The Impact of Two Decades of Humanitarian and Development Assistance and the Projected Mortality Consequences of Current Defunding to 2030: Retrospective Evaluation and Forecasting Analysis

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ABSTRACT

Background. Official Development Assistance (ODA) accounts for the majority of humanitarian and development assistance in the world's most vulnerable countries and has played a pivotal role in advancing global health. This study aimed to comprehensively evaluate the impact of ODA funding on mortality across the past two decades, and to project the potential consequences of current defunding trends.

Methods. We conducted an integrated retrospective and forecasting analysis using longitudinal panel data from 93 low-income and middle-income countries (LMICs). First, we estimated the association between ODA per-capita funding and mortality outcomes from 2002 to 2021 using a two-ways fixed-effects multivariable Poisson regression models with robust standard errors, adjusted for all relevant demographic, socioeconomic, and health-system covariates. We then assessed age-specific and cause-specific effects, performing extensive sensitivity and triangulation analyses to test the robustness and causal interpretation of results. Finally, we integrated the retrospective impact estimates into validated country-level microsimulation models to forecast mortality under alternative defunding scenarios up to 2030.

Findings. Higher ODA funding levels were associated with a 23% reduction in age-standardised all-cause mortality (rate ratio [RR]:0.77; 95% Confidence Interval: 0.70-0.85) and a 39% reduction in under-five mortality (RR:0.61,0.49-0.75). ODA funding was associated with large mortality declines in major communicable diseases: 70% for HIV/AIDS (RR:0.30,0.24-0.39), 56% for malaria (RR 0.44, 0.35-0.56), and 54% for neglected tropical diseases (RR 0.46, 0.36-0.59). Significant reductions were also observed in mortality from tuberculosis, diarrhoeal diseases, lower respiratory infections, and maternal and perinatal causes. Forecasting analyses projected that ongoing reductions in ODA funding could, under a severe defunding scenario, result in 22.6 million (95% Uncertainty Interval: 16.3–29.3) additional deaths across all ages by 2030, including 5.4 million (4.1–6.8) among children under five. Under a mild defunding scenario—defined as a continuation of current downward trends—the projected excess deaths would be 9.4 million (6.2–12.6) overall and 2.5 million (1.8–3.2) among children under five.

Interpretation. ODA funding has played a decisive role in reducing preventable mortality across LMICs over the past two decades, and the abrupt withdrawal of this support threatens to cause millions of avoidable deaths, reversing decades of progress in global health.

Funding. RF Catalytic Capital, Inc (RFCC grant FA-01713), Spanish Ministry of Science and Innovation.

INTRODUCTION

In 1969, the Development Assistance Committee (DAC) of the Organization for Economic Cooperation and Development (OECD)—now composed of 38 high-income and upper-middle-income donor countries—introduced the concept of Official Development Assistance (ODA) to standardize member governments' aid to developing countries.[1,2] In 1970, the General Assembly of the United Nations proposed donor countries to allocate 0.7% of their Gross National Product (GNP) to ODA —a target that only a few countries have met to this day. ODA constitutes the core and most rigorously measured component of assistance, representing the large majority of external financing for the least developed countries (LDCs). ODA flows consist of grants—which make up the largest share of ODA—and concessional loans provided to the official sectors of countries and territories on the DAC List of ODA Recipients, as well as to international NGOs and multilateral development institutions.[3] At a high level, ODA can be delivered bilaterally, from donor governments to recipient countries, or multilaterally to eligible multilateral organizations like UN agencies and the Global Fund, through technical cooperation or humanitarian assistance. To be counted as ODA, financial disbursements must meet criteria set by the OECD DAC. ODA does not include military aid, except for the cost of using armed forces to deliver humanitarian aid. It also excludes spending on peacekeeping unless it is closely related to development. ODA eligible countries are LDCs, Low- and Middle-income Countries (LMICs), fragile and conflict affected regions in sub-Saharan Africa, South East and the Middle East. Its focus areas are health, education, water and sanitation, agriculture and food security, infrastructure and energy, environmental protection, governance, humanitarian aid, and conflict resolution.

In 2023, total ODA reached USD 250.3 billion, with the United States, Germany, Japan, France, and the United Kingdom contributing roughly 70% of the total.[3,4] All of these major donors—except Japan—reduced their ODA in 2024, marking the first such decline in nearly three decades. Should all the planned 2025 cuts be implemented, it would mark the first historical instance of these four countries reducing ODA at the same time for two consecutive years.[5] The United States Agency for International Development (USAID), the world's largest bilateral aid agency, was dismantled in July 2025, with an announced reduction of its programs by 83%.[6] The resulting loss in funding is currently estimated at nearly 40%.[4] The projected ODA cuts will fall disproportionately on the poorest countries. In 2025, least developed countries (LDCs) are expected to experience a 13–25% reduction in net bilateral ODA, while countries in sub-Saharan Africa could face declines of 16–28%.[5] Bilateral ODA for health is projected to drop by 19–33% compared to 2023 levels. Outlooks beyond 2025 remain highly uncertain, as budgets for 2026 and 2027 have been announced, though in some donor countries they have not yet been formally approved and budgeting cycles vary significantly across DAC members.[4,5] However, preliminary projections point to further significant reductions from major DAC donors, amounting to an estimated overall decline of 11.3% from 2025 to 2026,[4] and resulting by 2026 in estimated reductions in ODA funding—relative to 2023 levels—of 56.1% for the United States, 38.9% for the United Kingdom, 36.0% for Germany, 18.5% for France, and similarly large decreases for nearly all other donor countries, with only a few exceptions.[4,5]

In the absence of alternative funding sources, these abrupt cuts on ODA funding are expected to have profound effects over the next few years on the health of the populations affected. Large-scale modelling studies indicate that the sudden cuts of USAID and its recent dissolution would result in significant increases in mortality. A recent study in LMICs combined a retrospective analysis of the past two decades of USAID's impact with a forecasting model, projecting 14.1 million deaths by 2030—including 4.5 million child deaths—if funding for former USAID programs were nearly entirely halted.[6] Other models in a smaller subset of LMICs estimate that ending US health funding in 2025–30 could add over 4 million AIDS deaths, more than 600,000 TB deaths, and 2.5 million child deaths, alongside millions of unplanned pregnancies and unsafe abortions.[7]

To our knowledge, there are no studies that have evaluated the health impact of ODA in LMICs, or tried to estimate the effects of its current defunding. This study aims to comprehensively evaluate the impact of ODA funding from all OECD donors - including support for health care, nutrition, humanitarian relief, education, and infrastructure — on mortality in LMICs over the past two decades, and to estimate the impact of its current reduction and alternative defunding scenarios up to 2030.

METHODS

Study design

Our study design and analytical approach are the same as our recent study on the health impact of USAID defunding,[6] and integrated two complementary components: a retrospective (ex-post) impact evaluation covering the period 2002–2021 (more recent years were excluded due to limited data availability across all variables), and a forecasting (ex-ante) analysis from 2025 to 2030. Both analyses were built upon a common data architecture, study design, and analytical framework to ensure methodological consistency and comparability.

The retrospective impact evaluation employed a longitudinal ecological design, in which countries served as the primary unit of analysis and were observed across multiple time points. This panel dataset incorporated aggregated demographic, socioeconomic, health, and ODA indicators compiled from multiple publicly available international sources (see appendix p. 4 for full data details). The analytic sample included 93 LMICs, representing 6.3 billion individuals, selected from the global set of nations based on income classification criteria, data availability and data consistency (appendix p. 5 provides a detailed description of the country selection criteria). Models including all LMICs were also estimated as sensitivity analysis (appendix p. 32).

Study variables

The main dependent variable in the analysis was age-standardized all-cause mortality rate (ASMR) per 1000 inhabitants. In addition, mortality was examined across different age groups, including within child mortality (children younger than 1 year and 5 years per 1000 live births). To examine cause-specific associations, we identified a set of mortality categories corresponding to ODA's strategic health priorities and to conditions strongly associated with poverty, as informed by prior research.[8-12] Each category was defined in accordance with the International Classification of Diseases, 10th Revision (ICD-10). The selected causes included tuberculosis (A15–A19, B90), HIV/AIDS (B20–B24), maternal causes (O00–O99), lower respiratory infections (J09–J22, P23, U04), malnutrition (E00–E02, E40–E46, E50, D50–D53, D64.9, E51–E64), diarrhoeal diseases (A00, A01, A03, A04, A06–A09), malaria (B50–B54, P37.3, P37.4), and neglected tropical diseases (A66, A67, A69.1, A71, A77, A78, A79, B55–B56, B57, B65, B66, B73–B74, B76–B77, B79, B83, B88.0, B88.1).

Our exposure variable was the financial assistance provided by OECD official donors in sectors encompassing determinants and interventions with plausible impacts on mortality. These included: Social Infrastructure and Services, covering education; health; population policies and reproductive health; water supply and sanitation; government and civil society; social protection; and housing policy; Multi-sector/Cross-cutting areas, such as general environmental protection, food security and safety, and disaster risk reduction; Humanitarian Aid, including emergency response, reconstruction relief and rehabilitation, and disaster prevention and preparedness. Sectors with negligible effects on health in recipient countries—such as donors' administrative costs, support for refugees in donor countries, and unspecified interventions—were excluded. The selected sectors represented approximately 55% of all ODA funding over the study period. In sensitivity analyses, we also explored models that used total ODA across all sectors as the exposure variable (See appendix p 28). The ODA funding per capita was calculated, similarly to previous studies,[6,13,14] by dividing the total disbursed amount (numerator, in monetary values) by the total population (denominator) for each of the 93 countries across each fiscal year from 2002 to 2021. As in previous studies,[6,15] we categorized the ODA funding per capita to estimate the non-linear dose–response relationship associated with increasing levels of intervention implementation. In the absence of established reference values in the literature—and in line with previous evaluations that classify interventions intensity into four levels (baseline, low, intermediate and high),[6,15] we categorized intervention intensity using quartiles of its distribution: baseline, considered a level of exposure with negligible effects on the outcome ($0–12.35 per capita per year); low ($12.36–28.70); intermediate ($28.71–50.39); high ($50.40 and higher). A categorical specification was adopted rather than a continuous one because the functional form of the dose–response relationship between ODA funding and mortality outcomes was not known a priori. In addition, the exposure variable contained potential outliers that could exert disproportionate influence on effect estimates in continuous models. Nonetheless, we conducted a series of robustness checks using both continuous specifications and alternative categorical thresholds, including quintiles and deciles of exposure. The results were consistent across all model variants, confirming the stability of the findings and the baseline choice (see appendix p. 12-32 for detailed descriptions of these sensitivity analyses and alternative categorizations).

All relevant time-variant demographic, socioeconomic, and health-care adjusting variables, according to the literature[6,13,14,16,17] were included in the models, expanding the set of covariates used in our previous USAID study:[6] economic downturns; gross domestic product (GDP) per capita at purchasing power parity (PPP); income inequality measured by the Gini Index; fertility rate; access to adequate sanitation facilities; primary education enrollment rate; education expenditure; population using at least basic drinking water services; military expenditure; health expenditure; availability of nursing personnel and of hospital beds per 1,000 inhabitants; and the presence of armed conflict or war within the country. Additional covariates and specifications were also tested in sensitivity analyses (appendix p. 12-32). As in previous studies,[6,15] to harmonize the model with the categorized exposure variables and to mitigate the influence of potential outliers, we dichotomized these covariates according to their median value over the period (except for economic downturn and armed conflict or wars index, see appendix p. 4-5). Moreover, we included time dummy variables (for 2009, 2015, 2020, and 2021) to adjust for major economic and health shocks that occurred globally in the past two decades.[6,18]

Data sources

Data on age-standardized mortality, per cause and age groups, were collected from the Global Burden of Disease Collaborative Network.[18] The data on ODA funding were collected from the OECD Creditor Reporting System,[19] flow-based ODA. Demographic, socioeconomic, and healthcare-related variables were obtained from the World Bank data and the WHO Global Health Observatory data.[20] The complete list of data sources and related detailed methods is presented in the appendix (p. 4).

Statistical analyses

In the retrospective impact evaluation, we estimated the association between per capita ODA funding and age-standardised mortality—both overall and within age-specific and cause-specific groups—over the period 2002–2021. As in our previous USAID study,[6] Poisson multivariable regression models with robust standard errors and two-way fixed effects (for country and year) were employed. This approach, widely applied in global health and development economics, allows for the estimation of intervention effects on mortality outcomes using longitudinal, aggregate-level panel data.[6,15,16] The inclusion of fixed effects terms accounts for time-invariant, unobserved characteristics of each country—such as geographical, infrastructural, historical, or sociocultural factors—that could confound the relationship between the intervention and the outcome. By controlling for these latent attributes, the model isolates within-country variations over time, thereby strengthening causal inference. To assess the robustness and consistency of the estimates, we conducted an extensive suite of sensitivity analyses, including alternative model specifications, adjustment sets, and exclusion criteria (appendix p. 10-32). The results of these analyses consistently supported the stability of the main findings.

A wide range of sensitivity analyses were performed: first, to assess the sensitivity of the results to the exposure specification, we re-estimated the models using continuous measures of ODA per capita and alternative categorical groupings, varying both the number of categories and the threshold values. Second, to evaluate the external validity of our findings—that is, to test whether the observed associations held across a broader global context—we expanded the sample to include more countries and territories worldwide. Third, to examine the potential influence of temporal dynamics, we re-specified the models using alternative sets of time variables to capture different trend structures. Finally, to strengthen causal inference and validate the overall impact evaluation, we conducted triangulation analyses[21] and applied Bradford Hill criteria for causal inference.[22]

All data processing and statistical analyses were conducted using *Stata*, version 17.0 (StataCorp LLC, College Station, TX, USA).

For the forecasting analysis, we employed validated country-level microsimulation models to project the potential health effects of the ongoing ODA defunding and its phased withdrawal through 2030. Microsimulation represents one of the most rigorous and accurate forecasting techniques, as it enables the integration of country-specific characteristics and their associated outcome probabilities directly into the modelling framework. This approach is particularly robust when model parameters are derived from retrospective, real-world cohorts, as it preserves the empirical distribution of variables, their intercorrelations, and country-level temporal dynamics.[23] Building on established methodologies,[6,24,25] our modelling framework comprised two main stages. In the first stage, we generated a synthetic cohort encompassing all countries for the period 2024–2030 by extrapolating and modelling each country-level independent variable from the retrospective dataset. In the second stage, we used these projected inputs within the same multivariable Poisson regression models employed in the retrospective (ex-post) analysis, thereby incorporating the effect estimates derived from those models to forecast mortality outcomes.

Three ODA funding scenarios were simulated. The first represented a *business-as-usual* trajectory, maintaining ODA funding at 2023 levels (the last year for which consolidated country-specific data were available). The second modelled a *severe defunding* scenario, incorporating the currently projected 15.8% ODA funding reduction in 2025 (related to 2024 estimates, and based on consolidated projections)[4] followed by a substantial funding decrease, stabilizing to baseline levels (below 12.3U$ per capita) from 2026 to 2030 (appendix p. 33). The third modelled a *mild defunding scenario*, with the same 2025 reduction of the previous one, but a 10.6% yearly reduction (corresponding to the average reduction of the last two years, 2024-2025, and close to the current estimated 11.3% reduction for 2026)[4] from 2026 to 2030. For each outcome and scenario, we conducted 1,000 Monte Carlo simulations, allowing model parameters to vary within their empirical probability distributions across iterations. Comparisons between scenarios focused on all-age and under-five mortality, expressed as mortality rate ratios and absolute differences in deaths, including estimates of cumulative excess mortality over the entire 2025–2030 period. All forecasting procedures adhered to international model reporting standards (ISPOR–SMDM guidelines)[26] and were implemented in *R*, version 4.1.2. Detailed documentation of the modelling process—including calibration, validation, parameter distributions for the Monte Carlo simulations, and full model equations—is provided in the appendix (p. 33-39).

Role of the funding source

The funder had no role in the study design, data collection, data analysis, data interpretation, or writing of the manuscript and the decision to submit for publication.

RESULTS

We calculated the mean values and trends of all the variables in the selected countries over the study period (2002–21; table 1). Overall ASMR started in 2002 at 11.50 (Standard Deviation – SD: 3.5) per 1000 population and decreased by 12% until 2021, whereas the under-five mortality started at 73.6 (45.6) and decreased by 49%. On average, ODA funding increased by 109% (from $22.7 to $47.5 capita), whereas the average funding per country increased by 222% (from $283.1 million to $910.4 million). Overall, socioeconomic and health conditions showed notable improvement over time. GDP per capita increased, reflecting stronger economic performance, while access to adequate sanitation, basic water coverage, and primary education also advanced. Health expenditure and the availability of nursing personnel expanded, indicating greater investment in healthcare systems. At the same time, fertility rates and income inequality declined, suggesting demographic and social progress. Military expenditure and the occurrence of conflicts decreased slightly, while the incidence of economic downturns varied across periods. Taken together, these trends point to broad progress in social development, education, and health, despite persistent inequalities among countries.

We calculated the associations between different levels of ODA funding per capita and decreases in mortality rates by age groups (table 2). High levels of funding were associated with lower mortality, in particular a 23% reduction for overall ASMR, 33% for under-1 mortality, and 39% for under-five mortality. When causes of death in all-age mortality were analysed (Table 3), ODA funding was associated with large mortality declines in major communicable diseases: 70% for HIV/AIDS, 56% for malaria, and 56% for nutritional deficiencies, among others.

All findings remained consistent across all sensitivity analyses, confirming the robustness of the results, and across all triangulation analyses, which further strengthened confidence in the causal interpretation of the observed associations (appendix pp. 29-31). In addition, all sensitivity, and complementary analyses were systematically evaluated against the established Bradford Hill criteria for causal inference in epidemiological research,[22] providing an additional layer of validation for the plausibility and coherence of the estimated effects (appendix p. 8).

The microsimulation models (table 3) projected that, under the severe defunding scenario, the anticipated reduction in ODA per capita funding would result in a cumulative total of 22.6 million (95% uncertainty interval [UI] 16.3–29.3) excess deaths across all ages by 2030, including 5.4 million (4.1–6.8) deaths among children under 5 years of age. Under the mild defunding scenario, the cumulative number of excess deaths by 2030 was estimated at 9.4 million (6.2–12.6) across all ages and 2.5 million (1.8–3.2) among children under 5 years.

