



Environmental Accounting and Planetary Health: How Adjusted Net Savings and Governance Quality Moderate Air-Pollution Deaths and Climate-Sensitive Malaria across Countries

Teryima Samuel Orshi*

Department of Financial Intelligence, College of Accounting Sciences, University of South Africa,
Pretoria, P.O. Box 392, UNISA, 0003, South Africa.

*Corresponding author's e-mail: orshits@unisa.ac.za | teryimaorshi@gmail.com

DOI: [10.35898/ghmj-931371](https://doi.org/10.35898/ghmj-931371)

ABSTRACT

Background: Climate degradation and air pollution are escalating threats to global health. Unregulated emissions and ecosystem damage may function as hidden, un-audited liabilities on a nation's balance sheet, crystallizing as excess mortality and disease where governments may lack the capacity to recognize and manage them.

Aims: This study tests whether Adjusted Net Savings (ANS) and a governance-quality index moderate the cross-country association between PM2.5 exposure and air-pollution-attributable mortality, and the sensitivity of malaria incidence to temperature and precipitation anomalies.

Methods: Cross-sectional data for a purposively selected sample of 56 countries were compiled from World Bank and WHO sources. PM2.5, ANS, and a governance index (Government Effectiveness/Regulatory Quality), averaged over 2015–2021, were related to 2021 air-pollution mortality (age-standardized; $n = 54$) and malaria incidence ($n = 31$) using moderated OLS with HC3 standard errors, controlling for income, health expenditure, and urbanization. A 2000–2021 country–year panel of 22 malaria-endemic countries, with country and year fixed effects, tested whether governance and ANS moderate malaria's response to climate anomalies, with permutation and wild-bootstrap checks.

Results: PM2.5 was positively associated with mortality in most specifications. The $\text{PM2.5} \times \text{ANS}$ interaction was negative but did not reach conventional significance ($\beta = -0.025$, 95% CI $[-0.05, 0.00]$, $p = 0.056$) and was not robust to log or income-group specifications; the governance interaction was null. In the panel, warm anomalies raised malaria incidence where governance was weak but not where it was strong (temperature $\times$ governance $\beta = -0.33$, 95% CI $[-0.48, -0.17]$, permutation $p < 0.001$); ANS did not moderate this response.

Conclusion: Evidence that ANS flattens the PM2.5–mortality association is weak and suggestive. Governance quality, however, was associated with a weaker malaria response to warm anomalies in endemic countries. These are associations, not confirmed causal protection; larger longitudinal studies are needed.

Keywords: *Adjusted Net Savings; Air pollution mortality; Environmental accounting; Governance quality; Cross-country analysis*

Received: 13 September 2026

Reviewed: 22 September 2026

Revised: 10 October 2026

Accepted: 20 October 2026.

© Yayasan Aliansi Cendekiawan Indonesia Thailand (Indonesian Scholars' Alliance). This is an open-access following Creative Commons License Deed - Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0)

1. Introduction

Climate change and ambient air pollution are now leading contributors to the global burden of disease. The World Health Organization estimates that ambient air pollution causes 4.2 million deaths annually, with 99% of the world's population breathing air that exceeds WHO guideline levels and the heaviest burden falling on low- and middle-income countries (World Health Organization, n.d.-a). Independent Global Burden of Disease analyses converge on a similar order of magnitude (Cohen et al., 2017), the latest ranking particulate matter air pollution as the leading contributor to global disease burden in 2021 (Brauer et al., 2024), and the Lancet Commission on Pollution and Health attributes

approximately nine million premature deaths a year to pollution of all forms (Landrigan et al., 2018; Fuller et al., 2022). The Lancet Countdown tracks a parallel and worsening set of climate-sensitive health indicators, including expanding climatic suitability for vector-borne disease transmission (Romanello et al., 2024; Watts et al., 2021), and a temperature–malaria meta-analysis further links warming to malaria transmission dynamics (Murugan & Shrivastav, 2025; see also Caminade et al., 2014; Pascual et al., 2006). Malaria is a clearly climate-sensitive outcome, so institutions that sustain vector control, case management, and surveillance could plausibly weaken the translation of temperature and rainfall anomalies into disease; we test this channel directly alongside the air-pollution question.

What existing epidemiological models rarely incorporate is the institutional and financial-accounting architecture that determines whether a given level of pollution exposure translates into a given level of harm. The social and environmental accounting literature argues that unregulated emissions and resource depletion function as hidden, unaudited liabilities: costs that are never recognized in national accounts and therefore never actively managed, until they crystallize as excess mortality and disease burden (Bebbington & Larrinaga, 2014; Gray et al., 1996). An analogous mechanism has been reported at the level of the firm: carbon accounting systems moderate, not merely record, the relationship between a firm's environmental strategy and its realized environmental performance (Bui et al., 2022; for the research agenda, Hartmann et al., 2013). This firm-level evidence is only an analogy for national accounts.

At the sovereign level, the World Bank's Adjusted Net Savings (ANS) adjusts gross national saving for fixed-capital consumption, education spending, resource depletion, and carbon dioxide and particulate-emission damage (World Bank, 2026a; Lange et al., 2018), building on the “genuine savings” concept of Hamilton and Clemens (1999) and the comprehensive-wealth framework of Arrow et al. (2012). ANS thus indicates whether national wealth is being maintained; it does not measure accounting sophistication, “green-accounting compliance,” or governance quality. We use it only as a hypothesized, indirect proxy for how fully environmental costs enter national economic accounting, an interpretation that is conceptual, not observed. Because ANS deducts particulate-emission damage, a $PM_{2.5} \times ANS$ interaction may be partly mechanical, so we also test a variant excluding it. A second, more familiar proxy is a sovereign governance-quality index, built here from the Worldwide Governance Indicators' Government Effectiveness and Regulatory Quality estimates (Kaufmann et al., 2011). However, the World Bank's own review of sovereign ESG methodologies found that roughly 90% of the variation in such scores is explained by national income alone (World Bank, 2021). A small OECD-based literature has linked institutional quality to the pollution–mortality relationship (Solarin et al., 2026), but, like the broader epidemiological literature (Cohen et al., 2017; Landrigan et al., 2018), it treats governance and income as independent predictors rather than moderators of the exposure–health relationship itself, and the sovereign-ESG divergence literature examines why governance scores diverge without testing whether they change pollution's health impact. To our knowledge, no prior study has tested an ANS-type environmental-accounting indicator, as distinct from a composite perception score, as such a moderator across a broad, income-diverse sample, although we did not conduct a systematic literature search.

