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The Cost of Cutbacks: How Reduction in Development Assistance for Health May Affect Progress Made in HIV/AIDS Control in Africa

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Abstract: Background/Objectives: The recent Executive Order suspending the United States Agency for International Development (USAID) programmes, including Development Assistance for Health (DAH), has sparked serious debates about the sustainability of ongoing HIV/AIDS control programmes, particularly in Africa. In this study, we examined HIV/AIDS-specific DAH allocation to Africa from 1990 to 2022, and the potential effects of funding cutbacks on disease outcomes. **Methods**: We nested 54 countries within five sub-regions of Africa and applied linear mixed-effects models to estimate the effects of DAH on HIV/AIDS incidence and mortality rates, accounting for clustering by sub-region and potential variability due to baseline incidence and mortality and other sources of heterogeneity. **Results**: Total DAH allocated to Africa increased from US$534,343 in 1990 to US$5,273,264 in 2022. The United States (U.S.) public sector contributed nearly two-thirds (US$58,399,088; 63.01%) of the total funding. Most of these funds were disbursed to Southern and Eastern Sub-Saharan Africa (SSA), particularly countries with the highest HIV/AIDS burdens, including South Africa and Kenya. The fixed effects results and predicted margins indicate that, in addition to having a direct effect, U.S. public sector-specific DAH moderates the effectiveness of other international donor funding and domestic general government health spending (GHES) on HIV/AIDS incidence and mortality. **Conclusions**: Based on the historical trends and funding interactions, the cutback in U.S. DAH could be associated with weakening of the overall effectiveness of other donor funding and GHES. However,

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any future effects are contingent on African countries' resilience to evolving challenges and resource allocation.

Keywords: development assistance for health; HIV/AIDS; Africa

1. Introduction

The global fight against HIV/AIDS has historically relied on a diverse combination of funding flows, and the United States (U.S.) Government has played a very crucial role through its international development policies and programmes [1–4]. Since its inception in 2003, the U.S. President's Emergency Plan for AIDS Relief (PEPFAR) has provided over $100 billion in the fight against HIV/AIDS, making the U.S. public sector the single largest contributor to global HIV/AIDS control funding over the last two decades [5,6]. A substantial portion of these funds has been channelled to Sub-Saharan Africa (SSA), which carries the highest disease burden globally, to support programmes aimed at HIV/AIDS prevention, treatment, and healthcare services [1,4,7]. Several studies have examined the direct effect of these initiatives and other international Development Assistance for Health (DAH) on HIV/AIDS outcomes in Africa. Some data indicate that DAH has contributed to enhancing access to antiretroviral treatment, strengthening healthcare services, and reducing HIV/AIDS-related mortality [1,4,8–10]. In a recent systematic review based on 102 studies, Xie and colleagues found that increasing international aid was associated with significant improvements in life expectancy and several other health outcomes, albeit with some inconsistencies [11].

However, the reliance on international aid raises serious concerns about the sustainability of the gains and progress made thus far, particularly in an era of changing political priorities, emerging socio-economic challenges among donor countries, and global events (e.g., the COVID-19 pandemic)—all of which have the potential to redirect or reduce funding [7,12–16]. On 20 January 2025, the U.S. President Donald Trump issued an Executive Order to evaluate and possibly realign U.S. foreign aid to meet contemporary and emerging needs. This order imposed a three-month (90 days) suspension on new obligations and disbursements, followed by a stop-work order for most existing programmes, including DAH, freezing service delivery in many countries worldwide [17]. This sudden shift in the U.S. foreign aid policies has raised concerns about the future of HIV/AIDS control and its broader implications, particularly in Africa.

Amidst the disruption and debates, questions have arisen regarding the synergy between U.S. DAH and other funding sources. Some researchers argue that this funding cutback will not only affect HIV/AIDS outcomes directly but will also alter the synergistic benefits derived from domestic health investments and other international donor funding. However, it remains unclear whether the cut in U.S. DAH flows will weaken existing beneficial synergies or if the remaining funding streams can compensate for the suspended U.S. DAH initiatives. Without addressing these concerns, the world risks sacrificing the potential benefits of integrated funding efforts and, ultimately, the long-established progress and success in global HIV/AIDS control.

Our study, utilising historical data, sought to address these intriguing questions by examining the direct effect of U.S. DAH, other international DAH, and domestic general GHES on HIV/AIDS incidence and mortality rates and, most importantly, their interactions. The findings of this study are intended to inform policy discussions on domestic and international donor funding reforms and to contribute novel evidence on donor-specific initiatives and integrated funding streams that reinforce successful HIV/AIDS control in Africa.

2. Materials and Methods

2.1. Conceptual Framework

The conceptual framework for this study was developed from prior literature [2,4,8–10,18–23] and theoretical models and constructs including Bronfenbrenner's ecological system model [24], the Dahlgren-Whitehead model of health determinants [25], and the World Health Organisation's (WHO) framework on social determinants of health [26], illustrating the effect of macro-level factors on HIV/AIDS outcomes (Figure 1). The outermost circle represents the global domain where donor funding plays a crucial role in the fight against HIV/AIDS. Within this sphere, the U.S. public sector-specific DAH is highlighted as a pivotal factor that not only exerts a direct effect but also moderates the effect of other donor funding streams. Moving inward, the African regional circle captures policies and cross-country agreements that shape the health landscape in the region, while the innermost circle represents country-level elements, including socio-economic indicators, health policy, and workforce capacity. At the core, HIV/AIDS outcomes, specifically incidence and mortality rates, are determined by the interaction among the layers of factors through continuous feedback loops.

