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DOES FUNDING FOR HIV AND SEXUALLY TRANSMITTED DISEASE PREVENTION MATTER?

Evidence From Panel Data

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Since the onset of the AIDS epidemic, the Centers for Disease Control and Prevention (CDC) has allocated several billion dollars for the prevention of HIV and other sexually transmitted diseases (STDs) in the United States. Using state-level data from 1981 to 1998, the authors found that greater amounts of prevention funding in a given year are associated with reductions in reported gonorrhea incidence rates in subsequent years. The authors conclude that funding for STD and HIV prevention, on the whole, appears to have a discernable impact on the incidence of STDs.

Keywords: *HIV; sexually transmitted diseases; gonorrhea, Centers for Disease Control and Prevention*

Sexually transmitted diseases (STDs) impose a substantial health and economic burden on the United States. More than 774,000 AIDS cases and 440,000 total deaths in persons with AIDS have been reported to the Centers for Disease Control and Prevention (CDC), and an estimated 40,000 Americans are infected with HIV each year (Division of HIV Prevention 2001). In

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addition to HIV, other STDs such as chlamydia, gonorrhea, syphilis, genital herpes, and human papillomavirus have been described as a "hidden epidemic" in the United States, with more than 12 million new cases occurring each year (Institute of Medicine 1997). These STDs can result in serious long-term health consequences such as cancer and infertility, and STDs during pregnancy can result in fetal death or disability. Furthermore, the presence of these other STDs can facilitate the transmission and acquisition of HIV (Wasserheit 1992).

The CDC is the nation's lead federal agency in STD and HIV prevention and the primary distributor of federal funds to state and local health departments and various nongovernmental agencies for STD and HIV prevention programs (Foster et al. 1999; Institute of Medicine 1997). Since the onset of the AIDS epidemic, the CDC has allocated several billion dollars for the prevention of STDs and HIV in the United States. If the prevention activities funded by CDC are effective in preventing STDs and HIV, then the amount of such funding might be an important determinant of STD and HIV incidence rates.

In this exploratory analysis, we examined the association between state-level gonorrhea incidence rates and state-level funding from the CDC for the prevention of STDs and HIV. Our goal was to determine if an association between funding and gonorrhea incidence rates could be detected at the state level over time.

It is important, however, to note several reasons why such an association might not be detected at the state level even if the activities supported by prevention funding do indeed reduce STD incidence rates. First, the influence of prevention activities in a given state might be small relative to other factors that affect gonorrhea incidence rates. Furthermore, because interstate travel is common, changes in gonorrhea incidence rates in a given state might affect gonorrhea incidence rates in neighboring states. Second, HIV and STD prevention funding is used to support a wide range of prevention activities, some of which might have little or no effect on gonorrhea incidence despite having a substantial impact on HIV or other STDs. Third, underreporting of gonorrhea cases might blur any association between prevention activities and actual gonorrhea incidence rates. In addition, if activities supported by prevention funding help to increase detection of new STDs and to reduce underreporting, a positive association between funding and reported STD rates might be detected.

Despite the potential problems associated with an ecological analysis of the association between gonorrhea incidence rates and prevention funding, such an approach is perhaps the only way to examine the impact of HIV and STD prevention activities at the state-population level. This analysis can help answer the question: Is there any discernable impact of prevention funding on gonorrhea incidence rates?

This article is organized as follows. The first section provides a brief overview of STD and HIV prevention funding in the United States; the second section describes the data and sources; the third section describes the estimation methodology; the fourth section presents the estimation results; the fifth section examines the robustness of the findings; and the sixth section concludes.

BACKGROUND: STD AND HIV PREVENTION FUNDING IN THE UNITED STATES

FEDERAL PREVENTION FUNDING

In fiscal year 1999, the CDC allocated approximately $560 million to state and local health departments and various nongovernmental agencies to support STD and HIV prevention and control activities. These activities generally include (a) screening for HIV and other STDs; (b) counseling to help uninfected persons remain uninfected and to help infected persons avoid infecting others; (c) educational and risk reduction interventions to increase awareness of the potential risks of sexual activity and to teach methods to reduce this risk, such as abstinence or the use of condoms; (d) medical treatment of persons with curable bacterial STDs such as chlamydia, gonorrhea, and syphilis; and (e) notification and treatment of the sex partners of persons with STDs (Valdiserri et al. 1997; Institute of Medicine 1997).

