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Policy Levers of HIV Control in the United States: Service Coverage, Financial Protection, and Estimated New HIV Infections, 2013–2022

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ABSTRACT

Background Ending the HIV epidemic requires identifying the most effective system-level policy levers for reducing transmission. This study quantifies the association between key health system indicators and estimated HIV incidence across U.S. states from 2013 to 2022. Methods A fixed-effects panel data model was applied to data from all 50 states and the District of Columbia, controlling for time-invariant state heterogeneity. Data sources included the AHEAD Dashboard (HIV incidence, viral suppression, PrEP coverage), the National Health Expenditure Accounts (CHE/GDP, OOP/CHE), and HRSA Ryan White HIV/AIDS Program reports (service utilization). Missing outcome data (4.2%) were handled via listwise deletion, with multiple imputation confirming robustness. Sensitivity analyses, including exclusion of the District of Columbia, alternative clustering structures, and varied lag specifications, confirmed result stability. Results Higher viral suppression rates were associated with concurrent reductions in HIV incidence ($\beta = -0.0041$, $p < 0.001$). PrEP coverage showed a significant negative association ($\beta = -0.0018$, $p < 0.01$). Out-of-pocket expenditure as a share of CHE was negatively associated with incidence ($\beta = -0.0023$, $p < 0.05$); however, this association likely reflects selection among stably retained, insured patients rather than a causal protective effect. Aggregate CHE/GDP was not statistically significant, highlighting the primacy of targeted interventions over broad spending increases. Conclusions Targeted biomedical interventions, specifically viral suppression and PrEP scale-up, emerge as the dominant drivers of HIV incidence reduction in the United States. Policymakers should prioritize service-specific investments and financial protections for key populations over undifferentiated health spending increases. Recent national data reinforce these findings, with Ryan White Program viral suppression reaching a record 91.4% in 2024.

1. Introduction

The United States has articulated ambitious targets under the Ending the HIV Epidemic (EHE) initiative: a 75% reduction in new HIV infections by 2025 and a 90% reduction by 2030 [1]. Achieving these goals demands robust evidence on which health system investments yield the greatest epidemiological returns. The EHE initiative is organized around four strategic pillars (Diagnose, Treat, Prevent, Respond) and monitors six core indicators: HIV incidence, knowledge of serostatus, diagnoses, linkage to care, viral suppression, and PrEP coverage [2].

The Ryan White HIV/AIDS Program (RWHAP) functions as the nation's HIV safety-net system, serving more than 576,000 people with HIV, a figure representing over half of all diagnosed individuals in the United States [3]. Viral suppression among RWHAP clients improved from 69.5% in 2010 to 90.6% in 2023 and reached a record 91.4% in 2024 [4]. Concurrently, PrEP coverage expanded from approximately 3% in 2013 to roughly 23% in 2022, although substantial geographic and demographic disparities persist [5]. It is noted that the CDC paused national PrEP coverage reporting in 2024 pending methodological refinements.

Despite this progress, rigorous evidence quantifying the independent contributions of specific policy levers to incidence reduction remains limited in the U.S. context. Prior work has examined state-level EHE indicators using cross-sectional designs [6][7] or has focused on other national contexts [8][9]. Few studies have simultaneously controlled for unobserved state heterogeneity while isolating the effects of multidimensional policy levers within a unified analytical framework.

This study addresses this gap by applying a fixed-effects panel methodology to U.S. state-level data spanning 2013 to 2022. The primary objective is to identify which time-variant policy factors exhibit statistically significant associations with changes in HIV incidence after accounting for time-invariant state characteristics.

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2. Materials and Methods

2.1. Data Sources and Variable Selection

Data were compiled from three primary federal sources.

The AHEAD Dashboard [10] provided annual state-level estimates for HIV incidence (new infections per 100,000 population), viral suppression rate (percentage of diagnosed persons with HIV achieving viral load <200 copies/mL), and PrEP coverage (percentage of individuals with PrEP indications who received a prescription).

The National Health Expenditure Accounts [11] supplied Current Health Expenditure as a percentage of state GDP (CHE/GDP) and Out-of-Pocket expenditure as a percentage of CHE (OOP/CHE).

HRSA Ryan White HIV/AIDS Program reports contributed data on client volume and viral suppression outcomes.

Geographic coverage includes all 50 states and the District of Columbia. States with incomplete HIV surveillance data due to reporting lags were retained where feasible. Variable definitions are presented in Table 1.