DISCUSSION

Our study provides the first comprehensive evaluation of the impact of ODA funding over the past two decades and projects the effects of alternative defunding scenarios on mortality. High levels of ODA were associated with a 23% reduction in all-age mortality and a 39% reduction in under-five mortality between 2002 and 2021, with particularly strong effects on all-age mortality rates from HIV/AIDS (70%), nutritional deficiencies (56%), malaria (56%), diarrhoeal diseases (55%), and neglected tropical diseases (54%). All associations showed a dose–response relationship according to the levels of funding. The forecasting models projected that current funding cuts, followed by severe reductions of ODA to minimal levels, could lead to 22.6 million additional deaths by 2030, including 5.4 million among children under five. Even under mild defunding scenarios that simply extend current downward trends, these excess deaths would amount to 9.4 million and 2.5 million, respectively.

In terms of effect size, our findings align with estimates from other studies that have assessed deaths attributable to cuts in foreign assistance using different methodological approaches. Existing estimates suggest, for example, that USAID programmes avert approximately 3.3 million (uncertainty interval: 2.3–5.6 million) all-cause, all-age deaths each year.[8] Another recent analysis, focusing on a smaller set of LMICs, estimated that eliminating US foreign assistance on health between 2025 and 2030 could result in more than 4 million additional AIDS deaths, over 600,000 TB deaths, and 2.5 million child deaths, alongside millions of unintended pregnancies and unsafe abortions.[7] Furthermore, our recent study[6] estimated that high levels of USAID funding were associated with a 15% reduction in all-age mortality and a 32% reduction in under-five mortality over the past two decades. The study also projected that the near-complete dismantling of former USAID programs could result in 14.1 million deaths by 2030, including 4.5 million child deaths.

Although differences in the set of countries analyzed, model adjustments, funding indicators and their sectoral coverage, exposure categorization and thresholds, and the characteristics of the defunding scenarios prevent direct comparisons of effect sizes with previous studies—including our recent USAID analysis[6] —a larger effect of ODA is nonetheless expected. This is because ODA represents substantially higher levels of funding than those provided by individual donors.

Over the past decades, Official Development Assistance has supported a broad array of interventions across numerous sectors[1] — from governance and human rights to public infrastructure such as roads, water and sanitation systems, and electricity networks. ODA has also funded initiatives in agriculture and food security, environmental protection, education and training programs, poverty and inequality reduction efforts, and a wide range of health-related interventions, including health promotion, vaccination campaigns, the provision of medicines and diagnostic tools, and the strengthening of healthcare systems. ODA has also played a key role in responding to humanitarian emergencies arising from wars and natural disasters, providing humanitarian aid and conflict resolution initiatives. Interventions across these domains can profoundly shape health outcomes, influencing not only healthcare directly but also the upstream determinants of mortality and the broader social determinants of health. In fact, poverty reduction efforts alone have shown substantial impacts on lowering both adult and child mortality rates. Evidence from LMICs indicates that cash transfer programmes can decrease adult female mortality by around 20% and child mortality by 8%.[27] Even larger effects have been documented in certain settings—for instance, an 18% decline in under-five mortality in Brazil[15] and a 24% reduction across Latin America.[28] Education likewise plays a pivotal role in improving health outcomes. A global meta-analysis estimated that each additional year of schooling reduces adult mortality risk by approximately 1.9%.[29] Furthermore, children of mothers who complete secondary education face up to a 31% lower risk of dying before the age of five.[30] Nutritional interventions, particularly those addressing child malnutrition, have also been highly effective in reducing mortality.[31] Similarly, improvements in access to clean water, sanitation, and hygiene can cut child mortality by roughly 17%.[32] Beyond addressing the social determinants of health, ODA also plays a vital role in strengthening and sustaining health systems, supporting disease control and eradication efforts, and enhancing preparedness for outbreaks and epidemics. These contributions occur both bilaterally—through direct partnerships between donor and recipient countries—and multilaterally,[2] via funding to international organizations such as the World Health Organization (WHO), the United Nations Children's Fund (UNICEF), the Global Alliance for Vaccines and Immunization (GAVI), and the Global Fund to Fight AIDS, Tuberculosis and Malaria, among others.

The dismantling of USAID has triggered widespread alarm among humanitarian and development organizations, which have criticized the lack of adequate notice and the absence of a structured plan for a phased transition. At the same time, announced major aid cuts from the United Kingdom, France, Germany, the Netherlands, Belgium, and several other donors have signaled a systemic funding crisis across the humanitarian and development architecture.[4,33,34] This abrupt withdrawal leaves little scope for the implementation of adaptive strategies, rendering the most severe repercussions unavoidable, unless other public and private donors step up. The immediate humanitarian fallout is likely to be devastating, but the medium- and long-term consequences for global health, economic development, and social stability could be even more far-reaching.[5] Beyond disrupting ongoing service delivery and community resilience efforts, the decision risks dismantling institutional capacities painstakingly built over decades of international cooperation. Even with the previous level of resources, recovering from such a shock would be a long and painful. Such a downturn would not only erode the financial foundations of global solidarity but also threaten to reverse three decades of unprecedented gains in health, education, and poverty reduction. This contraction of development financing is unfolding amid an escalating global polycrisis—marked by overlapping health emergencies, climate shocks, geopolitical instability, and economic volatility—which magnifies both human vulnerability and systemic fragility. In this context, the withdrawal of donor support risks amplifying inequalities within and between countries, while undermining progress toward the Sustainable Development Goals. Although many LMICs have strengthened their leadership and capacity to advance their own development agendas—often through sustained collaboration with external partners—the scale and suddenness of current funding reductions make it unlikely that their negative impacts, in health and other sectors, can be effectively mitigated in the short to medium term, unless drastic response measures are taken.

This study has limitations. First, the causal interpretation of the statistical associations presented here warrants careful consideration. Although the application of sensitivity and triangulation analyses, combined with the use of the Bradford Hill criteria, provides substantial support for a causal interpretation, the study design cannot entirely preclude the influence of residual confounding or unmeasured contextual factors. Consequently, while the evidence is consistent with a causal relationship between ODA-supported interventions and mortality reduction, it should not be construed as definitive proof of causality. A second limitation concerns the reliance on aggregate-level (ecological) data. Analyses conducted at this level are inherently subject to the risk of ecological fallacy, meaning that associations observed at the country level may not necessarily hold true at the individual or household level. Nevertheless, the aggregate design also offers distinct analytical advantages. It enables the capture of broader, system-level dynamics and potential spillover effects that individual-level studies may fail to detect—particularly relevant in the context of national or regional development programmes where indirect benefits and network effects can play a critical role. Moreover, although this study employed a comprehensive set of covariate adjustments—derived from the established literature—and incorporated two-way fixed effects for both country and year, the possibility of residual confounding cannot be fully excluded. Sensitivity analyses using alternative adjustment sets and health outcomes, lend further support to the robustness of the findings and suggest that the estimated effects of ODA funding are unlikely to be substantially biased by omitted variables. Nevertheless, as in all observational analyses, unmeasured or context-specific factors may still contribute to the observed associations. Importantly, the sensitivity and triangulation analyses consistently revealed statistically significant relationships, and the magnitude of the estimated effects aligns with those reported in comparable studies, reinforcing both their internal validity and external plausibility. A further limitation concerns the study's inability to disentangle the specific interventions or causal pathways through which ODA per capita funding influences mortality outcomes. While the extensive sensitivity and triangulation analyses, as well as comparisons with prior empirical work, enhance confidence in the overall effect estimates, they cannot identify the relative contribution of individual ODA-funded initiatives. Only programme-specific evaluations or quasi-experimental studies could precisely assess the effectiveness of distinct interventions within the broader ODA portfolio. A further limitation pertains to the inherent uncertainty of the forecasted scenarios. This uncertainty arises primarily from two sources: first, the difficulty in predicting with precision which specific ODA programmes will be scaled back or terminated over the short, medium, and long term; and second, the challenge of incorporating potential exogenous shocks, such as geopolitical instability, economic downturns, or climate-related crises, that could substantially alter future trajectories. While these factors introduce variability into the projections, the primary objective of this analysis was not to capture every possible permutation of future aid patterns. Crucially, the analysis was not designed to forecast precise all-age or child mortality rates by 2030, but rather to quantify the relative divergence in mortality outcomes between three scenarios, isolating the effect of changes in the primary exposure variable: ODA funding. This comparative approach provides a robust framework for assessing the potential human costs associated with large-scale aid withdrawal, while acknowledging the uncertainty that necessarily accompanies forward-looking projections. Consequently, although exogenous factors such as macroeconomic fluctuations, climate-related shocks, or armed conflict may influence future mortality trends and cause deviations from our projections, the relative comparisons between scenarios—particularly the estimated mortality rate ratios and differences in the number of deaths—are expected to remain stable and robust. These comparative measures capture the directional impact of changes in ODA funding under consistent assumptions, thereby providing a reliable basis for interpreting the potential consequences of large-scale aid reductions.

Despite the limitations inherent to observational and forecasting approaches, the principal strength of this study lies in the breadth and rigor of its analytical framework. A comprehensive series of sensitivity analyses consistently confirmed the robustness of the results across alternative model specifications, variable selections, and estimation strategies. Moreover, the triangulation analyses integrating difference-in-difference and propensity-score matching estimators provided convergent evidence supporting the causal interpretation of the ex-post impact evaluation findings. The integration of these empirical results with externally validated microsimulation models further enhanced the internal consistency and external validity of the projected scenarios (appendix p. 33-40).

Our findings underscore the pivotal contribution of ODA funding to mortality reduction across low- and middle-income countries over the past two decades. The evidence indicates that an abrupt and severe contraction of this funding could have grave repercussions, potentially resulting in a global death toll approaching—or even exceeding—that of the COVID-19 pandemic. Even under mild defunding scenarios that merely continue current downward trends, substantial increases in preventable adult and child deaths—potentially amounting to tens of millions of excess deaths—are likely in the coming years. Beyond the immediate and dramatic human toll, these funding cuts risk reversing decades of hard-won progress in development and global health, particularly in the most vulnerable countries.

RESEARCH IN CONTEXT

We searched PubMed for reports examining the effects of official development assistance (ODA) on mortality worldwide. The search was conducted in two streams: one broadly addressing ODA and another explicitly focused on humanitarian assistance, to capture studies that might not have used ODA-specific descriptors. The ODA search string included the following descriptors:

International cooperation"[tiab] OR "International funding"[tiab] OR "international investment*"[tiab] OR "foreign investment*"[tiab] OR "global health investment*"[tiab] OR "global health funding"[tiab] OR "International aid"[tiab] OR "official development assistance"[tiab] OR "foreign aid"[tiab] OR "foreign assistance"[tiab] OR "development aid"[tiab] OR "ODA"[tiab] OR "Development assistance for health"[tiab]) AND ("Mortality"[tiab] OR "Life Expectancy"[tiab] OR "death*"[tiab] OR "Fatal*"[tiab]) AND ("Program Evaluation"[tiab] OR "Outcome Assessment"[tiab] OR "impact evaluation" OR "health effect" OR "causal effect" OR "effectiveness" OR "Evaluation" OR "Modelling")

An analogous search strategy was applied for humanitarian assistance (see Supplementary Material). Searches were conducted in titles, abstracts, and keywords. Of 399 records retrieved, 74 met the inclusion criteria, and after abstract screening, 12 were identified as directly relevant to the research question.

Across the reviewed literature, the effectiveness and impact of international cooperation and ODA on mortality have been evaluated through various modeling studies, primarily program-specific models of PEPFAR funding disruptions that show significant excess deaths among children, mothers, and those with HIV when funding is halted or frozen. Country-level longitudinal research further links child-health ODA to lower infant and under-5 mortality rates, while effects on maternal and neonatal outcomes are mixed and seem to depend on subsector composition, funding stability, and coordination. Overall, the evidence suggests that targeted, stable ODA contributes to mortality reduction, whereas sudden cuts or aid sanctions are associated with increased deaths and service coverage losses.

Despite this evidence, most studies concentrate on models or US-funded programs, leaving the effects of overall ODA, including differences among other donors, on mortality less understood. There is a need for research that combines retrospective data and projections across a broader set of countries, especially those most vulnerable to ODA shocks, to fully understand the effects of funding fluctuations on mortality.

Contributors

DR developed the study concept. GB and AFS collected the data. DR and RVRA accessed and verified the data. DR, GB, AFS, LS, RVRA designed the study investigation. AFS did the retrospective data analysis. RVRA did the forecasting analysis. DR accessed and verified the codes and routines. DR wrote the first draft of the manuscript, with the support of AFS, RVRA, DP, CM, GB. All authors contributed to data interpretation and reviewed and edited the manuscript. All authors consented to submit the manuscript, with DR taking responsibility for the final decision to submit it. DR secured the funding, coordinated and supervised the study process.

Declaration of interests

We declare no competing interests.

Data sharing statement

The data used are public and available from the OECD CRS (https://data-explorer.oecd.org/) the Global Burden of Disease (https://vizhub.healthdata.org/gbd- results/), WHO (https:// platform.who.int/mortality), and the World Bank (https://data. worldbank.org/region/world).

Acknowledgments

We acknowledge support from RF Catalytic Capital, Inc (RFCC grant FA-01713), and from grant CEX2023-0001290-S funded by MCIN/AEI/10.13039/501100011033 and support from Generalitat de Catalunya through the CERCA Program. DMC, DR, and LS acknowledge funding from the Medical Research Council (MR/Y004884/1).

GB acknowledges funding from the EU's Horizon Europe research and innovation programme under grant agreement 101057114.

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TABLES AND FIGURES

Figure 1. ODA funding per capita by quartiles across the selected 93 Low- and Middle-Income Countries in A) 2002 and B) 2021, Age-Standardized Mortality Rates by 1,000 Inhabitants in C) 2002 and D) 2021, Under-five Mortality Rates by 1,000 live births in E) 2002 and F) 2021.

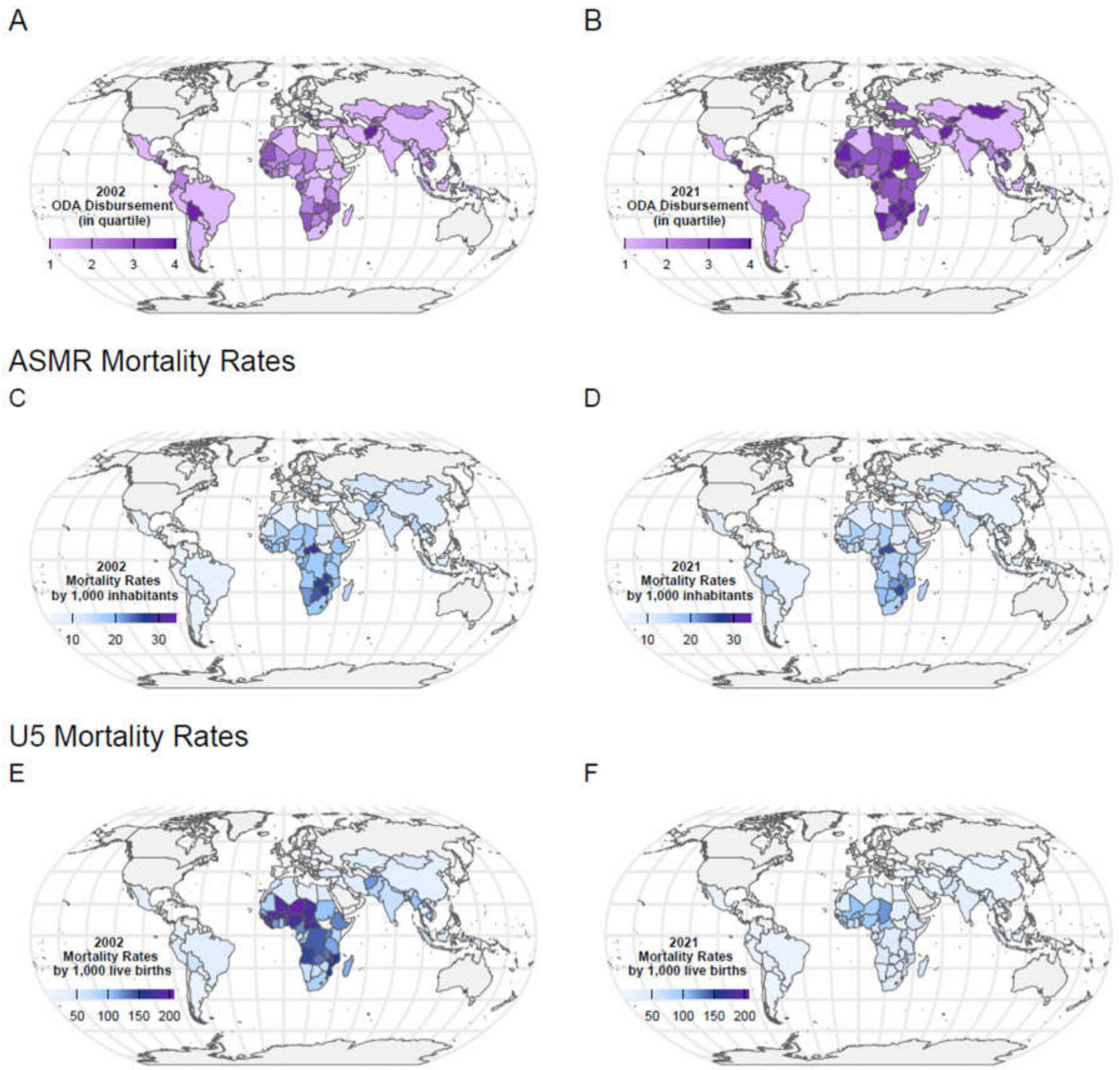

Table 1: Descriptive statistics of mortality rates, ODA funding, and demographic, socioeconomic, and health-care-related variables in the selected countries (n=93) from 2002 to 2021.

