Unequal Eradication: The Economic Legacy of Malaria

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1 Identification of the Topic

The topic of this paper, the economic costs and development consequences of malaria in Sub-Saharan Africa, arose from an interdisciplinary interest in how historical policy decisions shape present-day inequalities. One of our members went to Kenya for a Geography field trip in February this year. There, he witnessed the impacts of malaria first-hand and learnt from his Geography professor (Prof David Taylor) that the World Health Organisation (WHO) deemed Africa "too poor" to be saved from malaria in the past. This prompted our team to explore what "too poor" meant to the WHO, and how this long-term spatial disparity in malaria eradication efforts institutionalised uneven development across regions. By revisiting this episode through an economic lens, we aim to understand how health policy neglect in the 1950s may have constrained Africa's human capital accumulation and economic growth for decades thereafter.

2 Motivation and Importance of the Study

Malaria is one of the most devastating public health and economic challenges in Sub-Saharan Africa. Despite being theoretically eradicable, it continues to kill over 600,000 people annually around the world. The WHO African Region accounts for more than 90% of global cases and deaths, 76% of whom are children under five (World Health Organization, 2024). Its persistence is not merely a biological or medical failure but a deeply political and economic one.

In 1955, the WHO launched its Global Malaria Eradication Programme (GMEP) with a stated long-term goal to eradicate the disease entirely from the planet, fuelled by the effectiveness of two new tools: the insecticide dichlorodiphenyltrichloroethane (DDT) and the antimalarial drug chloroquine (Thellier et al., 2024). However, the organisation explicitly excluded Sub-Saharan Africa, citing "implementation difficulties," "adverse environments," and "low income levels" (World Health Organization, 2019).

This decision institutionalised the idea that Africa was "too poor" to benefit from eradication efforts. The one-size-fits-all campaign model, successful elsewhere, was deemed incompatible with Africa's weak health infrastructure, poor communication networks, and limited fiscal capacity. Rather than adapt strategies to local contexts, global health leaders implicitly accepted malaria's persistence as inevitable, a view that has shaped funding priorities and policy decisions for decades (Nájera et al., 2011). Fast forward to the present, the African region accounts for 95% of all malaria cases (World Health Organization, 2024), while countries such as the United States are completely malaria-free.

This framing matters because malaria is not only a disease but a development trap. It lowers productivity, reduces schooling and cognitive outcomes, drives fertility decisions, and perpetuates poverty. Historical neglect, justified by perceptions of Africa's poverty, may itself be a reason for the region's continued underdevelopment. Understanding the economic costs of malaria and the consequences of withholding eradication efforts is therefore crucial for reframing future global health priorities.

Building on this context, our study contributes to understanding the enduring effects of global policy inequality by linking health exclusion to long-run educational and economic outcomes. By quantifying how the GMEP's exclusion shaped Sub-Saharan Africa's developmental trajectory, we aim to highlight the importance of adapting health interventions to local conditions and challenge the notion that economic

capacity should determine access to global health initiatives. Initially, we intended to investigate the legacy effects of the WHO's exclusion of Africa from the GMEP, focusing on how this historical decision could explain the region's persistent development gap relative to other parts of the world that benefited from early eradication campaigns. However, after doing more research for our data, we realised that some countries in Sub-Saharan Africa have recently received malaria treatment, hence we decided to shift our focus to comparing the effects of malaria treatment (or the lack thereof) within Sub-Saharan Africa instead. This will also make regional effects easier to control for and boost the credibility of our results.

3 Literature Review

To date, malaria remains one of the most significant public health challenges in Sub-Saharan Africa and is a major barrier to human capital formation (Kim, 2025). Its effects extend beyond immediate health outcomes, influencing children's educational attainment, cognitive development, and long-term economic productivity. The adverse educational effects of a malaria infection are transmitted through three principal pathways: school absenteeism, impaired short-term cognitive function that reduces learning efficiency, and impaired long-term cognitive development that constrains cumulative learning capacity (Angrist et al., 2023). Interventions such as malaria chemoprevention have proven effective in mitigating these educational losses. Empirical findings indicate that school-based chemoprevention can enhance sustained attention and other cognitive skills, with a small but significant effect size achieved at relatively low cost (Angrist et al., 2023). Beyond individual cognition, malaria also influences broader patterns of educational attainment. The disease reduces potential years of schooling through morbidity and mortality shocks while lowering the quality of learning achieved per year of schooling (Kim, 2025). Evidence from Tanzania's Roll Back Malaria (RBM) campaign shows that children exposed to eradication efforts attended on average 0.56 additional years of school, with comparable gains in Sri Lanka and multiple Latin American countries (Kim, 2025). These findings suggest that malaria eradication enhances both the quantity and quality components of human capital accumulation, thereby contributing to sustained improvements in educational outcomes and productivity (Kim, 2025).

At the household level, malaria further affects fertility and intergenerational investment decisions. The decline in child mortality reduces the cost of childbearing and encourages larger families, whereas declines in morbidity raise the returns to educational investment and encourage higher-quality, lower-quantity outcomes (Becker & Lewis, 1973). Evidence from Tanzania illustrates that following the RBM campaign, gross fertility fell by 6.13% and child mortality by 9.4%, resulting in a net fertility reduction of 3.2% (Kim, 2025). These results imply that the reduced cost of investing in child quality outweighs the reduced cost of child quantity, promoting sustained human capital accumulation. This intergenerational effect is reinforced as healthier children become healthier adults who invest more heavily in their own children's education (Daruich, 2018).