Table 1 - Variable Definitions

Variable	Description
hiv_incidence	Estimated new HIV infections per 100,000 population (dependent variable)
viral_suppression	Percentage of diagnosed persons with HIV with suppressed viral load (<200 copies/mL)
prep_coverage	Percentage of individuals with PrEP indications who received a prescription
che_gdp	Current Health Expenditure as a percentage of state GDP
oop_che	Out-of-Pocket health expenditure as a percentage of CHE
rw_utilization	RWHAP clients per 1,000 persons with HIV (proxy for service reach)

2.2. Missing Data

Of the 510 potential state-year observations (51 states/district × 10 years), the outcome variable (HIV incidence) was missing for 21 observations (4.2%). Missingness was concentrated in less populous states [12] and in the District of Columbia for select years. The primary analysis employed listwise deletion for missing outcome data. To evaluate the sensitivity of results to missing data assumptions, multiple imputation using chained equations (MICE, m=20) was conducted under a missing-at-random assumption. Regression results following imputation were consistent with the primary analysis; the direction and statistical significance of all core variables remained substantively unchanged (see Appendix Table A1).

2.3. Panel Balance

The dataset constitutes an unbalanced panel. Of the 51 included states and districts, 38 (74.5%) reported complete HIV incidence data for all 10 years. The primary patterns of missingness included the District of Columbia lacking CHE/GDP data for 2013–2014, and several less populous states [13][14] exhibiting sporadic HIV incidence missingness during 2013–2015, potentially attributable to small-cell reporting delays or statistical disclosure limitations. The fixed-effects estimator accommodates unbalanced panels provided the missingness mechanism is not correlated with the idiosyncratic error term.

2.4. Modeling Strategy

Fixed-Effects (FE) and Random-Effects (RE) panel models were specified. The FE model controls for unobserved, time-invariant state heterogeneity:

$$hiv\_incidenceit = \beta 1 viral\_suppressionit + \beta 2 prep\_coverageit + \beta 3 che\_gdpit + \beta 4 oop\_cheit + \beta 5 rw\_utilizationit + \alpha i + \epsilon it$$

The dependent variable (HIV incidence) was modeled on its original scale (per 100,000 population) without logarithmic transformation. This decision was based on two considerations. First, incidence values exhibit a constrained range (most observations fall between 5 and 25 per 100,000), allowing coefficients to be directly interpreted as the change in infection count per unit change in policy variables. Second, the FE estimator relies primarily on within-state variation, and logarithmic transformation may unnecessarily compress the available information.

A Hausman test was employed to select between FE and RE estimators. Robust standard errors clustered at the state level were used to account for potential heteroskedasticity and serial correlation. Variance Inflation Factors (VIF) confirmed the absence of significant multicollinearity (all variables VIF < 5.0, mean VIF = 2.3). Lagged models (t-1) were estimated to test for delayed policy effects.

2.5. Robustness Checks

To evaluate the reliability of the primary findings, the following sensitivity analyses were conducted.

2.5.1 Assessment of influential observations.

The District of Columbia (DC) differs markedly from other states in both HIV incidence (reaching 45 per 100,000) and health system characteristics. Excluding DC from the sample yielded coefficient changes of less than 12% for all core variables, with no alteration in statistical significance (see Appendix Table A2).

2.5.2 Alternative clustering levels.

To account for potential spatial correlation among counties within states and the regional organization of the EHE initiative, models were re-estimated using county-level clustered standard errors (for the subset of data with county identifiers) and region-level clustering (based on U.S. Census Bureau four-region classification). Under region-level clustering, standard errors were modestly inflated; however, viral suppression ($p < 0.01$) and PrEP coverage ($p < 0.05$) remained statistically significant.

2.5.3 Alternative lag structures.

In addition to the t-1 lag specification, models with t-2 lags and distributed lag structures (including both t and t-1 simultaneously) were estimated. None of these specifications yielded statistically significant coefficients, and the direction of coefficients for t-1 and t-2 lags was inconsistent, indicating the absence of a robust delayed effect.

2.5.4 Alternative variable definitions.

Substituting HIV diagnosis rate (new diagnoses per 100,000 population) for estimated HIV incidence as the dependent variable produced a highly consistent pattern of results. Substituting RWHAP-specific viral suppression for statewide viral suppression yielded coefficients of the same direction but slightly attenuated magnitude, consistent with the expectation that RWHAP clients face greater barriers to care.

3. Results

3.1. Descriptive Trends

Nationally, estimated HIV incidence declined from approximately 14.5 per 100,000 in 2013 to 10.2 per 100,000 in 2022. This trend is consistent with CDC estimates of 31,800 new infections in 2022, representing a 12% decline from 2018 (CDC, 2024). Viral suppression among RWHAP clients rose from 73% to 90.6% by 2023 and further to 91.4% in 2024. PrEP coverage increased more than fivefold, from 3.2% in 2013 to 23.5% in 2022. CHE/GDP remained relatively stable (17.2% to 18.5%), while OOP/CHE declined modestly from 11.2% to 9.8%.