This study addresses that gap, asking: to what extent do Adjusted Net Savings and a governance-quality index moderate the cross-country association between $PM_{2.5}$ exposure and air-pollution-attributable mortality and, exploratorily, malaria incidence? Figure 1 sets out the conceptual model: $PM_{2.5}$ is hypothesized to affect health directly, while ANS and the governance index (“environmental-financial governance” in Figure 1) condition the strength of that relationship. $PM_{2.5}$ has no established causal pathway to malaria (a Ghanaian trial of household air-pollution interventions found no significant association with malaria infection; Asante et al., 2023), so that analysis is exploratory. A second moderation model therefore replaces $PM_{2.5}$ with climate anomalies as the exposure and tests the same two moderators (see Methods). Formally, we hypothesize that (H1) $PM_{2.5}$ exposure is positively associated with air-pollution-attributable mortality and, exploratorily, malaria incidence; (H2) as direct effects, governance quality and Adjusted Net Savings are negatively associated with these outcomes; (H3) the $PM_{2.5} \times$ governance-index and (H4) $PM_{2.5} \times ANS$ interactions are negative, meaning a weaker $PM_{2.5}$ –outcome association at higher governance or ANS; (H5) exploratorily, the interaction is more negative for mortality than for malaria, given malaria's dependence on ecological and vector-biology factors (a descriptive comparison, as outcomes differ in scale); and (H6) exploratorily, temperature and precipitation anomalies raise within-country malaria incidence, less so where governance or ANS is higher.

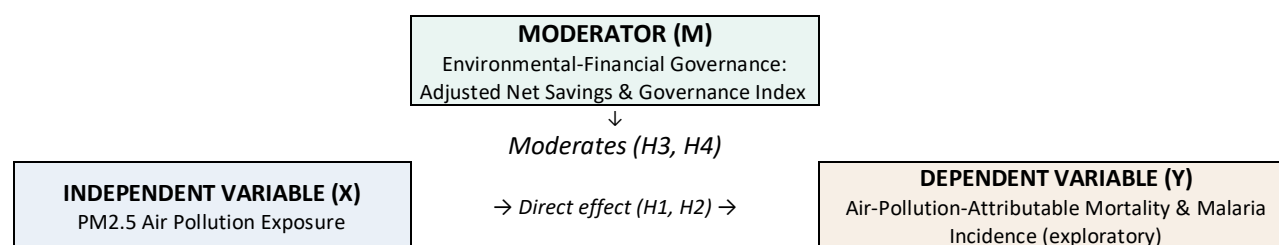


Figure 1. Conceptual framework: standard moderation model in which environmental-financial governance (M; ANS and a governance index) moderates the direct effect of air-pollution exposure (X) on air-pollution-attributable mortality and, exploratorily, malaria incidence (Y).

2. Methods

This study uses a cross-sectional design covering 56 countries selected purposively to span all four World Bank income groups and major regions, subject to indicator availability (counts by group in Appendix A). It is a convenience sample, not a probability sample of the 217 World Bank reporting economies: economies without a WHO AIR_42 estimate, including small island states, were not included, and selection on data availability may favor countries with stronger statistical systems, so results pertain to this sample. Fifty-four countries had complete data (the United Arab Emirates and Malawi lack ANS data); the malaria subsample comprises the 33 countries with WHO malaria data, 31 of them complete. Because the WHO's ambient-air-pollution-mortality indicator (AIR_42) is published for a single reference year (2021 at the time of collection) and the World Bank's ANS series only through 2021, 2015–2021 predictor averages are related to 2021 outcomes. Averaging smooths transient shocks, and governance moved little within countries (mean within-country SD 0.07–0.08 versus between-country SD 0.94–0.97), but because the window includes the outcome year it does not establish temporal precedence; a 2015–2020 check is in Table 5. Malaria incidence was fixed to 2021 for comparability; a 2023 robustness check (see Results) suggests this does not drive the findings.

Data were compiled from the World Bank World Development Indicators and Worldwide Governance Indicators and the WHO Global Health Observatory (World Bank, 2026b, 2026c, 2026d; World Health Organization, n.d.-b, n.d.-c). Indicators were PM2.5 mean exposure (EN.ATM.PM25.MC.M3), Adjusted Net Savings incl. particulate damage (NY.ADJ.SVNG.GN.ZS) and, for sensitivity analysis, excluding it (NY.ADJ.SVNX.GN.ZS), GDP per capita, PPP, health expenditure, urban population, the WGI Government Effectiveness and Regulatory Quality estimates, and WHO indicators AIR_42 and MALARIA_EST_INCIDENCE; sensitivity analyses added population aged 65+ (SP.POP.65UP.TO.ZS) and clean-cooking access (EG.CFT.ACCS.ZS, a household-air-pollution proxy). PM2.5, ANS, and a governance index (the standardized average of the two WGI estimates; Kaufmann et al., 2011) were averaged over 2015–2021. Dependent variables were 2021 ambient-air-pollution-attributable mortality (per 100,000 population, age-standardized; modelled by WHO from PM2.5 exposure–response functions, so part of the PM2.5–mortality association is built in) and malaria incidence (per 1,000 population at risk); GDP per capita (logged), health expenditure (% GDP), and urbanization (%) were controls, so income was accounted for in every model. All continuous regressors were mean-centered. Missing data were handled by listwise deletion: the mortality sample (N = 54) drops two cases (the United Arab Emirates and Malawi) missing ANS data; no values were imputed. Climate data were annual mean temperature and precipitation from the World Bank Climate Change Knowledge Portal (CRU TS 4.07), and annual malaria incidence (2000–2021) came from the WHO series above.

The baseline model regresses each outcome on PM2.5, the governance index, ANS, and controls. Moderation is tested via the product-term specification (Brambor et al., 2006): $\text{outcome} = b_0 + b_1(\text{PM2.5}_c) + b_2(\text{Mc}) + b_3(\text{PM2.5}_c \times \text{Mc}) + \text{controls}$, with PM2.5 and moderator M mean-centered (Aiken & West, 1991), so b_1 is the PM2.5 effect at the sample-mean moderator level. A negative b_3 means the marginal PM2.5 effect ($b_1 + b_3 \cdot M$) declines as the moderator rises (see Figures 2 and 3). Two moderation models add, in turn, a PM2.5 $\times$ governance-index interaction (H3) and a PM2.5 $\times$ ANS interaction (H4). Models were estimated by ordinary least squares with heteroskedasticity-robust (HC3) standard errors (MacKinnon & White, 1985; Long & Ervin, 2000), for mortality (N = 54) and, given its smaller risk-exposed subsample, malaria (N = 31). Variance inflation factors (Table 2; computed for each model including

interaction terms), Breusch-Pagan and Jarque-Bera tests, and a 2023-outcome malaria check were used as diagnostics; marginal effects were evaluated at the 25th, 50th, and 75th moderator percentiles. Because the cross-sectional design precludes fixed effects, results are cross-country associations, not causal estimates. Income was retained because it is a plausible common cause of governance and health, so omitting it could bias governance coefficients; models with and without $\ln$ GDP are in Table 5, and the resulting imprecision is treated as a limitation (see Discussion).