	2002	2011	2021	Change from 2002 to 2021
Mortality rate				
Overall ASMR per 1000 population	11.5 (3.5)	9.7 (2.6)	10.1 (3.4)	-12%
Children younger than 1 years per 1000 live births	51.1 (25.3)	39.3 (22.8)	28.2 (16.9)	-45%
Children younger than 5 years per 1000 live births	73.6 (45.6)	54.3 (37.0)	37.8 (26.4)	-49%
ODA amount (constant US$)				
Average funding per country (in millions of US$)	283.1 (301.2)	681.5 (815.5)	910.4 (900.3)	+222%
ODA per capita	22.7 (22.8)	40.8 (36.6)	47.5 (44.3)	+109%
Population size				
All 93 countries	4,756,821,733	5,501,385,778	6,283,142,334	+32%
Other covariates				
Economic downturn (%)	4.63 (5.98)	4.23 (6.82)	5.25 (5.40)	+13%
GDP per capita PPP (US$)	6,435.6 (5,084.7)	9,152.22 (7,290.1)	10,423.4 (7,791.6)	+62%
Gini index	0.60 (0.07)	0.58 (0.08)	0.57 (0.07)	-5%
Fertility Rate	3.96 (1.75)	3.56 (1.59)	3.12 (1.35)	-21%
Adequate Sanitation (% population)	49.9 (30.5)	58.9 (29.5)	66.8 (29.0)	+34%
Primary Education (% population)	58.2 (26.2)	63.2 (26.1)	68.7 (26.1)	+18%
Education expenditure (% in public institutions)	87.1 (11.6)	89.1 (10.1)	88.6 (11.0)	+2%
Basic water coverage (% population)	70.3 (20.8)	76.8 (18.3)	82.8 (16.5)	+18%
Military expenditure (% GDP)	2.01 (1.31)	1.81 (1.12)	1.94 (1.81)	-3%
Health expenditure (% GDP)	5.03 (2.07)	5.47 (2.31)	6.36 (3.08)	+26%
Nurse rate per 1,000 population	1.82 (2.01)	2.23 (2.33)	2.46 (2.10)	+35%
Hospital bed rate per 1,000 population	1.90 (1.74)	2.04 (1.97)	2.02 (1.94)	+6%
Conflict or war at country	0.08 (0.18)	0.05 (0.11)	0.05 (0.11)	-38%

Note: Data are presented as mean (SD), percentage, or absolute number. Mortality (all ages) is expressed per 1000 population, and mortality for children younger than 5 years and 1 year are per 1000 live births. ASMR=Age-Standardized Mortality Rate. ODA stands for the Official Development Assistance. GDP values are reported in constant US dollars, adjusted for purchasing power parity (PPP).

Table 2: Adjusted rate ratios from multivariable fixed-effects Poisson models with robust standard errors for the association between mortality rates and annual ODA per capita in the selected countries (n=93) from 2002 to 2021.

	Mortality		
	Overall (ASMR)	Child - Under 1 years	Child - Under 5 years
ODA per capita			
Baseline (mean $ 5.83, 0–12.35)	base	base	base
Low (mean $19.83, 12.36–28.70)	0.898***	0.860***	0.831***
	[0.840,0.959]	[0.779,0.949]	[0.749,0.923]
Intermediate (mean $38.05,28.71–50.39)	0.818***	0.720***	0.669***
	[0.746,0.897]	[0.632,0.820]	[0.581,0.771]
High (mean $91.11, 50.40 or more)	0.771***	0.672***	0.606***
	[0.697,0.853]	[0.553,0.817]	[0.489,0.752]
Control variables			
Economic downturn	1.036**	0.993	0.988
	[1.003,1.070]	[0.903,1.091]	[0.881,1.107]
GDP per capita PPP	0.945***	0.808***	0.796***
	[0.915,0.976]	[0.748,0.873]	[0.737,0.859]
Gini Index	1.040	1.057	1.047
	[0.990,1.093]	[0.958,1.166]	[0.949,1.154]
Fertility Rate	0.992	1.048	1.068*
	[0.934,1.054]	[0.974,1.128]	[0.992,1.151]
Adequate Sanitation	0.951*	0.915	0.917
	[0.901,1.004]	[0.821,1.020]	[0.819,1.028]
Primary education	0.970	0.933	0.930
	[0.929,1.014]	[0.852,1.023]	[0.843,1.026]
Education expenditure	0.958*	0.919***	0.893***
	[0.915,1.002]	[0.869,0.972]	[0.836,0.954]
Basic Water Coverage	0.968*	0.893***	0.874***
	[0.933,1.004]	[0.859,0.929]	[0.836,0.915]
Military expenditure	1.055*	1.094**	1.094**
	[0.998,1.116]	[1.018,1.175]	[1.006,1.189]
Health expenditure	0.938*	0.970	0.970
	[0.874,1.008]	[0.903,1.043]	[0.899,1.046]
Nurses rate	0.886***	0.853**	0.835***
	[0.854,0.920]	[0.749,0.971]	[0.730,0.955]
Hospital beds rate	0.997	1.033	1.039
	[0.975,1.020]	[0.972,1.097]	[0.977,1.105]
Conflict or war at country	1.051	1.257***	1.288***
	[0.878,1.256]	[1.080,1.464]	[1.074,1.544]
Time trend control			
y2009	1.006	1.052***	1.054***
	[0.986,1.026]	[1.023,1.082]	[1.021,1.087]
y2015	0.966***	0.917***	0.893***
	[0.941,0.992]	[0.878,0.957]	[0.850,0.938]
y2020	1.017	0.766***	0.746***
	[0.984,1.051]	[0.733,0.801]	[0.711,0.782]
y2021	1.138***	0.748***	0.718***
	[1.076,1.204]	[0.687,0.814]	[0.660,0.780]
Number of observations	1,851	1851	1,851
Number of countries	93	93	93

Note: Data are presented as rate ratio coefficients (95% CI). In the row headers, values represent the mean (range: lowest to highest). Time shocks control for specific years associated with economic or health crises (2009, 2015, 2020, and 2021). ASMR = age-standardized mortality rate. ODA stands for the Official Development Assistance. The symbols '***' , '**' and '*' denote significance at 1%, 5%, and 10%, respectively.

Table 3: Adjusted rate ratios from multivariable fixed-effects Poisson models with robust standard errors for the association between mortality rates for specific causes of death and annual ODA per capita in the selected countries from 2002 to 2021.

	Tuberculosis	HIV/AIDS	Maternal	Lower respiratory infections	Nutritional deficiencies	Diarrhoeal diseases	Malaria	Neglected tropical diseases
Baseline (mean $ 5.83, 0–12.35)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low (mean $19.83, 12.36–28.70)	0.797	0.807	0.879	0.796	0.750	0.741	0.770	0.772
	[0.693,0.917]	[0.689,0.946]	[0.800,0.966]	[0.697,0.909]	[0.551,1.019]	[0.584,0.940]	[0.697,0.851]	[0.695,0.858]
Intermediate (mean $38.05,28.71–50.39)	0.652	0.439	0.733	0.637	0.514	0.528	0.568	0.576
	[0.539,0.788]	[0.367,0.525]	[0.617,0.871]	[0.540,0.751]	[0.363,0.727]	[0.406,0.687]	[0.472,0.684]	[0.477,0.696]
High (mean $91.11, 50.40 or more)	0.608	0.304	0.704	0.575	0.440	0.451	0.443	0.463
	[0.493,0.750]	[0.239,0.388]	[0.574,0.862]	[0.469,0.705]	[0.299,0.646]	[0.331,0.613]	[0.348,0.564]	[0.363,0.590]
Number of observations	1851	1851	1851	1851	1851	1851	1520	1851
Number of countries	93	93	93	93	93	93	76	93

Note: Data are presented as rate ratio coefficients (95% CI). All models were adjusted for covariates (table 1).

Table 4: Numbers of avoidable deaths from the comparison of the severe and mild defunding forecast scenarios of ODA defunding versus business-as-usual scenario in the selected countries (n=93) from 2025 to 2030.

	Severe Defunding Scenario		Mild Defunding Scenario	
Year	Number of deaths at all ages	Number of deaths children younger than 5 years	Number of deaths at all ages	Number of deaths children younger than 5 years
2025	695,238 [480,896-925,512]	224,277 [142,710-314,979]	695,238 [480,896-925,512]	224,277 [142,710-314,979]
2026	4,486,968 [3,215,658-5,835,758]	1,119,987 [843,775-1,412,122]	1,314,371 [843,431-1,780,633]	381,966 [280,347-482,880]
2027	4,430,867 [3,174,936-5,761,892]	1,074,327 [808,843-1,354,556]	1,492,358 [907,708-2,096,265]	419,116 [294,948-540,145]
2028	4,375,551 [3,135,291-5,691,126]	1,030,665 [778,165-1,300,448]	1,760,884 [1,033,766-2,511,910]	484,834 [320,793-645,168]
2029	4,320,847 [3,095,604-5,619,549]	988,676 [744,281-1,247,281]	1,950,490 [1,251,529-2,652,479]	492,752 [342,570-642,641]
2030	4,266,854 [3,056,869-5,549,646]	948,401 [714,627-1,196,828]	2,203,076 [1,480,686-2,914,731]	522,844 [373,340-670,317]
Cumulative 2025-2030	22,576,325 [16,262,532-29,293,416]	5,386,333 [4,060,147-6,837,148]	9,416,417 [6,199,048-12,642,581]	2,525,789 [1,819,015-3,199,818]

Data are number of deaths [95% uncertainty intervals]

Supplementary Materials

The Impact of Two Decades of Humanitarian and Development Assistance and the Projected Mortality Consequences of Current Defunding to 2030: Retrospective Evaluation and Forecasting Analysis

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PART I - OVERVIEW OF DATA SOURCES AND OVERALL METHODOLOGICAL APPROACH

1. DATASET

The data used in this study were obtained from multiple organizational platforms, as detailed in Web Table 1. All variables are aggregated at the country or territory level.

For some covariates, data were not available for certain countries across the full 2002–2021 period. In these cases, we applied an exponential decay method to extrapolate values when at least two time points were available; countries with only a single observation for a variable were excluded from analysis. Importantly, none of the outcome variables (mortality rates) or the exposure variable (ODA amounts) were interpolated or extrapolated.

Overall, the inclusion of carefully extrapolated covariates improved the control of confounding and enhanced the precision of both retrospective and predictive models.

Web Table 1. Data sources and description of variables, 2002-2021.

Variable	Years	Units of Analysis	Source
Mortality	1980 to 2021	Country/Territory level	GBD
ODA disbushment amount	1960 to 2024	Country/Territory level	OECD
Population estimates	1980 to 2021	Country/Territory level	GBD
GDP per capita PPP (US$)	1960 to 2023	Country/Territory level	World Bank
Current health expenditure (% of GDP)	2000 to 2022	Country/Territory level	WHO
Fertility rate	1990 to 2021	Country/Territory level	WHO
Gini Index	1960 to 2023	Country/Territory level	World Bank
Education expenditure (% of GDP)	2000 to 2023	Country/Territory level	UNESCO
Primary education (% population)	1970 to 2023	Country/Territory level	UNESCO
Piped Water (% population)	2000 to 2022	Country/Territory level	WHO
Adequate sanitation (% population)	2000 to 2022	Country/Territory level	WHO
Hospital bed rate (per 1,000 population)	1970 to 2021	Country/Territory level	WHO
Nurse rate (per 1,000 population)	1990 to 2021	Country/Territory level	WHO
Military expenditure (% of GDP)	1960 to 2023	Country/Territory level	SIPRI
Conflict or war at country	1960 to 2024	Country/Territory level	V-Dem

Note: GDB = Global Burden of Disease. ODA stands for the Official Development Assistance. GDP = Gross Domestic Product. PPP = Purchasing Power Parity. UNESCO = United Nations Educational, Scientific and Cultural Organization. WHO = World Health Organization. SIPRI = Stockholm International Peace Research Institute.

1.1 Analytical Scope: Selected Time Horizons for Retrospective and Forecasting Approaches

The full study period extends from 2002 to 2030 and is structured into two components:

- Retrospective Analysis (2002–2021):

The year 2002 marks the beginning of the retrospective series, as it represents the first year with available data on actual ODA disbursements at the country level. Although obligation data have existed for earlier years, these do not ensure that funds were effectively spent or disbursed. The endpoint, 2021, corresponds to the most recent year for which Global Burden of Disease (GBD) mortality estimates are available.

- Forecasting Analysis (2022–2030):

The projection period begins in 2022 and extends through 2030. The year 2030 was selected to coincide with the target deadline for achieving the Sustainable Development Goals (SDGs).

1.2 Rationale for using ODA disbursement per capita

We opted to use ODA disbursements per capita because this measure captures the amount of aid that was effectively transferred to each country in relation to its population size. Adjusting for population is essential for ensuring comparability across countries and over time, as it normalizes differences in demographic scale and provides a more accurate sense of the potential influence of aid on individuals. This per-capita approach also enables a more meaningful interpretation of aid intensity, facilitating the assessment of whether higher levels of support correlate with improved health outcomes.

1.3 Selection of the 93 Countries included in the analysis

From a total of 204 countries and territories worldwide, we selected 93 low-, lower-middle-, and upper-middle-income countries (LICs, LMICs, and UMICs) for inclusion in this study.

The 71 high-income countries (HICs) were excluded because they are not the primary focus of ODA assistance, which is directed toward low- and middle-income settings. Moreover, HICs differ substantially in socioeconomic and health system characteristics, and including them would reduce comparability and weaken the internal validity of the analysis.

Additional exclusions were made to ensure data consistency and methodological rigor. Countries that are not recipients of ODA were omitted, since disbursement data are available for only about 130 LMICs. We also removed Small Island Developing States (SIDS) due to their unique geographic, demographic, and economic profiles, as well as their distinct ODA receipt dynamics, which differ markedly from those of continental LMICs.

The Syrian Arab Republic was excluded because the magnitude and conflict-driven nature of its ODA inflows are extreme outliers in comparison with other countries. South Sudan was removed because it is recognized as an independent country only for part of the study period, making it impossible to construct a consistent historical series.

A small set of countries - Bhutan, Bulgaria, Costa Rica, Eritrea, Panama, Romania, Russia, Turkmenistan, Venezuela, and Yemen - were also excluded due to missing data in key covariates, which would compromise the integrity of the statistical models.

Together, these exclusions were essential to maintain a coherent, comparable, and internally valid analytical sample, ensuring that the study results accurately reflect the associations under investigation.

1.4 The Importance of Using Categorical Variables

In this study, we chose to work with categorized variables for several reasons. First, categorical measures provide clearer and more actionable thresholds, which are particularly useful for policy-oriented interpretation. Second, they help reduce the influence of extreme or over-dispersed values in both observed and extrapolated data for the independent variables, including the main exposures and covariates. Third, and most importantly, categorizing the main exposure into multiple levels allows for a more transparent evaluation of dose–response patterns, especially when the underlying relationship is not linear.

In this context, the dose–response analysis examines how different levels of ODA per capita (the “dose”) correspond to variations in age-standardized mortality rates (the “response”). This approach, widely applied in epidemiology and public health,[1-10] helps determine whether higher levels of programme coverage are associated with progressively stronger effects, thereby strengthening causal interpretation of the observed associations.

Furthermore, the use of quartiles of ODA disbursement per capita, specifically among low-income countries, reflects the strategic priorities of donor agencies, which concentrate efforts in these settings.

This classification better captures the operational context in which ODA is most relevant and facilitates a more accurate understanding of funding distribution patterns. Restricting the reference group to low-income countries also avoids distortions that could arise from comparing these countries with middle- or high-income settings, which typically receive less external assistance and have greater domestic fiscal capacity.

PART II – RETROSPECTIVE ANALYSIS

2. EMPIRICAL METHODS

2.1. Poisson regression – Fixed Effects

We estimate fixed-effects models using Poisson regressions with robust standard errors to retrospectively assess and forecast the impact of ODA disbursements on health outcomes. The equation describing the relationship between mortality rates and the covariates is given by:

$$log\ (\mu_{it}) \ = \log(pop_{it}) + \sum_{q=0}^{3} \beta_q ODA_{qit} + \sum_{s=4}^{8} \beta_s T_y + \sum_{k=9}^{18} \beta_k X_{kit} + \alpha_i + u_{it}$$

where:

- t denotes the year, i represents an individual country, and q indexes the categories of per capita ODA amounts.
- μ_{it} represents the expected number of events of interest, death count, observed in country i in year t. The death numbers used in this study are:
  - Age-standardized (i.e., all ages and all causes) – main outcome,
  - by different age groups, including child mortality (children under five per 1,000 live births and infants under one year per 1,000 live births).
  - by causes of deaths linked to ODA priorities and poverty-related conditions based on existing literature.[11–21] These were defined using the International Classification of Diseases, 10th revision (ICD-10), and included:
    - tuberculosis (A15–A19, B90),
    - HIV/AIDS (B20–B24),
    - maternal causes (O00–O99),
    - lower respiratory infections (J09–J22, P23, U04),
    - malnutrition (E00–E02, E40–E46, E50, D50–D53, D64.9, E51–E64),
    - diarrheal diseases (A00, A01, A03, A04, A06–A09), malaria (B50–B54, P37.3, P37.4), and
    - neglected tropical diseases (NTDs, ICD-10: A66, A67, A69.1, A71, A77, A78, A79, B55–B56, B57, B65, B66, B73–B74, B76–B77, B79, B83, B88.0, B88.1, B88).
- pop_{it} are the population of interest size in the time *t* for the observation *i*.
- ODA_{qit} are the ODA per capita in categories (quartile, 4 groups) observed at the country i in year t, with associated coefficients β_q. The categories are defined as follows:
  - $q = 0$: Extreme low or no ODA per capita (baseline ≈ US$ 5.83 per capita),
  - $q = 1$: Low (25th percentile ≈ US$ 19.83 pc),
  - $q = 2$: Intermediate (50th percentile or median ≈ US$ 38.05 pc), and
  - $q = 3$: High (75th percentile ≈ US$ 91.11 pc).
- T_y are dummy variables representing previous crisis events with coefficients $\beta_4, \beta_5, .., \beta_8$ from the specific years *y*, with y= 2009, 2015, 2020 and 2021 respectively.
- X_{kit} represents different control covariates, each one with a coefficient of β_k (Economic downturn, GDP per capita PPP, Gini Index, Fertility Rate, Adequate Sanitation, Primary education, Education expenditure, Basic Water Coverage, Military expenditure, Health expenditure, Nurses rate, Hospital beds rate, and Conflict or war at country).
- α_i is the fixed effect (time-invariant) term for each country/territory, and u_{it} was the error term.

3. RESULTS

This section describes the sensitivity and triangulation analyses[22] performed to ensure the robustness of our findings. The selection of these analyses was not arbitrary; rather, it was informed by well-established principles of causal inference widely recognized in the health and epidemiological literature, particularly the Bradford Hill criteria.

