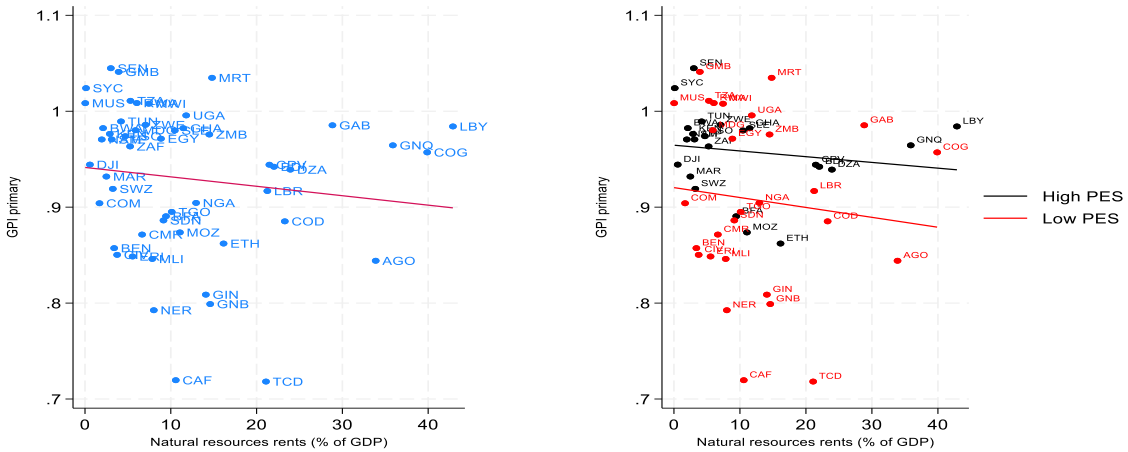
Following Savoia and Sen (2012), Mohsin and Jamaani (2023) and Bitoto and Nkoa Ongo (2024), we use the total natural resource rents as a percentage of GDP as the independent variable of interest. Total natural resource rents are the sum of oil rents, natural gas rents, coal rents, mining rents, and forestry rents. The control variables used are public education spending, annual GDP per capita growth rate, and women's political empowerment.

Following Philippot (2010), Cockx and Francken (2016), and Bitoto and Nkoa Ongo (2024), we use government expenditure on education as a percentage of GDP to measure public education spending. Public education spending can directly reduce gender educational inequality. Keynes (1936) supports the idea that public spending plays a fundamental role in the redistribution of resources. According to him, increased public expenditure stimulates demand and reduces economic inequality. This means that investing in public services, such as education, can reduce gender inequalities. Musgrave (1992) argues that the redistribution of public spending is seen as an essential catalyst for reducing inequalities, including gender inequalities. It has a redistributive effect and reduces economic constraints. In addition, when natural resource rents are used to increase public education investment through public education expenditure, it can also reduce gender educational inequality. Therefore, public education expenditure can play both direct and interactive effects with natural resource rents on gender educational inequality.

Figure 1 (1a,b,c) seems to suggest that the level of resource rents a country collects is negatively correlated with gender educational equality (left-hand side scatter). However, splitting the sample into countries with low and high levels of government education expenditure (right-

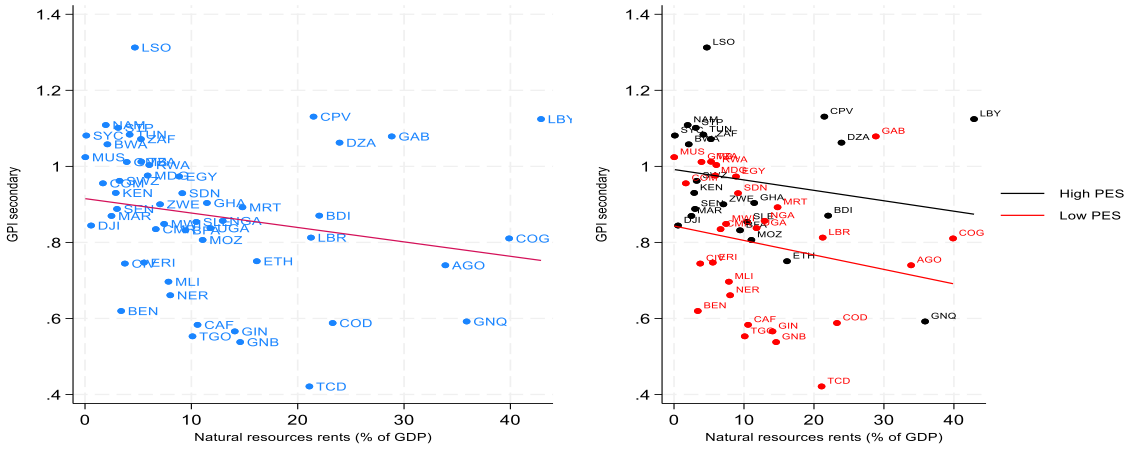
hand side scatter) shows that the effect of natural resource rents on gender educational equality can be heterogeneous, depending on how much public education expenditure is invested[2].

(1a)



PES: Public education spending (% GDP)

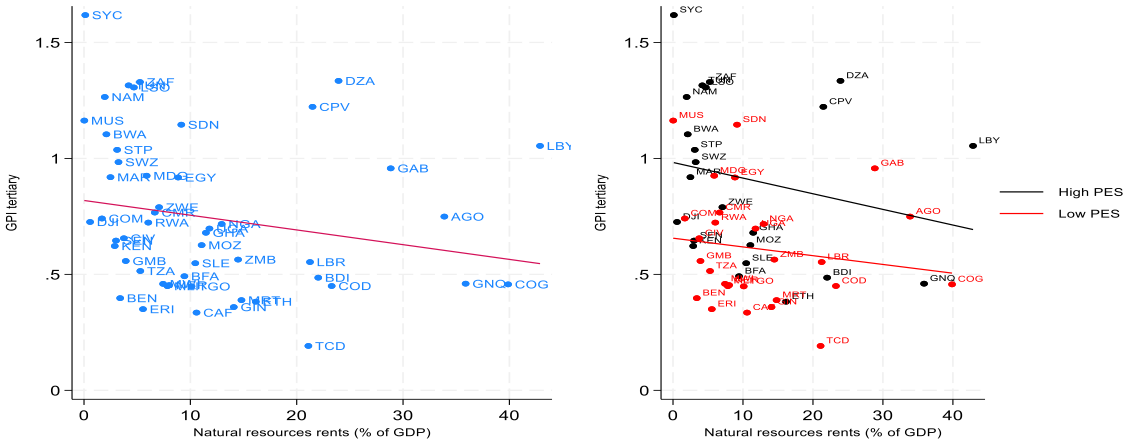
(1b)



PES : Public education spending (% GDP)

[2] Following Masi et al. (2024), to divide the sample, we consider the mean value of government education expenditure from the WDI (World Bank, 2024).

(1c)



PES : Public education spending (%GDP)

Source: author

Economic growth can have a negative effect on gender educational inequality in a country. Tzannatos (1999) indicated that rapidly growing economies open new opportunities for educated girls. Economic growth increases household income, which reduces the trade-offs against girls. Unfavourable trade-offs can be the withdrawal of girls from school for domestic work or early marriages. Becker (2022) indicates that households optimize their investment in education according to their income: at higher incomes, investment in all children increases. Jayachandran (2015) argues that gender gaps narrow as countries grow. However, Duflo (2012) indicates that growth can reduce gender inequalities, but not automatically. If growth is concentrated in male-dominated sectors such as the extractive industries, it can exclude women and reinforce gender biases (Ross, 2008). Furthermore, without targeted policies, growth does not necessarily benefit girls, particularly in rural areas (Blackden and Wodon, 2006).

Women political empowerment is measured by the proportion of seats held by women in national parliaments. Women political empowerment can increase gender equality in education. This is because women leaders prioritize gender issues. Women leaders tend to give higher priority to social spending, in particular education and health for children, especially girls (Chattopadhyay and Duflo 2004). Their presence in politics has a role model effect. Their presence in politics changes social norms, showing that women can be leaders. This reinforces the educational aspirations of girls and families and leads to an increase in female enrolment (Beaman et al., 2012). Women local leaders are often perceived as less corrupt and closer to the needs of families. They can improve the targeting of education policies towards girls (Dollar et al., 2001).

As a robust analysis, we also add other control variables, namely urbanization, foreign direct investment, and democracy. The addition of other control variables mitigates the problem of omitted variable bias (Behaghel, 2012). The variables, their definitions, and sources are presented in Table A2 (Appendix), while the descriptive statistics are presented in Table 1.