Because the ANS interaction was marginal, we assessed its stability (Table 5): ANS excluding particulate damage; parsimonious, income-group, age-structure, and clean-cooking specifications; log outcomes; Cook's distance (Cook, 1977) and leave-one-country-out re-estimation; a 2015–2020 predictor window; and an income-residualized index and separate WGI components. We report exact p-values, confidence intervals, standardized interaction, ΔR^2 , and Holm-adjusted p-values (Holm, 1979) for the four primary interaction tests. The smallest interaction detectable with 80% power was about 2.8 standard errors (≈ 0.037 ; malaria ≈ 0.31).

To test climate sensitivity, we built a country–year panel of the 22 malaria-endemic sample countries (mean incidence ≥ 1 per 1,000, complete 2000–2021 series, ANS available). The outcome was $\ln$ incidence; temperature and precipitation were standardized within country, so coefficients are per within-country SD of anomaly. Models included country and year fixed effects, which absorb time-invariant confounders such as income level and surveillance quality, and interacted each anomaly with the country's mean governance index or ANS; standard errors were clustered by country. Because 22 clusters is few, we added permutation (2,000 reshuffles of governance across countries) and Webb wild-cluster bootstrap p-values, a temperature $\times \ln$ GDP control, a one-year lag, leave-one-country-out re-estimation, and a restriction to 15 countries with incidence ≥ 10 per 1,000. Malaria volatility was the standard deviation of detrended $\ln$ incidence, regressed on ANS, governance, and climate variability (the detrended SD of temperature and the coefficient of variation of precipitation). We also added mean temperature and precipitation as controls to the cross-sectional mortality and malaria models. Holm adjustment covered 12 moderation tests: four cross-sectional, four volatility, and four panels.

Ethical Considerations

No individual-level or identifiable data were collected or processed, so the study poses no direct risk to human subjects and required no additional institutional ethics review. The author will supply an institutional exemption or determination statement if the journal requires one.

3. Results

Table 1 describes the 54-country mortality sample (mean PM2.5 24.4 $\mu\text{g}/\text{m}^3$; mean mortality 40.8 per 100,000), in which PM2.5 correlated with mortality at $r = 0.74$. The governance index and $\ln$ GDP correlated at $r = 0.91$; Table 2 shows that only $\ln$ GDP (11.2) and the governance index (7.5–8.3) had VIFs above 5. Table 3 reports the mortality models. PM2.5 was significant in Models 1 and 3 ($\beta = 0.652$, $p = 0.002$; $\beta = 0.697$, $p < 0.001$) but not in Model 2 ($\beta = 0.571$, $\text{SE} = 0.349$, $p = 0.102$), so H1 held in two of three specifications. Neither governance construct was independently significant (H2 not supported). The PM2.5 $\times$ governance-index interaction (Model 2) was correctly signed but not significant ($\beta = -0.107$, $p = 0.673$, 95% CI $[-0.60, 0.39]$; H3 not supported); its near-collinearity with income limits what this null can show. The PM2.5 $\times$ Adjusted Net Savings interaction (Model 3) was negative with a confidence interval that just includes zero ($\beta = -0.025$, $\text{SE} = 0.013$, $p = 0.056$, 95% CI $[-0.05, 0.00]$; standardized $\beta = -0.13$; $\Delta R^2 = 0.018$; robust Wald $p = 0.062$; Holm-adjusted $p = 0.22$). This misses the conventional 5% threshold, so H4 is not supported at that level and the evidence is weak and suggestive.

The estimated marginal effect of PM2.5 on mortality fell from 0.83 at the 25th percentile of ANS to 0.53 at the 75th, a roughly 36% difference in fitted slopes, not a reduction in mortality. Table 4 reports these slopes: the lower confidence bound moves toward zero as ANS rises, from $[0.42, 1.24]$ to $[0.10, 0.97]$, and stays above zero only up to an ANS of about 19% of GNI (Figure 2; 5 of 54 countries lie above it). This is a statistical association, not evidence that ANS protects health, and the overlapping intervals mean the attenuation cannot be clearly distinguished from noise.

Table 1. Descriptive statistics and Pearson correlations, mortality estimation sample (N = 54). ANS = Adjusted Net Savings. Correlations are shown below the diagonal.

Variables	Mean	SD	Min	Max	1	2	3	4	5	6
1. Mortality (per 100,000)	40.83	27.18	5.33	103.20	—					
2. PM2.5 ($\mu\text{g}/\text{m}^3$)	24.42	17.17	5.93	72.49	0.74	—				
3. ANS (% of GNI)	9.96	8.53	-4.73	31.14	-0.09	0.13	—			
4. Governance index	0.00	1.00	-1.32	1.93	-0.78	-0.60	0.24	—		
5. In GDP per capita	8.94	1.60	6.16	11.37	-0.77	-0.53	0.23	0.91	—	
6. Health expenditure (% GDP)	6.66	3.18	2.27	16.95	-0.73	-0.60	-0.13	0.71	0.71	—
7. Urbanization (%)	62.73	22.74	20.77	100.00	-0.65	-0.46	0.18	0.73	0.86	0.63

Table 2. Variance inflation factors by model (interaction terms included in Models 2 and 3). Governance and income exceed the conventional threshold of 5.

Regressors	Model 1	Model 2	Model 3
PM2.5	1.88	3.39	1.92
Governance index	7.53	8.34	8.13
Adjusted Net Savings	1.45	1.48	1.78
PM2.5 $\times$ Governance index	—	2.09	—
PM2.5 $\times$ ANS	—	—	1.41
In GDP per capita	11.21	11.22	11.21
Health expenditure	2.87	3.17	3.19
Urbanization	4.24	4.28	4.24

Table 3. OLS regression results, dependent variable: air-pollution-attributable mortality (per 100,000, 2021). Robust (HC3) SE in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Regressors	Model 1	Model 2	Model 3
Intercept	41.244*** (2.044)	40.127*** (3.749)	41.717*** (2.044)
PM2.5	0.652*** (0.215)	0.571 (0.348)	0.697*** (0.200)
Governance Index	-0.921 (4.178)	-1.985 (5.085)	-3.741 (4.913)
Adjusted Net Savings	-0.271 (0.322)	-0.296 (0.332)	-0.034 (0.358)
PM2.5 $\times$ Governance Index	—	-0.107 (0.254)	—
PM2.5 $\times$ ANS	—	—	-0.025* (0.013)
In GDP per capita	-7.034* (4.208)	-6.950 (4.297)	-6.887 (4.341)
Health expenditure	-1.985 (1.248)	-2.180 (1.348)	-1.337 (1.374)
Urbanization	0.100 (0.160)	0.110 (0.161)	0.109 (0.165)
N	54	54	54
R ² (Adj. R ²)	0.774 (0.746)	0.776 (0.742)	0.793 (0.761)

Note. Predictors are mean-centered. Exact p-values: Model 1 PM2.5 0.002; Model 2 PM2.5 0.102 and interaction 0.673; Model 3 PM2.5 < 0.001 and interaction 0.056.