In epidemiology, causal inference is traditionally guided by several criteria, the most enduring and influential of which are the Bradford Hill criteria.[23] These include: (1) Strength of the association, (2) Consistency, (3) Specificity, (4) Temporality, (5) Biological gradient, (6) Plausibility, (7) Coherence, (8) Experiment, and (9) Analogy. Our analytical strategy was designed to reinforce, as comprehensively as possible, the causal interpretation of the statistical associations observed in this study in light of these nine principles. A summary of how each criterion was addressed is presented in the Web Table 2 below.

Web Table 2. Analytical strategy used according to Bradford Hill`s criteria.

Bradford Hill`s criteria		Analytical strategy used in the paper
Criteria	**Meaning**	
1. Strength of the association	The stronger the association between exposure and effect (e.g., high relative risk), the more likely it is to be causal.	The strong association and statistical significance observed between higher ODA per capita disbursements and reductions in overall mortality satisfy Bradford Hill's first criterion, strength of association.
2. Consistency	If different studies, across various populations and settings, observe the same association, it strengthens the causal hypothesis.	To assess the external validity of our findings, we stratified the models by countries' income classifications (Low-Income, Lower-Middle-Income, and Upper-Middle-Income; Web Table 10) and further disaggregated estimates by sex and detailed age groups (Web Tables 12, 13 and 14). These heterogeneity analyses showed that the relationship between ODA disbursements and reductions in overall mortality is broadly consistent across economic settings and population subgroups.
3. Specificity	If a specific exposure leads to a single effect (or a limited number of effects), this supports causality.	We re-estimated the models using age-standardized mortality from different causes of death, obtaining stronger effects in causes – such as HIV/AIDS – where ODA is expected to have more impact (see Web Table 11).
4. Temporality	The exposure must precede the effect in time (a fundamental principle for establishing causality).	The use of longitudinal panel data spanning two decades allows for a rigorous evaluation of temporal relationships. In addition, we tested alternative specifications for the time variables to determine whether the results might be influenced by temporal confounding or artifacts of model specification (Web Table 8). The findings remained stable across these variations, providing support for temporal consistency. These checks, together with country fixed-effects models and other strategies to isolate confounding influences, help to better identify the relationship between ODA per capita and changes in mortality over time.
5. Biological gradient	(Dose-Response Relationship) – If increased exposure levels correspond to a greater risk of the effect, this supports causality.	Using categorical variables allowed us to examine dose–response patterns across increasing levels of intervention intensity (from lowest to highest) and their relationship with mortality. A clear gradient emerged, with higher coverage levels associated with greater reductions in mortality across nearly all outcomes considered. In addition, we estimated models using a continuous measure of ODA per capita disbursement (Web Tables 6 and 7). The consistency in the direction and magnitude of the effects across both categorical and continuous specifications provides strong evidence of a dose–response relationship, consistent with Bradford Hill's biological gradient criterion.

Bradford Hill`s criteria		Analytical strategy used in the paper
Criteria	**Meaning**	
6. Plausibility	The proposed causal relationship should align with existing scientific knowledge and biological mechanisms.	The plausibility of ODA's impact on reducing mortality is outlined in the conceptual framework presented in Web Figure 2 (Research in Context, page 25 of the manuscript) and is well supported by existing literature, with several prior studies demonstrating similar effects.[11–13,16–21,25,26]
7. Coherence	The relationship should be consistent with what is already known about the disease or effect being studied.	This criterion refers to the replication of a causal association across different studies, populations, time periods, and methodological approaches. Numerous studies examining the relationship between ODA and similar health outcomes are cited in the Discussion section, further supporting this dimension of evidence. By applying multiple analytical strategies, including alternative specifications of the exposure variable (from categorical levels to continuous measures), and triangulation using DiD combined with PSM, we strengthen the coherence and consistency of our findings. The convergence of results across methods that rely on different assumptions and are subject to distinct sources of bias reinforces the overall causal interpretation.
8. Experiment	If experiments (such as clinical trials or natural experiments) confirm the association, this strengthens the causal inference.	Although this criterion recognizes that randomized experiments typically provide the strongest basis for causal inference, it also notes that even randomized trials can produce weak causal conclusions if their design is inadequate. Importantly, the criterion does not preclude the possibility of drawing causal inferences from quasi-experimental or observational designs. When rigorously executed, applying established causality principles and incorporating extensive sensitivity and triangulation analyses—well-designed observational studies can yield credible causal evidence.[27] In our case, the combination of DiD with PSM (triangulation analysis; see Web Tables 16 and 17) functions as a quasi-experimental strategy that approximates the conditions of a randomized controlled trial. Matching reduces selection bias by balancing observable characteristics, while the DiD framework accounts for time-invariant unobserved confounding through differencing. Together, these methodological features enhance the internal validity of the estimates and support a causal interpretation of the association between ODA disbursements and reductions in mortality.
9. Analogy	If a similar association has been demonstrated between another factor and a comparable effect, it may suggest causality.	The effects of ODA programs in other countries have been well documented in previous research, as summarized in the Research in Context section of the manuscript (page 16). Our findings are further supported by the criterion of analogy, given that similar international aid initiatives have shown beneficial impacts on population health outcomes in low- and middle-income countries.[19] The consistent direction and magnitude of our estimates, confirmed through multiple robustness checks, including fixed-effects models, and DiD with PSM, parallel evidence from studies evaluating the effects of other targeted financial assistance programs on health indicators. Moreover, the association we observe between higher ODA disbursements and lower overall mortality is analogous to the well-documented impacts of major global health initiatives such as the Global Fund and PEPFAR.[11,19] This alignment with established evidence from comparable large-scale development programs strengthens the plausibility and credibility of our conclusions.

3.1. Fit and sensitivity tests

Concerning our study on the effect of ODA on overall mortality, we conducted a series of sensitivity analyses to ensure the robustness of our findings.

As a first step, we applied the Hausman test to determine the most appropriate model specification, random or fixed effects, for the overall mortality data. Based on several goodness-of-fit criteria, including the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and Log-likelihood values, the fixed-effects model proved to be the most suitable for analyzing the effects of ODA per capita on mortality (see Web Table 3).

Second, we altered the model specifications by comparing pure cross-sectional regressions (without the panel design), with models including only country fixed effects, country/year fixed effects, and fully adjusted versions (see Web Table 4).

Third, to evaluate the influence of ODA categorization, we re-estimated the models using alternative threshold definitions, dummy, tercile, quintile, and decile classifications (see Web Table 5). Varying the categorization of ODA per capita enabled us to test whether (1) modeling ODA as four categories while other covariates remained binary inflated the estimated effects, and (2) modifying the thresholds of the categorical exposure variable substantially altered the observed results.

Fourth, we estimated models treating ODA per capita as a continuous variable (see Web Tables 6 and 7). The findings were consistent with those of the main specification, confirming the robustness of the observed relationships.

Fifth, to assess the role of temporal effects, we tested alternative specifications for the time dummies (see Web Table 8).

Sixth, we explored heterogeneity by conducting stratified analyses according to countries' income classifications (Low-Income, Lower-Middle-Income, and Upper-Middle-Income; see Web Table 10). Additional stratified analyses were performed by sex and by female age groups to capture potential gender- and age-specific patterns (see Web Tables 12–14).

Seventh, we performed specificity tests. These analyses focused exclusively on health-related ODA funding and its association with mortality from specific disease categories (HIV/AIDS, malaria, maternal health, and others) (see Web Table 11).

Eighth, to further assess the robustness and substantive relevance of our findings, we estimated multivariable fixed-effects Poisson models examining the association between age-standardized all-cause mortality and total annual per-capita ODA funding (see Web Table 15). This analysis offers an additional layer of triangulation by testing the extent to which the observed associations persist when considering a broader and more aggregated measure of development assistance.

Overall, given that our main results remained consistent across this broad range of sensitivity analyses, we conclude that the findings and inferences of this study are robust and stable.

Web Table 3. Hausman test between fixed effect and random effect Poisson models – Overall Mortality.

	Overall Mortality	
	Fixed Effect	**Random effect**
Number of observations	1,851	1,851
Number of countries	93	93
Log likelihood	-3,437,559	-3,438,993
Akaike information criterion (AIC)	6,875,158	6,878,030
Bayesian information criterion (BIC)	6,875,268	6,878,152
Hausman test	**$\chi 2$ =283.83; p-value= 0.000**	

Web Table 4. Rate Ratios from the fixed effect Poisson models for the association between overall mortality rates with ODA per capita across adjustment levels, from 2002-21 in selected countries (n=93).

	Poisson			
	Unadjusted	**Country FE**	**Country/Year FE**	**Adjusted**
ODA per capita				
Baseline (mean $ 5·83, 0–12·35)	base	base	base	base
Low (mean $19·83, 12·36–28·70)	1.199***	0.893***	0.894***	0.898***
	[1.138,1.262]	[0.844,0.946]	[0.844,0.948]	[0.840,0.959]
Intermediate (mean $38·05,28·71–50·39)	1.337***	0.815***	0.816***	0.818***
	[1.275,1.401]	[0.743,0.895]	[0.738,0.902]	[0.746,0.897]
High (mean $91·11, 50·40 or more)	1.373***	0.781***	0.782***	0.771***
	[1.300,1.451]	[0.705,0.866]	[0.700,0.873]	[0.697,0.853]
Control variables				
Economic downturn				1.036**
				[1.003,1.070]
GDP per capita PPP				0.945***
				[0.915,0.976]
Gini Index				1.040
				[0.990,1.093]
Fertility Rate				0.992
				[0.934,1.054]
Adequate Sanitation				0.951*
				[0.901,1.004]
Primary education				0.970
				[0.929,1.014]
Education expenditure				0.958*
				[0.915,1.002]
Basic Water Coverage				0.968*
				[0.933,1.004]
Military expenditure				1.055*
				[0.998,1.116]
Health expenditure				0.938*
				[0.874,1.008]
Nurses rate				0.886***
				[0.854,0.920]
Hospital beds rate				0.997
				[0.975,1.020]
Conflict or war at country				1.051
				[0.878,1.256]
Time trend control				
y2009			1.027***	1.006
			[1.015,1.038]	[0.986,1.026]
y2015			0.933***	0.966***
			[0.896,0.971]	[0.941,0.992]
y2020			0.971	1.017
			[0.906,1.042]	[0.984,1.051]
y2021			1.049	1.138***
			[0.954,1.154]	[1.076,1.204]
Number of countries	2002	2002	2002	1851
Number of countries		101	101	93

Source: Author's data analysis for 1,851 observations – 93 countries/territories in the World, from 2002 to 2021.
Note: Data are presented as rate ratio coefficients (95% CI). In the row headers, values represent the mean (range: lowest to highest). Time shocks control for specific years associated with economic or health crises (2009, 2015, 2020, and 2021). ASMR = age-standardized mortality rate. ODA stands for the Official Development Assistance. The symbols '***' , '**' and '*' denote significance at 1%, 5%, and 10%, respectively.

Web Table 5. Rate Ratios from the fixed effect Poisson models for the association between overall mortality rates with ODA per capita categorization (different types), from 2002-21.

	ODA per capita categorization			
	Median	**Terciles**	**Quintiles**	**Deciles**
ODA per capita				
1st dummy (baseline – below median)	base			
2nd dummy (median and above)	0.896*** [0.840,0.955]			
1st tercile (baseline)		base		
2nd tercile		0.920*** [0.873,0.968]		
3rd tercile		0.847*** [0.792,0.905]		
1st quintile (baseline)			base	
2nd quintile			0.922** [0.863,0.985]	
3rd quintile			0.849*** [0.780,0.924]	
4th quintile			0.789*** [0.714,0.871]	
5th quintile			0.773*** [0.694,0.861]	
1st decile (baseline)				base
2nd decile				0.984 [0.930,1.041]
3rd decile				0.917* [0.835,1.007]
4th decile				0.885** [0.800,0.980]
5th decile				0.844*** [0.758,0.940]
6th decile				0.795*** [0.701,0.903]
7th decile				0.770*** [0.672,0.883]
8th decile				0.734*** [0.644,0.836]
9th decile				0.739*** [0.641,0.852]
10th decile				0.722*** [0.634,0.822]
Control variables				
Economic downturn	1.035** [1.004,1.068]	1.032* [0.998,1.067]	1.032* [0.999,1.067]	1.030* [0.998,1.064]
GDP per capita PPP	0.947*** [0.913,0.982]	0.941*** [0.911,0.971]	0.952*** [0.920,0.985]	0.952*** [0.922,0.983]
Gini Index	1.045* [0.994,1.099]	1.040 [0.987,1.095]	1.042 [0.991,1.095]	1.039 [0.988,1.092]
Fertility Rate	0.998 [0.938,1.061]	0.995 [0.936,1.058]	0.989 [0.931,1.050]	0.989 [0.931,1.050]
Adequate Sanitation	0.947* [0.887,1.010]	0.952* [0.898,1.009]	0.945* [0.889,1.003]	0.946** [0.896,0.999]
Primary education	0.959* [0.914,1.005]	0.967 [0.928,1.009]	0.961* [0.923,1.001]	0.966* [0.930,1.003]
Education expenditure	0.957*	0.956*	0.963*	0.962*

	[0.915,1.002]	[0.908,1.007]	[0.922,1.005]	[0.921,1.005]
Basic Water Coverage	0.968*	0.971	0.965**	0.966**
	[0.932,1.005]	[0.934,1.009]	[0.933,0.998]	[0.933,0.999]
Military expenditure	1.051*	1.065	1.053	1.051*
	[0.992,1.114]	[0.985,1.152]	[0.990,1.121]	[0.996,1.109]
Health expenditure	0.940*	0.941	0.940*	0.938*
	[0.875,1.009]	[0.875,1.012]	[0.874,1.012]	[0.873,1.009]
Nurses rate	0.887***	0.887***	0.886***	0.886***
	[0.855,0.920]	[0.855,0.920]	[0.854,0.919]	[0.854,0.920]
Hospital beds rate	0.994	0.992	0.995	0.997
	[0.974,1.015]	[0.969,1.016]	[0.972,1.019]	[0.975,1.020]
Conflict or war at country	1.081	1.048	1.036	1.034
	[0.903,1.293]	[0.883,1.243]	[0.868,1.237]	[0.863,1.238]
Time trend control				
y2009	1.005	1.003	1.010	1.010
	[0.987,1.023]	[0.986,1.020]	[0.989,1.031]	[0.989,1.032]
y2015	0.962***	0.961***	0.966***	0.967***
	[0.936,0.989]	[0.935,0.988]	[0.943,0.989]	[0.944,0.990]
y2020	1.009	1.011	1.022	1.027
	[0.975,1.043]	[0.976,1.048]	[0.987,1.059]	[0.991,1.064]
y2021	1.127***	1.126***	1.137***	1.141***
	[1.062,1.197]	[1.062,1.194]	[1.074,1.203]	[1.079,1.207]
Number of observations	1851	1851	1851	1851
Number of countries	93	93	93	93

Source: Author's data analysis for 1,851 observations – 93 countries/territories in the World, from 2002 to 2021.
Note: Data are in Rate Ratio (RR) coefficients (95% CI) unless otherwise specified. The confidence intervals are in parentheses. Time shocks are controls for specific years of economic and health crisis (2008, 2015, 2019, 2020 and 2021). The symbols '***', '**' and '*' denote significance at 1%, 5%, and 10% respectively.

Web Table 6. Rate Ratios from the fixed effect Poisson models for the association between overall mortality rates with ODA per capita using all continuous variables (except year), from 2002-21.

	Poisson			
	Unadjusted	**Adjusted$1**	**Adjusted$10**	**Adjusted$100**
ODA per capita	0.998***	0.999***	0.987***	0.876***
	[0.996,0.999]	[0.998,1.000]	[0.978,0.996]	[0.803,0.956]
Control variables				
Economic downturn		1.001	1.001	1.001
		[0.999,1.003]	[0.999,1.003]	[0.999,1.003]
GDP per capita PPP		1.000***	1.000***	1.000***
		[1.000,1.000]	[1.000,1.000]	[1.000,1.000]
Gini Index		1.454*	1.454*	1.454*
		[0.963,2.195]	[0.963,2.195]	[0.963,2.195]
Fertility Rate		1.126***	1.126***	1.126***
		[1.056,1.201]	[1.056,1.201]	[1.056,1.201]
Adequate Sanitation		1.001	1.001	1.001
		[0.999,1.003]	[0.999,1.003]	[0.999,1.003]
Primary education		1.000	1.000	1.000
		[0.999,1.001]	[0.999,1.001]	[0.999,1.001]
Education expenditure		1.000	1.000	1.000
		[0.998,1.003]	[0.998,1.003]	[0.998,1.003]
Basic Water Coverage		0.995**	0.995**	0.995**
		[0.990,1.000]	[0.990,1.000]	[0.990,1.000]
Military expenditure		1.002	1.002	1.002
		[0.979,1.026]	[0.979,1.026]	[0.979,1.026]
Health expenditure		1.005	1.005	1.005
		[0.990,1.020]	[0.990,1.020]	[0.990,1.020]
Nurses rate		1.002	1.002	1.002
		[0.990,1.015]	[0.990,1.015]	[0.990,1.015]
Hospital beds rate		0.987	0.987	0.987
		[0.968,1.005]	[0.968,1.005]	[0.968,1.005]
Conflict or war at country		1.083	1.083	1.083
		[0.961,1.220]	[0.961,1.220]	[0.961,1.220]
Time trend control				
y2009		0.993	0.993	0.993
		[0.980,1.006]	[0.980,1.006]	[0.980,1.006]
y2015		0.992	0.992	0.992
		[0.975,1.010]	[0.975,1.010]	[0.975,1.010]
y2020		1.107***	1.107***	1.107***
		[1.072,1.143]	[1.072,1.143]	[1.072,1.143]
y2021		1.210***	1.210***	1.210***
		[1.171,1.251]	[1.171,1.251]	[1.171,1.251]
Number of observations	2002	1592	1592	1592
Number of countries	101	80	80	80

Note: Data are presented as rate ratio coefficients (95% CI). In the row headers, values represent the mean (range: lowest to highest). ASMR = age-standardized mortality rate. ODA stands for the Official Development Assistance. The symbols '***' , '**' and '*' denote significance at 1%, 5%, and 10%, respectively.

Web Table 7. Rate Ratios from the fixed effect Poisson models for the association between overall mortality rates with continuous ODA per capita using, from 2002-21.