Table 1 shows that, on average, African countries have yet to achieve gender equality in primary, secondary, and tertiary education. Over the period 2000-2022, the average gender equality index for primary, secondary and tertiary education is 0.932, 0.882, and 0.780, respectively. At the primary education level, Senegal records the highest average gender parity index (1.045), while Chad exhibits the lowest (0.709). At the secondary level, Lesotho shows the highest average gender equality in education (1.313), whereas Chad again ranks lowest (0.404). At the tertiary level, Seychelles displays the highest degree of gender education equality (1.617), in contrast to Chad, which records the lowest value (0.177). Table 1 reveals that most of the variability in gender educational inequality stems from cross-country differences, as indicated by a substantially higher between standard deviation relative to the within component.

Over the period 2000-2022, the average income from natural resources is 11.53% of GDP. Libya records the highest share of natural resource rents, amounting to 42.883% of GDP, whereas Mauritius exhibits the lowest share, with natural resource rents representing only 0.028% of GDP.

Over the period 2000-2022, the average public spending on education is estimated to be around 4% of GDP. Lesotho has the highest level of public education spending in percentage of GDP (8.892%) compared to Nigeria, which has the lowest level of public education spending (0.439%).

The annual GDP per capita growth rate over the same period was 1.6%. Women are also less represented in African parliaments, with an average of 18% over the period 2000-2022.

Table 1: Descriptive statistics, 2000-2022

			Std. dev.				
Variables	Observations	Mean	Overall	Between	Within	Min	Max
Primary education-GPI	929	0.932	0.093	0.077	0.053	0.6134	1.164
Secondary Education-GPI	681	0.881	0.202	0.188	0.086	0.287	1.388
Tertiary Education-GPI	657	0.780	0 .359	0.334	0.118	0.064	1.710
Total natural resources rents	1129	11.525	11.740	10.407	5.708	0.002	88.592
Government expenditure on education	848	4.067	2.036	1.840	0.984	0.349	13.220

GDP per capita growth	1171	1.600	6.008	1.389	5.856	-49.128	91.781
Women political empowerment	1133	18.001	11.653	9.660	6.477	0	63.75

Source: author

2.3. Estimation methods

To estimate our models, we begin by using ordinary least squares (OLS) with heteroscedasticity correction. OLS can serve as a basis for comparison with other sophisticated estimators. This method is used at least as a starting point. However, this method does not consider the endogeneity of the natural resources' rents, which may arise from three sources, namely reverse causality, measurement errors, and omitted variable bias. The estimated effects of natural resources rents could be affected by reverse causality (Masi et al., 2024). If natural resource extraction reinforces gender educational inequalities, gender inequalities can accentuate the "*curse*." Indeed, gender inequality reduces a country's ability to impose fair taxation of rents, demand transparency in natural resource management, and promotes productive uses of these resources, particularly in education and economic diversification. Dollar et al. (2001) and Brollo and Troiano (2016) argue that more educated women and women's empowerment can contribute to better governance and better use of public resources. Countries deprived of part of their human capital become less productive in the long run, even with natural rents. This leads to less economic diversification with an economy trapped in extractive industries, more volatile growth, and more resource-dependent growth. Klasen (2002), Klasen and Lamanna (2009), Minasyan et al. (2019), and Altuzarra et al. (2021) have shown that gender educational inequality significantly slows growth. Measurement errors are also inherent in macroeconomic data. Resource rents are also subject to measurement errors that arise because such measures are based on estimates (Bitoto and Nkoa Ongo, 2024; Masi et al., 2024). Other control variables could affect the formation of gender educational inequalities, which can lead to omitted variable bias.

To correct these endogeneity problems, we use Two-stage least squares (TSLS). TSLS allows us to take these problems into account and provide more reliable estimates. We use external instruments such as the commodity net export price index, which is the individual commodities weighted by the ratio of net exports to total commodity trade. Commodity prices have already been used by Brückner (2012), Collier and Goderis (2012), Carrère et al. (2016) and Bazillier and Girard (2020) as an external instrument for natural resources.

The commodity net export price index (CNEPI) is from the International Monetary Fund (IMF). We used it to isolate exogenous shocks to natural resource revenues. This external instrument is correlated with the endogenous variable, natural resources rents, but uncorrelated with gender (in)equality in education. The correlation between the external instrument and natural resources rents is (-0.415) and significant at 1%. On the other hand, the external instrument is not significantly correlated with gender inequality in primary, secondary, and tertiary education, with respective values of (-0.016), (0.056), and (-0.070).

The CNEPI captures exogenous shocks to international commodity prices, weighted by the country's net export structure. As such, it is strongly correlated with natural resource rents in exporting countries. An increase in international commodity prices raises export revenues, extractive rents, and, indirectly, the share of natural resource rents in GDP. This structural relationship ensures the statistical relevance of the instrument. In resource-rich countries, the CNEPI therefore constitutes a determinant of resource-based revenues.

Variations in the CNEPI are largely exogenous to domestic conditions. International commodity prices are determined by global demand, geopolitical shocks, worldwide business cycles, and international technological innovations. Individual countries, particularly in Africa, do not influence world prices. Consequently, the CNEPI should affect gender educational inequalities only through its effects on natural resource rents. It is therefore plausible that the CNEPI satisfies the exclusion restriction. The diagnostic tests of the validity of the instrument in the results tables (section 3) confirm that this instrument is valid.

While TSLS is our main estimator, we also use limited information maximum likelihood (LIML) to account for potential instrument weakness. LIML is used at least for comparison purposes (or robustness check). LIML is an alternative estimator that has better small-sample properties than 2SLS with weak instruments. LIML is a linear combination of the OLS and 2SLS estimate with the weights depending on the data, and the weights happen to be such that they approximately eliminate the 2SLS bias. LIML is generally preferred to 2SLS in the presence of weak instruments (Hahn et al., 2004). However, when TSLS and LIML produce the same results (or very similar results), this indicates that the instruments used are strong and valid, the model is correctly identified, and the estimates are robust and reliable.

TSLS estimates the results at the average. This means that they do not account for heterogeneous effects of natural resources on gender educational inequalities in education.

Indeed, African countries have different levels of gender equality in education. Over the period 2000-2022, at primary, secondary, tertiary levels, only 30.77%; 28.85% and 23% of African countries have achieved gender equality while in most countries, inequalities remain high. In addition, most of the variability in gender educational inequality stems from cross-country differences (Table 1). Furthermore, figure A1 of the distributions of gender educational inequalities show that these inequalities are not normally distributed. In this respect, the effects of natural resources can be differentiated according to the extent of gender inequalities in education. Therefore, we also use the instrumental variable quantile regressions (IVQR) which allow these problems to be considered. IVQR allows for heterogeneity, non-normal distribution and endogeneity to be considered. In IVQR, the 50th quantile is the median effects, while estimates from TSLS and LIML are the mean. IVQR is not only used for robustness checks but also to test hypothesis 2 (H2).

3. Results and discussion

This section presents the results and discussion.

3.1. Baseline results: OLS, TSLS, and LIML

Table 2 shows the results of the OLS and TSLS. Tests of the internal validity of the model confirm that the instruments used are valid. Indeed, the p-value of Hansen's J statistic (Hansen, 1982) is greater than 10% in all regressions using TSLS. This indicates that the instruments used are not correlated with the error terms. In addition, the Kleibergen-Paap rk LM test (Kleibergen and Paap, 2006) rejects the null hypothesis that the model is underidentified, i.e., that the instruments are not correlated with the endogenous variable. This further confirms the validity of the instruments used. In addition, the Stock and Yogo (2005), Cragg-Donald (1993) Wald F-statistic, and Sanderson–Windmeijer (2016) F-tests for instrument weakness show a statistic greater than 10. This confirms that the instruments are relevant and valid. When using LIML, we find similar results to those of the TSLS[3]. This implies the absence of weak instruments. 2SLS and LIML are convergent and asymptotically equivalent. The similarity between 2SLS and LIML estimates suggests that our results are not driven by weak instruments and are robust to alternative IV estimation methods. Therefore, the estimated effects of natural resources rents on gender inequalities in education are stable and reliable.

[3] The results of the LIML are not reported in Table 2 because they are very similar to those of the TSLS.

Table 2 shows that natural resources rents reduce gender educational equality in Africa, regardless of the level of education, i.e., primary, secondary, and tertiary. Moreover, the equality-reducing effect of natural resource exploitation increases with the level of education. *This result confirms the natural resource curse hypothesis (Hypothesis 1)*. They indicate that countries rich in natural resources invest less in education, and in particular, girls' education. Rising revenues from the exploitation of natural resources reduces the incentive to invest in human capital. This finding confirms that of Gylfason (2001), who shows that the more a country depends on natural resources, the less it invests in education.