Malaria also exerts a significant strain on national economic growth. Cross-country evidence indicates that GDP per capita growth rates are approximately 1.3% lower in malaria-endemic countries than in non-endemic ones (Andrade et al., 2022). The burden is similarly evident at the household level. In Uganda, households bear over 70% of total societal malaria costs, with mean outpatient treatment estimated at $15.12 per case (Snyman et al., 2024). Productivity losses are responsible for these expenditures, comprising up to 88% of household costs due to time lost from work and caregiving

responsibilities (Snyman et al., 2024). Notably, poorer households spend a much larger portion of their income on malaria, with the economic burden reaching 26% of total consumption in the lowest income quintile compared to just 8% among the wealthiest, thereby increasing the risk of catastrophic health expenditure (Snyman et al., 2024). At the macroeconomic level, the cumulative cost of malaria is immense. In Uganda, the illness was estimated to cost $577 million (1.4% of GDP) in 2021 (Snyman et al., 2024). Structural economic models suggest that complete eradication could raise long-run per capita income by approximately 6.8%, with improved learning quality accounting for 74% of near-term income gains (Kim, 2025).

Malaria chemoprevention programs rank among the most cost-effective human capital interventions globally. In learning-adjusted metrics, such interventions yield between five and eight additional learning-adjusted years of development (LAYD) per $100 invested, outperforming many traditional education programs (Angrist et al., 2023). Policy recommendations underscore the importance of geographically targeted interventions. For instance, in Baringo County, Kenya, malaria transmission is concentrated in low-altitude riverine zones with perennial incidence, requiring continuous, localised control measures (Omondi et al., 2017). Advances in vaccine development also offer promising returns, as economic modelling suggests that vaccines achieving over 60% efficacy would fully recover their costs within one generation through associated income gains, especially in regions where infection prevalence exceeds 20% (Kim, 2025).

Nonetheless, key gaps persist in the literature, particularly regarding the mediating pathways between socioeconomic position and malaria outcomes. Limited evidence suggests that housing quality and food security explain 24.9% and 18.6% of the socioeconomic position effect on malaria, respectively (Tusting et al., 2017), while other protective factors, such as education, interventions, and nutrition, require further causal mediation analysis (Wafula et al., 2023). Methodological limitations, such as reliance on cross-sectional designs and inadequate confounder adjustment, continue to act as constraints to further inference. Moreover, the lack of standardised, comparable cost-of-illness data across endemic countries further compounds policy challenges (Wafula et al., 2023). Addressing these evidence gaps through longitudinal, interdisciplinary, and standardised research frameworks remains essential for designing malaria control policies that effectively link improved health to sustained economic growth and human capital development.

4 Research Question

This paper examines how malaria prevalence, shaped by historical and institutional decisions that excluded much of Sub-Saharan Africa from early eradication efforts, continues to affect long-run human capital and economic development. Specifically, it asks:

> ***How does malaria prevalence, partly driven by the World Health Organization's (WHO) decision to exclude Sub-Saharan Africa from the Global Malaria Eradication Programme (GMEP), influence long-run educational and economic outcomes in the region?***

This question is motivated by the enduring debate surrounding the WHO's mid-twentieth-century stance that Africa was "too poor" to benefit effectively from eradication (Packard, 2009; WHO, 2019). The

omission of Sub-Saharan Africa from the 1955 GMEP reflected not merely technical constraints but also a broader pattern of uneven development and implicit cost–benefit calculations of human life (Nájera, González-Silva, & Alonso, 2011). By contrast, regions such as the Americas and South Asia benefited from large-scale campaigns that significantly reduced malaria prevalence and generated measurable gains in human capital (Bleakley, 2010).

Building on this historical context, this study investigates whether the persistence of malaria in Sub-Saharan Africa has had long-term implications for schooling, cognitive development, and productivity. Evidence from Angrist et al. (2023) shows that malaria chemoprevention yields measurable cognitive gains (Cohen's d = 0.12) and cost-effective improvements in learning-adjusted years of development (LAYD), reinforcing the idea that malaria control is a vital input to human capital formation. This study extends that insight to a macroeconomic level, linking the legacy of differential eradication to present-day development gaps.

5 Methodology and Empirical Strategy

To identify the causal effects of malaria prevalence on long-run human capital outcomes, this paper employs a **difference-in-differences (DiD)** approach following Bleakley (2010) and Cutler et al. (2010). The empirical design exploits spatial and temporal variation in malaria eradication exposure across regions affected and unaffected by the WHO's Global Malaria Eradication Programme.

5.1 Empirical Framework

We estimate the impact of malaria exposure on long-run development outcomes using a difference-in-differences (DiD) framework that exploits variation in baseline malaria endemicity and the post-2005 period during which large-scale eradication funding accelerated.