The resources allocated by the CDC represent the majority of federal STD and HIV prevention funding.[1] In this analysis, we focused on the general STD and HIV prevention awards distributed to the 50 states and the District of Columbia. These general prevention awards represent the vast majority of federal funds provided to state health departments for STD and HIV prevention.[2] Several metropolitan areas also receive awards, which we included as part of that area's state allocations (i.e., awards to Los Angeles are treated as awards to California).

PREVENTION FUNDING FROM OTHER SOURCES

Although CDC funding represents the bulk of federal prevention expenditures for STD and HIV prevention, substantial prevention funding is available from nonfederal sources as well.[3] State and local governments also allocate resources for prevention. Obtaining reliable estimates of annual, state-level funding for STD and HIV prevention from nonfederal sources during a series of years is virtually impossible. For example, STD and HIV prevention-specific funding estimates are difficult to obtain from state and local agencies because many prevention activities at the state and local level overlap with HIV care and treatment, general health education programs, and other health and social services. We therefore focused our analysis exclusively on funds distributed by the CDC. As described later, however, we did address the exclusion of non-CDC prevention funds when examining the robustness of our results.

PREVIOUS RESEARCH ON THE EFFECTIVENESS OF STD AND HIV PREVENTION

A vast literature has documented the effectiveness of various STD and HIV prevention interventions in reducing risky sexual behavior (for example, by increasing condom usage or by decreasing the number of sex partners).[4] In general, activities such as educational programs and screening and counseling have been found to reduce risky sexual behavior, which in turn would be expected to reduce a person's risk of acquiring an STD. A few studies have shown evidence of decreased STD incidence among participants in STD and HIV prevention activities. For example, randomized, controlled trials found that adolescents and young adults who received HIV risk reduction counseling were 20% to 30% less likely to be diagnosed with a new STD than those who received informational messages only (Kamb et al. 1998) and that minority women at high risk for STDs who participated in a three-session, small group behavioral intervention had lower incidence rates of gonorrhea and chlamydia than did those in the control group (Shain et al. 1999). These programs are examples of prevention activities that states might undertake with the general prevention awards from the CDC.

PREVIOUS RESEARCH ON THE RELATIONSHIP BETWEEN PREVENTION FUNDING AND STD AND HIV INCIDENCE

Although previous research has demonstrated the effectiveness of various STD and HIV prevention activities, little attention has been focused on the importance of funding for these prevention activities. Simple observations of national trends in STD rates and STD prevention funding have provided anecdotal evidence of the importance of funding, showing that increases in syphilis and gonorrhea incidence rates have followed periods of declining federal support (in inflation-adjusted dollars) for STD prevention (Chaulk and Zenilman 1997).

To our knowledge, however, this postulated association (funding decreases lead to higher STD rates, or funding increases lead to lower STD rates) has never been examined rigorously. Our contribution to this literature is a detailed analysis of the relationship between federal STD and HIV prevention dollars and reported gonorrhea incidence rates, based on panel data from 50 states and the District of Columbia from 1981 to 1998.

We focused on gonorrhea because it is the only STD (besides syphilis) for which long-term, state-level incidence data is available. We used gonorrhea rather than syphilis as an outcome measure because gonorrhea is far more common and more evenly distributed across states than syphilis, thereby making cross-state comparisons in incidence more reliable. For example, fewer than 10,000 cases of primary and secondary syphilis were reported to the CDC each year from 1997 to 2000, whereas more than 300,000 cases of gonorrhea were reported annually during the same time period (Division of STD Prevention 2001). Primary and secondary syphilis is so concentrated geographically that in 1999, about 80% of the nation's counties reported no cases, whereas 1% of the nation's counties accounted for more than half of all cases (CDC 2001).

DATA

Our data consisted of 918 observations: 18 annual observations (1981 through 1998) for all 50 states and the District of Columbia.[5] State-level gonorrhea incidence data were obtained from state STD surveillance reports maintained by the CDC. State-level sociodemographic data were obtained from a variety of sources (see Table 1).

Funding amounts for STD and HIV prevention allocated by the CDC were obtained from archived records. We included HIV prevention funding because HIV prevention activities that decrease a person's risk of acquiring HIV (such as abstinence or condom use) might be expected to decrease the person's risk for acquiring and transmitting gonorrhea as well. Prevention funding was based primarily on general HIV prevention awards and STD prevention awards to state health departments.[6]

The median amount of funding (per capita) was \$0.67 and ranged from \$0.09 to \$12.03 (see Figure 1). The median gonorrhea incidence rate was 181 cases per 100,000 persons and ranged from 4 to 2,634 (see Figure 2). In gen-