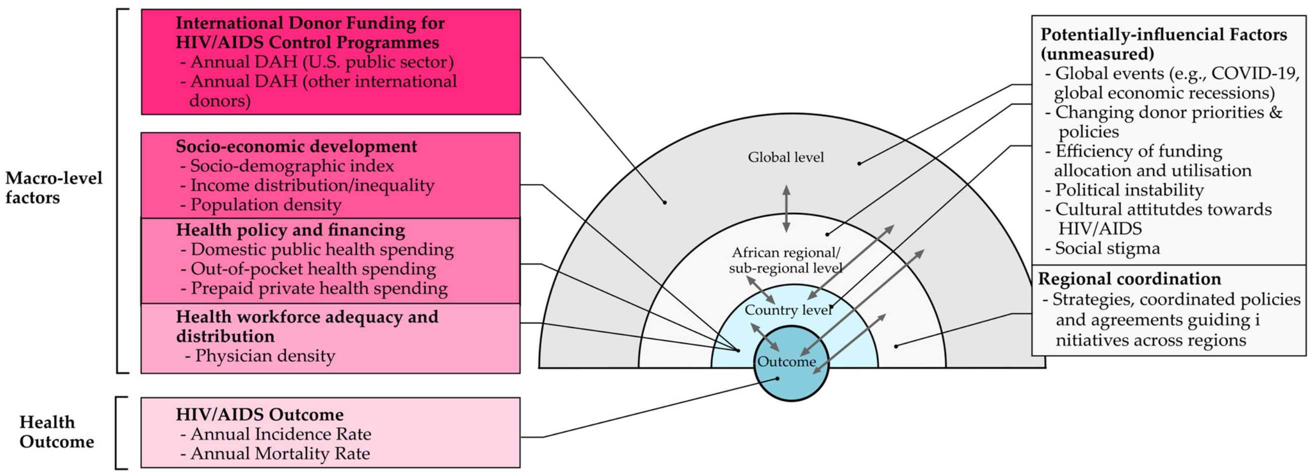

Figure 1. Conceptual Framework. This figure was developed based on insights drawn from relevant sources, ensuring that it reflects key factors influencing HIV/AIDS outcomes in Africa. The concentric circles illustrate the various macro- and structural-level factors shaping HIV/AIDS outcomes in Africa. The outermost ring represents upstream factors at the global level, emphasising development assistance for health (DAH) from the United States (U.S.) Public Sector and other international donors. The middle ring encapsulates mid-stream factors at the regional and sub-regional levels, including strategies, coordinated policies, and agreements guiding initiatives across African sub-regions. The innermost ring reflects downstream factors at the country level, encompassing socio-economic determinants (e.g., socio-demographic index, income distribution/inequality, population density), health policy and financing (including domestic public health spending, out-of-pocket health spending, and prepaid private health spending), as well as the adequacy and distribution of the health workforce (physician density). Additionally, unmeasured confounders such as political stability, cultural attitudes towards HIV/AIDS, and social stigma play a crucial role. At the core of this framework lie HIV/AIDS incidence and mortality outcomes, quantified by annual incidence and mortality rates per 100,000 people. The bidirectional arrows denote feedback loops, illustrating how factors across different levels of the causal chain interact, influencing one another and ultimately shaping the outcome. Due to data availability constraints, only variables highlighted in the pink boxes were included in the statistical analysis.

Within this framework, three critical questions were addressed: (1) How were international donor funds for HIV/AIDS control disbursed across the African sub-regions and countries during the last 32 years, and what trends can be observed in the evolution of these allocation patterns? (2) How did the U.S. public sector-specific DAH interact with other donor funding and GHES in shaping HIV/AIDS control efforts in Africa? (3) What might these historical associations imply for future trends, assuming that resource allocation and disease patterns continue as they have in previous periods? Although we use the terms disbursement and allocation interchangeably throughout this paper, we are specifically referring to disbursement, the actual release and transfer of funds, as validated by our data sources.

2.2. Target Region and Countries

This serial cross-sectional ecological study was conducted as part of the Sub-Saharan Africa Research for Sustainable Development (SSARSD) Project initiatives. The goals and objectives of this project are published elsewhere [27]. Our study focused on the African continent, a high-burden HIV/AIDS region, and a major beneficiary of DAH [1,4,7]. Africa is one of the six global continents and the second most populous region after Asia. It is divided into five sub-continents: Central, Eastern, Northern, Southern, and Western Africa, which comprise 54 sovereign states, each with unique socio-cultural and economic characteristics [28]. In terms of land size, Algeria is the largest country; however, Nigeria has the largest population in the region [29]. With approximately 1.4 billion people, Africa accounts for about 18% of the global population, with projections indicating it will become the most populous continent by 2060 [30]. The region's population is predominantly youthful, with a median age of about 19 years. Despite recent progress, Africa faces significant health challenges, including infectious diseases such as tuberculosis (TB), malaria, and HIV/AIDS. Availability and access to quality health services also vary widely, with many populations still lacking access to essential healthcare services. Efforts to strengthen health systems have recently focused on universal health coverage (UHC), community-based care, and tackling social determinants of health to improve outcomes [31]. Most African countries are currently transitioning from centrally planned economies to liberal market-based economies [29]. The complete list of countries is presented in Table 1.

2.3. Variables and Data Source

We assembled a comprehensive, aggregate-level dataset from reputable sources, including the Institute for Health Metrics and Evaluation (IHME) and the World Inequality Data (WID) lab, to examine the effect of HIV/AIDS-specific DAH on HIV/AIDS incidence and mortality across Africa (Table S1). We chose to use data from these sources because of their consistent provision of high-quality, regularly updated, and standardised datasets that were essential for our serial, cross-sectional ecological study. While alternative data sources exist, many lack the same level of completeness, methodological transparency, and standardisation required for our study. To date, IHME remains the most comprehensive source of global health data, with well-documented and standardised health financing and epidemiological indicators [32]. Similarly, for about a decade, the WID has consistently produced high-quality, nationally comparable data on the various dimensions of inequality through evidence-based research, making the WID the most comprehensive open-access source of global inequality data [33]. These combined strengths made IHME and WID the superior choice for our study to ensure that our results are both reliable and reproducible.

Table 1. Sources and distribution of HIV/AIDS-specific development assistance for health (DAH) across Africa, 1990–2022.

	United States Public Sector					Other International Donors				
Region/Country	**1990**	**2022**	**Total (1990–2022)**	**Median**	**Interquartile Range (IQR)**	**1990**	**2022**	**Total (1990–2022)**	**Median**	**IQR**
Central Africa										
Angola	220	17,048	292,450	9848	647–15,089	82	10,796	259,796	4961	1622–12,693
Cameroon	296	101,689	622,547	5524	223–27,608	88	47,896	579,146	18,300	579–30,458
Central African Republic	69	10,192	86,471	1954	75–3061	19	15,485	247,069	6393	345–12,523
Chad	159	8899	111,448	1428	342–6892	2577	14,342	329,348	6965	2975–15,469
Congo	50	4152	42,420	1117	39–1922	8	7841	145,867	3695	515–7563
Democratic Republic of Congo	980	103,010	1,065,907	17,541	1038–61,344	10,015	55,502	1,262,142	44,185	2738–67,400
Equatorial Guinea	2	103	3810	1	0–103	3	2608	34,081	12	32,143
Gabon	21	698	15,853	225	12–831	2	3339	61,981	1544	22–2921
Sao Tome and Principe	8	2023	13,885	117	6–621	1	4898	53,728	668	25–2647
Sub-region	1805	247,814	2,254,791	703	39–5524	12,795	162,707	2,973,158	2975	302–11,262
Eastern Africa										
Burundi	205	24,949	233,886	4201	205–12,259	96	16,753	426,658	15,111	882 - 20,138
Comoros	11	851	13,671	185	33–697	1	3615	57,257	733	157–2807
Djibouti	26	611	33,650	628	26–1774	6	3291	117,903	3516	179–6146
Eritrea	131	4177	97,458	2739	143–4186	15	7617	260,522	7617	856–12,507
Ethiopia	2426	146,934	3,492,492	82,387	4055–187,851	3764	88,865	2,396,746	70,536	14,179–88,865
Kenya	3409	324,109	6,430,490	161,959	14,219–372,810	18,973	109,057	2,033,820	67,565	20,892–98,800
Madagascar	195	4015	78,617	2533	212–3476	30	7807	200,763	5402	232–9378
Malawi	1308	209,916	2,013,290	35,219	11,341–90,054	2095	84,257	2,111,738	71,714	12,147–114,210
Mauritius	10	428	9717	16	5–411	1	3219	48,454	236	9–2972
Mozambique	1992	382,558	4,042,448	63,990	2166–244,619	3336	108,294	1,957,063	63,016	5461–108,294
Rwanda	313,903	86,028	2,069,012	63,490	3504–86,667	99,987	34,189	1,397,188	34,189	5200–59,871
Seychelles	0	0	1886	0	0–1	0	0	9686	0	0–72
Somalia	132	4103	44,589	706	93–2240	16	7497	142,612	3141	118–7933
South Sudan	154	54,466	240,929	294	112–14,301	60	30,362	205,605	1098	257–11,904
Tanzania	0	314,037	5,071,245	112,160	7850–314,037	26,790	64,987	2,349,792	64,229	17,352–119,253
Uganda	2307	310,491	5,398,838	176,254	8763–299,376	2213	93,288	1,824,540	57,251	21,022–86,849
Zambia	1733	270,598	4,107,366	112,261	11,847–228,169	2803	68,115	1,678,906	54,344	9346–76,743
Zimbabwe	1439	194,929	1,778,476	34,590	7816–97,346	11,172	81,341	2,275,025	64,960	18,686–115,723
Sub-region	329,381	2,333,200	35,158,060	3520.5	205–70,262	171,358	812,554	19,494,278	9234	1166–57,740
Northern Africa										
Algeria	10	389	4257	5	0–137	0	1770	30,251	136	12–1544
Egypt	16	3517	22,844	280	9–1021	0	5819	59,749	1093	361–2999
Libya	3	0	185	0	0–3	0	1282	28,053	77	9–1282
Morocco	46	5121	31,935	555	3–1350	0	7463	122,778	3490	1905–5514
Sudan	222	12,410	203,026	2567	159–12,244	41	18,314	385,003	9045	508–17,907
Tunisia	27	1459	13,007	29	0–553	0	3047	44,714	420	6–2139
Sub-region	324	22,896	275,254	44	0–864	41	37,695	670,548	1262	45–3371
Southern Africa										
Botswana	775	34,198	1,341,181	34,198	843–56,662	1070	5879	304,508	6494	1280–15,802
Eswatini	0	53,531	673,237	8242	0–39,476	0	6507	325,252	6797	400–16,379