Girls' education is particularly neglected because of male sector specialization and the reinforcement of patriarchal norms. In these masculinized extractive sectors, there are fewer perceived opportunities for women, leading to less educational investment for them. Similarly, resource enrichment can reinforce traditional social norms, where girls' education is not valued. Boserup (1970) argues that the nature of economic activities, particularly mining and extractive sectors, shapes the gender division of labor and thereby reinforces gender inequalities. Because extractive industries are physically demanding and traditionally male-dominated, they tend to strengthen men's economic position relative to women. This male specialization in resource-intensive sectors can marginalize women, limit their access to education and labor market opportunities, and ultimately exacerbate gender inequality. This finding also confirms that of Ross (2008), who shows that oil-rich countries tend to have less female participation in public and economic life because of reinforced social norms. In countries like Nigeria, the oil windfall has not translated into equitable educational progress (Sala-i-Martin and Subramanian, 2012). The same is true in other countries such as Algeria, Morocco, and Tunisia (Ross, 2008) and Tanzania (Mugaya, 2020). In a panel of 94 countries, Oniyangi (2013) finds that natural resources have a negative effect on gender secondary educational equality.

This result confirms the *gendered Dutch disease hypothesis*. The exploitation of natural resources reduces gender equality in education. Dutch disease can also lead to a demand bias in education. When a country experiences a boom in natural resources (oil, minerals, etc.), it often sees its economic structure deindustrialize (Corden and Neary, 1982). Resource extraction creates low-skilled jobs (mining, oil) for men, with little need for high levels of education. Extractive sectors such as oil, gas, and mining are often not very intensive in terms of skilled labour. As a result, there is less expected return on educational investment, especially for girls,

perceived as a lower priority (Ross, 2008). Families invest even less in secondary and tertiary education for girls. Using an event study design, Grecu and Bataille (2024) find that over the period 1951 and 2010 giant oil discoveries are associated with relatively worse female outcomes including lower educational attendance in tertiary education among women relative to men. Giant oil discoveries are associated with wider educational gap between men and women.

Table 2. Natural resources and gender inequality in education: OLS and TSLS results

	GPI primary		GPI Secondary		GPI tertiary	
Variables	OLS	TSLS	OLS	TSLS	OLS	TSLS
Natural resources	-0.0155***	-0.0149***	-0.0308***	-0.0312***	-0.0798***	-0.0858***
	(0.00135)	(0.00139)	(0.00304)	(0.00329)	(0.00765)	(0.00909)
Government Education Expenditure	0.00931***	0.00758***	0.0533***	0.0494***	0.0762***	0.0722***
	(0.00139)	(0.00138)	(0.00383)	(0.00391)	(0.00672)	(0.00701)
GDP per capita growth	0.000974	0.000548	0.00106	0.000250	-0.00630*	-0.00859**
	(0.00112)	(0.00111)	(0.00241)	(0.00258)	(0.00326)	(0.00340)
Women political empowerment	0.00193***	0.00163***	0.00406***	0.00360***	0.00468***	0.00427***
	(0.000234)	(0.000229)	(0.000441)	(0.000440)	(0.000924)	(0.000934)
Constant	0.886***	0.904***	0.642***	0.676***	0.514***	0.563***
	(0.00977)	(0.00980)	(0.0228)	(0.0232)	(0.0374)	(0.0401)
Observations	651	601	472	434	464	423
R-squared	0.218	0.192	0.441	0.412	0.399	0.396
Prob > F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sanderson-Windmeijer F Statistic		1817.29		1448.96		491.53
Kleibergen-Paap rk LM P-value		0.0000		0.0000		0.0000
Cragg-Donald Wald F statistic		4865.542		3923.527		1683.146
Hansen J P-value		0.9116		0.9033		0.1293

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Source: author

The results also show that in African countries, the negative effects of natural resources on gender equality in education increase with the level of education. This result suggests that the reductive effect of gender equality in education is more pronounced at levels of education where inequalities are greater, such as at secondary and tertiary levels. Table 1 illustrates that access to education becomes increasingly unequal with increasing levels of education. Over the period 2000-2022, the average gender equality for primary, secondary and tertiary education is 0.932, 0.882 and 0.780, respectively.

Access to primary education has become much more democratic thanks to national and international policies (Millennium Development Goals, MDGs; Sustainable Development Goals, SDGs; universal access programs), but secondary and tertiary education remain elitist. In a context of natural resources, wealthy families, often headed by men, invest more in boys' education. Girls are subject to unfavorable budgetary trade-offs when it comes to long and costly studies. As a result, the gender educational inequality increases with the level of education (Tansel, 2002; Evans and Yuan, 2022).

3.2. Robustness checks

This section presents several robustness checks on the effects of natural resources on gender educational inequality in Africa.

3.2.1. Alternative dependent variable

To test the robustness of our results, we use an alternative dependent variable. We use the primary net school enrollment and the secondary net school enrollment gender parity index (GPI). These variables are from the WDI of the World Bank (2025). Net enrolment rate is the number of children of official school age who are enrolled in education expressed as a percentage of the total population of children of official school age. Net enrollment rates account for school quality. For example, it does not account for repetitions in school. This variable is only available for primary and secondary education. Table 3 shows that, in Africa, natural resource rents are associated with lower levels of gender educational equality, and this negative relationship intensifies as the level of education increases. This result is consistent with the baseline results (Table 2).

Table 3. Alternative dependent variable

		Estimation method: TSLS
Variables	Net GPI primary	Net GPI secondary
Natural resources	-0.0167***	-0.0270***
	(0.00344)	(0.00468)
Government Education Expenditure	0.0132***	0.0729***
	(0.00203)	(0.00563)
GDP per capita growth	0.00258*	0.00572*
	(0.00153)	(0.00308)
Women political empowerment	0.00147***	0.00342***
	(0.000380)	(0.000868)
Constant	0.900***	0.607***
	(0.0170)	(0.0362)

Observations	294	212
R-squared	0.209	0.514
Prob > F	0.0000	0.0000
Sanderson-Windmeijer F Statistic	1148.99	608.93
Kleibergen-Paap rk LM P-value	0.0001	0.0000
Cragg-Donald Wald F statistic	1740.599	1828.590
Hansen J P-value	0.2005	0.4535

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Source: author

3. 2.2. Alternative main independent variable

As an additional robustness check, we replace the baseline measure of natural resources with natural resources exports as a share of total merchandise exports. This variable is proxied with ores and metals exports as a share of total merchandise exports and is drawn from the WDI (World Bank, 2025). The results confirm that natural resource exports are associated with a reduction in gender educational equality in Africa, with the adverse effects on gender equality in education becoming more pronounced at higher levels of schooling (Table 4). Overall, the baseline findings remain robust to the use of an alternative measure of the key independent variable (Table 2).

Table 4. Alternative independent variable of interest

	Estimation method: TSLS		
Variables	GPI primary	GPI secondary	GPI tertiary
Natural resource exports	-0.000686**	-0.00233***	-0.00600***
	(0.000284)	(0.000570)	(0.000910)
Government Education Expenditure	0.00531***	0.0375***	0.0690***
	(0.00150)	(0.00419)	(0.00770)
GDP per capita growth	0.000524	0.000845	-0.00730
	(0.000961)	(0.00255)	(0.00480)
Women political empowerment	0.00177***	0.00388***	0.00499***
	(0.000268)	(0.000499)	(0.00112)
Constant	0.899***	0.713***	0.515***
	(0.0109)	(0.0237)	(0.0379)
Observations	518	371	390
R-squared	0.119	0.308	0.258
Prob > F	0.0000	0.0000	0.0000
Sanderson-Windmeijer F Statistic	331.80	105.61	156.46
Kleibergen-Paap rk LM P-value	0.0000	0.0000	0.0000
Cragg-Donald Wald F statistic	1014.653	435.476	429.740

Hansen J P-value	0.8253	0.8233	0.4823

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Source: author

3.2.3. Additional control variables

In an additional robustness check, we add other control variables to our model. These variables are urbanization (% of population), foreign direct investments (net inflows in percentage of GDP), and democracy. Urban population refers to people living in urban areas. Foreign direct investments are the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments. Democracy is measured by voice and accountability which captures perceptions of the extent to which a country's citizens can participate in selecting their government, as well as freedom of expression, freedom of association, and a free media. The data are from WDI from the World Bank (2025). Adding control variables reduces the omitted variable bias (Behaghel, 2012). Table 5 presents the results. The results show that urbanization increases gender equality in education at all levels. While FDI increases gender equality only at the primary level, democracy increases it at the secondary level. Despite the inclusion of these variables in our model, the results in Table 5 are robust to the baseline one (Table 2): Natural resource rents undermine gender equality in education in Africa, with the adverse effects becoming more pronounced at higher levels of education.