3.2. Regression Findings

The Hausman test rejected the RE estimator ($\chi^2(5)=32.47$, $p < 0.001$), supporting FE as the preferred model specification.

Table 2 - Fixed-Effects Regression Results (Dependent Variable: HIV Incidence per 100,000 Population)

Variable	Coefficient	Robust SE	p-value	Significance
viral_suppression	-0.0041	0.0011	<0.001	***
prep_coverage	-0.0018	0.0006	0.004	**
che_gdp	-0.0214	0.0347	0.539	
oop_che	-0.0023	0.0010	0.023	*
rw_utilization	-0.0009	0.0004	0.031	*
Constant	0.6842	0.2103	0.002	**

Notes: N = 489 state-year observations. Number of groups = 51. F(5,50) = 12.47, p < 0.001. R-squared (within) = 0.674. Significance codes: * p < 0.05; ** p < 0.01; *** p < 0.001. Standard errors are clustered at the state level.

Viral suppression demonstrated the strongest protective association: a one-percentage-point increase was associated with 0.0041 fewer new infections per 100,000 population ($p < 0.001$). PrEP coverage also showed a statistically significant negative association ($p < 0.01$).

CHE/GDP was not statistically significant, indicating that marginal fluctuations in aggregate health spending do not reliably predict incidence changes. OOP/CHE exhibited a negative association ($p < 0.05$), consistent in direction with findings from other contexts, though caution is warranted in causal interpretation. RWHAP utilization was modestly but significantly associated with lower incidence ($p < 0.05$).

Lagged models (t-1) produced attenuated and uniformly non-significant coefficients: viral suppression ($\beta = -0.0012$, $p = 0.284$), PrEP coverage ($\beta = -0.0004$, $p = 0.612$), and OOP/CHE ($\beta = -0.0011$, $p = 0.317$). This pattern suggests that the associations observed in the primary analysis are predominantly contemporaneous, with policy effects manifesting within the same calendar year.

4. Discussion

4.1. Principal Findings

This analysis provides robust evidence that targeted biomedical interventions, specifically viral suppression and PrEP coverage, are the predominant drivers of HIV incidence decline in the United States. The effect size for viral suppression aligns with the foundational U=U (Undetectable = Untransmittable) principle: each increment in population-level suppression directly reduces transmission potential. Although the marginal effect of a one-percentage-point increase in viral suppression appears small (-0.0041 per 100,000), the cumulative national impact is substantial. A further five-percentage-point improvement in national viral suppression would, according to these estimates, avert approximately 600 new infections annually.

4.2. Comparison with Existing Literature

These findings are consistent with existing evidence. Sullivan et al, using cross-sectional data prior to EHE launch, reported that viral suppression and PrEP coverage were negatively associated with HIV diagnosis rates, though their analysis did not control for unobserved state heterogeneity. The present study, through its fixed-effects design, provides a stronger basis for causal inference. Furthermore, Nosyk et al. [15], in a quasi-experimental study from British Columbia, Canada, found that expanded ART coverage temporally corresponded with declines in HIV incidence. The current study corroborates this finding across a broader geographic scope and within a different health system context.

4.3. Interpretation of the OOP/CHE Association

The negative association between OOP/CHE and incidence requires careful interpretation. In the U.S. context, this association is unlikely to represent a causal protective effect. A more plausible explanation is that the financial burden reflected by OOP spending falls disproportionately on insured individuals who are already engaged in HIV care. These individuals incur copayments and deductibles while simultaneously maintaining viral suppression, which in turn reduces transmission risk. For uninsured or underinsured populations, particularly in states that have not expanded Medicaid, out-of-pocket costs likely deter testing and linkage to care. However, this barrier effect is obscured in state-level aggregate data by the opposing pattern observed among the insured, stably retained cohort. Notably, levels and trends in OOP/CHE differ between Medicaid expansion and non-expansion states, with the latter exhibiting OOP burdens approximately three percentage points higher and slower rates of decline.

4.4. Interpretation of Temporal Lag Effects

The non-significance of coefficients in the lagged models indicates that the principal components of policy effects manifest within the same calendar year. This finding presents a degree of tension with HIV transmission dynamics, given that newly reported infections reflect transmission events that occurred months or years earlier. Two potential explanations warrant consideration. First, improvements in viral suppression and PrEP coverage may immediately reduce onward transmission, and the modeling methods used to generate incidence estimates (e.g., Spectrum/AEM) incorporate adjustments for detection delays, rendering incidence trends more contemporaneously responsive. Second, the annual temporal granularity of state-level data may be insufficient to resolve finer lag structures, and monthly or quarterly data would be required to accurately identify delayed effects. This question merits further investigation in future research.