TABLE 1: Variables: Means, Standard Errors, Descriptions, and Sources

Variable	M	SE	*Description*	*Source*
GONORRHEA	257	303	Gonorrhea incidence rate (new cases reported per 100,000 population) in year *t*	Centers for Disease Control and Prevention (CDC 1999a)
FUNDING	0.76	0.93	Average of combined CDC funding to state for STD and HIV prevention (in 1998 dollars per capita) in fiscal years *t*-1, *t*-2, *t*-3	CDC[a]
AIDS DEATHS	5.46	11.0	Average AIDS death rate (deaths in persons with AIDS age 18 and older per 100,000 overall population) in years *t*-4 through *t*-1	CDC[b] (1999b)
YOUTH	0.16	0.02	Fraction of state population who are age 15 to 24 in year *t*	U.S. Census Bureau (quoted in CDC 1999a)
ROBBERY	1.65	1.74	Robberies committed per 100 state population in year *t*	U.S. Department of Justice (http://www.ojp.usdoj.gov/bjs/datast.htm)
CIGARETTES	10.9	2.76	State per capita cigarette consumption (cartons of 10 packs), based on population age 18 and older, in year *t*	Orzechowski and Walker (2003)
INCOME	22.8	4.05	State per capita income, 1998 dollars (thousands) in year *t*	U.S. Department of Commerce (http://www.bea.doc.gov/bea/regional/spi)
POVERTY	0.14	0.04	Fraction of state population who live in poverty in year *t*	U.S. Census Bureau (http://www.census.gov/hhes/poverty/histpov/hstpov21.htm)
ALCOHOL	2.50	0.67	Apparent state per capita alcohol consumption (gallons of ethanol), based on population age 14 and older, in year *t*	National Institute on Alcohol Abuse and Alcoholism (http://www.niaaa.nih.gov/publications/pcyr7097.txt) and Nephew et al. (2000)

NOTE: STD = sexually transmitted disease.
a. Obtained from various CDC records as described in the Data section; see also note 6.
b. Obtained from surveillance records maintained by the CDC's Division of HIV/AIDS Prevention (1999b). AIDS mortality data contained missing values when a state reported three or fewer AIDS deaths within a given year. In such instances, the number of AIDS deaths was assumed to be zero.

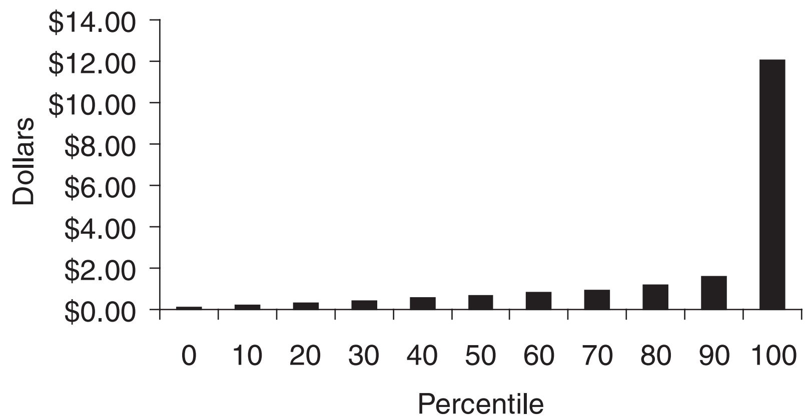

Figure 1: Distribution of State-Level STD and HIV Prevention Funding (Dollars per Capita), 1981 to 1998

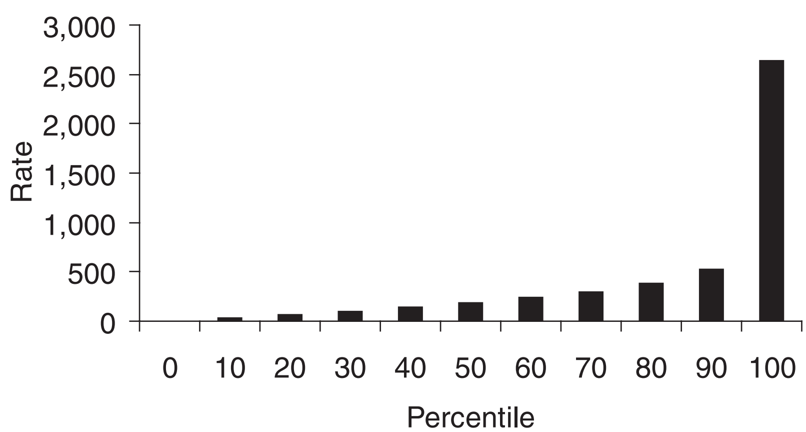

Figure 2: Distribution of State-Level Gonorrhea Incidence Rates (New Cases per 100,000 Persons), 1981 to 1998