Table 5. Additional control variables

	Estimation method: TSLS		
Variables	GPI primary	GPI secondary	GPI tertiary
Natural resources	-0.0107***	-0.0180***	-0.0829***
	(0.00130)	(0.00285)	(0.00859)
Government Education Expenditure	0.00313**	0.0411***	0.0570***
	(0.00124)	(0.00381)	(0.00721)
GDP per capita growth	0.00150*	0.00199	-0.00239
	(0.000770)	(0.00202)	(0.00326)
Women political empowerment	0.00151***	0.00364***	0.00550***
	(0.000236)	(0.000474)	(0.000831)
Urbanization	0.000829***	0.00221***	0.00905***
	(0.000194)	(0.000383)	(0.000654)
Foreign direct investment	0.00100*	-0.000127	0.00287
	(0.000533)	(0.000986)	(0.00176)
Democracy	0.00163	0.0219**	-0.0262
	(0.00457)	(0.0101)	(0.0241)

Constant	0.887***	0.619***	0.184***
	(0.0138)	(0.0286)	(0.0472)
Observations	567	407	405
R-squared	0.185	0.428	0.545
Prob > F	0.0000	0.0000	0.0000
Sanderson-Windmeijer F Statistic	1725.40	1383.91	473.19
Kleibergen-Paap rk LM P-value	0.0000	0.0000	0.0000
Cragg-Donald Wald F statistic	3946.222	3185.159	1278.755
Hansen J P-value	0.8143	0.4959	0.3090

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Source: author

3.3. Accounting for heterogeneity

To account for between country heterogeneity (Table 1, Figure A1) in the effect of natural resource rents on gender educational inequalities in Africa, we use instrumental-variable quantile regressions (IVQR). This method analyses the effect of an explanatory variable on the entire distribution of a dependent variable, and not just on the mean (as in OLS, TSLS, and LIML). They are particularly appropriate for taking heterogeneous effects into account and are particularly useful in the analysis of inequality. They allow us to see whether the effects of natural resources differ depending on whether we are at the bottom, middle, or top of the distribution of gender (in)equality in education. IVQR was introduced by Chernozhukov and Hansen (2005). We use the smoothed instrumental variable quantile regression estimators of Kaplan (2021, 2022) and Kaplan and Sun (2017), who show that smoothing improves both computation time and statistical accuracy. In addition, this estimator can handle models with multiple endogenous terms, as well as allow for simultaneity and reverse causality. The results are presented in Tables A3-A5 (in the Appendix).

The results show that natural resources reduce gender equality at all levels of education in Africa, which is consistent with Table 2. Moreover, the effect of natural resources in reducing gender equality is higher in countries with high levels of gender educational inequality (Q 0.10; Q 0.25) than in those with low levels of inequality (Q 0.75; 0.90). *This result confirms Hypothesis 2*. Natural resources exacerbate existing gender educational inequality by reinforcing traditional norms that marginalize women. Furthermore, the mean effect (Table 2) and the median effect (Q 0.50, Tables A3-A5) are relatively similar. The convergence between the mean and the median constitutes an implicit robustness test. It reinforces the credibility of the results by showing that the conclusion does not depend on the estimation method or on

strong assumptions about the normality of the errors. This result means that the exploitation of natural resources systematically tends to negatively affect gender equality in education.

3.4. Does public education spending moderate the negative effect?

African countries spend on average of 4.1% of their GDP on education, with 52% of countries not reaching this level. Government education spending reduces gender education inequality in Africa (Tables 2-5, A3-A5). In other words, it increases gender educational equality. This result confirms Keynes's (1936) idea that public spending plays a fundamental role in the redistribution of resources. Public spending on education has a redistributive effect and reduces economic constraints. Targeted public spending on education (scholarships, canteens, school supplies, transport) helps offset the direct and opportunity costs of educating girls. Bourguignon (2003) finds that public education support programs increase girls' enrollment more, as they are often more disadvantaged at the outset. Furthermore, investments in educational infrastructure (separate latrines, security, gender-sensitive teacher training) create a more welcoming environment for girls, leading to a reduction in school dropout rates. Ben Saâd and Assoumou-Ella (2019) and Mbodji (2023) found that public education spending has a positive effect on gender educational equality. Duflo (2012) shows that investing in women, through education, is both an end and a means of development. In Africa, the role of governments through their increase in public education spending is therefore decisive.

While natural resource rents are considered an important source of revenue for governments, there has not been a systematic analysis of whether natural resource-rich countries can increase public education spending to mitigate or neutralise gender educational inequality. We therefore link public education spending and gender educational inequality, on the one hand, and natural resources and gender educational inequality, on the other. We follow Masi et al. (2024) to estimate and present interaction effects. Table 6 presents the interactive effects of natural resources and public education expenditure on gender educational (in)equality in Africa. The results show that the interaction term is significantly positive, suggesting that the negative effect of natural resource rents on gender educational equality is offset when the level of government education expenditure increases.

Resource wealth can provide governments with additional revenues that can finance education expenditure. For example, in the Middle East, Fargues (2005) indicated that oil revenues may

have enabled governments to finance welfare systems that benefited the population through subsidized health care and education. In recent decades, Botswana—a resource-rich economy—has achieved notable progress in human capital development (Acemoglu et al., 2001; Gylfason, 2008a, 2008b). Diamond revenues have ensured stable financing for public education, contributing to a narrowing of the gender gap in schooling. This experience is consistent with the arguments of Davis (1995) and Stijns (2006, 2009), who emphasize that natural resource endowments can generate substantial public revenues that support broad-based investment in education.

Table 6. Interactive effects of natural resources and government education expenditure

		Estimation method: TSLS	
Variables	GPI primary	GPI secondary	GPI tertiary education
Natural resources	-0.0354***	-0.0715***	-0.141***
	(0.00765)	(0.0180)	(0.0349)
Government education expenditure	-0.000522	0.0318***	0.0520***
	(0.00268)	(0.00741)	(0.0127)
Natural resources * Government Education Expenditure	0.00499***	0.00988**	0.0131*
	(0.00162)	(0.00424)	(0.00779)
GDP per capita growth	0.000339	3.94e-05	-0.00934***
	(0.00107)	(0.00246)	(0.00347)
Women political empowerment	0.00155***	0.00343***	0.00401***
	(0.000231)	(0.000443)	(0.000930)
Constant	0.941***	0.755***	0.661***
	(0.0162)	(0.0383)	(0.0685)
Observations	601	434	423
R-squared	0.206	0.416	0.390
Prob > F	0.0000	0.0000	0.0000
Sanderson-Windmeijer F Statistic	115.87	65.08	47.94
Kleibergen-Paap rk LM P-value	0.0000	0.0000	0.0000
Cragg-Donald Wald F statistic	436.424	271.620	159.988
Hansen J P-value	0.7080	0.8053	0.1283
Thresholds	7.35	8.35	35.35

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Source: author

Following Masi et al. (2024) and Bitoto and Nkoa Ongo (2024), Table 7 and Figures A2-A4 (Appendix) present the marginal effects of natural resource rents at different levels of public education spending (% GDP). They show that the effect of natural resource rents on gender educational inequality is conditional on the size of government education expenditure. At high levels of public education spending, natural resources rents tend to increase gender education equality. The marginal effects of natural resource rents on gender educational inequality become

positive at the primary, secondary, and tertiary education levels only when public education spending is, respectively, 7.35%, 8.35%, and 35.35%, therefore indicating a positive moderating role of government education expenditure. The effect of natural resources on gender educational inequality is conditional on the size of public education spending. Natural resource rents can be used to finance educational equality at all levels in Africa by significantly increasing public education spending. African governments can invest natural resource revenues in education to mitigate gender educational inequality. This result confirms the *hypothesis (H3) that the natural resource curse can be mitigated by significantly raising public spending on education in Africa*.

