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MALARIA AND INFANT MORTALITY IN UGANDA: A COINTEGRATION ANALYSIS

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ABSTRACT

This study examines the relationship between malaria incidence and infant mortality in Uganda using quarterly data from 2000–2024 obtained from the World Bank. The variables were transformed into natural logarithms to reduce extreme variations and improve data stability. A cointegration approach was employed, with infant mortality rate (per 1,000 live births) specified as the dependent variable and malaria incidence (per 1,000 population at risk) as the independent variable. The normalized cointegrating vector revealed a negative long-run relationship between malaria incidence and infant mortality, implying results that contradict theoretical expectations. This suggests that other structural factors, including weak health infrastructure, malnutrition, and other childhood or prenatal infections, may play a more significant role in explaining infant mortality in Uganda. The error correction coefficients were negative and statistically significant, confirming long-run equilibrium adjustment and the existence of cointegration between the variables. Furthermore, Granger causality results indicated no significant predictive relationship from malaria incidence to infant mortality. The study recommends strengthening broader maternal and child healthcare interventions alongside malaria control programs.

KEY WORDS: *Cointegration, Malaria, Infant Mortality, Uganda*

INTRODUCTION

Malaria remains one of the leading public health challenges in Sub-Saharan Africa, particularly among children under five years of age. Despite global efforts to reduce malaria prevalence and child mortality, the disease continues to contribute significantly to preventable deaths in developing countries (WHO, 2023). In Uganda, malaria is endemic and accounts for a large proportion of outpatient visits, hospital admissions, and child morbidity and mortality. At the same time, infant mortality remains a critical indicator of population health and socio-economic development. Although Uganda has registered improvements in child survival over the past two decades, infant mortality rates remain relatively high compared to global averages (World Bank, 2024).

The relationship between malaria and infant mortality has attracted considerable empirical attention. Existing studies generally argue that malaria increases the risk of infant deaths through anemia, low birth weight, poor maternal health, and weakened immunity among infants (Snow et al., 2005; Sachs & Malaney, 2002). However, most previous studies have relied on cross-sectional or short-run analyses and have given limited attention to the long-run equilibrium relationship between malaria incidence and infant mortality, particularly in Uganda. Furthermore, few studies have applied cointegration techniques to investigate whether malaria and infant mortality move together over time despite short-run fluctuations.

This study addresses this gap by employing a cointegration analysis using quarterly time-series data for Uganda from 2000 to 2024. The study seeks to establish whether a stable long-run relationship exists between malaria incidence and infant mortality. Understanding this relationship is important for designing effective public health policies aimed at reducing infant mortality and improving child health outcomes. The findings are expected to provide policymakers with evidence on whether malaria control interventions alone are sufficient or whether broader health system strengthening measures are required to reduce infant mortality in Uganda.

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LITERATURE REVIEW

Malaria remains one of the leading causes of morbidity and mortality among children under five years globally, particularly in developing countries. According to the World Health Organization, malaria accounted for approximately 249 million cases and over 600,000 deaths worldwide in 2022, with children under five years constituting the most vulnerable group (WHO, 2023). Infant mortality, defined as the death of children before reaching one year of age, is widely used as an indicator of health system performance and socio-economic welfare. Studies have established that malaria contributes to infant mortality through severe anemia, low birth weight, premature births, and weakened immunity (Sachs & Malaney, 2002).

Several empirical studies have examined the relationship between malaria and infant mortality. Snow et al. (2005) found that malaria significantly increases child mortality in endemic regions of Africa. Similarly, Barat et al. (2011) observed that high malaria prevalence is associated with poor maternal and infant health outcomes. However, most global studies focus on short-run or cross-sectional relationships and pay limited attention to long-run dynamics between malaria incidence and infant mortality. This creates a methodological gap regarding whether the variables share a stable equilibrium relationship over time.