The interaction was not robust (Table 5). Excluding particulate damage from ANS left it essentially unchanged ($\beta = -0.025$, $p = 0.070$; $r = 0.996$ with ANS), so overlap with PM2.5 does not drive the pattern. It was similar with 2015–2020 predictors, without In GDP, and with age structure, but weaker in a parsimonious model and with income-group effects ($p = 0.217$), and absent in log-transformed specifications ($p = 0.501$ and 0.829). Five countries exceeded the Cook's distance threshold ($4/n$); leave-one-country-out estimates stayed negative, but p ranged from 0.005 to 0.320.

Governance interactions stayed null with separate WGI components, without In GDP, and with income-group effects (all $p > 0.5$); with the index residualized on income, the interaction was positive ($\beta = 0.457$, $p = 0.071$), against the hypothesized direction.

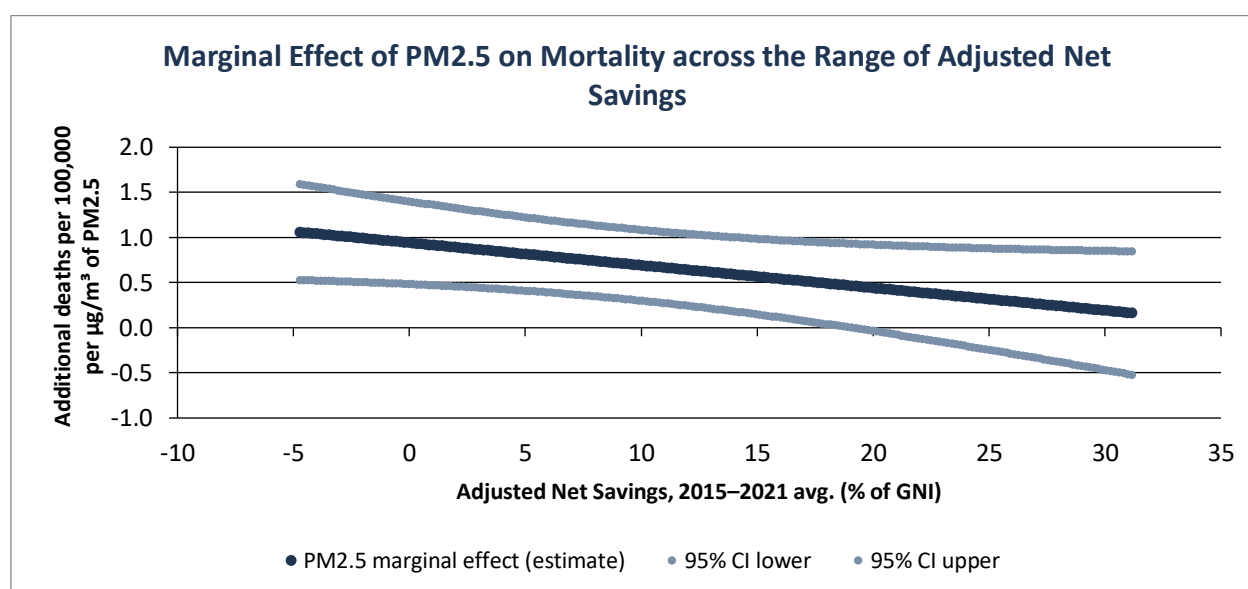


Figure 2. Estimated marginal effect of PM2.5 on air-pollution-attributable mortality (additional deaths per 100,000 for each $\mu\text{g}/\text{m}^3$) across the observed range of Adjusted Net Savings (% of GNI, 2015–2021 average), with 95% confidence interval (Model 3, Table 3; N = 54). The interval includes zero where its lower line crosses zero.

Malaria models (N = 31; Table 6) were exploratory: no coefficient reached conventional significance, and the PM2.5 $\times$ ANS ($\beta = -0.165$, 95% CI $[-0.38, 0.06]$, $p = 0.142$) and PM2.5 $\times$ governance-index ($\beta = -0.592$, $p = 0.919$) interactions were not significant, with ANS simple-slope intervals spanning zero at every percentile (Table 4). Coefficients on the two outcome scales are not comparable and no formal cross-outcome test was run, so H5 remains untested. Power was low: the smallest ANS interaction detectable was about 0.31 versus 0.037 for mortality. The sample cannot distinguish a true null from a smaller real effect. A robustness check re-estimating the malaria models with 2023 rather than 2021 incidence data (the two years correlate at $r = 0.99$ across the 33 countries with malaria data) produced closely comparable coefficients (PM2.5 $\times$ ANS: $\beta = -0.157$, $p = 0.121$) and a change in overall F-test significance ($p = 0.043$ versus 0.061) that is not read as substantive robustness. Breusch-Pagan tests found no significant heteroskedasticity ($p = 0.565$ and 0.622); Jarque-Bera tests indicated non-normal residuals ($p < 0.001$), consistent with right-skewed outcomes, so p-values, notably the H4 result, are indicative rather than definitive.

Climate sensitivity (H6). Across 22 endemic countries (484 country-years), a one-SD warmer-than-usual year was not on average significantly associated with malaria incidence at mean governance ($\beta = 0.157$, 95% CI $[-0.07, 0.39]$, $p = 0.18$), but governance moderated the response strongly (Table 7): temperature $\times$ governance $\beta = -0.328$ (95% CI $[-0.48, -0.17]$; permutation, wild-bootstrap, and Holm-adjusted p all < 0.001). A one-SD warm anomaly was associated with 0.30 log points higher incidence (about 35%; 95% CI $[0.07, 0.54]$) at the 10th percentile of governance among these countries, 0.18 $[-0.02, 0.39]$ at the median, and -0.03 $[-0.23, 0.17]$ at the 90th, so no sensitivity was detectable where governance was strongest. The interaction survived a temperature $\times$ ln GDP control ($\beta = -0.297$, $p = 0.003$), a one-year lag, the 15 high-incidence countries ($p = 0.008$), and leaving out any single country ($\beta -0.35$ to -0.27 , all $p < 0.001$). Precipitation anomalies showed no moderation ($p = 0.68$). For ANS the temperature interaction was positive, opposite to H6 ($\beta = 0.007$, $p = 0.066$; permutation $p = 0.08$; wild-bootstrap $p = 0.19$), so H6 is supported for governance but not ANS. Cross-country malaria volatility ($n = 22$) was unrelated to ANS ($\beta = 0.015$, $p = 0.40$) or governance ($p = 0.39$), and neither temperature nor precipitation variability interacted with either moderator (all $p > 0.46$). Adding mean temperature and precipitation to the cross-sectional models left the mortality PM2.5 $\times$ ANS interaction essentially unchanged ($\beta = -0.028$, $p = 0.052$) and the malaria interaction non-significant ($p = 0.24$).