The baseline DiD specification, consistent with *Appendix 10.1.1*, is:

$$Y_{ct} = \alpha + \beta(Exposure_c \times Post_t) + \mu_c + \lambda_t + \varepsilon_{ct}$$

Where:

- $\mathbf{Y_{ct}}$ is the outcome of interest for country *c* in year *t*. For economic outcomes, this is **log GDP per capita**. For education, we examine: (i) primary school enrolment (gross %), (ii) primary completion rate (%), and (iii) adult attainment of primary education among those aged 25+.
- $\mathbf{Exposure_c}$ denotes baseline malaria endemicity, defined as the standardised average malaria incidence (or prevalence when incidence is missing) during 2000-2002.
- $\mathbf{Post_t}$ equals 1 for years $t \geq 2005$, aligning with the period of intensified malaria control and Global Fund scale-up, and 0 otherwise.
- $\boldsymbol{\beta}$ captures the differential post-2005 change in the outcome for countries with higher baseline malaria exposure.
- μ_c and λ_t denote country and year fixed effects, absorbing time-invariant differences (e.g., geography, colonial history) and global shocks (e.g., commodity cycles, donor funding waves).
- Standard errors are clustered at the country level.

5.2 Control Variables

Appendix Sections 10.1.2-10.1.3 identify which covariates are valid (exogenous) controls and which are not. Controls such as fertility, HIV prevalence, under-five mortality, rainfall, and health spending are dropped because they shift the coefficient on **Exposure_c x Post_t** substantially or reverse its sign, which is classic evidence that they are endogenous to malaria and therefore "bad controls".

Following the incremental diagnostic procedure in **Appendix Table 6**, the final empirical framework retains only the two validated exogenous controls:

$$Y_{ct} = \alpha + \beta(Exposure_c \times Post_t) + \delta_1 AgriGDP_{ct} + \delta_2 PolStab_{c,t-1} + \mu_c + \lambda_t + \varepsilon_{ct}$$

Where:

- **Agriculture share of GDP (AgriGDP_{ct})**: Captures structural economic composition, largely predetermined relative to malaria interventions.
- **Lagged Political Stability ($\text{PolStab}_{c,t-1}$)**: Controls for institutional quality while avoiding simultaneity.

6 Data Description

6.1 Unit of Observation and Sample Construction

The empirical analysis employs a balanced country-year panel comprising all economies classified by the World Bank as Sub-Saharan Africa (SSA). Each observation represents a country c in year t, identified by its World Bank country name.

The sample spans 2000-2023, the period over which the Malaria Atlas Project (MAP) provides consistently comparable estimates of malaria burden. Sample size varies across outcomes because educational and governance series begin later for several countries. The panel contains roughly 800–900 country-year observations across about forty SSA countries over two decades.

6.2 Data Sources

We assemble a country–year panel from several harmonised sources:

- Malaria burden (MAP): annual Plasmodium falciparum incidence (Incidence of malaria, cases per 1,000 population at risk), parasite prevalence among children (Infection prevalence per 100 children), and malaria mortality (Mortality rate per 100,000).
- Malaria control interventions (WDI): Use of insecticide-treated bed nets (% of under-5 population) and Children with fever receiving antimalarial drugs (% of children under age 5 with fever).
- Economic outcomes and scale (WDI): GDP (current US$), GDP per capita (current US$), and Population, total.
- Economic structure and public spending (WDI): Agriculture, forestry, and fishing value added (% of GDP), Domestic general government health expenditure (% of GDP), and Current education expenditure, total (% of total expenditure in public institutions).

- Health and demographic context (WDI): Mortality rate, under-5 (per 1,000 live births), Prevalence of HIV, total (% of population ages 15–49), and Urban population (% of total population).
- Institutions (WGI, merged using WDI country codes): Political Stability and Absence of Violence or Terrorism (percentile rank).
- Climate and ecology (FAO and WDI): Average precipitation in depth (mm per year).
- Education outcomes (WDI): Primary completion rate, total (% of relevant age group), together with primary school enrolment and adult attainment of at least primary education among the population aged 25 and above.

6.3 Variable Definitions and Construction

Outcomes. The primary economic outcome is $\ln(\text{GDPpc}_{ct})$, the natural logarithm of GDP per capita (current US$). Educational outcomes, used for heterogeneous effect analysis, include:
(i) primary gross enrollment (% of school-age population),
(ii) primary completion rate (% of the relevant cohort), and
(iii) adult attainment of at least primary education among those aged 25+ (% of population).

Treatment and Exposure. Baseline malaria exposure for the country c is defined as the average MAP malaria burden between 2000-2002:

$$\text{Exposure}_c = \frac{1}{3} \sum_{\tau=2000}^{2002} \text{Incidence}_{c\tau}$$

If incidence data are unavailable, PfPR prevalence is used as a substitute.
For interpretability, exposure is standardised across countries to mean zero and unit variance:

$$\widetilde{\text{Exposure}}_c = \frac{\text{Exposure}_c - \bar{\text{Exposure}}}{s(\text{Exposure})}$$

The post-treatment period is defined as $\text{Post}_t = 1\{t \geq 2005\}$, corresponding to the onset of major international eradication funding (e.g., Global Fund, Roll Back Malaria, and widespread LLIN distribution).

Covariates. The final empirical framework employs a parsimonious and theory-consistent control set:
$Y_{ct} = \alpha + \beta(\text{Exposure}_c \times \text{Post}_t) + \delta_1 \text{AgriGDP}_{ct} + \delta_2 \text{PolStab}_{c,t-1} + \mu_c + \lambda_t + \varepsilon_{ct}$
Here, AgriGDP_{ct} captures structural economic dependence on agriculture—largely predetermined relative to malaria interventions - while $\text{PolStab}_{c,t-1}$ proxies institutional quality and is lagged one year to mitigate simultaneity.
These two controls are retained following an incremental diagnostic exercise (Appendix 10.1.3), which showed they produce negligible shifts in $\hat{\beta}$, in contrast to endogenous controls such as fertility and HIV prevalence.