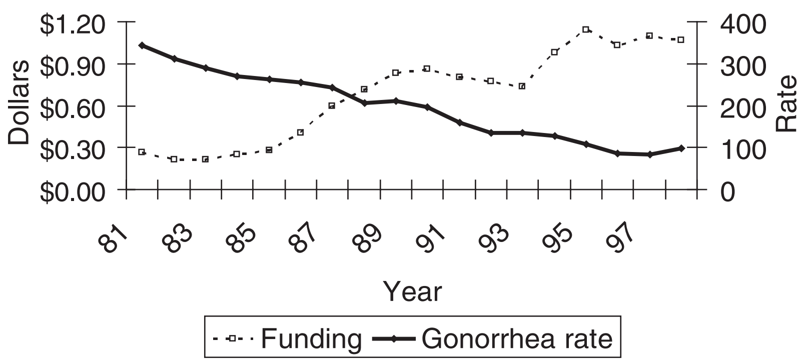

Figure 3: Median State Gonorrhea Incidence Rate (New Reported Cases per 100,000) and Prevention Funding (Dollars per Capita), 1981 to 1998

eral, median funding amounts increased over time, whereas median gonorrhea incidence rates decreased over time (see Figure 3).

If states with higher gonorrhea incidence rates tend to receive more STD and HIV prevention funding per capita than states with lower STD rates, funding allocation decisions could create a positive correlation between state gonorrhea incidence rates and state prevention funding in subsequent years. However, future gonorrhea incidence rates are not known when funding decisions are made. To detect any effects of funding on gonorrhea incidence rates in subsequent years, we examined the association between gonorrhea incidence rates (new cases reported per 100,000 persons) in year *t* and the average funding amounts in years *t*-1, *t*-2, and *t*-3.[7]

At first glance, there was no apparent association between the 3-year funding average and state gonorrhea incidence rates (see Figure 4). However, this crude analysis did not control for many other important factors that might affect gonorrhea incidence rates. For example, there may have been many constant, state-specific factors that affected gonorrhea incidence rates. When controlling for such factors by calculating the change in the state gonorrhea incidence rate (relative to that state's average incidence rate during all years), a possible association between prevention funding and gonorrhea incidence emerged (see Figure 5). To examine this association more rigorously, we needed to control for many additional factors that might affect gonorrhea incidence rates, such as factors that affect national trends in gonorrhea incidence and factors that affect state-level differences in gonorrhea incidence rates over time.

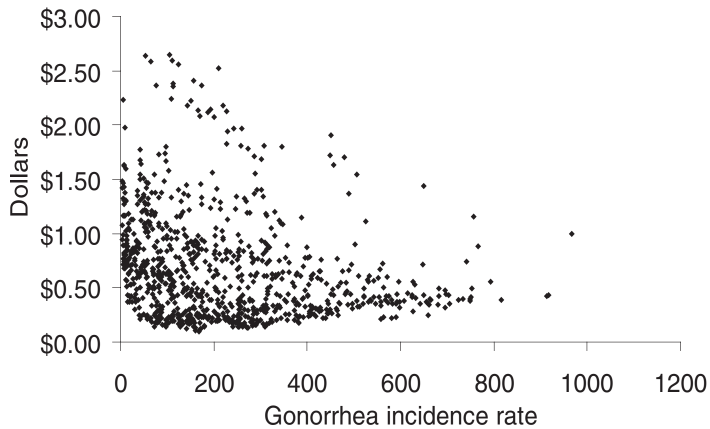

Figure 4: Scatterplot of State-Level Funding (Dollars per Capita) and Gonorrhea Incidence Rates (New Cases per 100,000), 1981 to 1998

NOTE: In this figure, funding for a given state in a given year was calculated as the average level of funding for that state in the 3 previous years. For clearer presentation, this figure excludes observations from Washington DC, for which the funding measure was more than $10 for some years.