Table 7. Marginal effects of natural resource rents at different levels of public education spending

Public education spending (%GDP)	GPI primary	GPI Secondary	GPI tertiary
0.35	-0.0357061***	-0.057962***	-0.0076175**
	(0.0065264)	(0.0155769)	(0.0037424)
1.35	-0.0302269***	-0.0505984***	-0.0073975***
	(0.0050894)	(0.0116336)	(0.0028498)
2.35	-0.0247477***	-0.043234***	-0.0071776***
	(0.0036751)	(0.0078014)	(0.0022132)
3.35	-0.0192684** *	-0.0358712***	-0.0069576***
	(0.0023254)	(0.0043822)	(0.0020825)
4.35	-0.0137892***	-0.0285077***	-0.0067376***
	(0.0012667)	(0.0032197)	(0 .0025371)
5.35	-0.00831***	-0.0211441***	-0.0065176*
	(0.0014485)	(0.0058608)	(0.0033465)
6.35	-.0028308	-.0137805	-0.0062977
	(0.0026245)	(0.0095474)	(0.0043154)
7.35	0.0026485	-.006417	-0.0060777
	(0.0039968)	(0.0134453)	(0.0053579)
8.35	0.0081277	0.0009466	-0.0058577
	(0.0054182)	(0.0174133)	(0.0064385)
9.35	0.0136069**	0.0083102***	-0.0056377
	(0.0068583)	(0.0214123)	(0.0075407)
10.35	0.0190861**	0.0156738	-0.0054178
	(0.0083073)	(0.0254278)	(0.0086564)
11.35	0.0245654**	0.0230373	-.0051978
	(0.0097613)	(0.029453)	(0.0097808)
12.35	0.0300446***	0.0304009	-0.0049778
	(0.0112184)	(0.0334844)	(0.0109113)
13.35	0.0355238 ***	0.0377645	-0.0047579
	(0.0126774)	(0.03752)	(0.0120462)
35.35			0.0000816
			(0.0373056)
36.35			0.0003015

		(0.0384575)
37.35		0.0005215
		(0.0396095)

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Source: author

Over the period 2000-2022, only Lesotho, Botswana, and Namibia devoted, respectively 8.89%, 8.75%, 8.45% of their GDP to invest in education, and are therefore likely to mitigate and neutralize gender education inequality at least at the primary and secondary education. In China, although their research is not on gender inequality in education, Sun et al. (2018) show that, over the period 1995-2015, the negative effect of natural resources on access to secondary education becomes positive when Chinese provinces devote at least 9.5% of their GDP to investment in secondary education.

Finally, when we use government expenditure on education as a percentage of total government expenditure (at least for a robustness check), we find similar results. General government expenditure on education (current, capital, and transfers) is expressed as a percentage of total general government expenditure on all sectors (including health, education, social services, etc.). It includes expenditure funded by transfers from international sources to the government. General government usually refers to local, regional, and central governments. This variable is also from WDI (World Bank, 2025).

The results show that natural resource rents reduce gender educational equality (Table A6). They also show that the interaction term between natural resource rents and gender educational equality is significantly positive. Therefore, government education expenditure as a share of total government expenditure moderates the negative effects of natural resource rents on gender educational equality (Table A6, Appendix). The marginal effects of natural resource rents on gender educational equality at different levels of government education expenditure as a share of total government expenditure in Table A7 and Figures A5-A7 (Appendix) indicate that the effect of natural resources on gender educational inequality depends on the size of government education expenditure. These effects become positive when the government expenditure on education as a percentage of total government expenditure reaches 27.5%, 37. 5% and 67.5%, respectively for primary, secondary and tertiary education. Overall, the findings show that natural resource rents exacerbate gender inequality in education, especially at higher levels, but this effect can be mitigated through increased public education spending.

4. Conclusion and Policy Implications

This research analyzed the effects of natural resource rents on gender educational inequality. It covered a panel of 52 countries over the period from 2000 to 2022. We used the two-stage least squares (2SLS), the Limited Information Maximum Likelihood (LIML) and the instrumental variable quantile regression (IVQR). After extensive robustness checks, we found that natural resource rents reduce gender educational equality in primary, secondary, and tertiary levels. This negative effect increases the level of education. These results confirm the hypothesis of a gender-based natural resource curse in Africa. In addition, this negative effect is more pronounced in countries with greater gender inequality in access to education. Hypothesis 2 is therefore also confirmed. However, this negative association between natural resources and gender educational equality is not a fatality: public education spending mitigates or neutralizes this negative effect. Public education spending could play a significant role. Significantly increasing public spending on education staves off this resource curse in education, which indicates that hypothesis 3 is also confirmed.

These results imply that while natural resources reduce gender educational equality in Africa, thus compromising the achievement of UN Sustainable Development Goals 4 and 10, as well as the African Union's Agenda 2063 in the areas of equality and education for all, increased public spending on education can ward off this curse. To promote gender equality in education at all levels, rents from natural resources should be used to invest in education through a substantial increase in public education spending.

On the demand side of education, governments can use natural resources rents to provide subsidies or grants and scholarships to female students to encourage them to study and push their educational levels as far as possible. Conditional cash transfers and targeted support to vulnerable families can also encourage them to send all their children to school, reducing early marriage and greatly increasing school attendance. Extending compulsory schooling duration and reducing attendance costs can increase access to education for all (Gunes, 2025). Raising community awareness of the importance of female education and how this can strengthen communities and national economies is also necessary.

On the supply side, governments should also create natural resource reserve funds, which can be used to increase investment in education. This can reduce education costs for poor families. In this case, budgeting for public spending on education should be gender sensitive.

Specifically, public spending on education should be used to increase the supply of education through the construction of schools close to homes, which could reduce the distances often involved in girls dropping out of school. Stimulating overall education expansion, especially in disadvantaged countries, can also have strong benefits for girls, at least in the medium to long runs (Baten et al., 2021). Extractive industries could consider increasing funding for education through Corporate social responsibility (CSR) initiatives in this sector or through other innovative channels of development finance (Cockx and Francken, 2016; Bitoto and Nkoa Ongo, 2024).Finally, increasing the diversification of the economies could also significantly contribute to reducing gender educational inequality (Savoia and Sen, 2021). Economic diversification acts as a structural lever that increases the returns on girls' education, stabilizes public funding, transforms social norms, and strengthens institutions, thereby contributing to a sustainable reduction in gender inequalities in education.

Despite the use of instrumental variables estimates (TSLS, LIML, IVQR) and extensive robustness checks, this research does not necessarily demonstrate causality. Causality is always difficult to isolate in macroeconomic phenomena. The instruments used may not eliminate reverse causality, leading to residual reverse causality. Therefore, we are cautious about claiming a causal relationship. At least, this work demonstrates strong associations between natural resources rents and gender educational inequality in Africa.

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Appendices

Table A1. List of countries

Algeria	Côte d'Ivoire	Lesotho	Rwanda
Angola	Djibouti	Liberia	São Tomé and Principe
Benin	Egypt	Libya	Senegal
Botswana	Equatorial Guinea	Madagascar	Seychelles
Burkina Faso	Eritrea	Malawi	Sierra Leone

Burundi	Eswatini	Mali	South Africa
Cabo Verde	Ethiopia	Mauritania	Sudan
Cameroon	Gabon	Mauritius	Tanzania
Central African Republic	Gambia	Morocco	Togo
Chad	Ghana	Mozambique	Tunisia
Comoros	Guinea	Namibia	Uganda
Democratic Republic of Congo	Guinea-Bissau	Niger	Zambia
Republic of Congo	Kenya	Nigeria	Zimbabwe

Table A2. Variables, definition, and sources

Variables	**Definitions**	**Sources**
Gross Primary School enrollment, gender parity index (GPI)	The gender parity index for gross enrollment ratio in primary education is the ratio of girls to boys enrolled at the primary level in public and private schools.	WDI (World Bank, 2024)
Gross Secondary School enrollment, gender parity index (GPI)	Gender parity index for gross enrollment ratio in secondary education is the ratio of girls to boys enrolled at the secondary level in public and private schools.	WDI (World Bank, 2024)
Gross tertiary school enrolment, gender parity index (GPI)	Gender parity index for gross enrollment ratio in tertiary education is the ratio of women to men enrolled at the tertiary level in public and private schools.	WDI (World Bank, 2024)
Total natural resources rents (% GDP)	Total natural resources rents are the sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents.	WDI (World Bank, 2024)
Government expenditure on education (% GDP)	General government expenditure on education (current, capital, and transfers) is expressed as a percentage of GDP. It includes expenditure funded by transfers from international sources to the government. General government usually refers to local, regional and central governments.	WDI (World Bank, 2024)
GDP per capita growth (%)	Annual percentage growth rate of GDP per capita based on constant local currency.	WDI (World Bank, 2024)
Women political empowerment	It is the proportion of seats held by women in national parliaments (%). Women in parliaments are the percentage of parliamentary seats in a single or lower chamber held by women.	WDI (World Bank, 2024)

Source: author

Table A3. Effects of natural resources rents on gender equality in primary education: IVQR results

Variables	Estimation method: IVQR				
	Dependent variable: Primary education Gender parity index				
	Q 0.10	Q 0.25	Q 0.50	Q 0.75	Q 0.90
Natural resources	-0.0147***	-0.0149***	-0.0149***	-0.0148***	-0.0133***
	(0.00152)	(0.00171)	(0.00171)	(0.00163)	(0.00139)