	Poisson			
	Unadjusted	**Adjusted$1**	**Adjusted$10**	**Adjusted$100**
ODA per capita	0.998***	0.998***	0.976***	0.782***
	[0.996,0.999]	[0.996,0.999]	[0.961,0.990]	[0.675,0.906]
Control variables				
Economic downturn		1.035**	1.035**	1.035**
		[1.002,1.069]	[1.002,1.069]	[1.002,1.069]
GDP per capita PPP		0.946***	0.946***	0.946***
		[0.915,0.978]	[0.915,0.978]	[0.915,0.978]
Gini Index		1.046*	1.046*	1.046*
		[0.995,1.100]	[0.995,1.100]	[0.995,1.100]
Fertility Rate		0.993	0.993	0.993
		[0.933,1.057]	[0.933,1.057]	[0.933,1.057]
Adequate Sanitation		0.950	0.950	0.950
		[0.894,1.010]	[0.894,1.010]	[0.894,1.010]
Primary education		0.961*	0.961*	0.961*
		[0.919,1.005]	[0.919,1.005]	[0.919,1.005]
Education expenditure		0.959*	0.959*	0.959*
		[0.916,1.004]	[0.916,1.004]	[0.916,1.004]
Basic Water Coverage		0.968*	0.968*	0.968*
		[0.932,1.004]	[0.932,1.004]	[0.932,1.004]
Military expenditure		1.065*	1.065*	1.065*
		[0.989,1.146]	[0.989,1.146]	[0.989,1.146]
Health expenditure		0.942	0.942	0.942
		[0.876,1.012]	[0.876,1.012]	[0.876,1.012]
Nurses rate		0.884***	0.884***	0.884***
		[0.854,0.915]	[0.854,0.915]	[0.854,0.915]
Hospital beds rate		0.991	0.991	0.991
		[0.967,1.016]	[0.967,1.016]	[0.967,1.016]
Conflict or war at country		1.058	1.058	1.058
		[0.891,1.257]	[0.891,1.257]	[0.891,1.257]
Time trend control				
y2009		1.006	1.006	1.006
		[0.988,1.025]	[0.988,1.025]	[0.988,1.025]
y2015		0.962***	0.962***	0.962***
		[0.936,0.987]	[0.936,0.987]	[0.936,0.987]
y2020		1.009	1.009	1.009
		[0.976,1.042]	[0.976,1.042]	[0.976,1.042]
y2021		1.124***	1.124***	1.124***
		[1.061,1.191]	[1.061,1.191]	[1.061,1.191]
Number of observations	2002	1851	1851	1851
Number of countries	101	93	93	93

Note: Data are presented as rate ratio coefficients (95% CI). In the row headers, values represent the mean (range: lowest to highest). ASMR = age-standardized mortality rate. ODA stands for the Official Development Assistance. The symbols '***' , '**' and '*' denote significance at 1%, 5%, and 10%, respectively.

Web Table 8. Rate Ratios from the fixed effect Poisson models for the association between overall mortality rates and ODA per capita using categorical variables, with different time shocks control, from 2002-21.

	Overall mortality rate by different time shock control			
	Main model	**4-years**	**5-years**	**All period**
ODA per capita				
Baseline (mean $ 5.83, 0–12.35)	base	base	base	base
Low (mean $19.83, 12.36–28.70)	0.898***	0.968	0.962*	0.972
	[0.840,0.959]	[0.927,1.010]	[0.922,1.004]	[0.932,1.014]
Intermediate (mean $38.05,28.71–50.39)	0.818***	0.950	0.943*	0.951
	[0.746,0.897]	[0.891,1.013]	[0.885,1.003]	[0.895,1.010]
High (mean $91.11, 50.40 or more)	0.771***	0.925**	0.920**	0.930**
	[0.697,0.853]	[0.861,0.993]	[0.858,0.987]	[0.869,0.995]
Control variables				
Economic downturn	1.036**	1.040***	1.049***	1.047***
	[1.003,1.070]	[1.010,1.072]	[1.018,1.080]	[1.020,1.073]
GDP per capita PPP	0.945***	0.982	0.988	0.995
	[0.915,0.976]	[0.950,1.014]	[0.959,1.017]	[0.968,1.022]
Gini Index	1.040	1.034	1.034	1.027
	[0.990,1.093]	[0.974,1.098]	[0.977,1.094]	[0.984,1.071]
Fertility Rate	0.992	0.935**	0.938**	0.931**
	[0.934,1.054]	[0.882,0.991]	[0.883,0.995]	[0.880,0.986]
Adequate Sanitation	0.951*	0.989	0.990	0.955**
	[0.901,1.004]	[0.932,1.050]	[0.940,1.043]	[0.916,0.995]
Primary education	0.970	1.037	1.025	1.033
	[0.929,1.014]	[0.992,1.083]	[0.981,1.072]	[0.987,1.081]
Education expenditure	0.958*	1.002	0.998	1.003
	[0.915,1.002]	[0.961,1.046]	[0.957,1.041]	[0.961,1.046]
Basic Water Coverage	0.968*	1.011	1.001	1.027
	[0.933,1.004]	[0.973,1.051]	[0.948,1.057]	[0.990,1.065]
Military expenditure	1.055*	1.033	1.033	1.029
	[0.998,1.116]	[0.992,1.076]	[0.991,1.076]	[0.992,1.067]
Health expenditure	0.938*	0.967	0.971	0.963
	[0.874,1.008]	[0.911,1.026]	[0.922,1.023]	[0.916,1.013]
Nurses rate	0.886***	0.953**	0.946***	0.959**
	[0.854,0.920]	[0.911,0.997]	[0.912,0.981]	[0.924,0.997]
Hospital beds rate	0.997	0.985	0.971**	0.980
	[0.975,1.020]	[0.954,1.018]	[0.945,0.998]	[0.952,1.009]
Conflict or war at country	1.051	1.060	1.076	0.949
	[0.878,1.256]	[0.904,1.243]	[0.920,1.259]	[0.801,1.124]
Time trend control				
Main Model				
y2009	1.006			
	[0.986,1.026]			
y2015	0.966***			
	[0.941,0.992]			
y2020	1.017			
	[0.984,1.051]			
y2021	1.138***			
	[1.076,1.204]			
Group of 4 years				
y2006-2009		0.919***		
		[0.901,0.938]		
y2010-2013		0.862***		
		[0.839,0.885]		
y2014-2017		0.814***		
		[0.783,0.846]		
y2018-2021		0.828***		
		[0.796,0.861]		

Group of 5 years				
y2007-2011			0.915***	
			[0.900,0.931]	
y2012-2016			0.850***	
			[0.819,0.881]	
y2017-2021			0.836***	
			[0.808,0.865]	
All period				
y2003				0.994
				[0.982,1.006]
y2004				0.985*
				[0.969,1.002]
y2005				0.951***
				[0.925,0.977]
y2006				0.917***
				[0.887,0.948]
y2007				0.912***
				[0.888,0.938]
y2008				0.898***
				[0.875,0.921]
y2009				0.871***
				[0.847,0.896]
y2010				0.865***
				[0.836,0.894]
y2011				0.850***
				[0.818,0.884]
y2012				0.829***
				[0.800,0.860]
y2013				0.823***
				[0.794,0.854]
y2014				0.819***
				[0.785,0.855]
y2015				0.801***
				[0.766,0.837]
y2016				0.787***
				[0.754,0.823]
y2017				0.774***
				[0.741,0.809]
y2018				0.761***
				[0.729,0.796]
y2019				0.750***
				[0.717,0.784]
y2020				0.819***
				[0.770,0.871]
y2021				0.911***
				[0.849,0.977]
Number of observations	1851	1851	1851	1851
Number of countries	93	93	93	93

Note: Data are in Rate Ratio (RR) coefficients (95% CI) unless otherwise specified. The confidence intervals are in parentheses. Time shocks are controls for specific years of economic and health crisis (2008, 2015, 2019, 2020 and 2021). The symbols '***', '**' and '*' denote significance at 1%, 5%, and 10% respectively.

Web Table 9. Rate Ratios for the association between overall mortality rates with ODA per capita, including AIC and BIC; from 2002-21.

	Poisson
	Adjusted
ODA per capita	
Baseline (mean $ 5·83, 0–12·35)	base
Low (mean $19·83, 12·36–28·70)	0.898***
	[0.840,0.959]
Intermediate (mean $38·05,28·71–50·39)	0.818***
	[0.746,0.897]
High (mean $91·11, 50·40 or more)	0.771***
	[0.697,0.853]
Control variables	
Economic downturn	1.036**
	[1.003,1.070]
GDP per capita PPP	0.945***
	[0.915,0.976]
Gini Index	1.040
	[0.990,1.093]
Fertility Rate	0.992
	[0.934,1.054]
Adequate Sanitation	0.951*
	[0.901,1.004]
Primary education	0.970
	[0.929,1.014]
Education expenditure	0.958*
	[0.915,1.002]
Basic Water Coverage	0.968*
	[0.933,1.004]
Military expenditure	1.055*
	[0.998,1.116]
Health expenditure	0.938*
	[0.874,1.008]
Nurses rate	0.886***
	[0.854,0.920]
Hospital beds rate	0.997
	[0.975,1.020]
Conflict or war at country	1.051
	[0.878,1.256]
Time trend control	
y2009	1.006
	[0.986,1.026]
y2015	0.966***
	[0.941,0.992]
y2020	1.017
	[0.984,1.051]
y2021	1.138***
	[1.076,1.204]
AIC	6,875,158
BIC	6,875,268
Number of observations	1851
Number of countries	93

Source: Author's data analysis for 1,851 observations – 93 countries/territories in the World, from 2002 to 2021.
Note: Data are in Rate Ratio (RR) coefficients (95% CI) unless otherwise specified. The confidence intervals are in parentheses. Time shocks are controls for specific years of economic and health crisis (2008, 2015, 2019, 2020 and 2021). The symbols '***', '**' and '*' denote significance at 1%, 5%, and 10% respectively.

Web Table 10. Rate Ratios from the fixed effect Poisson models for the association between overall mortality rates and ODA per capita, dividing the models by countries' income groups (heterogeneity analyses), from 2002-21.

	LIC	LMIC	UMIC	
	Low-Income	**Lower-Middle income**	**Upper-Middle income**	**LMIC**
ODA per capita				
Baseline (mean $ 5·83, 0–12·35)	base	base	base	base
Low (mean $19·83, 12·36–28·70)	0.853***	0.883***	0.963	0.898***
	[0.832,0.875]	[0.819,0.953]	[0.887,1.047]	[0.840,0.959]
Intermediate (mean $38·05,28·71–50·39)	0.757***	0.800***	1.025	0.818***
	[0.696,0.822]	[0.719,0.889]	[0.950,1.106]	[0.746,0.897]
High (mean $91·11, 50·40 or more)	0.705***	0.754***	0.929	0.771***
	[0.602,0.824]	[0.681,0.835]	[0.849,1.015]	[0.697,0.853]
Control variables				
Economic downturn	1.018	0.996	1.018	1.036**
	[0.954,1.085]	[0.948,1.046]	[0.991,1.045]	[1.003,1.070]
GDP per capita PPP	0.987***	0.959***	1.155***	0.945***
	[0.917,0.992]	[0.935,0.985]	[1.037,1.286]	[0.915,0.976]
Gini Index	1.065***	1.030	0.990	1.040
	[0.973,1.087]	[0.993,1.067]	[0.938,1.044]	[0.990,1.093]
Fertility Rate	1.051*	0.992	1.002	0.992
	[0.999,1.106]	[0.957,1.027]	[0.949,1.058]	[0.934,1.054]
Adequate Sanitation	0.918**	0.994	0.799***	0.951*
	[0.859,0.981]	[0.963,1.026]	[0.722,0.885]	[0.901,1.004]
Primary education	0.959	0.962	0.968	0.970
	[0.904,1.017]	[0.910,1.016]	[0.892,1.050]	[0.929,1.014]
Education expenditure	0.929*	0.955	0.942**	0.958*
	[0.859,1.005]	[0.896,1.019]	[0.892,0.994]	[0.915,1.002]
Basic Water Coverage	1.111*	0.977**	0.917***	0.968*
	[0.990,1.247]	[0.960,0.995]	[0.882,0.953]	[0.933,1.004]
Military expenditure	1.104**	1.016	1.016	1.055*
	[1.003,1.215]	[0.960,1.075]	[0.967,1.068]	[0.998,1.116]
Health expenditure	0.969	1.048*	0.897***	0.938*
	[0.913,1.027]	[0.994,1.105]	[0.874,0.920]	[0.874,1.008]
Nurses rate	0.883***	0.950***	0.862***	0.886***
	[0.823,0.948]	[0.918,0.984]	[0.848,0.877]	[0.854,0.920]
Hospital beds rate	1.030	1.013	0.935	0.997
	[0.985,1.077]	[0.991,1.036]	[0.803,1.090]	[0.975,1.020]
Conflict or war at country	1.181**	1.228**	0.793	1.051
	[1.021,1.367]	[1.018,1.481]	[0.543,1.158]	[0.878,1.256]
Time trend control				
y2009	1.048***	1.010	1.001	1.006
	[1.017,1.079]	[0.980,1.041]	[0.979,1.023]	[0.986,1.026]
y2015	0.937*	0.977	0.958***	0.966***
	[0.876,1.001]	[0.948,1.008]	[0.944,0.971]	[0.941,0.992]
y2020	1.040	1.033*	1.065**	1.017
	[0.979,1.104]	[0.996,1.071]	[1.000,1.134]	[0.984,1.051]
y2021	1.140***	1.141***	1.096*	1.138***
	[1.089,1.194]	[1.104,1.179]	[0.998,1.205]	[1.076,1.204]
Number of observations	380	837	634	1,851
Number of countries	19	42	32	93

Source: Author's data analysis for 1,851 observations – 93 countries/territories in the World, from 2002 to 2021.
Note: Data are in Rate Ratio (RR) coefficients (95% CI) unless otherwise specified. The confidence intervals are in parentheses. Time shocks are controls for specific years of economic and health crisis (2008, 2015, 2019, 2020 and 2021). The symbols '***', '**' and '*' denote significance at 1%, 5%, and 10% respectively.

Web Table 11. Rate Ratios from the fixed effect Poisson models for the association between overall mortality rates and ODA per capita, by different causes of deaths; from 2002-21.

	Tuberculosis	HIV/AIDS	Maternal Mortality	Lower Respiratory Infections	Nutritional Deficiencies	Diarrhoeal Diseases	Neglected Tropical Diseases	Malaria
ODA per capita								
Baseline (mean $ 5.83, 0–12.35)	base	base	base	base	base	base	base	base
Low (mean $19.83, 12.36–28.70)	0.797***	0.807***	0.879***	0.796***	0.750*	0.741**	0.772***	0.770***
	[0.693,0.917]	[0.689,0.946]	[0.800,0.966]	[0.697,0.909]	[0.551,1.019]	[0.584,0.940]	[0.695,0.858]	[0.697,0.851]
Intermediate (mean $38.05,28.71–50.39)	0.652***	0.439***	0.733***	0.637***	0.514***	0.528***	0.576***	0.568***
	[0.539,0.788]	[0.367,0.525]	[0.617,0.871]	[0.540,0.751]	[0.363,0.727]	[0.406,0.687]	[0.477,0.696]	[0.472,0.684]
High (mean $91.11, 50.40 or more)	0.608***	0.304***	0.704***	0.575***	0.440***	0.451***	0.463***	0.443***
	[0.493,0.750]	[0.239,0.388]	[0.574,0.862]	[0.469,0.705]	[0.299,0.646]	[0.331,0.613]	[0.363,0.590]	[0.348,0.564]
Control variables								
Economic downturn	0.984	1.104**	1.018	0.994	0.901	0.908	0.999	1.007
	[0.870,1.114]	[1.010,1.207]	[0.916,1.131]	[0.922,1.072]	[0.754,1.077]	[0.763,1.082]	[0.875,1.141]	[0.889,1.140]
GDP per capita PPP	0.897***	1.251	0.807***	0.963	0.967	0.792***	0.798	0.636***
	[0.833,0.965]	[0.837,1.871]	[0.753,0.865]	[0.906,1.024]	[0.808,1.158]	[0.743,0.844]	[0.607,1.050]	[0.499,0.811]
Gini Index	1.026	0.898	0.934*	0.982	0.868*	1.065	0.972	0.975
	[0.933,1.128]	[0.687,1.174]	[0.865,1.009]	[0.911,1.059]	[0.744,1.013]	[0.958,1.185]	[0.871,1.085]	[0.862,1.102]
Fertility Rate	1.083*	1.145	1.306***	1.068	1.563***	1.150***	1.123	1.171
	[0.997,1.176]	[0.917,1.430]	[1.205,1.416]	[0.972,1.173]	[1.291,1.892]	[1.109,1.193]	[0.882,1.431]	[0.870,1.576]
Adequate Sanitation	0.932	0.601***	0.902	0.971	1.133**	1.102	0.849	0.465***
	[0.806,1.079]	[0.435,0.829]	[0.791,1.030]	[0.890,1.060]	[1.021,1.257]	[0.925,1.313]	[0.639,1.127]	[0.328,0.660]
Primary education	0.987	0.890	0.939	1.093	0.981	0.905	0.934	0.900
	[0.915,1.065]	[0.741,1.068]	[0.843,1.046]	[0.978,1.222]	[0.848,1.135]	[0.788,1.040]	[0.825,1.057]	[0.772,1.050]
Education expenditure	0.890***	0.860	0.916**	0.906**	0.801***	0.801***	0.854***	0.849***
	[0.824,0.961]	[0.697,1.060]	[0.847,0.990]	[0.827,0.992]	[0.720,0.891]	[0.722,0.888]	[0.767,0.951]	[0.761,0.947]
Basic Water Coverage	0.882***	0.963	0.758***	0.875***	0.862**	0.830***	0.918	0.818**
	[0.850,0.916]	[0.792,1.171]	[0.719,0.800]	[0.817,0.937]	[0.766,0.969]	[0.773,0.892]	[0.788,1.069]	[0.674,0.992]
Military expenditure	1.106	1.190*	1.158	1.054	1.199*	1.077	1.189**	1.199**
	[0.935,1.308]	[0.994,1.424]	[0.968,1.384]	[0.932,1.194]	[0.988,1.455]	[0.943,1.230]	[1.010,1.400]	[1.011,1.422]
Health expenditure	0.987	1.167*	0.995	1.042	1.031	1.012	0.986	0.985
	[0.897,1.087]	[0.984,1.384]	[0.932,1.062]	[0.985,1.101]	[0.906,1.172]	[0.917,1.116]	[0.893,1.089]	[0.888,1.092]
Nurses rate	0.834***	0.821*	0.757***	1.000	0.934	0.801***	0.856***	0.860***
	[0.747,0.931]	[0.667,1.011]	[0.670,0.855]	[0.917,1.089]	[0.791,1.102]	[0.685,0.936]	[0.777,0.944]	[0.773,0.957]
Hospital beds rate	1.007	1.136	1.108**	1.038*	1.227***	1.056*	1.106	1.081
	[0.952,1.065]	[0.955,1.351]	[1.009,1.217]	[0.993,1.086]	[1.100,1.370]	[0.998,1.118]	[0.818,1.497]	[0.734,1.590]