In Sub-Saharan Africa, malaria remains a major public health challenge due to tropical climatic conditions, weak healthcare systems, and widespread poverty. The region accounts for more than 90% of global malaria cases and deaths (WHO, 2023). Studies conducted in countries such as Nigeria, Kenya, and Tanzania indicate that malaria contributes substantially to infant and child mortality (Aregawi et al., 2017). Research by Oyekale (2015) in Nigeria established that poor access to healthcare and persistent malaria transmission significantly increase infant mortality rates.

Despite these findings, most regional studies employ descriptive statistics, panel regressions, or demographic approaches without examining the long-run equilibrium relationship between malaria incidence and infant mortality using time-series econometric techniques such as cointegration analysis. Consequently, little is known about whether malaria and infant mortality move together over time in African economies characterized by persistent health challenges.

In Uganda, malaria is endemic and remains one of the leading causes of illness and death among children and pregnant women. According to the Uganda Ministry of Health, malaria contributes significantly to outpatient attendance, hospital admissions, and child mortality. Uganda has implemented several malaria control interventions, including insecticide-treated mosquito nets, indoor residual spraying, and improved access to antimalarial drugs. Despite these efforts, infant mortality rates remain relatively high (World Bank, 2024).

Previous studies in Uganda have mainly focused on determinants of child mortality, healthcare access, and malaria prevention strategies. For example, Nankabirwa et al. (2019) found that malaria prevention programs reduced under-five mortality in some districts. However, limited studies have specifically examined the long-run relationship between malaria incidence and infant mortality using cointegration techniques. Existing Ugandan studies largely rely on descriptive and cross-sectional analyses, thereby leaving a gap in understanding the dynamic interaction between the two variables over time. This study therefore contributes to literature by applying cointegration analysis to establish whether a stable long-run relationship exists between malaria incidence and infant mortality in Uganda.

This study is guided by the Health Production Function Theory developed by Grossman (1972). The theory views health as a form of human capital that can be improved or deteriorated depending on healthcare investment, disease prevalence, nutrition, and environmental conditions. According to the theory, increased disease burden such as malaria reduces health outcomes and increases the likelihood of mortality among vulnerable populations, particularly infants. The theory implies that persistent malaria incidence negatively affects infant survival through poor maternal health, anemia, and increased susceptibility to infections.

The conceptual framework assumes that malaria incidence influences infant mortality in Uganda. High malaria incidence is expected to increase infant mortality through severe infections, maternal complications, anemia, and weakened immunity among infants. However, other structural factors such as healthcare infrastructure, maternal education, nutrition, sanitation, and poverty may also influence infant mortality. The independent variable is malaria incidence (per 1,000 population at risk) while dependent variable is infant mortality rate (per 1,000 live births).

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DATA AND METHODS

This study employed a quantitative research design based on time-series analysis to examine the long-run relationship between malaria incidence and infant mortality in Uganda. The study utilized quarterly secondary data covering the period 2000–2024. A quantitative approach was preferred because it enables objective measurement and statistical analysis of relationships among variables over time (Creswell, 2014; Nahabwe & Maniple, 2025).

The study relied on secondary data obtained from the World Bank through the World Development Indicators database. The dependent variable was infant mortality rate (per 1,000 live births), while the independent variable was incidence of malaria (per 1,000 population at risk). The data series were transformed into natural logarithms to reduce heteroscedasticity, minimize extreme variations, and improve interpretation of the coefficients as elasticities (Gujarati & Porter, 2009; Nahabwe & Kagarura, 2025).

Since the study used macroeconomic time-series data for Uganda, no sampling procedure was applied because the analysis considered the entire available quarterly dataset for the study period. The study therefore adopted a census approach of all available observations from 2000 to 2024 (Nahabwe & Kagarura, 2025).

Data analysis was conducted using econometric techniques appropriate for non-stationary time-series data. The analysis began with descriptive statistics to summarize the characteristics of the variables (Kagarura & Nahabwe, 2025). Unit root tests, specifically the Augmented Dickey-Fuller (ADF) test, were employed to determine the order of integration of the variables. Testing for stationarity was necessary to avoid spurious regression results in time-series analysis (Dickey & Fuller, 1979; Nahabwe & Kagarura, 2025).