Government Education Expenditure	0.00862***	0.00758***	0.00758***	0.00754***	0.00502***
	(0.00145)	(0.00119)	(0.00119)	(0.00122)	(0.00123)
GDP per capita growth	0.000758	0.000548	0.000548	0.000531	0.000705
	(0.00132)	(0.00119)	(0.00119)	(0.00118)	(0.00120)
Women political empowerment	0.00163***	0.00163***	0.00163***	0.00164***	0.00143***
	(0.000251)	(0.000212)	(0.000212)	(0.000212)	(0.000198)
Constant	0.495***	0.654***	0.904***	1.154***	1.322***
	(0.0114)	(0.0106)	(0.0106)	(0.0104)	(0.00840)
Observations	601	601	601	601	601

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Source: author

Table A4. Effects of natural resources rents on gender equality in secondary education: IVQR results

	Estimation method: IVQR				
	Dependent variable: secondary education gender parity index				
Variables	Q 0.10	Q 0.25	Q 0.50	Q 0.75	Q 0.90
Natural resources	-0.0387***	-0.0317***	-0.0312***	-0.0302***	-0.0215***
	(0.00296)	(0.00260)	(0.00249)	(0.00268)	(0.00234)
Government Education Expenditure	0.0531***	0.0492***	0.0494***	0.0484***	0.0434***
	(0.00376)	(0.00498)	(0.00462)	(0.00489)	(0.00486)
GDP per capita growth	0.00122	0.000207	0.000250	0.000732	-0.000490
	(0.00266)	(0.00233)	(0.00211)	(0.00233)	(0.00280)
Women political empowerment	0.00457***	0.00365***	0.00360***	0.00350***	0.00294***
	(0.000327)	(0.000463)	(0.000469)	(0.000473)	(0.000469)
Constant	0.214***	0.425***	0.676***	0.933***	1.138***
	(0.0275)	(0.0274)	(0.0255)	(0.0263)	(0.0274)
Observations	434	434	434	434	434

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Source: author

Table A5. Effects of natural resources rents on gender equality in higher education: IVQR results

	Estimation method: IVQR				
	Dependent variable: tertiary education gender parity index				
Variables	Q 0.10	Q 0.25	Q 0.50	Q 0.75	Q 0.90
Natural resources	-0.0926***	-0.0872***	-0.0830***	-0.0794***	-0.0647***
	(0.00623)	(0.00852)	(0.0113)	(0.0133)	(0.0147)

Government Education Expenditure	0.0670***	0.0720***	0.0747***	0.0770***	0.0762***
	(0.00637)	(0.00603)	(0.00666)	(0.00683)	(0.00860)
GDP per capita growth	-0.00597*	-0.00898***	-0.00862**	-0.00875**	-0.00575
	(0.00329)	(0.00345)	(0.00371)	(0.00390)	(0.00641)
Women political empowerment	0.00386***	0.00384***	0.00423***	0.00452***	0.00565***
	(0.000739)	(0.000814)	(0.000895)	(0.00108)	(0.00154)
Constant	0.0632*	0.280***	0.544***	0.802***	1.021***
	(0.0345)	(0.0459)	(0.0504)	(0.0541)	(0.0498)
Observations	435	435	435	435	435

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Source: author

Table A6. Direct and interactive effects of natural resources on gender inequality in education: alternative public education expenditure

	Estimation method: TSLS					
Variables	GPI primary		GPI secondary		GPI tertiary	
Natural resources	-0.0150***	-0.0335***	-0.0352***	-0.0727***	-0.0929***	-0.171***
	(0.00135)	(0.00752)	(0.00372)	(0.0169)	(0.00967)	(0.0428)
Government education expenditure gov expend.	0.00122*	-0.000915	0.00634***	0.00226	0.00320	-0.00503
	(0.000620)	(0.000838)	(0.00177)	(0.00219)	(0.00311)	(0.00528)
GDP per capita growth	-0.000212	-0.00122	-0.000650	-0.000854	-0.0114***	-0.0124***
	(0.00110)	(0.00108)	(0.00303)	(0.00295)	(0.00378)	(0.00376)
Women political empowerment	0.00204***	0.00168***	0.00485***	0.00464***	0.00625***	0.00586***
	(0.000235)	(0.000232)	(0.000501)	(0.000513)	(0.00105)	(0.00106)
Natural resources * Government education expenditure gov expend.		0.00118***		0.00241**		0.00494**
		(0.000437)		(0.00103)		(0.00247)
Constant	0.908***	0.957***	0.752***	0.820***	0.792***	0.935***
	(0.0134)	(0.0177)	(0.0339)	(0.0411)	(0.0655)	(0.102)
Observations	581	539	410	410	412	412
R-squared	0.177	0.179	0.224	0.228	0.248	0.245
Prob > F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sanderson-Windmeijer F Statistic	1761.96	88.90	1369.07	82.81	505.04	52.77
Kleibergen-Paap rk LM P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cragg-Donald Wald F statistic	4745.914	384.748	3732.403	322.927	1689.792	184.555
Hansen J P-value	0.9731	0.2051	0.3164	0.5341	0.4664	0.6562

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Source: author

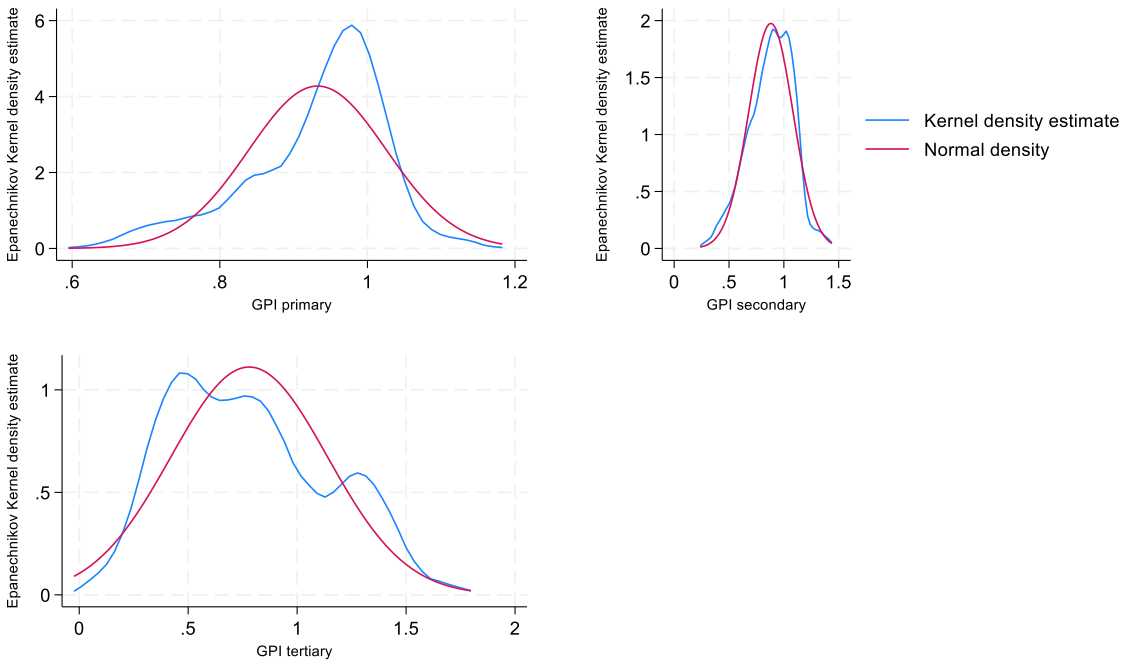
Table A7. Marginal effects of natural resource rents at different levels of alternative public education spending

Public education spending (% of total government expenditure)	GPI primary	GPI Secondary	GPI tertiary
2.5	-0.0323345***	-0.0590036***	-0.1126772***
	(0.0056253)	(0.01189)	(0.0338756)
7.5	-0.0257979***	-0.0496545***	-0.1037424***
	(0.0038369)	(0.0079602)	(0.0230195)
12.5	-0.0192614 ***	-0.0403054***	-0.0948077***
	(0.0021852)	(0.0045621)	(0.0131254)
17.5	-0.0127248***	-0.0309563***	-0.0858729***
	(0.0013435)	(0.0037033)	(0.0086423)
22.5	-0.0061882**	-0.0216072***	-0.0769382***
	(0.0024106)	(0.0064861)	(0.0153994)
27.5	0.0003484	-0.0122581	-0.0680034***
	(0.0040979)	(0.0102898)	(0.0256833)
32.5	0.006885	-0.0122581	-0.0590687
	(0.005895)	(0.0143229)	(0.0366355)
37.5	0.0134216*	0.0064402	-0.0501339
	(0.0077256)	(0.0184354)	(0.0477988)
42.5	0.0199582**	0.0157893	-0.0411992
	(0.0095706)	(0.0225841)	(0.0590536)
47.5	0.0264948**	0.0251384	-0.0322644
	(0.0114229)	(0.026752)	(0.070356)
67.5			0.0034746
			(0.1157622)
72.5			0.0124093
			(0.1271366)
77.5			0.0213441
			(0.1385157)