Table 1. *Cont.*

	United States Public Sector					Other International Donors				
Region/Country	**1990**	**2022**	**Total (1990–2022)**	**Median**	**Interquartile Range (IQR)**	**1990**	**2022**	**Total (1990–2022)**	**Median**	**IQR**
Lesotho	410	65,370	577,317	3342	293–30,313	225	15,984	408,954	12,602	1291–22,882
Namibia	707	71,082	1,347,383	32,218	707–71,082	1385	8678	486,842	12,000	2737–21,966
South Africa	3677	522,597	8,135,678	164,487	15,185–468,293	3164	112,359	2,538,446	94,203	8647–112,496
Sub-region	5569	746,778	12,074,796	24,625	544–60,303	5844	149,407	4,064,002	11,356	2123–23,821
Western Africa										
Benin	200	11,866	144,016	3649	262–7583	44	12,585	317,886	12,137	746–15,581
Burkina Faso	271	11,716	172,928	2995	504–8240	85	13,410	643,460	16,076	7933–29,425
Cabo Verde	0	571	8601	115	0–482	0	680	29,471	680	0–1535
Cote d'Ivoire	677	71,696	1,512,831	33,287	526–85,710	210	25,708	531,344	13,510	3966–25,473
Gambia	0	3114	53,611	2021	0–2790	0	3825	145,775	4973	286–7306
Ghana	413	30,709	604,773	19,496	6904–28,540	108	32,464	941,254	31,352	1830–45,967
Guinea	114	15,583	132,545	3848	1495–5148	37	20,816	230,989	6548	1951–10,859
Guinea-Bissau	55	5120	55,448	555	55–3432	279	8668	164,006	2834	752–8668
Liberia	107	10,480	127,521	1959	79–7275	51	9827	248,536	7661	266–12,708
Mali	158	13,360	204,609	6901	2386–8924	137	18,257	343,616	11,954	1439–16,381
Mauritania	11	1850	16,771	345	9–761	3	5297	70,162	1224	131–3620
Niger	148	9525	57,425	1687	148–2461	45	16,178	226,402	8384	657–11,350
Nigeria	1999	216,935	5,061,493	90,165	1999–274,701	1441	94,471	2,286,510	52,867	9432–112,113
Senegal	202	12,166	2,51,025	8337	2129–12,166	67	16,173	358,767	10,832	3704–16,506
Sierra Leone	155	18,833	1,37,782	1956	112–7641	32	17,635	302,103	8566	192–15,796
Togo	144	15,171	94,808	1784	102–4258	33	15,524	234,941	6387	490–11,908
Sub-region	4654	448,695	8,636,187	2311	170–8042	2572	3,11,518	7,075,222	6392	752–15,499.5
Overall (Africa)	341,733	3,799,383	58,399,088	1679	93–12,672	192,610	1,473,881	34,277,208	5194	676–18,036

Our outcome variables were aggregate-level, sex-specific age-standardised HIV/AIDS incidence and mortality rates per 100,000 population. For the predictors, we focused on three key funding streams: U.S. DAH, other international donor DAH, and GHES per capita. In the context of this study, U.S. DAH was defined as the U.S. public sector-specific DAH for HIV/AIDS control and excludes all other sources of DAH from the U.S. (those were added to other international donor DAH). It included funds for HIV/AIDS counselling and testing, treatment and support, health system strengthening and capacity building, human resource development, support for orphans and vulnerable children, prevention of mother-to-child transmission (MTCT), and prevention of new infections and drug resistance. Differentiating between funding sources allowed for a granular assessment of how different funding streams individually and jointly relate to HIV/AIDS outcomes.

We also incorporated several socio-economic and health system variables—income inequality (Gini coefficient), socio-demographic index (SDI), sex, physician density, out-of-pocket health spending (OOP), and pre-paid private health spending (PPPS)—as co-variates to account for potential confounding and country-level sources of heterogeneity in our mixed-effects analysis. These variables were carefully selected based on our conceptual framework. The period 1990 to 2022 was chosen to capture a transformative era marked by notable growth in international DAH and other HIV/AIDS control initiatives in Africa [3,11,34] and the availability of standardised, comparable, and high-quality data that were essential for our study [35]. This dual emphasis on theoretical relevance and data quality ensured a robust assessment of the effect of the predictors on HIV/AIDS outcomes in Africa. The Supplementary Material (Table S1) provides a detailed description of the variables and data sources.

2.4. Data Analysis

Data on HIV/AIDS-specific DAH funding allocation and distribution patterns in Africa were summarised using median, interquartile range (IQR), and changes over time. To answer our second and third research questions, we employed a multi-level linear mixed-effects model to test the associations between the set of predictors and the outcomes (HIV/AIDS incidence and mortality), as shown in our conceptual model, accounting for clustering by sub-region and potential variability due to baseline HIV/AIDS incidence and mortality and other sources of heterogeneity at the sub-region and country levels. We nested 54 countries within the five sub-regions of Africa, according to the United Nations (UN) country groupings. In line with best practice guidance for linear mixed-effects modelling [36], different models were developed and compared to determine the best-fitting model for the study data (Figure S1).

The primary model, with an unstructured covariance matrix, included fixed effects for: U.S. DAH, other international donor DAH (Other DAH), GHES, interaction terms between U.S. DAH, Other DAH, and GHES, income inequality (Gini), SDI, physician density, OOP, and PPPS, allowing for random intercepts at sub-region and CompID (composite ID group defined by country and sex) levels and random slopes for U.S. DAH at CompID level. Interactions and random slopes were explored using marginal plots and Best Linear Unbiased Prediction (BLUP), respectively. Given the need for model comparison, and our large sample size, the maximum likelihood estimation (MLE) method was chosen over restricted maximum likelihood (RMLE) [37]. Akaike (AIC) and Bayesian Information (BIC) Criteria indices were used to compare models. In cases of conflicting results, BIC was used, given its robustness for identifying the correct model structure in mixed modelling [38].