Table 4. Simple-slope (marginal) effect of PM2.5 on air-pollution mortality and malaria incidence at percentiles of each moderator, with 95% confidence intervals (Models 2–3, Table 3; Model 6, Table 6).

Moderators	Percentile	PM2.5 slope	95% CI
Adjusted Net Savings (Model 3)	25th	0.830	[0.42, 1.24]
Adjusted Net Savings (Model 3)	50th	0.753	[0.36, 1.15]
Adjusted Net Savings (Model 3)	75th	0.532	[0.10, 0.97]
Governance Index (Model 2)	25th	0.663	[0.21, 1.11]
Governance Index (Model 2)	50th	0.599	[0.01, 1.19]
Governance Index (Model 2)	75th	0.462	[−0.66, 1.58]
ANS, malaria (Model 6)	25th	2.214	[−1.47, 5.90]
ANS, malaria (Model 6)	50th	1.612	[−1.67, 4.89]
ANS, malaria (Model 6)	75th	−0.223	[−3.41, 2.96]

Table 5. Sensitivity of the PM2.5 × moderator interaction to specification (HC3 SE). Coefficients in the two log specifications are on the log scale and are not comparable in size with the others. Holm-adjusted p-values for the four primary interaction tests: governance index 1.00, ANS 0.22 (mortality); governance index 1.00, ANS 0.43 (malaria). A joint test of both interactions in one model was not significant (F = 1.40, p = 0.257).

Specifications	N	β (SE)	95% CI	p
PM2.5 × ANS interaction (mortality)				
Model 3 (reference)	54	−0.025 (0.013)	[−0.051, 0.001]	0.056
ANS excluding particulate damage	54	−0.025 (0.014)	[−0.052, 0.002]	0.070
Predictors averaged over 2015–2020	54	−0.024 (0.014)	[−0.052, 0.003]	0.080
Parsimonious (PM2.5, ANS, interaction only)	54	−0.020 (0.016)	[−0.051, 0.012]	0.217
PM2.5, ANS, interaction, ln GDP only	54	−0.026 (0.012)	[−0.049, −0.003]	0.025
Model 3 without ln GDP	54	−0.025 (0.015)	[−0.055, 0.005]	0.098
Model 3 + income-group effects	54	−0.020 (0.016)	[−0.052, 0.012]	0.217
Model 3 + population aged 65+	54	−0.024 (0.013)	[−0.050, 0.002]	0.066
Model 3 + aged 65+ and clean-cooking access	54	−0.025 (0.011)	[−0.046, −0.005]	0.017
ln mortality (log scale)	54	−0.0003 (0.0004)	[−0.0011, 0.0005]	0.501
ln mortality, ln PM2.5 (log scale)	54	−0.0022 (0.0101)	[−0.0219, 0.0176]	0.829
PM2.5 × governance-index interaction (mortality)				
Model 2 without ln GDP	54	−0.118 (0.290)	[−0.687, 0.451]	0.685
Model 2 + income-group effects	54	0.043 (0.243)	[−0.434, 0.520]	0.861
Index residualized on ln GDP	54	0.457 (0.253)	[−0.039, 0.952]	0.071
Government Effectiveness only	54	−0.061 (0.223)	[−0.497, 0.376]	0.786
Regulatory Quality only	54	−0.179 (0.321)	[−0.807, 0.450]	0.577

Table 6. OLS regression results, dependent variable: malaria incidence (per 1,000 population at risk, 2021), malaria-risk subsample. Robust (HC3) SE in parentheses. *p<0.10, **p<0.05, ***p<0.01.

Regressors	Model 4	Model 5	Model 6
Intercept	91.357*** (22.625)	89.777*** (33.324)	98.696*** (24.020)
PM2.5	0.585 (1.611)	0.508 (2.718)	1.111 (1.564)
Governance Index	−33.374 (85.958)	−33.876 (88.918)	−39.858 (84.482)
Adjusted Net Savings	−4.607 (3.431)	−4.624 (3.574)	−3.538 (2.969)
PM2.5 × Governance Index	—	−0.592 (5.800)	—
PM2.5 × ANS	—	—	−0.165 (0.112)
ln GDP per capita	−66.939 (75.992)	−66.055 (81.451)	−73.158 (68.983)
Health expenditure	−4.962 (16.272)	−4.103 (18.998)	0.537 (15.624)
Urbanization	1.145 (3.086)	1.003 (3.374)	1.319 (2.719)
N	31	31	31
R ² (Adj. R ²)	0.468 (0.335)	0.469 (0.308)	0.513 (0.365)

Table 7. Moderation of the within-country response of ln malaria incidence (2000–2021) to climate anomalies, 22 endemic countries. Anomalies are standardized within country except where stated; clustered SE by country. Governance-index primary model: permutation $p < 0.001$ (2,000 reshuffles), wild-cluster bootstrap $p < 0.001$, leave-one-country-out $\beta -0.35$ to -0.27 (all $p < 0.001$), Holm-adjusted $p < 0.001$ across 12 moderation tests. ANS primary model: permutation $p = 0.08$, wild-bootstrap $p = 0.19$.

Specifications (country and year fixed effects)	N (countries)	β (SE)	95% CI	p
Temperature anomaly $\times$ governance index				
Primary model	484 (22)	-0.328 (0.078)	[-0.482, -0.174]	<0.001
+ temperature $\times$ ln GDP	484 (22)	-0.297 (0.100)	[-0.492, -0.102]	0.003
One-year lagged anomaly	462 (22)	-0.414 (0.118)	[-0.646, -0.183]	<0.001
Countries with incidence ≥ 10 per 1,000	330 (15)	-0.188 (0.071)	[-0.327, -0.049]	0.008
Anomaly in $^{\circ}\text{C}$ (per $^{\circ}\text{C}$)	484 (22)	-1.361 (0.279)	[-1.907, -0.815]	<0.001
Precipitation anomaly $\times$ governance index				
Primary model	484 (22)	0.026 (0.063)	[-0.097, 0.150]	0.677
Temperature anomaly $\times$ ANS				
Primary model	484 (22)	0.0070 (0.0038)	[-0.0005, 0.0144]	0.066
+ temperature $\times$ ln GDP	484 (22)	0.0078 (0.0034)	[0.0012, 0.0145]	0.021
Precipitation anomaly $\times$ ANS				
Primary model	484 (22)	0.0003 (0.0021)	[-0.0037, 0.0043]	0.882

4. Discussion

These results offer, at most, weak and suggestive support for the study's central thesis. Consistent with the epidemiological literature (Brauer et al., 2024; Cohen et al., 2017; Landrigan et al., 2018; World Health Organization, n.d.-a), PM2.5 exposure was consistently associated with mortality (about 0.7 age-standardized deaths per 100,000 per $\mu\text{g}/\text{m}^3$ in Model 3; because AIR_42 is itself modelled from PM2.5, part of this association is built in). The association was estimated to be weaker where ANS was higher (Figures 2 and 3), consistent, but not demonstrating, a role for environmental-economic management such as emission-standard enforcement, clean-energy investment, or health-system capacity, none of which was measured; any accounting mechanism is a possible pathway, not an established cause. The interaction was marginal and sensitive to functional form, income-group effects, and individual countries (Table 5).