Estimation Setup. All regressions include country fixed effects (μ_c) and year fixed effects (λ_t) to absorb time-invariant and global shocks, respectively. Standard errors are clustered at the country level. Country-specific linear trends ($\theta_c t$) are added in robustness tests to allow for heterogeneous growth trajectories. Alternative specifications replace malaria incidence with PfPR or mortality to verify the consistency of results.

6.4 Descriptive Overview

Sub-Saharan African countries exhibit substantial variation in baseline malaria exposure and post-2005 improvements. Countries in West and Central Africa remain most exposed, while southern African countries experience near-elimination. Across the region, malaria incidence and child mortality declined sharply after 2005, coinciding with widespread LLIN adoption. Institutional quality and agricultural shares vary more slowly, providing cross-sectional heterogeneity useful for identifying summary statistics and pairwise correlations. Appendix 10.1.4 confirms these relationships and highlights sufficient within-country variation over time for DiD estimation.

7 Preliminary Findings

7.1 Preferred Fixed-Effects Specification

	ln_gdp_pc	enroll_primary_gross	primary_completion	attain_primary_25p
	(1)	(2)	(3)	(4)
Agri share of GDP	-0.0121**	-0.2624	-0.1131	0.3486
	(0.0058)	(0.2397)	(0.1761)	(0.2359)
Political Stability (lag)	0.0040***	-0.0393	-0.0227	0.1193*
	(0.0014)	(0.0715)	(0.0703)	(0.0620)
Exposure × Post	-0.0115	1.273	0.5938	-2.428
	(0.0417)	(2.352)	(1.688)	(1.673)
Observations	874	667	546	184
Size of the 'effective' sample	42	42	41	38
R^2	0.95608	0.83830	0.86158	0.96426
Pseudo R^2	1.1433	0.20161	0.22705	0.36328
Adjusted R^2	0.95255	0.82081	0.84316	0.94638
Adjusted Pseudo R^2	1.0889	0.18004	0.20013	0.29098
country fixed effects				
year fixed effects				

Table 1: SSA, Preferred specification across outcomes (country and year FE; clustered by country)
Empirical Regression with Controls

Table 1 presents our preferred specification for Sub-Saharan Africa, estimating the association between malaria exposure and key development outcomes using a fixed-effects framework with country and year fixed effects. The models include controls for agriculture's share of GDP and lagged political stability, with standard errors clustered at the country level. Across all outcomes, the R^2 values are high, ranging

between 0.84 to 0.95 with 874 country-year observations for log GDP per capita, 667 for primary enrollment, 546 for primary completion, and 184 for adult attainment of primary schooling.

Several clear patterns emerge from the coefficients. First, agriculture's share of GDP is negatively associated with log GDP per capita, with a coefficient of -0.0121 (SE = 0.0058) and is statistically significant at the 5% level. This is consistent with the idea that more agrarian economies countries tend to be less industrialised and less productive. Second, lagged political stability is positively associated with income, with a coefficient of 0.0040 (SE = 0.0014) and is statistically significant at the 1% level. This suggests that institutional quality plays an important role in long-run human capital accumulation because stable institutions make it easier for governments to deliver public services, maintain consistent health and education policies, and support economic activity.

For educational outcomes, most structural controls remain small and insignificant, but adult primary attainment (primary_25p) shows a meaningful positive association with political stability, with a coefficient of 0.1193 (SE = 0.0620), which is statistically significant at the 10% level. This indicates that institutional stability also plays a meaningful role in long-run human capital accumulation, even if short-run schooling measures (like enrollment and primary completion) might not respond as strongly.

7.2 Standardized Effects to Compare Economic vs Educational Outcomes

Outcome	$\hat{\beta}$ (SD units)	SE	N	Countries	Years
GDP (z)	-0.012	0.043	874	42	22
Edu Index (z)	0.047	0.094	701	42	22
Edu PCA (z)	-0.291	0.112	115	32	22
Enroll (z)	0.055	0.101	667	42	22
Completion (z)	0.030	0.085	546	41	22
Attain 25+ (z)	-0.103	0.071	184	38	22

Notes: Outcomes are standardized (z-scores), so coefficients are SD changes. Models include country and year fixed effects and controls for agriculture share of GDP and lagged political stability. Standard errors clustered by country.

Table 2: Standardised DiD effects (per 1 SD of the outcome): Economic vs. Education outcomes

Table 2 standardises each outcome into z-scores and re-estimates the difference-in-differences models to facilitate direct comparison between economic and educational effects. Interpreting all coefficients in standard deviation units allows us to assess whether malaria exposure disproportionately affects income formation or human capital accumulation.

The results show that the estimated effects are uniformly small and statistically insignificant across all outcomes. GDP changes by only –0.012 standard deviations, while the education outcomes (enrolment, completion, and adult primary attainment) range between –0.103 and +0.055 standard deviations. Although the point estimates differ in sign and magnitude, the relatively large standard errors mean that these effects are econometrically indistinguishable from one another and from zero. There is also no evidence in this specification that malaria exposure exerts a systematically larger influence on economic outcomes than on educational ones. Taken together, the standardized estimates suggest that any long-run

developmental effects of malaria exposure are likely modest and not concentrated within a single outcome category.

These patterns motivate extending the analysis by using treatment proxies, such as nets or antimalarial treatment, to assess in future work which type of malaria intervention generates more meaningful improvements in economic and educational outcomes.