Conflict or war at country	1.159	2.120**	1.092	1.145	1.576*	1.324*	1.716***	1.707***
	[0.839,1.600]	[1.195,3.760]	[0.853,1.398]	[0.868,1.512]	[0.977,2.542]	[0.960,1.827]	[1.231,2.394]	[1.230,2.369]
Time trend control								
y2009	1.033	1.111***	1.074***	1.034**	1.079***	1.089**	1.118***	1.134***
	[0.980,1.089]	[1.037,1.189]	[1.025,1.125]	[1.002,1.068]	[1.027,1.133]	[1.014,1.170]	[1.079,1.159]	[1.086,1.183]
y2015	0.911***	0.798***	0.876***	0.948**	0.849***	0.825***	0.835***	0.824***
	[0.878,0.945]	[0.715,0.890]	[0.830,0.925]	[0.907,0.991]	[0.789,0.914]	[0.750,0.907]	[0.759,0.918]	[0.744,0.913]
y2020	0.819***	0.680***	0.750***	0.800***	0.714***	0.691***	0.845***	0.866***
	[0.746,0.898]	[0.605,0.765]	[0.698,0.805]	[0.744,0.861]	[0.612,0.832]	[0.611,0.783]	[0.775,0.921]	[0.796,0.943]
y2021	0.811***	0.632***	0.753***	0.764***	0.605***	0.664***	0.804***	0.826***
	[0.707,0.930]	[0.557,0.717]	[0.696,0.814]	[0.685,0.852]	[0.538,0.679]	[0.556,0.794]	[0.737,0.876]	[0.759,0.898]
Number of observations	1851	1851	1851	1851	1851	1851	1851	1520
Number of countries	93	93	93	93	93	93	93	76

Note: Data are presented as rate ratio coefficients (95% CI). In the row headers, values represent the mean (range: lowest to highest). Time shocks control for specific years associated with economic or health crises (2009, 2015, 2020, and 2021). ASMR = age-standardized mortality rate. ODA stands for the Official Development Assistance. The symbols '***' , '**' and '*' denote significance at 1%, 5%, and 10%, respectively.

Web Table 12. Rate Ratios from the fixed effect Poisson models for the association between mortality rates and ODA per capita, by different age groups; from 2002-21.

	Neonatal	Infancy	Preschool	Child	School-age	Adult	Elderly	Overall
	0 to 28 days	0 to 1 year	2 to 4 years	Under 5 years	5 to 9 years	10 to 54 years	55+ years	
ODA per capita								
Baseline (mean $ 5.83, 0–12.35)								
Low (mean $19.83, 12.36–28.70)	0.876***	0.860***	0.780***	0.831***	0.848***	0.884***	0.926***	0.898***
	[0.800,0.960]	[0.779,0.949]	[0.682,0.892]	[0.749,0.923]	[0.771,0.932]	[0.820,0.952]	[0.886,0.968]	[0.840,0.959]
Intermediate (mean $38.05,28.71–50.39)	0.784***	0.720***	0.579***	0.669***	0.709***	0.719***	0.921**	0.818***
	[0.706,0.871]	[0.632,0.820]	[0.482,0.695]	[0.581,0.771]	[0.628,0.799]	[0.638,0.810]	[0.854,0.994]	[0.746,0.897]
High (mean $91.11, 50.40 or more)	0.776***	0.672***	0.484***	0.606***	0.674***	0.632***	0.892***	0.771***
	[0.668,0.902]	[0.553,0.817]	[0.372,0.629]	[0.489,0.752]	[0.576,0.790]	[0.545,0.734]	[0.823,0.967]	[0.697,0.853]
Control variables								
Economic downturn	1.016	0.993	0.989	0.988	0.970	1.050**	1.022***	1.036**
	[0.934,1.106]	[0.903,1.091]	[0.814,1.201]	[0.881,1.107]	[0.876,1.074]	[1.002,1.100]	[1.005,1.038]	[1.003,1.070]
GDP per capita PPP	0.827***	0.808***	0.729***	0.796***	0.856**	1.010	0.965***	0.945***
	[0.763,0.895]	[0.748,0.873]	[0.645,0.823]	[0.737,0.859]	[0.749,0.977]	[0.909,1.121]	[0.947,0.984]	[0.915,0.976]
Gini Index	1.074	1.057	0.988	1.047	0.937*	0.998	1.043**	1.040
	[0.981,1.176]	[0.958,1.166]	[0.881,1.107]	[0.949,1.154]	[0.870,1.010]	[0.938,1.061]	[1.005,1.083]	[0.990,1.093]
Fertility Rate	1.023	1.048	1.200***	1.068*	1.165***	1.032	0.956*	0.992
	[0.954,1.096]	[0.974,1.128]	[1.081,1.332]	[0.992,1.151]	[1.083,1.253]	[0.968,1.100]	[0.912,1.003]	[0.934,1.054]
Adequate Sanitation	0.959	0.915	0.894	0.917	0.918	0.917	0.977	0.951*
	[0.882,1.042]	[0.821,1.020]	[0.777,1.028]	[0.819,1.028]	[0.812,1.038]	[0.769,1.093]	[0.949,1.005]	[0.901,1.004]
Primary education	0.961	0.933	0.912	0.930	0.961	0.944	1.004	0.970
	[0.893,1.033]	[0.852,1.023]	[0.786,1.057]	[0.843,1.026]	[0.880,1.048]	[0.861,1.036]	[0.958,1.052]	[0.929,1.014]
Education expenditure	0.946**	0.919***	0.847***	0.893***	0.884***	0.949	0.976	0.958*
	[0.905,0.990]	[0.869,0.972]	[0.777,0.923]	[0.836,0.954]	[0.831,0.940]	[0.878,1.025]	[0.933,1.022]	[0.915,1.002]
Basic Water Coverage	0.909***	0.893***	0.791***	0.874***	0.858***	0.973	0.954*	0.968*
	[0.878,0.941]	[0.859,0.929]	[0.728,0.860]	[0.836,0.915]	[0.815,0.903]	[0.932,1.015]	[0.910,1.001]	[0.933,1.004]
Military expenditure	1.077**	1.094**	1.118*	1.094**	1.100**	1.072	1.020	1.055*
	[1.003,1.156]	[1.018,1.175]	[0.979,1.277]	[1.006,1.189]	[1.011,1.197]	[0.986,1.166]	[0.974,1.068]	[0.998,1.116]
Health expenditure	0.961	0.970	0.972	0.970	0.952	1.005	0.921***	0.938*
	[0.904,1.021]	[0.903,1.043]	[0.888,1.064]	[0.899,1.046]	[0.879,1.031]	[0.941,1.074]	[0.891,0.953]	[0.874,1.008]
Nurses rate	0.853**	0.853**	0.781***	0.835***	0.798***	0.884***	0.936***	0.886***
	[0.748,0.973]	[0.749,0.971]	[0.652,0.935]	[0.730,0.955]	[0.738,0.862]	[0.850,0.919]	[0.923,0.948]	[0.854,0.920]
Hospital beds rate	1.027	1.033	1.087	1.039	1.175***	1.036*	0.975***	0.997
	[0.964,1.094]	[0.972,1.097]	[0.980,1.205]	[0.977,1.105]	[1.084,1.273]	[0.998,1.075]	[0.960,0.989]	[0.975,1.020]

Conflict or war at country	1.145**	1.257***	1.333**	1.288***	1.550***	1.311**	0.872	1.051
	[1.005,1.306]	[1.080,1.464]	[1.036,1.716]	[1.074,1.544]	[1.269,1.894]	[1.064,1.615]	[0.696,1.093]	[0.878,1.256]
Time trend control								
y2009	1.044***	1.052***	1.057**	1.054***	1.043	1.010	1.002	1.006
	[1.016,1.072]	[1.023,1.082]	[1.012,1.104]	[1.021,1.087]	[0.989,1.100]	[0.987,1.034]	[0.992,1.012]	[0.986,1.026]
y2015	0.943***	0.917***	0.829***	0.893***	0.896***	0.951***	0.978**	0.966***
	[0.909,0.978]	[0.878,0.957]	[0.784,0.875]	[0.850,0.938]	[0.868,0.926]	[0.928,0.974]	[0.962,0.995]	[0.941,0.992]
y2020	0.800***	0.766***	0.697***	0.746***	0.744***	0.977	1.074***	1.017
	[0.764,0.838]	[0.733,0.801]	[0.648,0.750]	[0.711,0.782]	[0.698,0.792]	[0.931,1.025]	[1.041,1.109]	[0.984,1.051]
y2021	0.805***	0.748***	0.650***	0.718***	0.708***	1.077**	1.178***	1.138***
	[0.747,0.868]	[0.687,0.814]	[0.593,0.712]	[0.660,0.780]	[0.675,0.742]	[1.005,1.155]	[1.086,1.278]	[1.076,1.204]
Number of observations	1851	1851	1851	1851	1851	1851	1851	1851
Number of countries	93	93	93	93	93	93	93	93

Note: Data are presented as rate ratio coefficients (95% CI). In the row headers, values represent the mean (range: lowest to highest). Time shocks control for specific years associated with economic or health crises (2009, 2015, 2020, and 2021). ASMR = age-standardized mortality rate. ODA stands for the Official Development Assistance. The symbols '***' , '**' and '*' denote significance at 1%, 5%, and 10%, respectively.

Web Table 13. Rate Ratios from the fixed effect Poisson models for the association between mortality rates and ODA per capita, by sex, from 2002-21.

	Male	**Female**
ODA per capita		
Baseline (mean $ 5·83, 0–12·35)	base	base
Low (mean $19·83, 12·36–28·70)	0.930*	0.941
	[0.859,1.007]	[0.866,1.023]
Intermediate (mean $38·05,28·71–50·39)	0.840***	0.826***
	[0.739,0.956]	[0.716,0.953]
High (mean $91·11, 50·40 or more)	0.773***	0.733***
	[0.660,0.904]	[0.616,0.873]
Control variables		
Economic downturn	0.997	1.014
	[0.952,1.044]	[0.963,1.068]
GDP per capita PPP	1.034	1.037
	[0.986,1.085]	[0.983,1.094]
Gini Index	0.980	0.993
	[0.941,1.021]	[0.951,1.037]
Fertility Rate	1.007	1.020
	[0.970,1.047]	[0.983,1.059]
Adequate Sanitation	1.022	0.992
	[0.956,1.091]	[0.920,1.070]
Primary education	1.022	1.012
	[0.943,1.107]	[0.928,1.104]
Education expenditure	0.954*	0.954*
	[0.905,1.005]	[0.904,1.007]
Basic Water Coverage	0.971***	0.989
	[0.951,0.991]	[0.957,1.022]
Military expenditure	1.052	1.068
	[0.966,1.144]	[0.973,1.172]
Health expenditure	1.032**	1.067***
	[1.002,1.063]	[1.028,1.108]
Nurses rate	1.017	1.004
	[0.971,1.064]	[0.978,1.030]
Hospital beds rate	1.010	1.012
	[0.985,1.035]	[0.986,1.039]
Conflict or war at country	1.058	1.036
	[0.895,1.249]	[0.860,1.247]
Time trend control		
y2009	1.008*	1.002
	[0.999,1.018]	[0.989,1.014]
y2015	0.965***	0.961***
	[0.939,0.991]	[0.933,0.989]
y2020	1.111**	1.065
	[1.012,1.219]	[0.971,1.169]
y2021	1.126***	1.078**
	[1.050,1.207]	[1.017,1.142]
Number of observations	1561	1561
Number of countries	92	92

Source: Author's data analysis for 1,851 observations – 93 countries/territories in the World, from 2002 to 2021.
Note: Data are in Rate Ratio (RR) coefficients (95% CI) unless otherwise specified. The confidence intervals are in parentheses. Time shocks are controls for specific years of economic and health crisis (2008, 2015, 2019, 2020 and 2021). The symbols '***', '**' and '*' denote significance at 1%, 5%, and 10% respectively.

Web Table 14. Rate Ratios from the fixed effect Poisson models for the association between mortality rates and ODA per capita, by female age groups; from 2002-21.

	Children and adolescents	Youth and young adults	Young to middle-aged adults	Middle-aged adults	Elderly	Overall
	0 to 14 years	**15 to 29 years**	**30 to 44 years**	**45 to 59**	**60+ years**	**Female**
ODA per capita						
Baseline (mean $ 5.83, 0–12.35)	base	base	base	base	base	. _skip(0)
Low (mean $19.83, 12.36–28.70)	0.875**	0.881***	0.874***	0.922***	0.945**	0.941
	[0.767,0.999]	[0.804,0.965]	[0.801,0.954]	[0.876,0.971]	[0.895,0.999]	[0.866,1.023]
Intermediate (mean $38.05,28.71–50.39)	0.724***	0.685***	0.607***	0.793***	0.953	0.826***
	[0.610,0.859]	[0.592,0.792]	[0.512,0.719]	[0.708,0.889]	[0.876,1.036]	[0.716,0.953]
High (mean $91.11, 50.40 or more)	0.629***	0.575***	0.488***	0.711***	0.918*	0.733***
	[0.489,0.810]	[0.473,0.699]	[0.388,0.613]	[0.622,0.814]	[0.841,1.003]	[0.616,0.873]
Control variables						
Economic downturn	0.922	1.055	1.100**	1.035	1.015	1.014
	[0.803,1.060]	[0.972,1.145]	[1.008,1.200]	[0.987,1.085]	[0.993,1.038]	[0.963,1.068]
GDP per capita PPP	0.799***	0.935	0.989	0.947	0.962***	1.037
	[0.742,0.861]	[0.788,1.110]	[0.844,1.158]	[0.879,1.019]	[0.940,0.984]	[0.983,1.094]
Gini Index	1.050	0.955	1.027	1.150**	1.073***	0.993
	[0.951,1.159]	[0.868,1.050]	[0.897,1.176]	[1.011,1.307]	[1.019,1.130]	[0.951,1.037]
Fertility Rate	1.138***	1.159***	1.059	0.981	0.948***	1.020
	[1.086,1.192]	[1.080,1.245]	[0.965,1.161]	[0.862,1.118]	[0.915,0.983]	[0.983,1.059]
Adequate Sanitation	0.990	0.875	0.853	0.909**	0.977*	0.992
	[0.875,1.120]	[0.667,1.147]	[0.651,1.118]	[0.839,0.986]	[0.950,1.004]	[0.920,1.070]
Primary education	0.895**	0.885**	0.871**	0.955	0.994	1.012
	[0.823,0.974]	[0.794,0.985]	[0.779,0.974]	[0.899,1.014]	[0.960,1.030]	[0.928,1.104]
Education expenditure	0.893**	0.943	0.926	0.982	0.975	0.954*
	[0.818,0.975]	[0.836,1.062]	[0.803,1.068]	[0.932,1.035]	[0.945,1.006]	[0.904,1.007]
Basic Water Coverage	0.886***	0.897***	0.978	0.966*	1.007	0.989
	[0.850,0.923]	[0.853,0.943]	[0.920,1.041]	[0.929,1.004]	[0.993,1.021]	[0.957,1.022]
Military expenditure	1.126**	1.097*	1.099	1.064	1.026	1.068
	[1.010,1.255]	[0.991,1.214]	[0.979,1.233]	[0.984,1.150]	[0.978,1.075]	[0.973,1.172]
Health expenditure	0.977	1.015	1.030	0.938	0.943***	1.067***
	[0.883,1.082]	[0.920,1.119]	[0.889,1.194]	[0.867,1.015]	[0.926,0.960]	[1.028,1.108]
Nurses rate	0.764***	0.812***	0.800***	0.831***	0.886***	1.004
	[0.686,0.851]	[0.756,0.873]	[0.734,0.871]	[0.755,0.914]	[0.849,0.925]	[0.978,1.030]
Hospital beds rate	1.052	1.074	1.013	0.953**	0.979**	1.012

	[0.983,1.125]	[0.985,1.171]	[0.945,1.085]	[0.913,0.995]	[0.959,0.999]	[0.986,1.039]
Conflict or war at country	1.241*	1.303**	1.245	0.934	0.917	1.036
	[1.000,1.541]	[1.004,1.692]	[0.893,1.737]	[0.715,1.220]	[0.755,1.114]	[0.860,1.247]
Time trend control						
y2009	1.035**	1.020	1.015	0.977	0.999	1.002
	[1.004,1.066]	[0.996,1.045]	[0.985,1.045]	[0.946,1.009]	[0.980,1.018]	[0.989,1.014]
y2015	0.848***	0.863***	0.883***	0.970	0.969***	0.961***
	[0.801,0.898]	[0.832,0.896]	[0.833,0.937]	[0.919,1.025]	[0.946,0.992]	[0.933,0.989]
y2020	0.684***	0.867	0.962	1.089*	1.047	1.065
	[0.620,0.756]	[0.726,1.035]	[0.806,1.147]	[0.994,1.193]	[0.990,1.107]	[0.971,1.169]
y2021	0.655***	0.897*	0.989	1.172***	1.127***	1.078**
	[0.597,0.719]	[0.800,1.006]	[0.867,1.129]	[1.089,1.260]	[1.067,1.192]	[1.017,1.142]
Number of observations	1557	1561	1561	1561	1561	1561
Number of countries	92	92	92	92	92	92

Source: Author's data analysis for 1,851 observations – 93 countries/territories in the World, from 2002 to 2021.
Note: Data are in Rate Ratio (RR) coefficients (95% CI) unless otherwise specified. The confidence intervals are in parentheses. Time shocks are controls for specific years of economic and health crisis (2008, 2015, 2019, 2020 and 2021). The symbols '***', '**' and '*' denote significance at 1%, 5%, and 10% respectively.