Estimates were reported with their 95% confidence interval (CI) and *p*-values. All *p*-values were two-tailed and considered significant at a 5% significance level. All variables were log-transformed (natural log) given their positive skewness, and all predictors were mean-centered so that zero represents the average (mean) funding level, allowing the effects and interactions to be interpreted relative to typical conditions in the countries examined [37]. For positively skewed variables containing zero values (U.S. DAH, Other DAH, and PPPS), we applied a [log(x + 1)] transformation [39]. All preliminary assumptions relating to linearity, normal distribution, independence, and constant variance of the errors were met.

2.5. Robustness Assessment

One major challenge in analytical ecological studies is the potential effect of unmeasured confounding on the study results [40]. To address this concern, our mixed-effects models were carefully designed to account for key confounders and covariates. Specifically, we included adjustments for SDI (a composite measure of national socio-economic development), OOP, PPPS, income inequality, physician density, and other relevant factors (Table S1). Including these variables ensured that our analysis accurately captured the complex relationships among predictors, covariates, and HIV/AIDS outcomes.

To further test the validity of our findings, we conducted a series of robustness assessments, including a Monte Carlo simulation-based sensitivity analysis [41]. Specifically, we simulated a hypothetical confounder, U, drawn from a standard normal distribution, assuming it is associated with our primary predictors (U.S. DAH, Other DAH, and GHES) via a range of plausible lambda (λ) values (0.1 to 0.9), capturing the strength of these associations. For each plausible λ value, we generated new values for U, refitted the full mixed-effects model with U included as a covariate, and recorded the corresponding coefficient for U.S. DAH, Other DAH, and GHES. This procedure yielded a distribution of estimates that quantified the potential bias introduced by omitted variable confounding, allowing us to assess the robustness of our findings across a range of plausible λ values [42].

Also, we applied a jackknife (leave-one-country-out) procedure in our primary mixed-effects model to ensure that key interaction effects were not driven by any single country, especially those receiving high funding [43,44]. In addition, we computed and compared estimates across two sample periods—the full sample (1990–2021) and a restricted pre-COVID sub-sample (1990–2019)—to ensure the stability of the relationships between the funding streams and HIV/AIDS outcomes.

Moreover, we employed a comprehensive multi-method econometric strategy to address concerns about potential endogeneity and reverse causality. Our primary, complementary approaches included fixed-effects Instrumental Variable (IV) estimation [45–47], dynamic panel data modelling using the Arellano-Bond/System Generalised Method of Moments (GMM) [48,49], and a control function approach [50,51], with endogenous variables instrumented using their lagged values and instrument validity assessed via Hansen tests [52]. The analysis was performed using Stata v18 [53].

3. Results

3.1. HIV/AIDS-Specific Development Assistance for Health Allocation to Africa

We began by exploring how HIV/AIDS-specific DAH was disbursed among African countries during the last 32 years (between 1990 and 2022). Our findings indicate a substantial increase in funding, rising from US$534,343 in 1990 to US$5,273,264 in 2022 (≈887% growth). The total funding allocation from 1990 to 2022 was US$92,676,296, and the U.S. public sector contributed nearly two-thirds of the total amount (US$58,399,088; 63.01%). Southern and Eastern SSA countries received most of these funds (17.41% and 58.97%, respectively), aligning with their high HIV/AIDS burden. Specifically, South Africa, Kenya, Uganda, Mozambique, Zambia, and Zimbabwe were among the top beneficiaries, highlighting targeted support where it is most needed. In contrast, Northern African nations received comparatively lower DAH, consistent with their lower HIV/AIDS burden (Table 1).

3.2. Association Between DAH and HIV/AIDS Incidence and Mortality

In addition to the funding distribution patterns, we addressed two critical questions: (1) How U.S. DAH interacted with other donor funding and GHES in shaping HIV/AIDS control efforts in Africa during the last 32 years; (2) What these historical associations imply for future trends, assuming that resource allocation and disease patterns continue as they have in previous periods.

Accordingly, we report our mixed-effects test results focusing on the three key funding streams: U.S. DAH, Other DAH, and GHES. It is important to note that in our analysis, all predictors were mean-centred so that zero (0) represents the average (mean) funding level, one standard deviation below the mean (−1 SD) represents a low funding level, and one SD above the mean (+1 SD) represents a high funding level. The fixed effects results show that increased U.S. DAH was associated with a decrease in incidence rate ($\beta = -0.047$, $p = 0.006$). A similar inverse relationship was observed between Other DAH and HIV/AIDS incidence ($\beta = -0.046$, $p < 0.001$). Their interaction (U.S. DAH and Other DAH) was also significantly associated with lower incidence ($\beta = -0.013$, $p < 0.001$). In contrast, increased GHES correlated with a surge in HIV/AIDS incidence ($\beta = 0.108$, $p < 0.001$). However, this relationship was mitigated by the interaction between U.S. DAH and GHES ($\beta = -0.093$, $p < 0.001$). The interaction between Other DAH and GHES showed a significant positive association ($\beta = 0.016$, $p < 0.001$).

As illustrated in Figure 2A, when U.S. DAH was low (−1 SD), the effect of other international DAH on HIV/AIDS incidence was negligible. However, at average levels of U.S. DAH (Mean = 0), an increase in other international donor DAH (+1 SD) was associated with a significant decrease in incidence, a reduction that became even more pronounced when U.S. DAH was high (+1 SD). Similarly, when U.S. DAH was high, increased GHES (+1 SD) correlated with a significant reduction in HIV/AIDS incidence. Predicted margins computed over 27 combinations of funding levels confirmed this synergy; for example, the combination of high U.S. DAH (+1 SD), high other-donor DAH (+1 SD), and high domestic spending (+1 SD) yielded the lowest predicted log HIV/AIDS incidence (Figure 3). In real-world terms, where GHES and Other DAH were held high—specifically, with Other DAH around $100,000 and GHES at a value of 200 per capita (measured in purchasing power parity (PPP))- an increase in U.S. funding from approximately $56 to about $16,200 was associated with a decrease in HIV/AIDS incidence from roughly 181 to around 50 per 100,000 people, reflecting a 73% decline. In contrast, in situations where U.S. DAH was fixed at a low level (roughly $56) and Other DAH stayed high (about $100,000), the predicted margins revealed a counterintuitive result: as governments increased health spending from 11 per capita to about 200 per capita (in PPP), the estimated HIV/AIDS incidence rate rose from roughly 53 to around 181 per 100,000 people, potentially reflecting reactive government spending.

For HIV/AIDS mortality, although the main effects of U.S. DAH and Other DAH were not significant individually, their interaction was associated with a significantly lower mortality rate ($\beta = -0.025$, $p < 0.001$). In contrast, increased GHES was significantly associated with higher mortality ($\beta = 0.133$, $p < 0.001$). However, this effect was mitigated when GHES interacted with U.S. DAH ($\beta = -0.142$, $p < 0.001$). As shown in Figure 2, at low U.S. DAH (−1 SD), a one-unit increase in other international donor funding was associated with a 0.063 (95% CI: 0.05 to 0.077) unit increase in mortality. However, at high U.S. DAH (+1 SD), that same increase corresponded to a 0.078 (95% CI: −0.097 to −0.067) unit decrease in mortality. GHES showed similar margins, with a strong positive association at low U.S.