7.3 Comparison Nets vs Antimalarial Treatment

Outcome	Intervention	Effect	SE	t	p	Countries
GDP (z)	Mosquito nets	0.102	0.035	2.91	3.75e-03	748
GDP (z)	Antimalarial treatment	-0.164	0.035	-4.71	2.93e-06	748
Education Index (z)	Mosquito nets	0.314	0.038	8.30	6.37e-16	638
Education Index (z)	Antimalarial treatment	-0.162	0.038	-4.30	1.95e-05	638

Outcomes and interventions are standardized (z-scores). Estimates use OLS with HC3 robust standard errors. Each outcome year is matched to the closest treatment year within three years.

Table 3: Nets vs Antimalarial Treatment: nearest-year match ($|\Delta\text{year}| \leq 3$), standardized

Table 3 evaluates which intervention is more effective by comparing the estimated impacts of mosquito net usage and antimalarial drug treatment on economic and educational outcomes. The analysis is based on the nearest-year matched regression specification:

$$\mathbf{Y}_{c,t} = \alpha_c + \gamma_t + \beta_1 \,\text{nets}_{c,t} + \beta_2 \,\text{treat}_{c,t} + \varepsilon_{c,t}$$

where both outcomes and treatments are standardized to z-scores. This allows the coefficients to be interpreted as effect sizes in standard deviation units. The results show a clear and robust pattern. For GDP, mosquito nets have a positive and statistically significant effect ($\beta = 0.102,\ p = 0.0038$), whereas antimalarial treatment has a negative and significant association ($\beta = -0.164,\ p < 0.00001$). A similar contrast appears for education outcomes. Mosquito nets again show a strong positive effect on the Education Index ($\beta = 0.314,\ p < 10^{-15}$), while antimalarial treatment exhibits a negative effect ($\beta = -0.162,\ p < 0.0001$). Since all variables are expressed in standardized units, the estimates imply that expanding nets coverage improves both economic performance and education outcomes substantially more than expanding antimalarial drug treatment.

Hence, mosquito nets appear to be the more effective intervention across both dimensions. From a policy perspective, this supports prioritizing vector-control tools such as insecticide-treated nets, which yield consistently positive returns, while antimalarial treatment on its own may not produce comparable long-run gains.

7.4 Poor vs Non-Poor Countries: Evidence Against the WHO Assumption

Outcome	Intervention	Group	Effect	SE	t	p	Wald p (diff)
GDP (z)	Mosquito nets	Non-poor	-0.024	0.084	-0.28	7.79e-01	
GDP (z)	Mosquito nets	Poor (bottom tercile)	0.432	0.073	5.94	2.92e-09	4.24e-05
GDP (z)	Antimalarial treatment	Non-poor	-0.307	0.104	-2.95	3.16e-03	
GDP (z)	Antimalarial treatment	Poor (bottom tercile)	0.194	0.066	2.96	3.08e-03	4.59e-05
Education Index (z)	Mosquito nets	Non-poor	0.034	0.111	0.30	7.62e-01	
Education Index (z)	Mosquito nets	Poor (bottom tercile)	0.465	0.071	6.51	7.76e-11	1.11e-03
Education Index (z)	Antimalarial treatment	Non-poor	-0.048	0.102	-0.47	6.41e-01	
Education Index (z)	Antimalarial treatment	Poor (bottom tercile)	-0.177	0.159	-1.11	2.65e-01	4.92e-01

Baseline income is mean ln(GDPpc) over 2000–2004. SEs are clustered by country (HC1). Wald p tests equality of effects between groups.

Table 4: Heterogeneous effects by income: Poor vs non-poor (baseline 2000--2004), nearest-year matched, clustered SEs

Table 4 examines whether the impact of malaria control differs between poor and non-poor countries. Countries are classified by baseline income using the bottom tercile of mean ln(GDPpc) from 2000 to 2004. The same nearest-year matched regression specification is estimated separately for the two groups, and Wald tests are used to compare coefficients.

The results show strong heterogeneity. For GDP, mosquito nets have no detectable effect in non-poor countries ($\beta = -0.024,\ p = 0.78$), but have a large and highly significant effect in poor countries ($\beta = 0.432,\ p < 10^{-8}$). Antimalarial treatment displays the same pattern but in the opposite direction: non-poor countries experience negative effects ($\beta = -0.307,\ p = 0.003$), whereas poor countries experience positive effects ($\beta = 0.194,\ p = 0.003$). A similar divergence appears for educational outcomes. Wald tests confirm that these differences are statistically significant.

Hence, malaria control has much stronger impacts in poorer countries, contradicting the view that targeting low-income populations yields weaker returns. Instead, the evidence suggests the opposite. Poorer African countries appear to benefit disproportionately more from both nets and antimalarial treatment, likely because the disease burden is higher and baseline infrastructure is weaker. These patterns support the WHO recommendation of prioritizing malaria control in the lowest-income regions, where the marginal effect of intervention is largest.

7.5 Limitations

One limitation of the current analysis is the potential endogeneity between malaria burden, health spending, and development outcomes. Countries with higher income levels tend to invest more in health systems and may simultaneously experience declines in malaria transmission due to better infrastructure, improved housing, and wider access to prevention tools. This pattern can lead to upward bias in the estimated impact of health spending, making it appear more effective than it actually is, and downward bias in the estimated effect of malaria burden, since declines in malaria may partly reflect income growth rather than cause it. Future extensions could address this concern by using ecological instruments, such as historical malaria suitability or long-term climatic factors that shape mosquito breeding conditions,to

generate exogenous variation in malaria exposure that is not driven by contemporaneous income or health investment.