After confirming that the variables were integrated of the same order, the Johansen cointegration technique was employed to test for the existence of a long-run equilibrium relationship between malaria incidence and infant mortality. The Johansen cointegration method was preferred because it provides reliable estimates of long-run relationships among integrated variables in multivariate systems (Johansen, 1988). Where cointegration existed, a Vector Error Correction Model (VECM) was estimated to capture both short-run dynamics and long-run adjustments toward equilibrium (Engle & Granger, 1987).

In addition, Granger causality tests were performed to determine the direction of causality between malaria incidence and infant mortality. The study adopted a 5% level of significance in hypothesis testing. Statistical analysis was conducted using EViews software suitable for time-series analysis.

The selected methods were appropriate because cointegration and VECM approaches effectively handle non-stationary data and distinguish between short-run fluctuations and long-run equilibrium relationships. This provided robust evidence on the dynamic interaction between malaria incidence and infant mortality in Uganda.

RESULTS AND THEIR DISCUSSION

Appendix 1 presents the descriptive statistics for infant mortality and malaria incidence in Uganda for the period 2000Q1–2024Q4.

The results indicate that the mean infant mortality rate was 51.7 deaths per 1,000 live births, while the average malaria incidence was 357.7 cases per 1,000 population at risk. The relatively high mean values suggest that both malaria prevalence and infant mortality remained major public health concerns in Uganda during the study period. The maximum infant mortality rate was 89.3 deaths per 1,000 live births, whereas the minimum was 35.9, indicating substantial variation over time. Similarly, malaria incidence ranged from 250.82 to 508.43 per 1,000 population at risk.

The standard deviation for infant mortality was 16.56, while that of malaria incidence was 86.88, implying moderate fluctuations in the variables over the study period. The positive skewness values of 0.869 for infant mortality and 0.255 for malaria incidence indicate that both variables were positively skewed, meaning that observations were concentrated below the mean with a few extreme high values. The kurtosis values were below 3, suggesting that the distributions were platykurtic and less peaked than a normal distribution (Gujarati & Porter, 2009, Nahabwe & Maniple, 2025).

Furthermore, the Jarque-Bera statistics for both variables were statistically significant with probabilities below 0.05, implying that the variables were not normally distributed. However, non-normality is common in macroeconomic and health-related time-series data and does not invalidate econometric estimation, particularly in large samples (Brooks, 2019; Nahabwe & Maniple, 2025).

The descriptive findings are consistent with previous studies that identify malaria and infant mortality as persistent public health challenges in Sub-Saharan Africa (WHO, 2023; Sachs & Malaney, 2002). The results further suggest that Uganda experienced considerable fluctuations in malaria incidence and infant mortality over time due to changes in healthcare interventions, disease outbreaks, and socio-economic conditions.

The Johansen cointegration results are presented in appendix 8. The trace statistic indicated two cointegrating equations since the trace statistics of 27.592 and 6.656 exceeded the corresponding critical values of 15.495 and 3.841 at the 5% significance level. Similarly, the maximum eigenvalue statistics of 20.936 and 6.656 were greater than the critical values of 14.265 and 3.841 respectively. The associated probabilities were less than 0.05, leading to rejection of the null hypothesis of no cointegration.

The findings therefore confirm the existence of a long-run equilibrium relationship between malaria incidence and infant mortality in Uganda. This implies that although the variables may fluctuate in the short run, they tend to move together in the long run. The findings are consistent with Engle & Granger (1987) and Johansen (1988), who argue that cointegrated variables share a stable long-run relationship despite short-run disturbances.

The normalized cointegrating equation revealed that malaria incidence had a coefficient of -0.386 on infant mortality. This implies that a 1% increase in malaria incidence is associated with approximately a 0.386% decrease in infant mortality in the long run, holding other factors constant. This result is theoretically counterintuitive, as standard epidemiological and health production theories would expect higher malaria incidence to increase infant mortality due to its adverse effects on maternal health, anemia, low birth weight, and infant susceptibility to infections (Grossman, 1972; Sachs & Malaney, 2002). The unexpected negative sign may reflect underlying structural issues in the data such as measurement limitations, reporting inconsistencies, or the influence of omitted variables like improved reporting of malaria cases alongside declining infant deaths due to healthcare interventions.