ANS is a modelled composite dominated by savings rates and resource rents, not accounting practice. High-savings economic models, resource-rent structure, or other traits correlated with ANS (the highest-ANS countries were Singapore, Nepal, and Bangladesh) could produce the same pattern without an accounting-specific channel. ANS also deducts particulate damage; the estimate was unchanged without that component, but the two measures correlate at $r = 0.996$, so a partly mechanical link is not excluded. The governance index showed no moderation, but because it shares most of its variance with income ($r = 0.91$), its null is as consistent with collinearity as with absence of moderation, so we draw no comparison favoring either indicator type. The ANS interaction is a statistical moderation result from one cross-section, not proof that higher ANS causally protects populations; the 36% attenuation is a difference in fitted association, not a measured mortality reduction. For health management, exposure reduction remains the primary lever: the PM2.5 coefficient implies roughly seven additional deaths per 100,000 for every 10 $\mu\text{g}/\text{m}^3$ at mean ANS, and written policies may leave exposure unchanged where enforcement is weak, as in Thailand (Wongtongtair, 2025).

The malaria panel gives the clearest support for the governance theme, though still as association. Where governance was weaker, warm years coincided with higher malaria incidence; where it was stronger, none was detectable. Country fixed effects remove stable differences in income and surveillance, and the result persisted when temperature responses were allowed to vary with income. Possible channels, none measured here, are vector control, case management, and surveillance. Alternatively, governance may proxy for health-system capacity or reporting practice, and WHO malaria estimates are modelled, so some climate dependence may be built in. The 22 countries

cover only the lower part of the governance range, the moderator is a time-invariant average, and ANS did not show the same pattern, so we do not claim that environmental accounting mitigates climate-driven health volatility; cross-country malaria volatility was unrelated to either moderator.

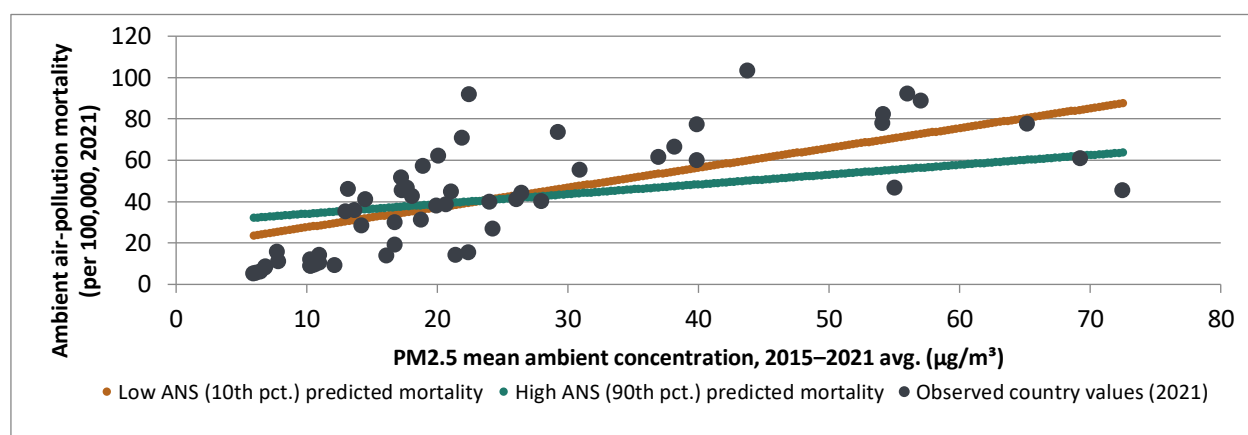


Figure 3. Predicted moderating effect of Adjusted Net Savings on the PM2.5-mortality relationship (Model 3, Table 3). Lines show fitted mortality at the 10th and 90th percentiles of ANS; points are the 56 sample countries (Model 3 was estimated on the 54 with ANS data).

The principal strength of this study is its explicit test, across a global, income-stratified convenience sample, of an ANS-based moderating mechanism that prior air-pollution health research has either ignored or proxied only generically (Solarin et al., 2026). The cross-sectional design cannot rule out time-invariant confounding that country fixed effects would otherwise absorb, and cannot fully resolve reverse causality between health burden and fiscal or governance performance; the predictor window also includes the outcome year. Disease burden, smoking, and household air pollution (proxied only by clean-cooking access) were not directly measured, age structure was captured only by the share aged 65+, and the cross-sectional malaria models lack vector-control and treatment variables (climate enters only as mean temperature and precipitation controls and, in the panel, as anomalies). The malaria subsample ($N = 31$) is underpowered, and residual non-normality, multiple testing, and specification sensitivity counsel caution around the borderline H4 result. The governance index is a substitute for the Sovereign ESG Data Portal score originally proposed, constructed from two Worldwide Governance Indicators components (Kaufmann et al., 2011), and its collinearity with income (variance inflation factors of 7.5–11) limits the precision with which a governance-specific effect can be isolated. As a convenience sample selected on data availability, the findings should not be generalized to all countries. Future work with a genuine multi-year panel for mortality, once denser WHO outcome data become available, could apply fixed effects and lagged or instrumental-variable designs to address these concerns directly.

5. Conclusion

This study asked whether Adjusted Net Savings and a governance-quality index moderate the cross-country association between air-pollution exposure and air-pollution-attributable mortality, and the climate sensitivity of malaria. PM2.5 exposure was consistently associated with higher mortality. The study finds evidence of a statistically marginal moderating association: ANS was linked to a flatter PM2.5–mortality slope, but the interaction missed conventional significance and was not robust to log specifications or income-group effects. The governance index showed no comparable moderation, though its collinearity with income limits that inference. For cross-sectional malaria the evidence remains uncertain given $N = 31$, but in 22 malaria-endemic countries warm anomalies raised malaria incidence where governance was weak and not where it was strong; ANS showed no such moderation, and malaria volatility was unrelated to either moderator. Causality is unresolved; larger longitudinal datasets and stronger causal designs are needed to determine whether accounting and governance mechanisms genuinely influence climate-sensitive and air-pollution-related health outcomes.