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

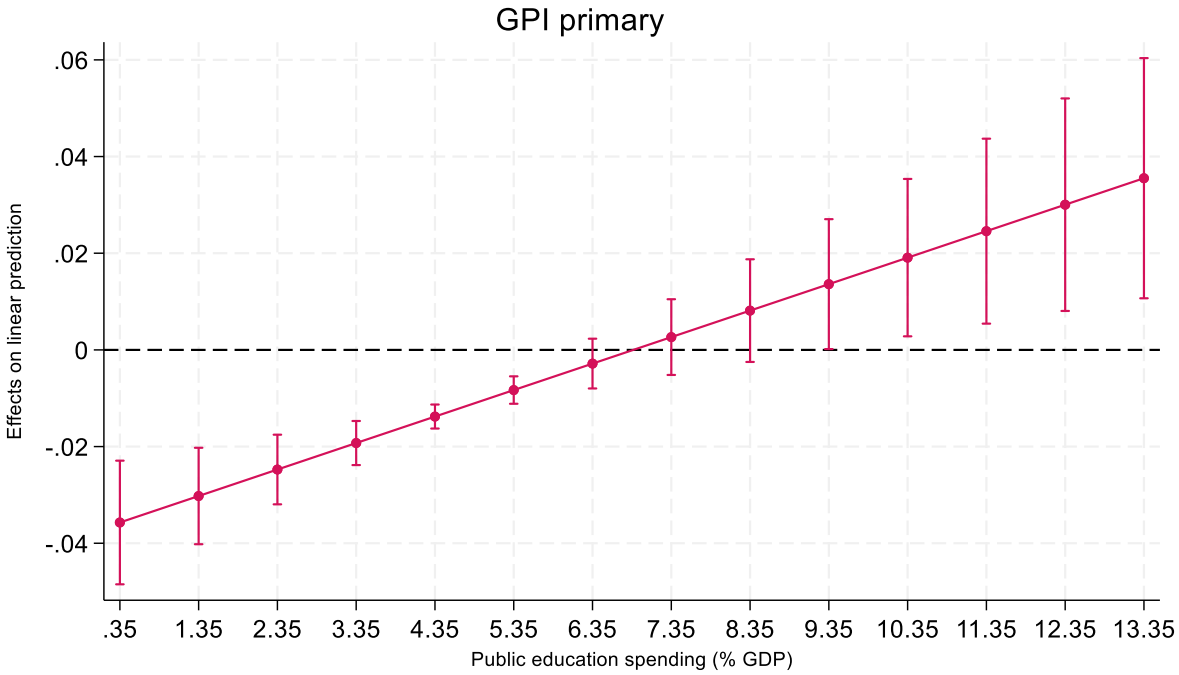
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Figure A1. Epanechnikov Kernel density estimate of gender educational inequality



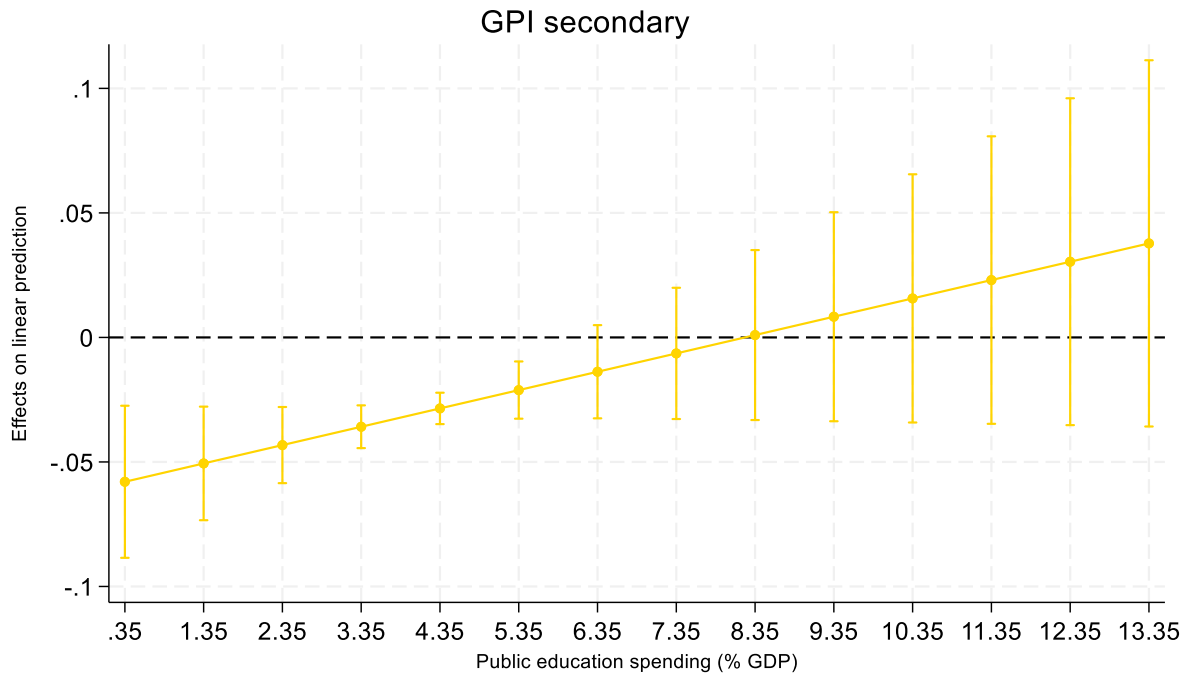
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Figure A2. Marginal effects of natural resources rents on GPI primary education at different levels of public education spending



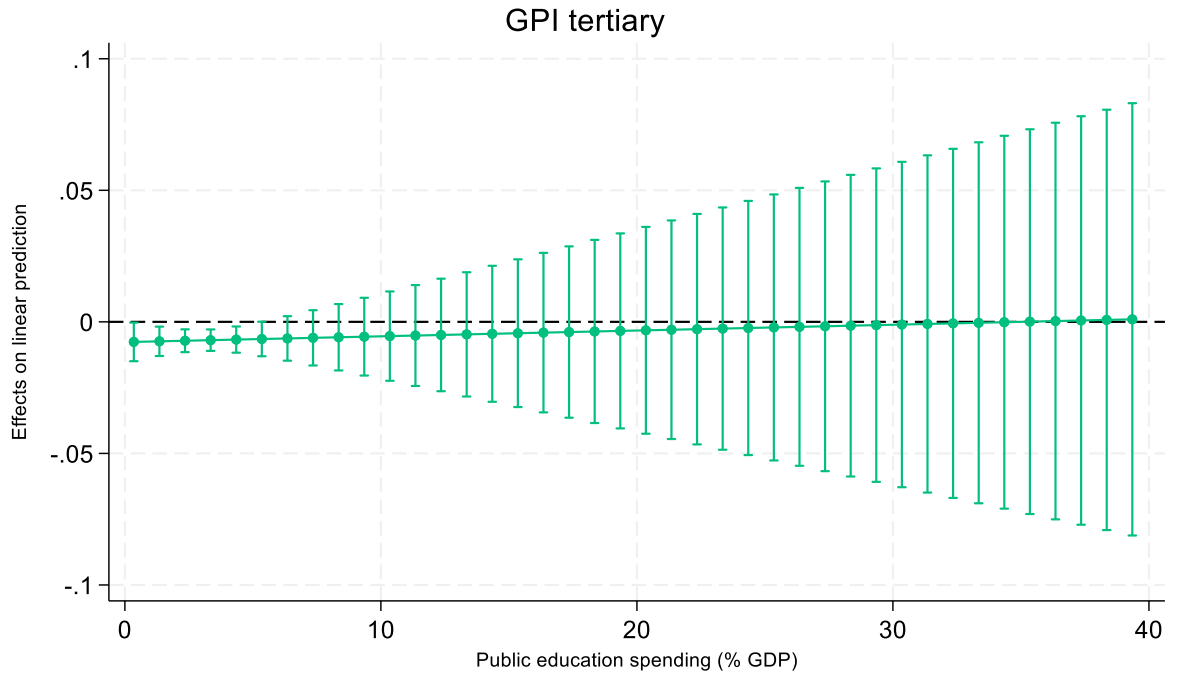
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Figure A3. Marginal effects of natural resource rents on GPI secondary education at different levels of public education spending