Web Table 15. Adjusted rate ratios from multivariable fixed-effects Poisson models for the association between age-standardized mortality and total annual per-capita ODA funding.

	Mortality		
	Overall (ASMR)	**Child - Under 1 years**	**Child - Under 5 years**
ODA per capita			
Baseline (mean $ 48.98, 0–104.71)	base	base	base
Low (mean $175.17, 104.72–247.53)	0.926*	0.930	0.955
	[0.847,1.013]	[0.793,1.090]	[0.797,1.145]
Intermediate (mean $339.84,247.54–451.72)	0.896**	0.882	0.893
	[0.815,0.986]	[0.746,1.042]	[0.730,1.091]
High (mean $801.04, 451.73 or more)	0.910*	0.926	0.944
	[0.824,1.005]	[0.774,1.107]	[0.762,1.170]
Control variables			
Economic downturn	1.035**	0.996	0.993
	[1.003,1.068]	[0.922,1.076]	[0.908,1.086]
GDP per capita PPP	0.942***	0.805***	0.796***
	[0.914,0.972]	[0.745,0.870]	[0.738,0.858]
Gini Index	1.043	1.064	1.058
	[0.990,1.099]	[0.957,1.183]	[0.948,1.181]
Fertility Rate	0.991	1.044	1.065
	[0.933,1.052]	[0.966,1.127]	[0.981,1.157]
Adequate Sanitation	0.955	0.921	0.920
	[0.903,1.010]	[0.812,1.044]	[0.798,1.061]
Primary education	0.968	0.922*	0.910**
	[0.925,1.014]	[0.844,1.006]	[0.828,1.000]
Education expenditure	0.959**	0.906***	0.870***
	[0.922,0.998]	[0.845,0.970]	[0.803,0.943]
Basic Water Coverage	0.967*	0.902***	0.886***
	[0.932,1.004]	[0.868,0.938]	[0.848,0.926]
Military expenditure	1.065	1.123**	1.124*
	[0.986,1.151]	[1.008,1.252]	[0.979,1.290]
Health expenditure	0.942	0.967	0.964
	[0.877,1.012]	[0.888,1.053]	[0.878,1.058]
Nurses rate	0.885***	0.839***	0.816***
	[0.854,0.918]	[0.744,0.945]	[0.724,0.919]
Hospital beds rate	0.989	1.014	1.014
	[0.963,1.016]	[0.956,1.075]	[0.951,1.082]
Conflict or war at country	1.052	1.288***	1.338***
	[0.886,1.248]	[1.088,1.525]	[1.083,1.652]
Time trend control			
y2009	1.002	1.040***	1.043***
	[0.985,1.019]	[1.015,1.065]	[1.016,1.070]
y2015	0.962***	0.909***	0.883***
	[0.936,0.989]	[0.875,0.944]	[0.849,0.917]
y2020	1.002	0.733***	0.702***
	[0.969,1.036]	[0.683,0.786]	[0.648,0.761]
y2021	1.119***	0.714***	0.675***
	[1.056,1.186]	[0.646,0.789]	[0.608,0.750]
Number of observations	1,851	1851	1,851
Number of countries	93	93	93

Note: Data are presented as rate ratio coefficients (95% CI). In the row headers, values represent the mean (range: lowest to highest). Time shocks control for specific years associated with economic or health crises (2009, 2015, 2020, and 2021). ASMR = age-standardized mortality rate. ODA stands for the Official Development Assistance. The symbols '***' , '**' and '*' denote significance at 1%, 5%, and 10%, respectively.

3.2 Triangulation: Difference-in-difference with Propensity Score Matching

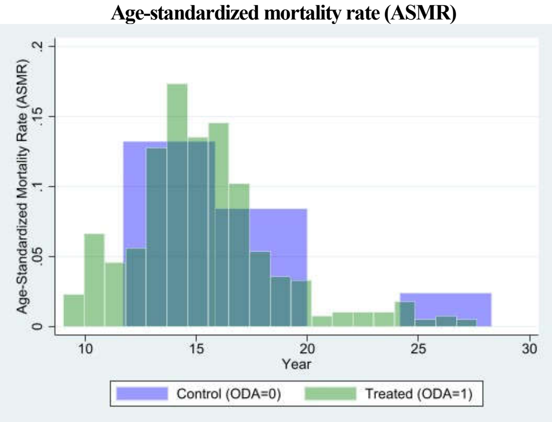
We assessed the impact of ODA disbursements per capita on mortality outcomes using a Difference-in-Differences (DiD) design, supplemented by Propensity Score Matching (PSM) as an additional robustness check. To enhance comparability between groups at baseline, the analysis was limited to low-income (LIC) and lower-middle-income (LMIC) countries. The final sample consisted of 440 countries and territories, classified into two groups: those receiving none or low levels of ODA disbursements (n = 20, control group) and those receiving intermediate to high levels (n = 420, treatment group). Mortality indicators were examined for the years 2002 and 2019.

We selected 2002 as the baseline year because it corresponds to the first year with available ODA disbursement information, while 2019 was chosen to minimize potential distortions associated with COVID-19-related mortality trends. The definition of ODA per capita categories mirrors that used in our primary regression models: countries in the lowest quartile (none or low disbursements) were assigned to the control group (coded as 0), and countries in the second through fourth quartiles (intermediate to high and consolidated disbursements) were assigned to the treatment group (coded as 1).

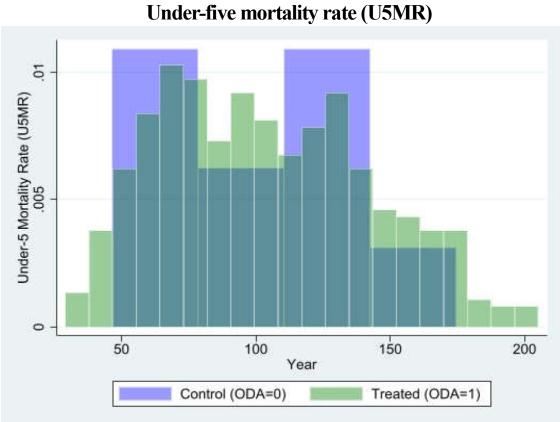
Web Figures 1 and 2 demonstrate that the crucial assumptions for PSM and DiD, common support and parallel trends, are met, thereby reinforcing confidence in the estimated treatment effects.

Web Figure 1. Evidence of common support in mortality rate distributions for treatment and control groups defined by ODA per capita disbursement levels.

Age-standardized mortality rate (ASMR)

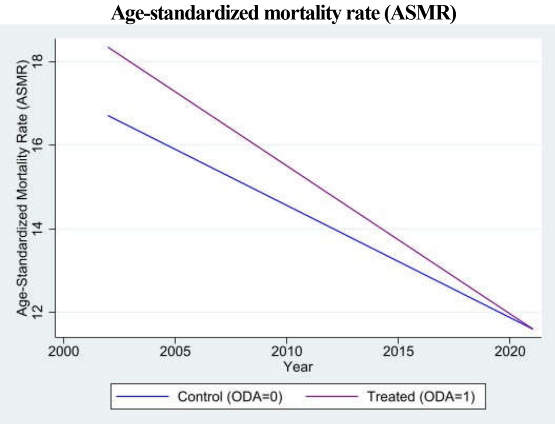


Under-five mortality rate (U5MR)

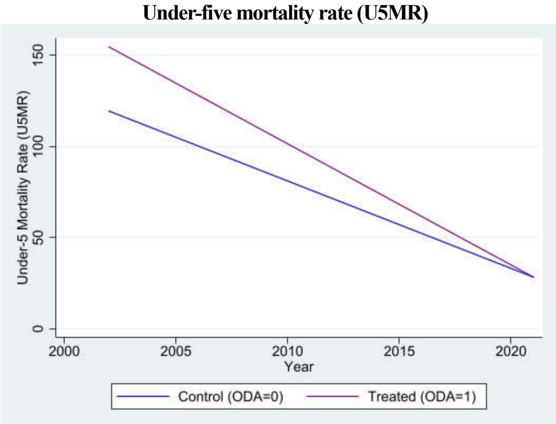


Web Figure 2. Assessment of the parallel trends assumption in mortality rates between treatment and control groups defined by ODA per capita disbursement levels.

Age-standardized mortality rate (ASMR)



Under-five mortality rate (U5MR)



Note: Since pre-treatment ODA disbursement data are not available, 2005 was defined as the first usable year in the series, allowing us to compare mortality trajectories in the periods preceding and following this reference point. Notably, the observed parallel trends remain consistent irrespective of the particular early-year cutoff selected.

We applied two complementary strategies to estimate the DiD effects combined with PSM. First, we employed the standard implementation using the STATA diff command. Second, we followed the stepwise approach recommended in the World Bank DiD handbook,[28] which estimates DiD effects through fixed-effects Poisson panel models and reports results as rate ratios (RR).

Web Table 16 summarizes the DiD results incorporating PSM. After adjusting for observable country/territory characteristics through kernel matching, the initial difference (2002) indicates that countries with higher ODA per capita disbursements exhibited higher overall mortality (ASMR) and under-5 mortality compared with those receiving little or no ODA. By 2019 (the second difference), mortality declined in both groups; however, the reduction was substantially larger among countries with higher ODA support, resulting in a statistically significant DiD estimate.

Web Table 17 presents the estimates from the fixed-effects Poisson panel models. These results corroborate the DiD findings, showing that higher ODA per capita levels were associated with greater reductions in overall and child mortality relative to countries/territories with minimal or no ODA disbursements. The estimated rate ratio [(RR = 0.978; 95% CI: 0.975–0.982); (RR = 0.960; 95% CI: 0.956–0.964)] reflects a modest but statistically meaningful protective effect.

Taken together, these analyses suggest that ODA disbursements contributed to measurable improvements in overall and under-5 mortality rates. The convergence of results from both PSM-adjusted DiD estimates and Poisson panel models strengthens the credibility of the findings presented in the main manuscript and underscores the robustness added through methodological triangulation.

Web Table 16. Propensity Score–Matched Difference-in-Differences Estimates of the impact of intermediate-to-high ODA per capita disbursements on overall and under-5 mortality in low- and lower-middleincome countries, 2002–2019.

	Overall ASMR	**Child** Under 5 years
Before (2002)		
Control	16.097	123.511
Treated	18.325	157.440
1st Difference (T-C)	2.229***	33.929***
	(0.000)	(0.003)
After (2019)		
Control	14.335	51.363
Treated	11.530	66.900
2nd Difference (T-C)	-2.804***	15.537***
	(0.001)	(0.011)
Diff-in-Diff	**-5.033*** (0.001)**	**-18.392*** (0.012)**

Web Table 17. Rate Ratios from the difference-in-difference fixed effect Poisson models for the association between mortality rates (overall and child) with intermediate to high ODA disbursement, in 2002 and 2019, in Low Income and Lower-Middle Income countries/territories.

	ASMR	U5MR
ODA per capita (dummies)		
ODA_dd	1.06382e+19***	2.42005e+35***
	[7.067e+15,1.601e+22]	[7.775e+31,7.532e+38]
ODA Intermediate to high	0.978***	0.960***
	[0.975,0.982]	[0.956,0.964]
Control Variables		
Economic downturn	0.985	0.652***
	[0.881,1.101]	[0.538,0.791]
GDP per capita PPP	0.875**	0.777**
	[0.766,0.998]	[0.620,0.973]
Gini Index	0.928**	0.971
	[0.876,0.984]	[0.872,1.080]
Fertility Rate	1.015	1.048
	[0.943,1.093]	[0.808,1.359]
Adequate Sanitation	0.966	0.733***
	[0.878,1.063]	[0.593,0.906]
Primary education	1.046	1.505***
	[0.916,1.196]	[1.149,1.971]
Education expenditure	1.023	0.949
	[0.920,1.137]	[0.827,1.089]
Basic Water Coverage	1.327***	1.242
	[1.176,1.498]	[0.939,1.642]
Military expenditure	1.107**	1.190***
	[1.020,1.202]	[1.097,1.291]
Health expenditure	0.935	0.882**
	[0.859,1.018]	[0.779,0.999]
Nurses rate	0.854***	0.832
	[0.769,0.949]	[0.606,1.141]
Hospital beds rate	1.107***	1.370**
	[1.030,1.189]	[1.067,1.758]
Conflict or war at country	1.188	1.349
	[0.927,1.523]	[0.937,1.941]
Number of observations	122	122
Number of countries	61	61

Source: Author's data analysis for 120 observations – 61 countries/territories in the World, over 2 years (from 2002 and 2019).

Note: Data are in Rate Ratio (RR) coefficients (95% CI) unless otherwise specified. The confidence intervals are in parentheses. The symbols '***' , '**' and '*' denote significance at 1%, 5%, and 10% respectively.

3.3 Analysis with 130 countries

Table 18: Adjusted rate ratios from multivariable fixed-effects Poisson models for the association between age-standardized mortality and annual ODA per capita.

	Mortality		
	Overall (ASMR)	Child - Under 1 years	Child - Under 5 years
ODA per capita			
Baseline (mean $ 5.83, 0–12.35)	base	base	base
Low (mean $19.83, 12.36–28.70)	0.931***	0.848***	0.838**
	[0.882,0.982]	[0.753,0.956]	[0.731,0.959]
Intermediate (mean $38.05,28.71–50.39)	0.856***	0.756***	0.729***
	[0.793,0.925]	[0.666,0.860]	[0.631,0.841]
High (mean $91.11, 50.40 or more)	0.887***	0.741***	0.727***
	[0.814,0.968]	[0.628,0.875]	[0.609,0.867]
Control variables			
Economic downturn	1.052**	1.002	1.005
	[1.012,1.093]	[0.921,1.090]	[0.909,1.110]
Gini Index	1.045*	1.086	1.086
	[0.997,1.095]	[0.980,1.204]	[0.980,1.204]
Fertility Rate	1.011	1.076*	1.098**
	[0.961,1.064]	[1.000,1.158]	[1.019,1.183]
Adequate Sanitation	0.917***	0.868*	0.869*
	[0.867,0.970]	[0.746,1.010]	[0.742,1.018]
Primary education	0.961*	0.925**	0.923**
	[0.920,1.004]	[0.860,0.995]	[0.859,0.993]
Education expenditure	0.957*	0.920***	0.897***
	[0.910,1.006]	[0.875,0.967]	[0.845,0.952]
Basic Water Coverage	0.973**	0.843***	0.816***
	[0.953,0.994]	[0.799,0.889]	[0.778,0.855]
Health expenditure	0.943	0.984	0.982
	[0.878,1.013]	[0.915,1.057]	[0.908,1.062]
Nurses rate	0.883***	0.851***	0.828***
	[0.852,0.916]	[0.768,0.943]	[0.751,0.913]
Hospital beds rate	0.994	1.013	1.007
	[0.963,1.026]	[0.947,1.083]	[0.935,1.085]
Time trend control			
y2009	0.996	1.026	1.026
	[0.972,1.022]	[0.980,1.074]	[0.977,1.076]
y2015	0.965**	0.921***	0.898***
	[0.937,0.994]	[0.876,0.969]	[0.853,0.946]
y2020	1.015	0.776***	0.747***
	[0.981,1.050]	[0.725,0.831]	[0.694,0.804]
y2021	1.125***	0.723***	0.689***
	[1.070,1.183]	[0.673,0.777]	[0.638,0.743]
Number of observations	2582	2582	2582
Number of countries	130	130	130

Note: Data are presented as rate ratio coefficients (95% CI). In the row headers, values represent the mean (range: lowest to highest). Time shocks control for specific years associated with economic or health crises (2009, 2015, 2020, and 2021). ASMR = age-standardized mortality rate. ODA stands for the Official Development Assistance. The symbols '***' , '**' and '*' denote significance at 1%, 5%, and 10%, respectively.

PART III - FORECASTING ANALYSIS

4. DESCRIPTION OF THE FORECASTING METHODOLOGY

This section outlines our approach to the forecast analysis. For this part of the study, we follow established international guidelines for modeling and reporting (ISPOR-SMDM).[29-31] As described earlier,[32] we employed a two-step methodology for this purpose. In the first step, we developed a synthetic cohort representing 93 countries from 2022 to 2030. We built this dataset based on the information collected during our earlier analysis. We aim to estimate potential future scenarios, particularly in light of possible changes in ODA funding. To achieve this, we examined the annual per capita financial support that these countries receive and categorized them into four distinct levels. Additionally, we analyzed three main policy scenarios to explore possible outcomes:

- **Business as Usual (BAU) scenario**: Assumes that ODA investment and funding levels remain constant from 2023 through 2030.
- **Severe Defund scenario**: Assumes constant ODA funding levels from 2023 to 2024. After that, we assume a 21.12% reduction in 2025 in the per capita values. From 2026 to 2030, all countries in the cohort are assumed to transition to the lowest funding level, simulating a dismantling of the project.
- **Mild Defund scenario**: Assumes the same reductions as the Severe Defund scenario until 2025. After this, project a yearly 10.56% reduction in the per capita values.

The second step is the forecasting and results analysis. We carried out Monte Carlo simulations, applying the same fixed-effects regression models described in Section 2. The goal was to predict the general age-standardized number of deaths (ASMR) per 1,000 inhabitants— calculated according to WHO methodology— and the under-five child mortality (U5MR) per 1,000 live births, for each year within the synthetic cohort. We collect the simulation results and estimate the number of avoided deaths for each scenario in comparison with the BAU, along with their confidence intervals.

5. PURPOSE OF THE FORECASTING AND ITS APPLICATIONS

The primary aim is to simulate the dismantling policies currently being enacted within ODA funding on a global scale. Our focus lies in evaluating the profound consequences of funding cuts on the tragic increase in fatalities that may ensue from these decisions.

6. DATA SOURCE AND INPUTS

The panel data used in this study combined aggregated demographic, socioeconomic, health, and ODA info from several sources (all sources are publicly available and listed in the Web Table 1). In the absence of reference values from the literature, we categorized all ODA information using the quartiles. The levels adopted in this study are baseline (0 to $12.35 per capita), low (25th percentile, $12.35 to $28.70), intermediate (50th percentile or median, $12.35 to $50.39), and high (75th percentile, $50.39 and above). This classification captures the context in which ODA operates, enabling a more accurate interpretation of funding patterns. As input for the modeling and forecasting phases, all control variables applied in the retrospective analysis were included in the models: gross domestic product (GDP) per capita at purchasing power parity (GDP pc PPP); public expenditures on education, health, and the military (each on as a percentage of GDP); literacy rate; Gini index; the percentage of households with inadequate sanitation and with access to piped water; the number of doctors per 1,000 population; and the number of hospital beds per 1,000 population.