6. Recommendations

These recommendations follow from the findings and are hypotheses for future research, not established policy. First, because PM2.5 remained consistently associated with mortality while the ANS interaction was weak and not robust, researchers and national statistical offices should test, with longitudinal data, whether the particulate-damage valuation within ANS tracks realized health outcomes before any further health-linked adjustment is proposed. Second, because the governance index could not be separated from income, future studies should use larger samples with income-residualized indices or individual WGI components to test whether governance moderates the PM2.5–mortality association independently of income.

Third, any use of an ANS-style metric in health policy should be accompanied by evidence on enforcement and implementation, which this study did not measure; this, too, is a hypothesis for future research. Fourth, in weak-governance, malaria-endemic settings, heat-anomaly early warning paired with vector control and case management is a hypothesis worth testing.

Conflict of Interest

There is no conflict of interest. Nothing to disclose.

Appendix A. Countries in the sample

Income group (World Bank)	n	Countries
High income	22	Australia; Canada; France; Germany; Ireland; Israel; Italy; Japan; Netherlands; New Zealand; Norway; Republic of Korea; Romania; Russian Federation; Saudi Arabia; Singapore; Spain; Sweden; Switzerland; United Arab Emirates†; United Kingdom; United States
Upper-middle income	11	Argentina; Brazil; China; Colombia; Indonesia; Kazakhstan; Malaysia; Mexico; South Africa; Thailand; Türkiye
Lower-middle income	15	Bangladesh; Cameroon; Côte d'Ivoire; Egypt; Ghana; India; Kenya; Morocco; Nepal; Nigeria; Pakistan; Philippines; Tanzania; Tunisia; Viet Nam
Low income	8	Burkina Faso; Ethiopia; Madagascar; Malawi†; Mali; Mozambique; Rwanda; Uganda

† Excluded from the regression models because Adjusted Net Savings data were missing (mortality N = 54). Malaria models use the 31 countries with complete data among the 33 with WHO malaria-incidence values (see Methods).

References

- Aiken, L. S., & West, S. G. (1991). Multiple regression: Testing and interpreting interactions. Sage Publications.
- Arrow, K. J., Dasgupta, P., Goulder, L. H., Mumford, K. J., & Oleson, K. (2012). Sustainability and the measurement of wealth. *Environment and Development Economics*, 17(3), 317–353. <https://doi.org/10.1017/S1355770X12000137>
- Asante, K. P., Wylie, B. J., Oppong, F. B., Quinn, A., Gyaase, S., Lee, A. G., Ae-Ngibise, K. A., Burkart, K., Boamah-Kaali, E. A., Kaali, S., Chillrud, S., Kinney, P. L., Owusu-Agyei, S., & Jack, D. (2023). Association between malaria and household air pollution interventions in a predominantly rural area of Ghana. *Malaria Journal*, 22, Article 106. <https://doi.org/10.1186/s12936-022-04431-z>
- Bebbington, J., & Larrinaga, C. (2014). Accounting and sustainable development: An exploration. *Accounting, Organizations and Society*, 39(6), 395–413. <https://doi.org/10.1016/j.aos.2014.01.003>
- Brambor, T., Clark, W. R., & Golder, M. (2006). Understanding interaction models: Improving empirical analyses. *Political Analysis*, 14(1), 63–82. <https://doi.org/10.1093/pan/mpi014>
- Brauer, M., Roth, G. A., Aravkin, A. Y., Zheng, P., Abate, K. H., Abate, Y. H., Abbafati, C., Abbasgholizadeh, R., Abbasi, M. A., Abbasian, M., Abbasifard, M., Abbasi-Kangevari, M., Abd ElHafeez, S., Abd-Elsalam, S., Abdi, P., Abdollahi, M., Abdoun, M., Abdulah, D. M., Abdullahi, A., . . . Gakidou, E. (2024). Global burden and strength of evidence for 88 risk factors in 204 countries and 811 subnational locations, 1990–2021: A systematic analysis for the Global Burden of Disease Study 2021. *The Lancet*, 403(10440), 2162–2203. [https://doi.org/10.1016/S0140-6736\(24\)00933-4](https://doi.org/10.1016/S0140-6736(24)00933-4)
- Bui, B., Houqe, M. N., & Zahir-ul-Hassan, M. K. (2022). Moderating effect of carbon accounting systems on strategy and carbon performance: A CDP analysis. *Journal of Management Control*, 33(4), 483–524. <https://doi.org/10.1007/s00187-022-00346-7>