The findings differ from most empirical literature, which generally establishes a positive relationship between malaria burden and infant mortality. For example, Snow et al. (2005) and Barat et al. (2011) found that higher malaria prevalence is associated with increased child and infant mortality in Sub-Saharan Africa due to the direct and indirect health complications caused by the disease. Similarly, Oyekale (2015) confirmed that malaria significantly worsens child health outcomes in developing countries. The divergence in this study's result suggests that in the Ugandan context, other structural factors such as improvements in neonatal care, immunization coverage, and health interventions may have contributed to reductions in infant mortality even during periods of high malaria incidence, thereby weakening the expected positive association.

The adjustment coefficients from the Vector Error Correction Model (VECM) were negative for both infant mortality (-0.001649) and malaria incidence (-0.036704). The negative signs imply convergence toward long-run equilibrium following short-run deviations. In particular, the infant mortality adjustment coefficient suggests that approximately 0.16% of disequilibrium is corrected each quarter, while malaria adjusts by approximately 3.67% toward equilibrium.

The significance of the adjustment coefficients confirms that the system experiences long-run equilibrium correction. This implies that malaria incidence and infant mortality cannot drift apart indefinitely because they are linked through a stable long-run relationship. These findings support the Health Production Function Theory by Grossman (1972), which posits that disease prevalence negatively affects health outcomes and mortality.

The study's findings differ from some earlier Ugandan studies that focused mainly on short-run impacts of malaria interventions without investigating long-run equilibrium relationships (Nankabirwa et al., 2019). By employing cointegration and VECM techniques, the current study provides deeper evidence that malaria and infant mortality are dynamically interconnected over time.

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LIMITATIONS

Despite providing important insights into the relationship between malaria incidence and infant mortality in Uganda, this study had several limitations. Firstly, the study relied entirely on secondary time-series data obtained from the World Bank. Secondary data may contain measurement errors, reporting inconsistencies, and missing observations that can affect the reliability of the estimated results (Gujarati & Porter, 2009; Nahabwe & Kagarura, 2025). In addition, quarterly data for some health indicators in developing countries are often interpolated from annual estimates, which may reduce precision.

Secondly, the study focused only on two variables, namely malaria incidence and infant mortality. However, infant mortality is influenced by several other socio-economic and health-related factors such as maternal education, nutrition, sanitation, poverty, immunization, and healthcare infrastructure (Sachs & Malaney, 2002). Excluding these variables may have resulted in omitted variable bias, thereby limiting the comprehensiveness of the findings.

Thirdly, the study employed cointegration and Vector Error Correction Model (VECM) techniques, which assume linear relationships among variables. In reality, the relationship between malaria incidence and infant mortality may be nonlinear and influenced by structural breaks arising from policy changes, disease outbreaks, or healthcare interventions over time (Brooks, 2019; Kagarura & Nahabwe, 2025). Failure to explicitly account for structural breaks may have affected the robustness of the long-run estimates.

Furthermore, the study was limited to Uganda, making it difficult to generalize the findings to other countries with different healthcare systems, environmental conditions, and socio-economic structures. The results therefore mainly reflect the Ugandan context.

Lastly, the study utilized quarterly data from 2000 to 2024, which, although adequate for time-series analysis, may still limit the ability to capture very long historical trends in malaria transmission and infant mortality dynamics. Future studies may consider using panel data across multiple countries and incorporating additional explanatory variables to provide broader and more robust evidence.

CONCLUSION

This study examined the long-run relationship between malaria incidence and infant mortality in Uganda using quarterly data from 2000 to 2024 within a cointegration framework. The study demonstrates that malaria remains an important public health concern with implications for child survival and overall health outcomes in Uganda. The findings suggest that infant mortality cannot be explained solely by malaria prevalence, but rather by a broader interaction of health, socio-economic, and institutional factors affecting child welfare.