7. POISSON MULTIVARIABLE REGRESSION MODELS WITH ROBUST STANDARD ERRORS AND FIXED-EFFECTS

To better capture the effects of interest in our study, we employed a Generalized Linear Model (GLM) with a Poisson distribution, incorporating robust standard errors to account for potential misspecification of the variance structure due to the panel data design.[33-37] Then, let Y_{it} be the observed count of deaths (general or under-five) and assuming $Y_{it} \sim Poisson(\mu_{it})$, the linear predictor of the model, considering the population offset and country fixed effect, is

$$\log(\mu_{it}) = \log(pop_{it}) + \beta 0 + \boldsymbol{X_{it}\beta} + \alpha_i + \theta_t, (1)$$

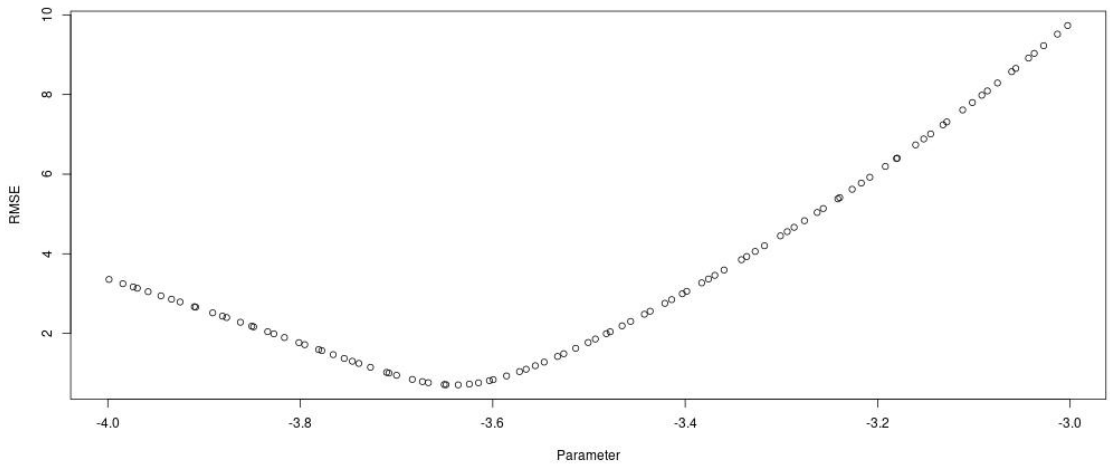
where μ_{it} is the expected number of the event of interest, pop_{it} and $\boldsymbol{X_{it}}$ are the population of interest size and the vector of covariates in time t for the observation i, respectively, β_0 is the intercept, $\boldsymbol{\beta}$ is the corresponding vector of regression coefficients, α_i denotes the unit-specific fixed effect (assumed time-invariant), and θ_t is the time-trend.

8. CALIBRATION, TIME TREND, AND MONTE CARLO SIMULATION

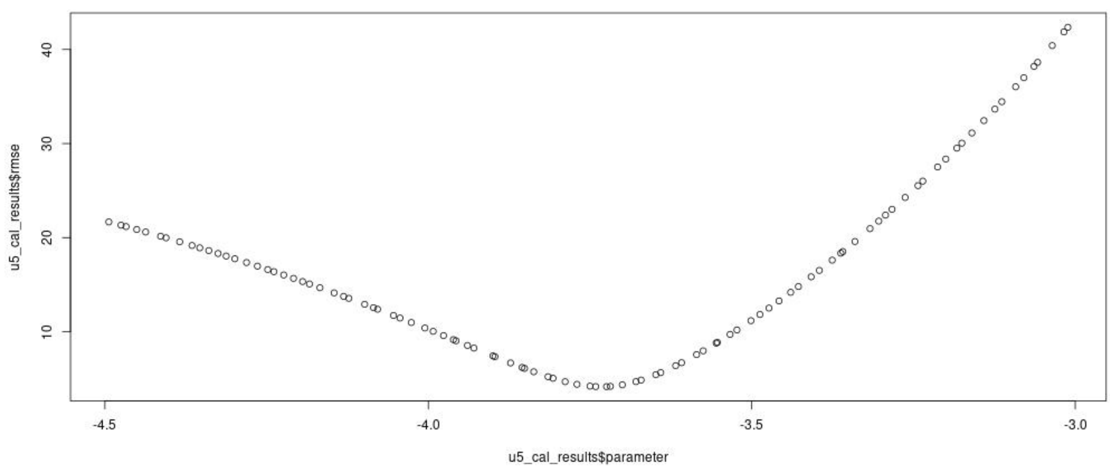
8.1 Calibration

In the forecasting analysis, all parameter estimates and their respective standard errors were derived from the retrospective dataset and the model. We calibrated the intercept, β_0 parameter of the regression model. The calibration process was based on data from 2015 to 2021. We applied Monte Carlo simulations with the BAU scenario, varying the value of β_0 to find the one with lower Root Mean Squared Error (RMSE) in each model, ASMR, and U5MR, independently.

To sample the calibration parameters, we utilized a Latin Hypercube Sample (LHS) method,[38] based on the *tgp* package in R.[39] First, we identified convergence zones for the parameters with small LHS samples and a lower number of simulations. After identifying these zones, we sampled 100 parameters and simulated each one a thousand times to compare their mean results with the mortality rates of 2015 to 2021. The RMSE results for each sample can be assessed in the web figures below.



Web Figure 3. RMSE results of all LHS parameters for the ASMR model**.**



Web Figure 4. RMSE results of 100 LHS parameters for the U5MR model.

The Web Table 19 presents the top six parameters with the lowest RMSE values. The calibrated values of β_0 for the ASMR and U5MR models were determined to be -3.662 and -3.724, respectively.

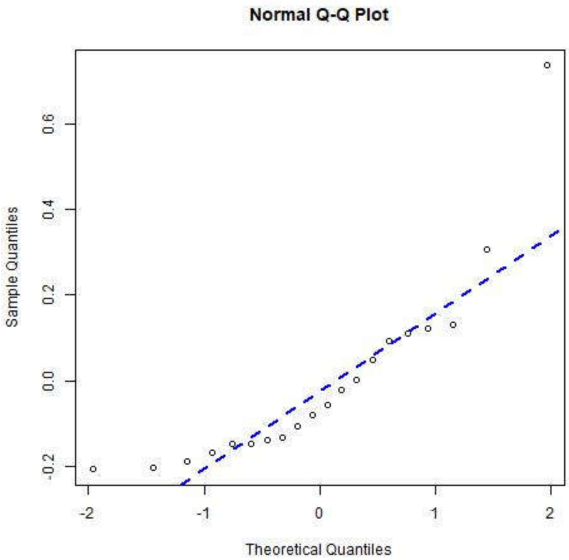
Web Table 19. Final estimates after model refinement and calibration based on minimum RMSE.

ASMR		U5MR	
Parameter	**RMSE**	**Parameter**	**RMSE**
-3.662	0.729	-3.724	4.161
-3.611	0.807	-3.741	4.164
-3.691	0.857	-3.718	4.186
-3.581	1.014	-3.750	4.207
-3.727	1.107	-3.700	4.351
-3.564	1.166	-3.770	4.405

8.2 Time trend

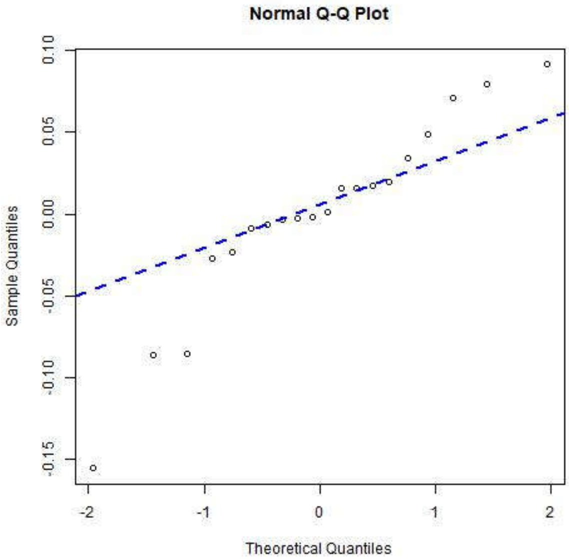
To estimate the underlying time trend in mortality rates, we fitted a generalized linear model (GLM) using the mortality rate per 1,000 inhabitants for the ASMR model and the mortality rate per 1,000 live births in the U5MR model, as the dependent variable and the calendar year as the independent variable. The model was specified with a quasipoisson distribution to account for potential overdispersion in the mortality data. In this framework, the expected mortality rate is modeled on the log scale, allowing the estimated coefficient associated with the year variable to be interpreted as the average annual relative change in the expected mortality rate.

The estimated coefficient associated with the year variable is -0.0125, with a standard error of 0.002, indicating a statistically significant decreasing trend in the log mortality rate over time. A residual analysis was conducted to assess the adequacy of the linear regression assumptions. In addition, the residuals appear to be symmetrically distributed around zero, supporting the appropriateness of the quasipoisson regression model.



Web Figure 5. Q-Q plot of the residuals from the quasipoisson model fitted to the ASMR per 1,000 inhabitants.

The same procedure was applied to the U5MR, resulting in an estimated coefficient of -0.041 with a standard error of 0.0003. As in the previous model, the regression assumptions were assessed and validated.



Web Figure 6. Q-Q plot of the residuals from the quasipoisson model fitted to U5MR per 1,000 live births.

8.3 Monte Carlo Simulation

We employed 1,000 Monte Carlo (MC) replications. This number was selected after confirming the stability of simulation outputs, which consistently converged between 300 and 500 replications.[31] All computational procedures were carried out using the free statistical software R (version 4.2.1) in a Linux environment. For each MC replication and policy scenario, the following prediction procedure was applied:

1. Based on the estimates obtained from the retrospective analysis, along with the time trend and their respective confidence intervals, we randomly selected a value for each parameter based on the normal distribution, with the mean and standard error being the point estimate and standard error from the regression analysis.
2. Using the synthetic cohort, we calculated the expected mean number of deaths for each observation, defined at the country-year level.
3. A count outcome was then generated by drawing from a Poisson distribution, with the previously estimated mean used as the distribution's parameter.
4. Steps 1 to 3 were repeated until the desired number of MC replications was reached.

It is important to highlight that Step 1 of the algorithm plays a key role in introducing randomness and uncertainty into the study, which is a crucial aspect in microsimulation approaches. The final predictions and corresponding uncertainty intervals for each outcome variable were derived from the simulation results: the mean of the 1,000 replications was used as the point estimate, while the 2.5th and 97.5th percentiles were used to construct 95% confidence intervals.

9. COMPLEMENTARY RESULTS

Web Table 20. Project Mortality rates per 1,000 inhabitants and their confidence intervals for the ASMR model for the three scenarios.

Year	BAU	Severe	Mild
2025	10.32 (9.38 - 11.31)	10.43 (9.5 - 11.43)	10.43 (9.5 - 11.43)
2026	10.19 (9.26 - 11.17)	10.9 (9.95 - 11.93)	10.4 (9.48 - 11.38)
2027	10.06 (9.15 - 11.03)	10.77 (9.82 - 11.78)	10.3 (9.39 - 11.28)
2028	9.94 (9.04 - 10.89)	10.63 (9.7 - 11.63)	10.22 (9.3 - 11.19)
2029	9.81 (8.92 - 10.75)	10.5 (9.58 - 11.49)	10.12 (9.23 - 11.09)
2030	9.69 (8.81 - 10.62)	10.37 (9.46 - 11.35)	10.04 (9.16 - 10.99)

Web Table 21. Project Mortality rates per 1,000 live births and their confidence intervals for the U5MR model for the three scenarios.

Year	BAU	Severe	Mild
2025	41.69 (36.48 - 47.6)	43.64 (38.29 - 49.78)	43.64 (38.29 - 49.78)
2026	39.99 (34.98 - 45.65)	49.74 (44.34 - 55.85)	43.32 (38.21 - 49.35)
2027	38.37 (33.56 - 43.78)	47.72 (42.55 - 53.55)	42.01 (37.10 - 47.90)
2028	36.81 (32.19 - 41.99)	45.77 (40.80 - 51.36)	41.02 (36.13 - 46.51)
2029	35.31 (30.89 - 40.31)	43.91 (39.12 - 49.26)	39.6 (34.92 - 44.84)
2030	33.87 (29.62 - 38.65)	42.12 (37.51 - 47.27)	38.42 (33.94 - 43.45)

Web Table 22. Mortality rate ratios of Severe and Mild scenarios related to the BAU confidence intervals for the ASMR model for the three scenarios.

Year	Severe/BAU	Mild/BAU
2025	1.01 (1.007 - 1.014)	1.011 (1.007 - 1.014)
2026	1.07 (1.051 - 1.092)	1.021 (1.013 - 1.029)
2027	1.07 (1.051 - 1.092)	1.024 (1.014 - 1.034)
2028	1.07 (1.051 - 1.092)	1.028 (1.016 - 1.040)
2029	1.07 (1.051 - 1.092)	1.032 (1.020 - 1.044)
2030	1.07 (1.051 - 1.092)	1.036 (1.024 - 1.049)

Web Table 23. Mortality rate ratios of Severe and Mild scenarios related to the BAU confidence intervals for the U5MR model for the three scenarios.

Year	Severe/BAU	Mild/BAU
2025	1.047 (1.029 - 1.067)	1.047 (1.029 - 1.067)
2026	1.245 (1.182 - 1.320)	1.083 (1.061 - 1.109)
2027	1.245 (1.182 - 1.319)	1.095 (1.066 - 1.127)
2028	1.245 (1.182 - 1.320)	1.115 (1.074 - 1.156)
2029	1.245 (1.182 - 1.320)	1.122 (1.081 - 1.164)
2030	1.245 (1.182 - 1.320)	1.135 (1.093 - 1.178)

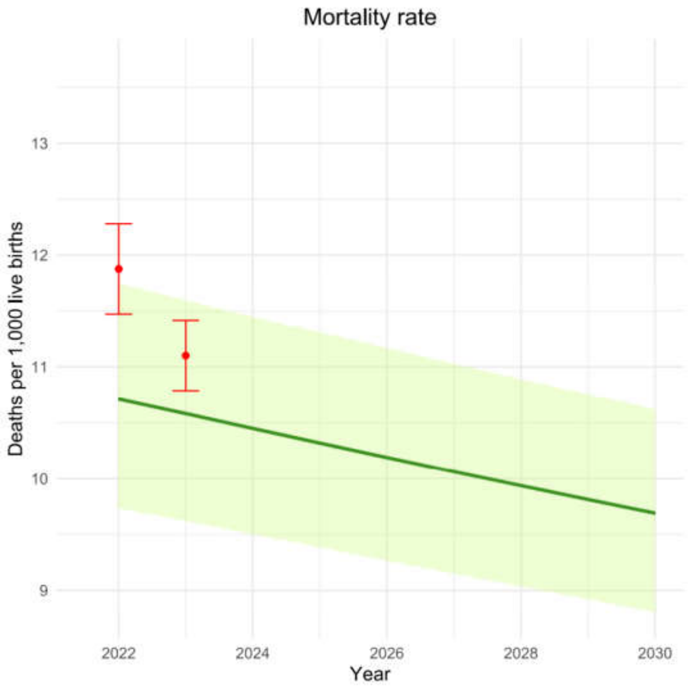
10. VALIDATION

To validate our approach, we implement two different strategies based on the specificities of each external data source. For the ASMR model, we predict expected values based on the United Nations World Population Prospects 2024 (WPP2024) association with our data. For the U5MR, we compare directly the existing values of the Unicef data source. A comparison between the simulated results and the values obtained from external sources can be assessed in the Web Table 24.

Web Table 24. Comparison between Simulated and external sources in 2022 and 2023 across the 93 Countries.

	ASMR			U5MR	
Year	**Model**	**WPP2024**	**WPP-Prediction**	**Model**	**Unicef**
2022	10.7 (9.73 - 11.7)	8.00	11.9 (11.5 - 12.3)	47.0 (41.1 - 53.9)	41.21
2023	10.6 (9.62 - 11.6)	7.30	11.1 (10.8 - 11.4)	45.3 (39.6 - 51.7)	39.34

For the ASMR model, we employ an alternative validation approach. We utilize the Crude Death Rate (deaths per 1,000 population) provided by the WPP2024 as a source of external data for validation (https://population.un.org/wpp). There are historical discrepancies between this data and the data used in this study, which can be attributed to differences in how each is calculated. Nevertheless, we leverage the historical correlation to predict values for 2022 and 2023. We achieve this by employing a linear regression model, where the mortality rates used in this study serve as the dependent variable, while the WPP2024 mortality rates and a time trend for the observed period act as independent variables. We applied the model using data from 2002 to 2021 and used it to forecast the values for 2022 and 2023, characterizing an external validation. The results can be appreciated in the Web Figure 7.



Web Figure 7. Simulated Under-Five Mortality Rates with Uncertainty Intervals and Observed Values from UNICEF (2022–2023).

For the U5MR model, we compared the under-five mortality rates (U5MR) simulated by our model with the official U5MR estimates available from UNICEF (source https://data.unicef.org/topic/childsurvival/under-five-mortality/#data) for the 93 countries included in the study. The comparison focused on the years 2022 and 2023. The observed values from UNICEF fall within the uncertainty intervals of our model and with similar trend, indicating strong agreement between the simulated and empirical data.

11. MAIN LIMITATIONS

The analysis conducted in this forecast was based on the international guidelines for modeling and reporting set by ISPOR-SMDM. Despite that, this study is subject to limitations. Our estimates were based on levels of funding values by country (Baseline, Low, Intermediate, and High), which restricts the sensitivity of the outcomes to minor changes in funding values, depending on whether the change in funding is sufficient to change the country level of funding. In addition, the effects of cutting off aid from countries could vary widely depending on specific factors in each country. Furthermore, because we lack clear information about how and where these funding cuts will occur, it is difficult to predict exactly where the impacts will be felt and how severe they will be. This could lead to an underestimation of the total number of deaths, as the broader structural effects on countries might extend beyond the immediate financial impacts. The indirect consequences of dismantling the ODA could also have a wider impact on health system infrastructure, potentially hindering progress on several agendas that are not addressed in this analysis.

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