DAH and a negative association at high levels. The predicted margins supported these findings. A scenario where Other DAH is maintained at a high level (a mean-centred value of 3.64, which back-transforms to roughly $100,000), two patterns were observed: First, when GHES is also high (mean-centred value of 1.43, or about 200 spending per capita in PPP), an increase in U.S. DAH from a low level (mean-centred value of –2.83, approximately $56) to a high level (mean-centred value of 2.83, roughly $16,200) was associated with a decline in predicted mortality from about 112 to 28 per 100,000 people—a reduction of roughly 75%. In a separate scenario, holding U.S. DAH low (–2.83, about $56 per capita) and Other DAH high (roughly $100,000), an increase in domestic government spending from low (mean-centred value of –1.43, around 11 per capita in PPP) to high (mean-centred value of 1.43, approximately 200 per capita in PPP) was associated with an increase in predicted mortality from roughly 27 to about 112 per 100,000 people.

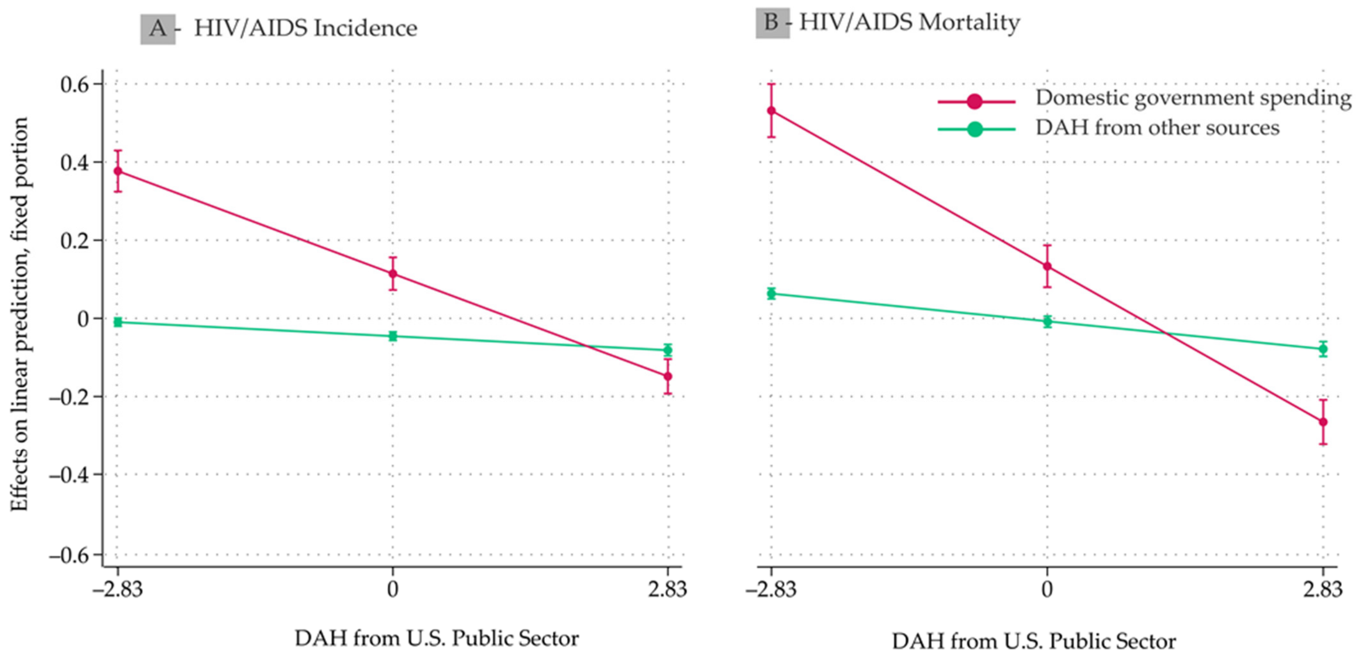

Figure 2. Interaction Plots showing Marginal Effects of Domestic Government Health Spending and Development Assistance for Health (DAH) Funding from International Donors (Excluding the United States (U.S.) Public Sector) on HIV/AIDS Incidence and Mortality Rates at Different Levels of U.S. Public Sector-Specific DAH among African Countries. (**A**) Effects of Other International Donor DAH (Green) and GHES (Red) on HIV/AIDS incidence rate at different levels of the U.S. Public Sector-specific DAH funding; (**B**) Effects of Other International Donor DAH (Green) and GHES (Red) on HIV/AIDS mortality rate at different levels of U.S. Public Sector-specific DAH. As illustrated in (**A**), for example, in countries where U.S. DAH is low (–1 standard deviation (SD)), the effect of other international DAH on HIV/AIDS incidence is negligible. However, at average levels of U.S. DAH (Mean = 0), an increase in other international DAH (+1 SD) is associated with a significant decrease in HIV/AIDS incidence, and this reduction is even more pronounced when U.S. DAH is high (+1 SD). Similar patterns were observed for domestic spending, with a strong positive effect (coefficient) at low U.S. DAH and a negative effect at high levels.

The random effects analysis reveals some variability in the effect of U.S. DAH on HIV/AIDS outcomes across Africa. In many countries, the population-specific estimates (BLUPs) of the random slopes show high variability (Figure S2). This heterogeneity indicates that the effect of U.S. DAH is context-dependent, likely reflecting country-level variations in funding implementation, effectiveness of public health initiatives, and local epidemiological situations.