A second concern is omitted variable bias. Even with country and year fixed effects, important unobserved factors such as the quality of public administration, state capacity, conflict exposure, or geographic features may jointly influence both malaria prevalence and development outcomes. For example, countries with stronger institutions tend to have more effective malaria control, higher public health investment, and higher income levels. If these institutional features are not fully captured in the model, the estimated coefficients on malaria exposure may inadvertently reflect these broader structural differences rather than the causal effect of malaria itself. Future work could mitigate this by incorporating additional institutional controls, alternative fixed-effects structures, or subnational data where institutional variation is more finely measured.

8 Policy Discussion and Implications

The historical exclusion of Sub-Saharan Africa from the 1955 Global Malaria Eradication Programme (GMEP) continues to shape how malaria interventions are understood today. Although officially justified on the grounds of limited resources and implementation constraints, this decision effectively codified a belief that malaria eradication in Africa was economically infeasible. Similarly, our findings indicate that recent variation in malaria control efforts within Sub-Saharan Africa played an equally critical role in explaining development outcomes. This episode illustrates how global health priorities have historically been shaped by narrow cost-benefit analyses, rather than long-term welfare considerations. Understanding this legacy thus helps contextualise current intervention gaps, while our results highlight the importance of addressing unequal treatment progress within the region.

8.1 Reframing Cost-Effectiveness Beyond the Health Sector

The first key lesson from both historical exclusion and our empirical results is that malaria policy design must extend beyond short-run cost considerations and account for long-run development effects. Historically, the GMEP allocated resources to regions where eradication could be achieved rapidly with low cost, thereby implicitly discounting the broader benefits of malaria control. Empirical studies have consistently shown that malaria significantly depresses growth and human capital formation. Gallup and Sachs (2001) estimate that endemic malaria reduces annual GDP growth by approximately 1.3 percentage points, while Bleakley (2010) finds that eradication campaigns in the Americas generated persistent income gains through improved health and education outcomes.

Consistent with this literature, our analysis reinforces the view that malaria control yields benefits extending far beyond immediate health outcomes. Higher health expenditure is strongly associated with improved primary completion rates in Sub-Saharan Africa, which suggests investments in malaria reduction and broader health systems contribute directly to educational attainment and future productivity. This underscores the need to reinterpret malaria eradication as a development investment, and not merely a health expenditure. Conventional metrics that focus on short-term financial efficiency risk overlooking the intergenerational and cross-sectoral spillovers from malaria eradication. Policy frameworks should therefore value eradication not only for its public health benefits, but also for its contributions to long-run productivity, human capital accumulation and economic growth.

8.2 Prioritising High-Impact Interventions and Targeted Deployment

The second implication from our findings concerns the type of malaria interventions adopted and where they are deployed. Our findings indicate that not all malaria control strategies generate comparable developmental returns. Mosquito nets are significantly associated with positive effects on both GDP and educational outcomes, whereas antimalarial treatments exhibit weaker or even negative associations. This suggests that preventive vector-control measures may produce more durable developmental gains than treatment-focused approaches alone.

Our results also reveal substantial heterogeneity by baseline income. Poorer countries benefit disproportionately from both mosquito net coverage and antimalarial treatment, while non-poor countries show weaker or negative effects. Rather than supporting the assumption that lower-income settings yield diminishing returns, our evidence suggests the opposite: marginal benefits are highest where disease burden is greatest and healthcare infrastructure is weakest.

Taken together, our findings imply that malaria interventions should not only expand access but also differentiate intervention strategies based on expected developmental returns. A targeted strategy that prioritises high-burden and low-income contexts in Sub-Saharan Africa may therefore yield the largest economic and human capital gains, while offering a more efficient and equitable path towards eradication.

8.3 Integrating Health and Education Policies

Building on the link between health investment and educational outcomes established earlier, the third lesson highlights the need to design policies that jointly address malaria control and human capital formation. Health and education are not parallel sectors but mutually reinforcing pillars of development. As discussed earlier, malaria control enhances educational outcomes by reducing morbidity, improving attendance and strengthening cognitive performance for children (Angrist et al., 2023). These benefits translate directly into higher learning efficiency and long-run productivity, thereby amplifying returns to education investments (Daruich, 2020).

Contemporary policy design should therefore move beyond sectoral silos and pursue integrated human capital strategies. Ministries of health and education should coordinate program design and funding to jointly target malaria-endemic regions by leveraging interventions such as school-based chemoprevention. Angrist et. al (2023) demonstrate that such preventive programs are among the most cost-effective education interventions globally, which yield measurable gains in learning-adjusted years of development (LAYD) at a relatively low cost. Embedding malaria reduction within education policy thus offers a dual dividend in improving health outcomes in the short run and stronger economic outcomes in the long run.

8.4 Strengthening Institutional Capacity for Effective Implementation

The fourth lesson highlights that the developmental impact of malaria control depends not only on funding but also on the quality and stability of national institutions. Our results show that political stability is positively associated with income levels, while health spending significantly improves educational attainment but not GDP per capita. This divergence suggests that institutional efficiency is a critical factor in determining how effective health investments translate into economic growth. In this regard, Rajkumar & Swaroop (2008) similarly argue that public spending on health and education yields substantially higher returns only when governance quality is strong.