The study further confirms the importance of adopting long-run analytical approaches when examining health-related variables that evolve over time. By establishing a stable equilibrium relationship between malaria incidence and infant mortality, the study highlights the interconnected nature of disease burden and population health outcomes in developing economies. The results therefore emphasize the need for integrated health policies that combine malaria prevention with improvements in maternal healthcare, nutrition, sanitation, and healthcare infrastructure.

RECOMMENDATIONS

The government of Uganda, through the Uganda Ministry of Health, should strengthen malaria prevention and control programs by increasing access to insecticide-treated mosquito nets, indoor residual spraying, and timely treatment services. Strengthening malaria control is essential because persistent malaria infections continue to undermine child survival and overall public health outcomes (WHO, 2023).

The government should also improve maternal and child healthcare services by increasing investment in healthcare infrastructure, skilled medical personnel, and access to essential medicines, particularly in rural areas. Improved healthcare systems can reduce infant mortality associated with preventable diseases and poor maternal health conditions (Sachs & Malaney, 2002).

Furthermore, policymakers should adopt integrated public health strategies that address other determinants of infant mortality such as malnutrition, poor sanitation, poverty, and limited access to clean water. Infant mortality is multidimensional and requires coordinated interventions beyond malaria control alone (World Bank, 2024).

Health development partners and non-governmental organizations should intensify community health education programs aimed at increasing awareness about malaria prevention, maternal healthcare, breastfeeding, and child nutrition. Public awareness campaigns can improve health-seeking behavior and reduce preventable infant deaths.

The government and health agencies should expand community-based healthcare outreach programs, especially in high malaria-risk regions. Mobile clinics and village health teams can improve early diagnosis and treatment of malaria among pregnant women and infants, thereby reducing severe complications and mortality.

In addition, health information systems should be strengthened to improve the quality, consistency, and timeliness of health data collection. Reliable health statistics are important for evidence-based policy formulation and monitoring of public health interventions (Gujarati & Porter, 2009; Kagarura & Nahabwe, 2025).

Future studies could incorporate additional explanatory variables such as maternal education, immunization coverage, healthcare expenditure, sanitation, poverty, and nutrition in order to provide a more comprehensive analysis of infant mortality determinants in Uganda.

Researchers could also consider employing nonlinear models and structural break tests to capture possible changes in the relationship between malaria incidence and infant mortality arising from policy reforms, pandemics, or major healthcare interventions over time (Brooks, 2019; Kagarura & Nahabwe, 2025).

Further research may also use panel data covering several Sub-Saharan African countries to allow comparative analysis and improve the generalizability of findings across different socio-economic and healthcare contexts.

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APPENDICES

Appendix 1: Descriptive statistics

	Infant Mortality rate (per 1,000 live births)	Malaria Incidence (per 1,000 population at risk)
Mean	51.70515	357.7355
Median	44.4	349.79
Maximum	89.3	508.43
Minimum	35.9	250.82
Std. Dev.	16.55787	86.88447
Skewness	0.869497	0.255279
Kurtosis	2.414271	1.541599
Jarque-Bera	13.609	9.649891
Probability	0.001109	0.008027
Sum	5015.4	34700.34
Sum Sq. Dev.	26319.67	724695.6
Observations	97	97

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Appendix 2: Unit root test, Infant_Mortality (in Level)

Null Hypothesis: LNMORTALITY has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.068405	0.9283
Test critical values:	1% level	-4.057528	
	5% level	-3.457808	
	10% level	-3.154859	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNMORTALITY)
Method: Least Squares
Date: 04/26/26 Time: 13:21
Sample (adjusted): 2000Q3 2024Q1
Included observations: 95 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNMORTALITY(-1)	-0.001517	0.001420	-1.068405	0.2882
D(LNMORTALITY(-1))	0.922520	0.040889	22.56159	0.0000
C	0.005136	0.006670	0.769975	0.4433
@TREND("2000Q1")	2.55E-06	1.97E-05	0.129504	0.8972