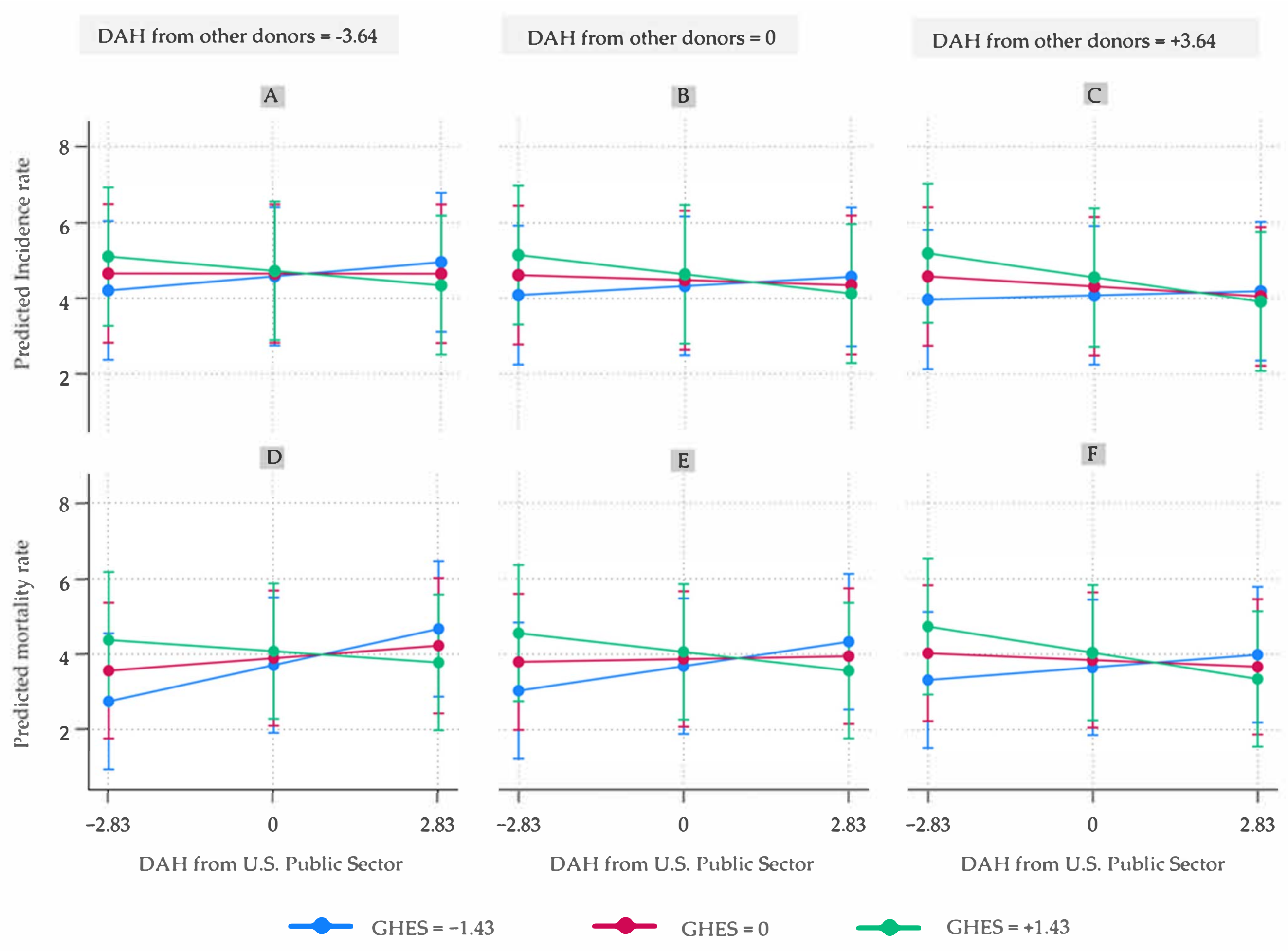

Figure 3. Predicted HIV/AIDS incidence and mortality rates at different levels of the United States (U.S.) public sector-specific Development Assistance for Health (DAH), other International Donor funding (Other DAH) and Domestic General Government Health Spending (GHES). (**A**) Predicted HIV/AIDS incidence rate when Other DAH is low and U.S. DAH and GHES are varied from low to high; (**B**) Predicted HIV/AIDS incidence rate when Other DAH is at its average and U.S. DAH and GHES are varied from low to high; (**C**) Predicted HIV/AIDS incidence rate when Other DAH is high and U.S. DAH and GHES are varied from low to high; (**D**) Predicted HIV/AIDS mortality rate when Other DAH is low and U.S. DAH and GHES are varied from low to high; (**E**) Predicted HIV/AIDS mortality rate when Other DAH is at its average and U.S. DAH and GHES are varied from low to high; (**F**) Predicted HIV/AIDS mortality rate when Other DAH is high and U.S. DAH and GHES are varied from low to high. For example, the combination of high U.S. DAH (+2.83), high other donor DAH (+3.64), and high GHES (+1.43) corresponds to the lowest predicted HIV/AIDS incidence rate (C), while the combination of low U.S. DAH (−2.83), high Other DAH, and high GHES yields relatively higher predicted mortality rate (F).

3.3. Additional Results

For HIV/AIDS incidence, dynamic system GMM results showed a statistically significant positive association between GHES and incidence, suggestive of reactive spending (an indication of reverse causality). The control function approach clarified this finding: when the endogenous (‘reverse causal’) component of GHES was isolated via residuals, it showed a significantly negative association with incidence, implying that once reverse causality is addressed, higher government spending would correlate with lower incidence. In contrast, for HIV/AIDS mortality, both fixed-effects IV and control function methods consistently yielded non-significant effects of GHES, suggesting that reverse causality was not a driving factor. Overall, the evidence points to a nuanced role of reverse causality in the incidence relationship, where reactive spending could obscure the true beneficial effects of GHES, while for mortality, there is little indication that reverse causality biased the estimates.

Regarding donor funding, the fixed-effects IV approach found no evidence that changes in HIV/AIDS mortality drove U.S. DAH funding, which contrasts with the mixed-effects model results (Table 2). The dynamic panel data model showed that U.S. DAH was largely influenced by past funding levels rather than current mortality rates. Similarly, the control function approach negligible residual endogeneity. Collectively, these findings indicate that reverse causality was not a major concern in explaining U.S. DAH, reinforcing the view that funding levels were reactive to contemporaneous changes in HIV/AIDS mortality.

Table 2. Results of multi-level linear mixed-effects models showing the association between various funding streams and HIV/AIDS incidence and mortality rate in Africa.

Effects	HIV/AIDS Incidence				HIV/AIDS Mortality			
	Coefficient	SE	95% CI	*p*	Coefficient	SE	95% CI	*p*
Fixed Effects								
U.S._DAH	−0.047	0.017	−0.081 to−0.013	0.006 *	0.027	0.024	−0.019 to 0.073	0.254
Other_DAH	−0.046	0.006	−0.057 to −0.035	<0.001 *	−0.007	0.007	−0.022 to 0.007	0.301
U.S._DAH#Other_DAH	−0.013	0.001	−0.015 to −0.010	<0.001 *	−0.025	0.002	−0.028 to −0.022	<0.001 *
GHES	0.108	0.021	0.066 to 0.150	<0.001 *	0.133	0.028	0.079 to 0.187	<0.001 *
U.S._DAH#GHES	−0.093	0.004	−0.102 to −0.084	<0.001 *	−0.142	0.006	−0.154 to −0.131	<0.001 *
Other_DAH#GHES	0.016	0.004	0.009 to 0.023	<0.001 *	0.001	0.005	−0.008 to 0.010	0.842
U.S._DAH#Other_DAH#GHES	0.0001	0.001	−0.001 to 0.001	0.838	0.004	0.001	0.002 to 0.006	<0.001 *
Physician density	0.024	0.039	−0.054 to 0.101	0.550	−0.100	0.051	−0.199 to −0.001	0.049 *
Gini coefficient	0.468	0.154	0.167 to 0.770	0.002 *	0.227	0.198	−0.161 to 0.616	0.251
SDI	−1.492	0.073	−1.635 to −1.349	<0.001 *	−1.755	0.094	−1.940 to −1.571	<0.001 *
Pre-paid private spending	−0.010	0.008	−0.025 to 0.004	0.166	0.028	0.010	0.009 to 0.047	0.004 *
Out-of-pocket spending	0.217	0.023	0.172 to 0.262	<0.001 *	0.243	0.030	0.185 to 0.301	<0.001 *
Sex								
Female	Ref		-				-	
Male	−0.158	0.303	−0.751 to 0.435	0.601	−0.136	0.353	−0.828 to 0.556	0.700
Intercept	4.638	0.947	2.782 to 6.495	<0.001 *	4.016	0.936	2.181 to 5.852	<0.001 *
Random effects								
Sub-region level								
Intercept	4.225	2.822	1.141 to 15.641		4.026	2.746	1.058 to 15.328	
Country level								
var(U.S._DAH)	0.031	0.005	0.023 to 0.041		0.058	0.009	0.043 to 0.077	
var(intercept)	2.466	0.346	1.873 to 3.247		3.420	0.483	2.594 to 4.510	
cov(U.S._DAH, intercept)	0.001	0.034	−0.064 to 0.067		−0.062	0.053	−0.166 to 0.042	
var(Residual)	0.053	0.002	0.050 to 0.056		0.088	0.002	0.083 to 0.093	
Nsite	5				5			
Nmix	108				108			
ICC	0.94				0.94			
N	2700				2700			

DAH: development assistance for health. U.S._DAH: U.S. public-sector specific DAH. Other_DAH: DAH from other international donors (excluding U.S. public sector funds). GHES: Domestic general government health spending. SDI: Socio-demographic index. SE: Standard error. CI: Confidence interval. var(U.S._DAH): Variance of the country-level random slope associated with U.S._DAH. cov(U.S._DAH, intercept): Covariance between random slope (U.S._DAH) and random intercept. var(Residual): Variance of the residuals. All variables were log-transformed (natural log), and all predictors were mean-centred. Nsite: Number of sub-region identity (ID) groups. Nmix: Number of CompID clusters (composite ID groups defined by country and sex). ICC: Unconditional (intercept-only) interclass correlation attributable to CompID nested within sub-region ID. N (Observation): Total sample size in the full model. # Interaction term. * Statistically significant at $p < 0.05$.