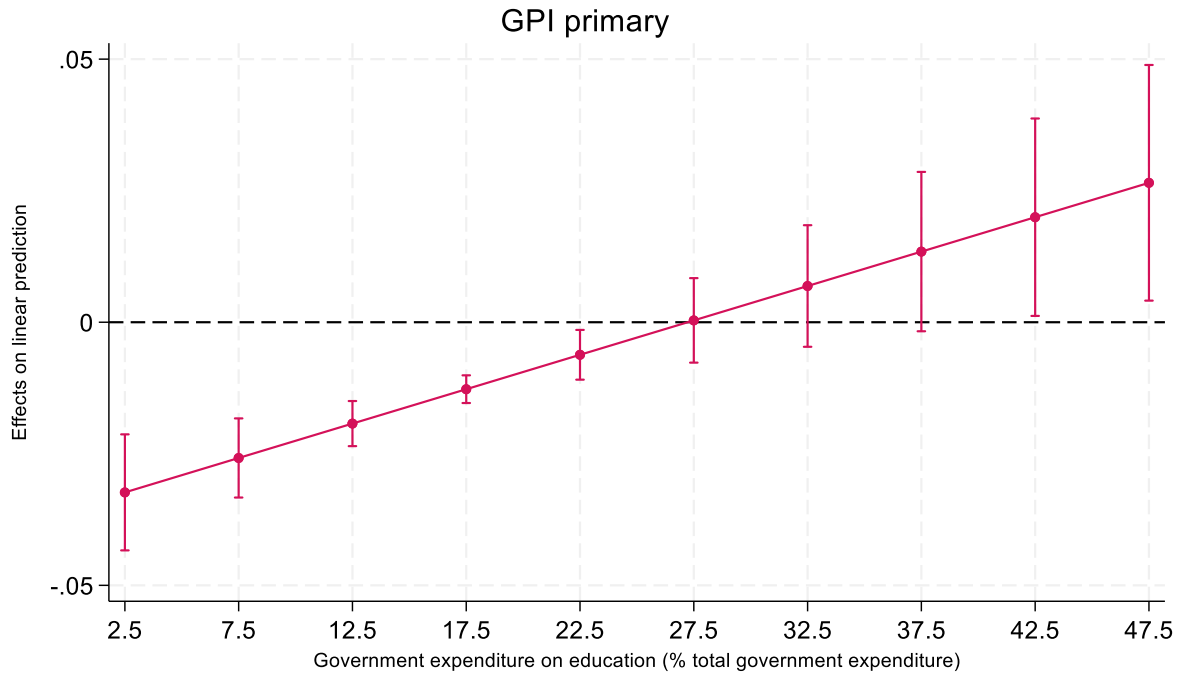
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Figure A4. Marginal effects of natural resource rents on GPI tertiary education at different levels of public education spending



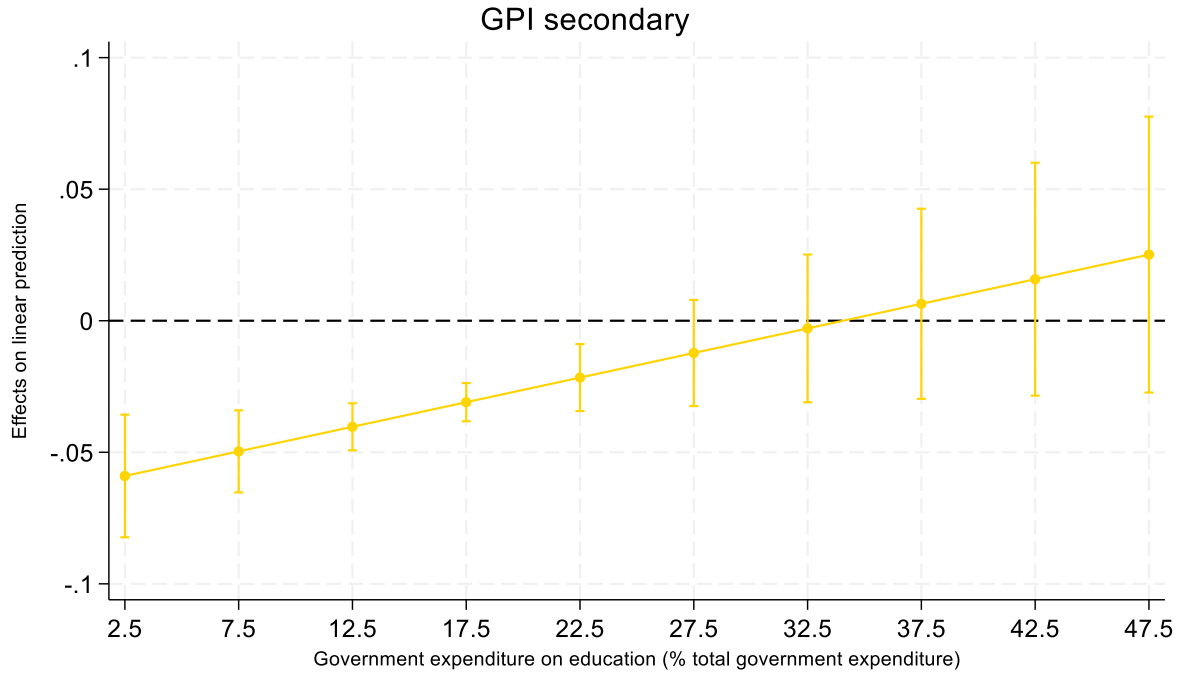
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Figure A5. Marginal effects of natural resource rents on GPI primary education at different levels of alternative public education spending



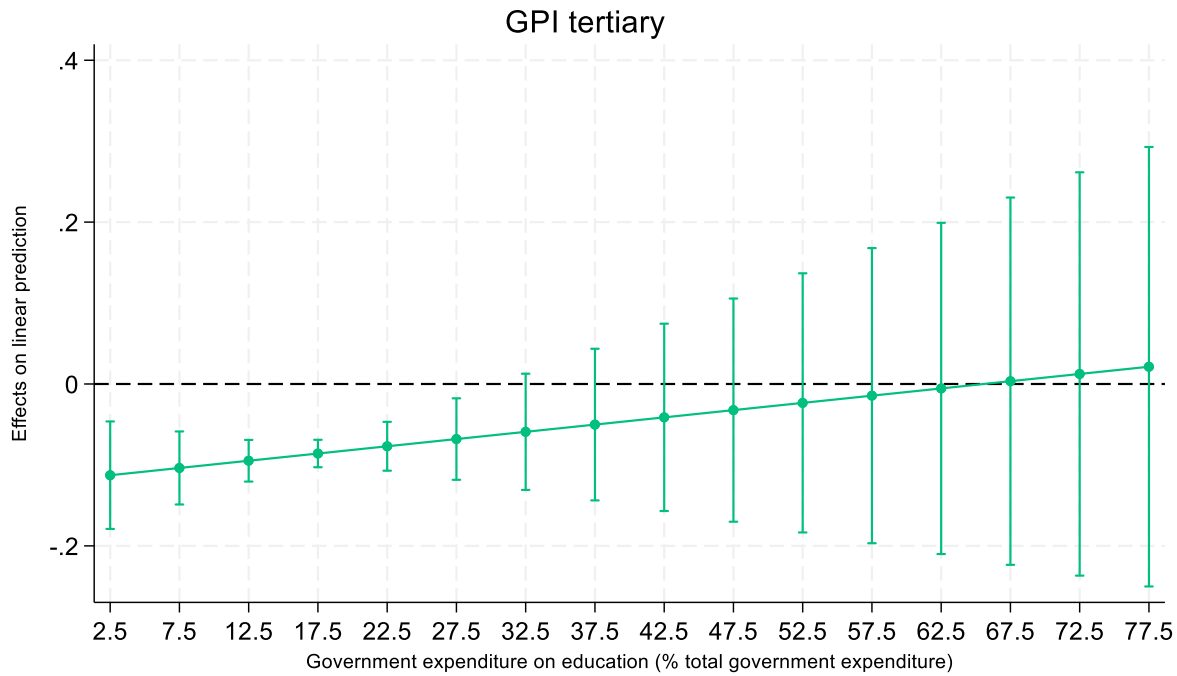
Source: author

Figure A6. Marginal effects of natural resource rents on GPI secondary education at different levels of alternative public education spending



Source: author

Figure A7. Marginal effects of natural resource rents on GPI tertiary education at different levels of alternative public education spending



Source: author