R-squared	0.975788	Mean dependent var	-0.009478
Adjusted R-squared	0.974989	S.D. dependent var	0.005707
S.E. of regression	0.000903	Akaike info criterion	-11.14159
Sum squared resid	7.41E-05	Schwarz criterion	-11.03406
Log likelihood	533.2254	Hannan-Quinn criter.	-11.09814
F-statistic	1222.472	Durbin-Watson stat	2.088760
Prob(F-statistic)	0.000000		

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Appendix 3: Unit root test, Infant_Mortality (in First difference)

Null Hypothesis: D(LNMORTALITY) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.871057	0.1766
Test critical values:	1% level	-4.057528	
	5% level	-3.457808	
	10% level	-3.154859	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNMORTALITY,2)
Method: Least Squares
Date: 04/26/26 Time: 13:29
Sample (adjusted): 2000Q3 2024Q1
Included observations: 95 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNMORTALITY(-1))	-0.100255	0.034919	-2.871057	0.0051
C	-0.001954	0.000671	-2.911990	0.0045
@TREND("2000Q1")	2.22E-05	7.16E-06	3.097424	0.0026

R-squared	0.095217	Mean dependent var	9.25E-05
Adjusted R-squared	0.075548	S.D. dependent var	0.000939
S.E. of regression	0.000903	Akaike info criterion	-11.15017
Sum squared resid	7.51E-05	Schwarz criterion	-11.06953
Log likelihood	532.6333	Hannan-Quinn criter.	-11.11759
F-statistic	4.840925	Durbin-Watson stat	2.019681
Prob(F-statistic)	0.010024		

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Appendix 4: Unit root test, Infant Mortality (in Second difference)

Null Hypothesis: D(LNMORTALITY,2) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-9.775476	0.0000
Test critical values:	1% level	-4.058619	
	5% level	-3.458326	
	10% level	-3.155161	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNMORTALITY,3)
Method: Least Squares
Date: 04/26/26 Time: 13:30
Sample (adjusted): 2000Q4 2024Q1
Included observations: 94 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNMORTALITY(-1),2)	-1.024892	0.104843	-9.775476	0.0000
C	-0.000113	0.000204	-0.556511	0.5792
@TREND("2000Q1")	4.23E-06	3.63E-06	1.164470	0.2473

R-squared	0.512224	Mean dependent var	-7.09E-17
Adjusted R-squared	0.501504	S.D. dependent var	0.001342
S.E. of regression	0.000948	Akaike info criterion	-11.05385
Sum squared resid	8.17E-05	Schwarz criterion	-10.97269
Log likelihood	522.5311	Hannan-Quinn criter.	-11.02107
F-statistic	47.78058	Durbin-Watson stat	2.000381
Prob(F-statistic)	0.000000		

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Appendix 5: Unit root test, Malaria (in level)

Null Hypothesis: LNMALARIA has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.315064	0.4216
Test critical values:	1% level	-4.057528	
	5% level	-3.457808	
	10% level	-3.154859	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNMALARIA)
Method: Least Squares
Date: 04/26/26 Time: 13:35
Sample (adjusted): 2000Q3 2024Q1
Included observations: 95 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNMALARIA(-1)	-0.017633	0.007617	-2.315064	0.0229
D(LNMALARIA(-1))	0.879624	0.047593	18.48208	0.0000
C	0.108574	0.047786	2.272102	0.0254
@TREND("2000Q1")	-0.000130	6.69E-05	-1.937457	0.0558

R-squared	0.794072	Mean dependent var	-0.006481
Adjusted R-squared	0.787283	S.D. dependent var	0.010009
S.E. of regression	0.004616	Akaike info criterion	-7.877170
Sum squared resid	0.001939	Schwarz criterion	-7.769639
Log likelihood	378.1656	Hannan-Quinn criter.	-7.833719
F-statistic	116.9675	Durbin-Watson stat	2.029583
Prob(F-statistic)	0.000000		

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Appendix 6: Unit root test, Malaria (in first difference)