Regarding whether donors rewarded countries with lower past HIV/AIDS incidence, again, we focused exclusively on U.S. DAH, which was previously characterised by clearly defined, performance-based metrics and consistent reporting standards, in contrast to Other DAH flowing from multiple sources with varied priorities, making them less directly comparable for assessing the targeted resource allocation. Under the premise that lower past incidence, a proxy for improved HIV/AIDS control, signalled programme effectiveness and merited further support, our primary specification (Option 1) found that a one-unit decrease in lagged HIV/AIDS incidence was associated with a 0.56-unit increase in subsequent U.S. DAH ($p = 0.058$). This negative association, alongside a significant, persistent effect of U.S. DAH (coefficient 1.55, $p < 0.001$), is consistent with the notion that donors might reward better-performing countries. However, the extremely low Hansen test p-value ($p < 0.001$) raised concerns about instrument validity and potential overidentification. The alternative specification (Option 2), which addressed the instrument validity concern, did so at the expense of precision. Thus, our findings underscore the trade-offs inherent in dynamic panel estimation and highlight the need for cautious interpretation.

4. Discussion

4.1. DAH Allocation and Its Effects on HIV/AIDS Incidence and Mortality

This study examined international aid disbursement for HIV/AIDS control and evolving funding patterns among African countries from 1990 to 2022. It further investigated how U.S. DAH interacted with other donor funding and domestic general government health expenditure, and explored what these historical associations might imply for future trends. The results show a substantial growth in HIV/AIDS-specific DAH in Africa over the 33 years examined, reflecting global efforts to combat the HIV/AIDS epidemic in the region. The U.S. public sector contributed nearly two-thirds of the overall funding. Most of these funds were channeled to Southern and Eastern SSA countries, specifically, those with high HIV/AIDS burdens, including South Africa, Zimbabwe, and Kenya. The concentration of DAH in these countries seems consistent with the priority of addressing the most affected regions. This targeted funding approach reflects the principles of health equity, which advocates for the allocation of resources to where they are most needed to maximise health gains [7,16,54]. The U.S. government's significant investment in HIV/AIDS programmes also highlights its pivotal role in global health initiatives, particularly through programmes such as PEPFAR, which has made substantial contributions to HIV/AIDS prevention, capacity building, and treatment efforts in Africa [5,6].

The results of our mixed-effects models indicate that reductions in U.S. DAH were associated with a diminished overall effectiveness of both domestic government health spending and other international donor funding for HIV/AIDS control. The fixed effect estimates and predicted margins revealed that the effects of international donor DAH and GHES on HIV/AIDS incidence and mortality were conditional on U.S. DAH. Notably, in scenarios where U.S. DAH was low, even with increased funding from other international donors and domestic governments, HIV/AIDS incidence remained relatively high, compared with when all funding streams were high. Similarly, when U.S. DAH was low but the other two funding streams were high, the predicted mortality rate was substantially high. In contrast, when high U.S. DAH was paired with high levels of international donor funding and domestic spending, the predicted HIV/AIDS mortality dropped considerably, suggesting a beneficial synergy between the three funding streams.

These empirical findings can be understood by considering the comprehensive role of the U.S. health aid in the global fight against HIV/AIDS. Previously, when the U.S. public sector programmes like PEPFAR were running at full capacity, with adequate funding, well-trained personnel, and effective management, they provided not only financial support for countries in Africa, but also essential technical expertise, close monitoring, and coordinated programmatic support that ensured sustainable, systemic improvements in HIV/AIDS prevention and care [5]. In its absence, alternative funding streams are likely to be deployed reactively, addressing immediate crises rather than supporting long-term capacity building, leading to fragmented service delivery and inefficiencies [55]. For example, the Joint United Nations Programme on HIV/AIDS (UNAIDS) case analyses and reports from countries in SSA, including Eswatini, South Africa, Nigeria, Kenya, and Zimbabwe, have linked the recent reductions in U.S. aid to disruptions in antiretroviral supply chains and gaps in prevention services (including pre-exposure prophylaxis and early infant diagnosis), thereby amplifying the epidemic despite increased levels of domestic and non-U.S. donor expenditures [56,57].

Regarding the 'beneficial' synergy between the funding streams, our research finds resonance with earlier studies emphasising the role of integrated financing in optimising system-wide efficiency and improvement in health outcomes. For instance, Atun et al. [58] demonstrated how integrating targeted health interventions into broader health systems can lead to more sustainable outcomes, while Lagomarsino and colleagues [16] provided evidence that diversified health financing—via comprehensive health insurance reforms—enhances system performance and resilience in low-resource settings. An integrated funding stream has proven effective in several African countries, where strategic regional partnerships and collaborations with multilateral organisations have mitigated the adverse effects of donor policy realignment [54,59]. These alternative health financing strategies not only provide essential resources for HIV/AIDS services, but also offer opportunities for a more integrated, sustainable financing models that bolster health systems and improve resilience [14]. By broadening the donor base, countries can reduce dependency on a single funding source and ensure continuity of vital HIV/AIDS services [11,12,60].

The considerable heterogeneity observed, with populations in Angola showing mitigation or reversal of the fixed protective effect, while those in the Democratic Republic of Congo, Burundi, and Zimbabwe experience amplified benefits, highlights the context-dependent nature of donor funding effects. These disparities suggest that locally specific factors such as health system strength, policy environments, and socio-economic conditions influence the success of external funding interventions. Moreover, the political economy of health—emphasising how power dynamics, governance structures, and economic policies shape resource allocation and policy priorities—might play a crucial role in determining how donor funding policies and terms of conditions affect national health systems and the delivery of essential services [60].

4.2. Policy Implications and Recommendations

Consistent with the literature [1–4], our study has shown that the U.S. public sector has been a driving force behind the global fight against HIV/AIDS, channelling large sums of money to the African region. Strategically, these funding initiatives have targeted critical areas of HIV/AIDS control, including counselling and testing, clinical care and support for patients, health system strengthening, human resource development, prevention of MTCT, support for orphans and vulnerable children, and prevention of new infections and drug resistance. As shown in the mixed-effects modelling, in addition to exerting a direct effect on HIV/AIDS incidence, U.S. DAH also enhances the effect of domestic government funding and other international donor DAH on HIV/AIDS incidence and mortality. Based on these historical trends and funding interactions, any cutbacks in U.S. DAH could be associated with a weakening in the overall effectiveness of Other DAH and GHES, contingent on African countries' resilience to evolving challenges, disease patterns, and the allocation of other resources in the future.