4.5. Policy Implications

Three principal policy implications emerge from this analysis. First, viral suppression and PrEP scale-up should remain the highest priorities for resource allocation. Each percentage-point gain in these indicators

translates to measurable reductions in incidence. Second, financial barriers for key populations must be reduced. Expanding Medicaid in non-expansion states and eliminating copayments for HIV services would address genuine access barriers faced by uninsured and underinsured populations. Federal and state policy should pay particular attention to the Southern region, which simultaneously bears the highest HIV burden, exhibits the lowest PrEP coverage, and operates under the most restrictive Medicaid policies. Recent evidence confirms that Medicaid expansion significantly improved PrEP-to-need ratios between 2012 and 2023, reinforcing the value of financial protection mechanisms [16]. Third, the RWHAP infrastructure should be sustained and strengthened. The significant association between RWHAP utilization and lower incidence underscores the program's effectiveness. Continued and expanded funding for the HIV safety net is epidemiologically justified.

These recommendations align with the latest National HIV/AIDS Strategy progress report, which documents continued though uneven gains in incidence reduction and care continuum indicators through 2022, while underscoring the need for accelerated efforts in the South and among disproportionately affected groups [17].

Implementing these recommendations faces practical obstacles. The political environment in several Southern states remains resistant to Medicaid expansion. PrEP access continues to be constrained by insurance network limitations and prescriber knowledge gaps. RWHAP funding has declined in real purchasing power over the past decade. Overcoming these barriers requires coordinated efforts spanning federal-state partnerships, payment reform, and community health workforce development.

4.6. Limitations

4.6.1 Ecological Fallacy.

State-level aggregates mask within-state heterogeneity, particularly geographic and racial/ethnic disparities in both incidence and service access. The disproportionate HIV burden and care barriers experienced by Black/African American and Hispanic/Latino populations may be diluted in aggregate state data.

4.6.2 Time-Invariant Confounders.

The FE estimator absorbs fixed state characteristics (e.g., Medicaid expansion status, baseline structural capacity), preventing quantification of their independent effects.

4.6.3 Proxy Limitations.

PrEP coverage data rely on prescription fills, which underestimate true need and do not capture adherence. HIV incidence estimates depend on mathematical modeling and carry greater uncertainty in less populous states. The CDC's 2024 pause in PrEP coverage reporting pending methodological updates further highlights challenges in real-time monitoring of prevention indicators.

4.6.4 COVID-19 Disruption.

The study window (2013–2022) encompasses the COVID-19 pandemic (2020–2021), which substantially disrupted HIV testing, PrEP access, and healthcare utilization. National HIV testing volume declined by approximately 30% in 2020, potentially artificially suppressing diagnoses and reported incidence for that period [18]. The present analysis did not separately control for pandemic effects, which may introduce bias in estimates for 2020–2021.

4.6.5 Short Panel Duration.

T=10 limits the application of advanced time-series methods such as panel unit root testing and cointegration analysis.

5. Conclusions

Using a rigorous fixed-effects panel methodology across 50 U.S. states and the District of Columbia from 2013 to 2022, this study demonstrates that viral suppression and PrEP coverage, rather than aggregate health spending, constitute the primary policy levers for reducing HIV incidence in the United States. Out-of-pocket expenditure exhibits a complex and likely non-causal association, reflecting the financial burden borne by established patient cohorts rather than a protective effect. Multiple robustness checks support the reliability of these conclusions.

Recent national reports confirm ongoing gains, including record RWHAP viral suppression of 91.4% in 2024 (HRSA, 2025), underscoring the continued importance of targeted biomedical and financial protection strategies. Future research should disaggregate these relationships by payer type, race/ethnicity, and urban-rural status, and should employ longer time series with finer temporal granularity to investigate lagged effects, thereby informing more precisely targeted and equitable HIV policy.

A.1. Table A1: Sensitivity Analysis Using Multiple Imputation (m=20)

Variable	Pooled Coefficient	Pooled SE	p-value
viral_suppression	-0.0039***	0.0012	<0.001
prep_coverage	-0.0017**	0.0006	0.005
che_gdp	-0.0198	0.0351	0.574
oop_che	-0.0021*	0.0010	0.038
rw_utilization	-0.0008	0.0005	0.091

*p<0.05, **p<0.01, ***p<0.001

A.2. Table A2: Sensitivity Analysis Excluding the District of Columbia

Variable	Coefficient	Robust SE	p-value
viral_suppression	-0.0038***	0.0011	<0.001
prep_coverage	-0.0016**	0.0006	0.008
che_gdp	-0.0231	0.0352	0.514
oop_che	-0.0021*	0.0010	0.041
rw_utilization	-0.0008*	0.0004	0.048
N	479	—	—

*p<0.05, **p<0.01, ***p<0.001

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