- Caminade, C., Kovats, S., Rocklöv, J., Tompkins, A. M., Morse, A. P., Colón-González, F. J., Stenlund, H., Martens, P., & Lloyd, S. J. (2014). Impact of climate change on global malaria distribution. *Proceedings of the National Academy of Sciences*, 111(9), 3286–3291. <https://doi.org/10.1073/pnas.1302089111>
- Cohen, A. J., Brauer, M., Burnett, R., Anderson, H. R., Frostad, J., Estep, K., Balakrishnan, K., Brunekreef, B., Dandona, L., Dandona, R., Feigin, V., Freedman, G., Hubbell, B., Jobling, A., Kan, H., Knibbs, L., Liu, Y., Martin, R., Morawska, L., . . . Forouzanfar, M. H. (2017). Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: An analysis of data from the Global Burden of Diseases Study 2015. *The Lancet*, 389(10082), 1907–1918. [https://doi.org/10.1016/S0140-6736\(17\)30505-6](https://doi.org/10.1016/S0140-6736(17)30505-6)
- Cook, R. D. (1977). Detection of influential observation in linear regression. *Technometrics*, 19(1), 15–18. <https://doi.org/10.1080/00401706.1977.10489493>
- Fuller, R., Landrigan, P. J., Balakrishnan, K., Bathan, G., Bose-O'Reilly, S., Brauer, M., Caravanos, J., Chiles, T., Cohen, A., Corra, L., Cropper, M., Ferraro, G., Hanna, J., Hanrahan, D., Hu, H., Hunter, D., Janata, G., Kupka, R., Lanphear, B., . . . Yan, C. (2022). Pollution and health: A progress update. *The Lancet Planetary Health*, 6(6), e535–e547. [https://doi.org/10.1016/S2542-5196\(22\)00090-0](https://doi.org/10.1016/S2542-5196(22)00090-0)
- Gray, R., Owen, D., & Adams, C. (1996). *Accounting and accountability: Changes and challenges in corporate social and environmental reporting*. Prentice Hall.
- Hamilton, K., & Clemens, M. (1999). Genuine savings rates in developing countries. *The World Bank Economic Review*, 13(2), 333–356. <https://doi.org/10.1093/wber/13.2.333>
- Hartmann, F., Perego, P., & Young, A. (2013). Carbon accounting: Challenges for research in management control and performance measurement. *Abacus*, 49(4), 539–563. <https://doi.org/10.1111/abac.12018>
- Holm, S. (1979). A simple sequentially rejective multiple test procedure. *Scandinavian Journal of Statistics*, 6(2), 65–70.
- Kaufmann, D., Kraay, A., & Mastruzzi, M. (2011). The worldwide governance indicators: Methodology and analytical issues. *Hague Journal on the Rule of Law*, 3(2), 220–246. <https://doi.org/10.1017/S1876404511200046>
- Landrigan, P. J., Fuller, R., Acosta, N. J. R., Adeyi, O., Arnold, R., Basu, N. N., Baldé, A. B., Bertollini, R., Bose-O'Reilly, S., Boufford, J. I., Breyse, P. N., Chiles, T., Mahidol, C., Coll-Seck, A. M., Cropper, M. L., Fobil, J., Fuster, V., Greenstone, M., Haines, A., . . . Zhong, M. (2018). The Lancet Commission on pollution and health. *The Lancet*, 391(10119), 462–512. [https://doi.org/10.1016/S0140-6736\(17\)32345-0](https://doi.org/10.1016/S0140-6736(17)32345-0)
- Lange, G.-M., Wodon, Q., & Carey, K. (Eds.). (2018). *The changing wealth of nations 2018: Building a sustainable future*. World Bank. <https://doi.org/10.1596/978-1-4648-1046-6>
- Long, J. S., & Ervin, L. H. (2000). Using heteroscedasticity consistent standard errors in the linear regression model. *The American Statistician*, 54(3), 217–224. <https://doi.org/10.1080/00031305.2000.10474549>
- MacKinnon, J. G., & White, H. (1985). Some heteroskedasticity-consistent covariance matrix estimators with improved finite sample properties. *Journal of Econometrics*, 29(3), 305–325. [https://doi.org/10.1016/0304-4076\(85\)90158-7](https://doi.org/10.1016/0304-4076(85)90158-7)
- Murugan, Y., & Shrivastav, V. (2025). Association between temperature and malaria (1959–2019): A systematic review and meta-analysis. *Archives of Public Health*, 83, 255. <https://doi.org/10.1186/s13690-025-01750-w>
- Pascual, M., Ahumada, J. A., Chaves, L. F., Rodó, X., & Bouma, M. (2006). Malaria resurgence in the East African highlands: Temperature trends revisited. *Proceedings of the National Academy of Sciences*, 103(15), 5829–5834. <https://doi.org/10.1073/pnas.0508929103>
- Romanello, M., Walawender, M., Hsu, S.-C., Moskeland, A., Palmeiro-Silva, Y., Scamman, D., Ali, Z., Ameli, N., Angelova, D., Ayeb-Karlsson, S., Basart, S., Beagley, J., Beggs, P. J., Blanco-Villafuerte, L., Cai, W., Callaghan, M., Campbell-Lendrum, D., Chambers, J. D., Chicmana-Zapata, V., . . . Costello, A. (2024). The 2024 report of the Lancet Countdown on health and climate change: Facing record-breaking threats from delayed action. *The Lancet*, 404(10465), 1847–1896. [https://doi.org/10.1016/S0140-6736\(24\)01822-1](https://doi.org/10.1016/S0140-6736(24)01822-1)
- Solarin, S. A., Erdogan, S., & Uzuner, G. (2026). Exploring determinants of air pollution-related mortality in OECD states: Socioeconomic, institutional, and health dimensions. *Quality & Quantity*, 60(5), 17195–17212. <https://doi.org/10.1007/s11135-026-02858-z>
- Watts, N., Amann, M., Arnell, N., Ayeb-Karlsson, S., Beagley, J., Belesova, K., Boykoff, M., Byass, P., Cai, W., Campbell-Lendrum, D., Capstick, S., Chambers, J., Coleman, S., Dalin, C., Daly, M., Dasandi, N., Dasgupta, S., Davies, M., Di Napoli, C., . . . Costello, A. (2021). The 2020 report of The Lancet Countdown on health and climate change: Responding to converging crises. *The Lancet*, 397(10269), 129–170. [https://doi.org/10.1016/S0140-6736\(20\)32290-X](https://doi.org/10.1016/S0140-6736(20)32290-X)
- Wongtongtair, S. (2025). Thailand policies for PM 2.5 and the hidden problems. *GHMJ (Global Health Management Journal)*, 8(1), 43–46. <https://doi.org/10.35898/ghmj-811208>
- World Bank. (2021). *Demystifying sovereign ESG*. World Bank Group. <https://documents1.worldbank.org/curated/en/842671621238316887/pdf/Demystifying-Sovereign-ESG.pdf>

- World Bank. (2026a). Adjusted net savings, including particulate emission damage (% of GNI) (NY.ADJ.SVNG.GN.ZS) [Data set]. World Development Indicators. Retrieved September 2026, from <https://data.worldbank.org/indicator/NY.ADJ.SVNG.GN.ZS>
- World Bank. (2026b). Adjusted net savings, excluding particulate emission damage (% of GNI) (NY.ADJ.SVNX.GN.ZS) [Data set]. World Development Indicators. Retrieved October 2026, from <https://data.worldbank.org/indicator/NY.ADJ.SVNX.GN.ZS>
- World Bank. (2026c). World Development Indicators [Data set]. Retrieved September 2026, from <https://databank.worldbank.org/source/world-development-indicators>
- World Bank. (2026d). Worldwide Governance Indicators [Data set]. Retrieved September 2026, from <https://www.worldbank.org/en/publication/worldwide-governance-indicators>
- World Health Organization. (n.d.-a). Worldwide ambient air pollution accounts for 29% of deaths from heart disease, stroke, lung cancer and chronic respiratory disease. Retrieved September 2026, from <https://www.who.int/teams/environment-climate-change-and-health/air-quality-energy-and-health/health-impacts/exposure-air-pollution/worldwide-ambient-air-pollution-accounts-for-29-of-deaths>
- World Health Organization. (n.d.-b). Ambient air pollution attributable death rate (per 100 000 population, age-standardized) (AIR_42) [Data set]. Global Health Observatory. Retrieved September 2026, from <https://www.who.int/data/gho>
- World Health Organization. (n.d.-c). Estimated malaria incidence (per 1000 population at risk) (MALARIA_EST_INCIDENCE) [Data set]. Global Health Observatory. Retrieved September 2026, from <https://www.who.int/data/gho>

Cite this article as:

Orshi, T. S. (2026). Environmental Accounting and Planetary Health: How Adjusted Net Savings and Governance Quality Moderate Air-Pollution Deaths and Climate-Sensitive Malaria across Countries. *GHMJ (Global Health Management Journal)*, 9(3), 331–342. <https://doi.org/10.35898/ghmj-931371>