Our findings also indicate that African governments tend to increase health spending reactively in response to rising HIV/AIDS incidence, rather than mortality. One possible explanation is that spikes in new infections generate considerable political and media pressure, leading to immediate initiatives and budget reallocations—as seen in parts of South Africa and Uganda, where governments rapidly scaled up treatment and preventive campaigns in the early 2000s when incidence numbers surged [61–66]. In contrast, mortality data—often delayed or underreported—may fail to create the same urgency, and the substantial donor funding directed toward treatment may further diminish the domestic political will and government motivation to adjust spending in response to death rates [67]. While uncertainties remain regarding the resumption of USAID programmes and funding initiatives, we recommend that African policymakers actively explore alternative and diversified health financing opportunities tailored to local needs. In doing so, it is crucial to engage closely with other international donors and regional development partners including the World Health Organisation and the World Bank, to build a broader funding base while simultaneously increasing domestic public health spending to reduce reliance on any single funding source. Moreover, it is important to consider integrating HIV/AIDS programmes into broader health systems to optimise resource allocation and programme efficacy. Strengthening coordination among governments, donors, and local communities will enhance resource utilisation and build a resilient, sustained response to HIV/AIDS across the continent.

4.3. Robustness of the Results

Our simulation-based sensitivity analysis indicates that our main results are robust to unmeasured confounding. For HIV/AIDS incidence, the adjusted coefficients for U.S. DAH and other international donor funding remained consistently negative with only modest fluctuations under plausible confounder strengths (λ between 0.1 and 0.5), indicating a robust inverse relationship with incidence. However, GHES consistently shows a positive effect, reflecting reactive spending in response to a higher epidemic burden. For HIV/AIDS mortality, whereas Other DAH retained a consistently negative association even under extreme confounding ($\lambda = 0.9$), GHES continued to show a stable positive relationship. Similarly, U.S. DAH was consistently associated with higher mortality. However, while our analysis supports the stability of this positive association between U.S. DAH and HIV/AIDS mortality, the fact that the primary model did not yield a statistically significant result means that this should be interpreted with caution. The simulation does not prove a causal relationship but rather suggests that the observed non-significant association is not merely an artefact of omitted variable bias within the tested range and assumptions.

The jackknife analysis, in which each composite country–sex unit was sequentially removed, revealed that the key three-way interaction effect among U.S. DAH, other donor DAH, and GHES was remarkably stable, even when excluding high-funding countries such as Kenya and South Africa. Moreover, comparisons between the full sample (1990–2021) and the pre-COVID sub-sample (1990–2019) showed that the primary funding (U.S. DAH, Other DAH, and GHES) effects and interactions persisted across both periods, further reinforcing the robustness of our findings.

4.4. Strengths and Limitations

One of the major strengths of this study is its comprehensive analysis of DAH flows to Africa over the last 33 years. Utilising multi-level mixed-effects models with post-estimation BLUP enhanced the robustness of our study by providing precise, unbiased estimates of the effects of diversified funding on HIV/AIDS outcomes. Our simulation-based sensitivity analyses and further robustness checks reinforced the validity of our findings. Incorporating social and ecological concepts into our discussion also provided a theoretically grounded exploration of how diverse funding streams may individually and jointly influence HIV/AIDS outcomes. Thus, our study extends existing knowledge by demonstrating the direct effects and moderating role of U.S. DAH in shaping HIV/AIDS incidence and mortality in Africa.

Despite these valuable insights, our study is not without limitations. Although not the aim of this study, measurement errors in funding allocations and the inherent constraints of ecological designs restrict our ability to draw causal inferences. Moreover, the ecological fallacy in aggregated study designs means that country-level associations may not accurately reflect individual-level risks. To mitigate this, we carefully confined our interpretations to population-level inferences rather than extending them to individual causality. It is important to also note that the validity of our simulation-based sensitivity analysis rests on two key assumptions: first, that the hypothetical confounder, U, is drawn from a standard normal distribution; and second, that U is associated with our primary predictors (U.S. DAH, Other DAH, and GHE) via a range of plausible lambda values (0.1 to 0.9), capturing the strength of these associations. However, we acknowledge that these idealised assumptions may oversimplify the inherent complexity and variability found in real-world situations.

Future epidemiological research focusing on Africa would benefit from incorporating sub-national data and qualitative methodologies to further explore the mechanisms underlying funding synergy. A critical evaluation of locally embedded challenges could enhance our understanding of how DAH impacts different contexts, ultimately informing more effective resource allocation strategies.

5. Conclusions

Our study examined international aid disbursement for HIV/AIDS control and evolving patterns among African countries, from 1990 to 2022. It also investigated how U.S. DAH interacted with other donors and domestic general government health funding, and further explored what these historical associations might imply for future trends. As with previous studies, our findings indicate that the U.S. public sector has contributed largely to the fight against HIV/AIDS in Africa through its international DAH initiatives. Returning to the initial questions posed, it is now possible to state that in addition to exerting a direct effect, the U.S. public sector-specific DAH moderates the effect of other international donor funding and domestic government health spending on HIV/AIDS incidence and mortality. Learning from these historical trends and funding interactions, we conclude that the cut in U.S. DAH flow through suspension of the USAID programmes, if not counterbalanced with alternative funding or increases in domestic funding and other donor interventions, risks eroding the long-established progress in HIV/AIDS control in Africa, especially in areas already vulnerable to systemic challenges. However, any future effects are contingent on the allocation of other resources and the resilience of African countries to evolving challenges, including disease patterns.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/venereology4020008/s1, Figure S1: Data analysis flowchart; Figure S2: Flipped two-way scatter plot showing population-specific random slope for the United States public sector-specific development assistance for health (DAH); Figure S3: Line plots of simulated adjusted coefficients for three health financing measures against varying levels of λ, which represent assumptions about the strength of an unmeasured confounder of the association between the predictors and HIV/AIDS outcomes; Table S1: List of variables and sources of data used to write this study.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

AHPC	Allied Health Professions Council
AIC	Akaike Information Criterion
BIC	Bayesian Information Criterion
BLUP	Best Linear Unbiased Prediction
CAR	Central African Republic
CI	Confidence Interval
COVID-19	Coronavirus Disease 2019
DAH	Development Assistance for Health
DRC	Democratic Republic of the Congo
GBD	Global Burden of Disease
GHES	Domestic General Government Health Expenditure per capita
GMM	Generalised Method of Moments
HIV/AIDS	Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome
ICC	Interclass Correlation
IHME	Institute for Health Metrics and Evaluation
IQR	Interquartile Range
IV	Instrumental Variable
MLE	Maximum Likelihood Estimation
MTCT	Mother-to-Child Transmission
OOP	Out-of-Pocket Health Expenditure
PEPFAR	President's Emergency Plan for AIDS Relief
PPP	Purchasing Power Parity
PPPS	Pre-paid Private Health Spending
RMLE	Restricted Maximum Likelihood Estimation
SD	Standard Deviation
SDI	Socio-Demographic Index
SE	Standard Error
SSA	Sub-Saharan Africa
SSARSD	Sub-Saharan Africa Research for Sustainable Development
TB	Tuberculosis
UHC	Universal Health Coverage
UN	United Nations
UNAIDS	Joint United Nations Programme on HIV/AIDS
U.S.	United States

USAID	United States Agency for International Development
WID	World Identity Database

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