Null Hypothesis: D(LNMALARIA) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.899836	0.1673
Test critical values:	1% level	-4.057528	
	5% level	-3.457808	
	10% level	-3.154859	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNMALARIA,2)
Method: Least Squares
Date: 04/26/26 Time: 13:35
Sample (adjusted): 2000Q3 2024Q1
Included observations: 95 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNMALARIA(-1))	-0.139174	0.047994	-2.899836	0.0047
C	-0.002027	0.001065	-1.902694	0.0602
@TREND("2000Q1")	2.00E-05	1.78E-05	1.125094	0.2635

R-squared	0.090294	Mean dependent var	-0.000169
Adjusted R-squared	0.070518	S.D. dependent var	0.004901
S.E. of regression	0.004725	Akaike info criterion	-7.840996
Sum squared resid	0.002054	Schwarz criterion	-7.760347
Log likelihood	375.4473	Hannan-Quinn criter.	-7.808408
F-statistic	4.565807	Durbin-Watson stat	1.916200
Prob(F-statistic)	0.012866		

Appendix 7: Unit root test, Malaria (in Second difference)

Null Hypothesis: D(LNMALARIA,2) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-9.623411	0.0000
Test critical values:	1% level	-4.058619	
	5% level	-3.458326	
	10% level	-3.155161	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNMALARIA,3)
Method: Least Squares

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Date: 04/26/26 Time: 13:32
Sample (adjusted): 2000Q4 2024Q1
Included observations: 94 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNMALARIA(-1),2)	-1.008657	0.104813	-9.623411	0.0000
C	-0.000953	0.001069	-0.891104	0.3752
@TREND("2000Q1")	1.58E-05	1.89E-05	0.832544	0.4073

R-squared	0.504385	Mean dependent var	4.74E-17
Adjusted R-squared	0.493492	S.D. dependent var	0.006972
S.E. of regression	0.004962	Akaike info criterion	-7.742710
Sum squared resid	0.002240	Schwarz criterion	-7.661541
Log likelihood	366.9074	Hannan-Quinn criter.	-7.709924
F-statistic	46.30510	Durbin-Watson stat	2.000388
Prob(F-statistic)	0.000000		

Appendix 8 Results of the Cointegration model

Date: 04/26/26 Time: 13:48
Sample: 2000Q1 2024Q4
Included observations: 100
Lags interval (in first differences): 1 to 3
Endogenous variables: INFANT_MORTALITY MALARIA
Deterministic assumptions: Case 3 (Johansen-Hendry-Juselius): Cointegrating relationship includes a constant. Short-run dynamics include a constant.

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.** Critical Value
None *	0.201578	27.59212	15.49471	0.0005
At most 1 *	0.069071	6.656174	3.841465	0.0099

Trace test indicates 2 cointegrating equation(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Max-eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.** Critical Value
None *	0.201578	20.93594	14.26460	0.0038
At most 1 *	0.069071	6.656174	3.841465	0.0099

Max-eigenvalue test indicates 2 cointegrating equation(s) at the 0.05 level

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* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

INFANT_MORTALITY	MALARIA
0.084638	0.032707
0.209452	-0.046858

Unrestricted Adjustment Coefficients (alpha):

D(INFANT_MORTALITY)	-0.019482	-0.005283
D(MALARIA)	-0.433655	0.349377

1 Cointegrating Equation

Log-Likelihood: -15.12759

Normalized coitnegrating coefficients (standard error in parentheses)

INFANT_MORTALITY	MALARIA
1.000000	0.386432
	(0.12212)

Adjustment coefficients (standard error in parentheses)

D(INFANT_MORTALITY)	-0.001649
	(0.00040)
D(MALARIA)	-0.036704
	(0.01455)

Appendix 7: Granger Causality

Pairwise Granger Causality Tests
Date: 04/26/26 Time: 13:54
Sample: 2000Q1 2024Q4
Lags: 3

Null Hypothesis:	Obs	F-Statistic	Prob.
MALARIA does not Granger Cause INFANT_MORTALITY	94	0.67480	0.5698
INFANT_MORTALITY does not Granger Cause MALARIA		2.53037	0.0624