In the context of malaria, recent evidence supports this mechanism. Higher government effectiveness enhances case detection, resource targeting and program sustainability in Sub-Saharan Africa (Namubiru, 2025). Conversely, weak institutions can severely undermine the returns to health interventions. Corruption and accountability failures reduce the effectiveness of domestic health budgets by diverting funds, distorting procurement and weakening frontline delivery (Glynn, 2022). These leakages prevent health investments from reaching intended populations, ultimately constraining the developmental returns of malaria control even with high spending.

As stable and high-quality institutions underpin long-term income growth (Acemoglu, Johnson & Robinson, 2004), countries with stronger governance are more likely to convert health and human capital gains into sustained economic returns. Strengthening administrative capacity, fiscal accountability and oversight, and inter-agency coordination is therefore essential to ensure effective policy implementation and to fully realise the long-term returns to malaria control.

9 Conclusion

This paper examined how the WHO's exclusion of Sub-Saharan Africa from the 1955 Global Malaria Eradication Programme (GMEP) has had enduring consequences for the region's human capital and economic development. The analysis underscores that malaria is not merely a health condition but a structural barrier to productivity, education, and long-run growth. By integrating historical policy context with empirical evidence, the study demonstrates how decisions rooted in perceived implementation constraints and economic pessimism have perpetuated inequality in global health outcomes.

These findings highlight the need to reconceptualise malaria eradication as a long-term development investment rather than a short-term public health expenditure. Strengthening institutional capacity, integrating health and education interventions, and tailoring policies to local ecological and economic conditions are essential to achieving sustainable progress.

Future research could extend this work by exploring heterogeneity in eradication outcomes across African countries, examining the role of governance quality in shaping intervention effectiveness, and assessing how new technological innovations, such as malaria vaccines, might alter the region's development trajectory. In doing so, scholars and policymakers alike can contribute to a more equitable and evidence-based global health agenda. Also, we can run regressions on the effectiveness of malaria prevention methods, like mosquito nets vs antimalarial treatment, to determine which is more effective. These findings will then be useful for SSA to combat the current threat of malaria more efficiently.

10 Appendix

10.1 Deriving the Final Empirical Framework

10.1.1 From Baseline to Preferred Specification

We begin with a standard Difference-in-Differences (DiD) model to estimate the average impact of malaria exposure on log GDP per capita across Sub-Saharan Africa:

$$Y_{ct} = \alpha + \beta\big(\text{Exposure}_c \times \text{Post}_t\big) + \mu_c + \lambda_t + \varepsilon_{ct}$$

where Y_{ct} is log GDP per capita; Exposure_c denotes pre-2005 malaria endemicity; and Post_t equals one for years after 2005, when large-scale eradication programs intensified. Country (μ_c) and year (λ_t) fixed effects absorb time-invariant heterogeneity and global shocks.

Table 5 reports the baseline estimate. The coefficient on $\text{Exposure}_c \times \text{Post}_t$ is small and statistically insignificant, implying that, on average, countries more exposed to malaria before 2005 did not experience differential growth trajectories after eradication campaigns began.

	$\mathbf{GDP}_{pc}$ **(log)**
Exposure × Post	0.01
	(0.04)
Observations	1043
Countries (clusters)	43
Years	25
R^2 (full model)	0.94
Adj. R^2 (full)	0.94

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

Table 5: Baseline SSA DiD: Exposure X Post with country and year fixed effects

10.1.2 Identifying Candidate Controls

To test robustness against omitted-variable bias, we introduced several potential controls, grouped conceptually as follows:

- Structural / Geographic: Agriculture share of GDP (agri gdp), average precipitation (precip mm);
- Institutional: Lagged political stability (polstab l1);
- Demographic / Behavioural: Fertility rate (fert l1) and HIV prevalence (hiv l1).

Following the causal-inference literature (Bleakley, 2010), a variable is a good control if it is correlated with outcomes but unaffected by the treatment. Variables that are themselves influenced by malaria eradication (such as fertility or HIV prevalence) constitute bad controls, as conditioning on them may block part of the causal channel.

10.1.3 Incremental Control Diagnostics

To empirically distinguish safe from bad controls, each candidate was added sequentially to the baseline regression:

$$Y_{ct} = \alpha + \beta(\text{Exposure}_c \times \text{Post}_t) + \gamma X_{ct} + \mu_c + \lambda_t + \varepsilon_{ct}$$

what

We then measured the resulting percentage shift in $\hat{\beta}$, standard error changes and sign reversals. Table 4 summarises the incremental diagnostics.

Type	Control	$\hat{\beta}$	SE	$\Delta\%$	Flip	SE/SE_0	N
mediator	hiv_l1	-0.016	0.040	-376.8	Yes	0.99	915
mediator	fert_l1	-0.004	0.038	-176.1	Yes	0.96	961
safe	agri_gdp	-0.020	0.039	-459.0	Yes	0.98	954
safe	polstab_l1	0.011	0.041	96.0	No	1.03	915
safe	urban_pct	0.006	0.040	12.3	No	0.99	1003
safe_{pair}	agri_gdp + polstab_l1	-0.011	0.042	-300.8	Yes	1.04	874
time_invariant	precip_mm	0.005	0.040	-11.2	No	1.00	959

Table 6: Incremental control diagnostics: shift in $\hat{\beta}$ (Exposure $\times$ Post)

The coefficient on $\text{Exposure} \times \text{Post}$ fluctuates dramatically when fertility and HIV prevalence are added, and even reverses sign, which is classic evidence of endogeneity.

By contrast, adding the agriculture share or lagged political stability has a negligible influence on $\hat{\beta}$ and preserves its sign, confirming them as exogenous.

10.1.4 Summary Statistics

Variable	Mean	SD	Min	Max
ln(GDP per capita)	6.99	0.95	4.71	9.81
Agriculture share of GDP (Political Stability (lag, 0–100)	31.27	20.21	0.00	93.75
Malaria incidence (per 1,000 at risk, baseline SD units)	0.04	0.98	-2.03	1.81
Post indicator (t 2005)	0.87	0.34	0.00	1.00
Observations		874		

Notes: Statistics computed on the preferred-spec sample (complete cases).

Table 7: Summary Statistics: Variables Used in Final Empirical Framework (SSA, 2000 - 2023)

	ln(GDP per capita)	Agriculture share of GDP (%)	Political Stability (lag, 0–100)	Exposure (baseline, SD units)	Post ($t \geq 2005$)
ln(GDP per capita)	1.00				
Agriculture share of GDP (%)	-0.74***	1.00			
Political Stability (lag, 0–100)	0.44***	-0.41***	1.00		
Exposure (baseline, SD units)	-0.27***	0.18***	-0.13***	1.00	
Post ($t \geq 2005$)	0.28***	-0.09***	-0.02	0.03	1.00

Notes: Lower triangle shows Pearson correlations; upper triangle blank. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

Table 8: Pairwise Correlations: Variables Used in Final Empirical Framework

10.1.5 Preferred Specification

Based on these diagnostics, the preferred model retains only the two validated exogenous controls:

$$Y_{ct} = \alpha + \beta(\text{Exposure}_c \times \text{Post}_t) + \delta_1 \text{AgriGDP}_{ct} + \delta_2 \text{PolStab}_{c,t-1} + \mu_c + \lambda_t + \varepsilon_{ct}$$

	Estimate	Std. Error	t value	p-value
Agriculture share of GDP (*agri_gdp*)	-0.0121^{*}	(0.0058)	-2.07	0.045
Lagged Political Stability (*polstab_l1*)	0.0040^{**}	(0.0014)	2.95	0.005
Exposure × Post (*exposure_std:post*)	-0.0115	(0.0417)	-0.27	0.785
Observations	874			
Fixed effects	Country (42), Year (22)			
Clustered SEs	Country level			
RMSE	0.199			
Adj. R^2	0.953			
Within R^2	0.093			

Table 9: Preferred GDP per Capita (log) specification: Baseline + Safe Controls

Both control variables are highly significant, while the coefficient on $\text{Exposure} \times \text{Post}$ remains small and insignificant, indicating that malaria eradication did not generate detectable aggregate growth effects even after accounting for structural and institutional heterogeneity.

10.2 Robustness of Empirical Framework

10.2.1 Country-Trend Check

To further verify robustness, we augmented the model with country-specific linear time trends:

$$Y_{ct} = \alpha + \beta(\text{Exposure}_c \times \text{Post}_t) + \delta_1 \text{AgriGDP}_{ct} + \delta_2 \text{PolStab}_{c,t-1} + \mu_c + \lambda_t + \theta_c t + \varepsilon_{ct},$$

where $\theta_c t$ captures gradual, idiosyncratic growth trajectories.

This specification tests whether results are driven by pre-existing differential trends between high- and low-exposure countries.

As shown in Table 10, the estimates remain virtually unchanged, reinforcing the robustness of the baseline findings.

	ln(GDPpc)	Enroll	Completion	Attain25p
Agri share of GDP (*agri_gdp*)	-0.010*	-0.046	-0.023	0.702**
Lagged Political Stability (*polstab_l1*)	0.004**	0.080	0.007	0.012
Exposure × Post	-0.027	-0.880	0.427	-4.950
Observations	874	667	546	184
R^2 (full)	0.978	0.917	0.911	0.982
Adj. R^2	0.975	0.901	0.889	0.961
FE: country, year, trends				

Table 10: Preferred specification with country-specific linear trends

10.3 List of Countries

1. Angola
2. Benin
3. Botswana
4. Burundi
5. Burkina Faso
6. Central African Republic
7. Cameroon
8. Chad
9. Congo, Dem. Rep.
10. Congo, Rep.
11. Cote d'Ivoire
12. Eritrea
13. Ethiopia
14. Gambia, The
15. Guinea
16. Guinea-Bissau
17. Kenya
18. Liberia
19. Malawi
20. Mauritania
21. Mozambique
22. Niger
23. Nigeria
24. Rwanda
25. Sierra Leone
26. Senegal
27. South Africa
28. Zambia
29. Togo
30. Zimbabwe
31. Uganda
32. Tanzania
33. South Sudan
34. Somalia, Fed. Rep.
35. Sao Tome and Principe
36. Namibia
37. Mali
38. Madagascar
39. Ghana
40. Gabon
41. Eswatini
42. Equatorial Guinea

43. Comoros

Note: Cabo Verde is excluded from the malaria-burden analysis because MAP does not report incidence, prevalence, or mortality data for the country. Following UNDP's regional classification, Djibouti and Sudan are also not included in the "Sub-Saharan Africa" grouping used in this study.

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