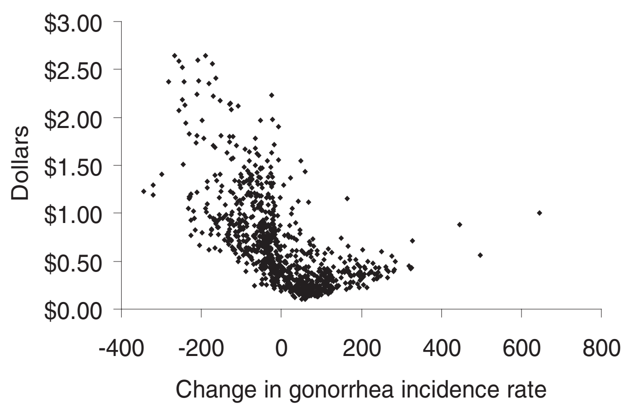

Figure 5: Scatterplot of State-Level Funding (Dollars per Capita) and Changes in Gonorrhea Incidence Rates (New Cases per 100,000), 1981 to 1998

NOTE: In this figure, change in gonorrhea incidence rates for a given state in a given year was calculated as the gonorrhea incidence rate for that state in the given year minus that state's average gonorrhea incidence rate across all time periods. Funding for a given state in a given year was calculated as the average level of funding for that state in the 3 previous years. For clearer presentation, this figure excludes observations from Washington DC, for which the funding measure was more than $10 for some years.

ESTIMATION METHODOLOGY

We used the following fixed effects model to examine the relationship between prevention funding and gonorrhea incidence rates:

$$\log(\text{GONORRHEA}_{i,t}) = \beta_0 + \beta_1\ \text{FUNDING}_{i,t} + \beta_2 \log(\text{GONORRHEA}_{i,t\text{-}1}) + \beta_{3i}\ \text{STATE}_i + \beta_{4t}\ \text{YEAR}_t + \beta_{5i}\ (\text{STATE}_i \times \text{TREND}) + \beta_{6i}\ (\text{STATE}_i \times \text{TREND}^2) + B_7 Z_{i,t} + \varepsilon_{i,t},$$

where i indexes states and t indexes years.[8] The dependent variable was the log of the gonorrhea incidence rate in state i in year t. We used the log of the incidence rates to allow for a nonlinear association with prevention funding. For example, achieving a decrease in the gonorrhea incidence rate from 10 to 0 would likely require more resources than would a decrease from 810 to 800, although these decreases are the same in absolute terms.

The independent variable of interest ($\text{FUNDING}_{i,t}$) was the average amount of funding (in 1998 dollars per capita allocated by the CDC) for STD and HIV prevention in state i in fiscal years t-3, t-2, and t-1. If increased funding leads to decreases in gonorrhea incidence rates at the state population level, we would expect β_1 to be negative.

We included dummy variables for state and year (STATE and YEAR) and a linear time trend (TREND), set to 1 in 1981, 2 in 1982, 3 in 1983, and so on. We also included a vector, Z, of observed, state-specific factors that may be associated with STD incidence (see Table 1). These additional factors were AIDS mortality rate, percentage of the population that is age 15 to 24, robbery rate, per capita cigarette consumption, per capita income, and poverty rate.

AIDS mortality was included as an additional explanatory variable because (a) AIDS mortality and awareness of AIDS mortality in a community might prompt safer sexual behavior and (b) AIDS mortality might influence STD rates through the loss from the population of those at higher risk of acquiring STDs (Chesson, Dee, and Aral 2003; Boily et al. 2004). We included the percentage of the population who are age 15 to 24 because gonorrhea incidence rates are typically higher in this age group (Division of STD Prevention 2001). Although STD rates are typically higher among minority groups, we did not include any controls for racial distributions in state population, as these distributions were highly correlated with the state dummy variables.[9]

We included the robbery rate as a proxy for illegal drug use (Corman and Mocan 2000), which, similar to alcohol consumption, is associated with risky sexual behaviors (Leigh and Stall 1993). We included cigarette consumption to control for general, population-level health behaviors that might vary across states and within states over time. Income and poverty measures were included because poverty and lack of access to quality health care are factors associated with STDs (Institute of Medicine 1997; Division of STD Prevention 2001).

DUMMY VARIABLES

The STATE variables were included to capture fixed, unobserved, state-specific factors that influence gonorrhea incidence, and the YEAR variables were included to capture time-varying factors common to all states. Some state-specific factors affecting gonorrhea incidence might change over time, and unless these changes over time occur uniformly across all states, they would not be captured by the YEAR variables. We therefore included linear and quadratic trend terms (TREND and its squared value, TRENDSQ), which we multiplied by the state dummy variables to allow the coefficients of TREND and TRENDSQ to vary by state.

MODEL VARIATIONS AND ESTIMATION PROCEDURE

We estimated three model specifications. Model 1 included FUNDING and the STATE and YEAR variables as independent variables. Model 2 included the variables listed for Model 1 as well as the *Z* vector of additional explanatory variables. Model 3 included the variables listed for Model 2 as well as the TREND and TRENDSQ interaction variables.

We used two estimation procedures: ordinary least squares (OLS) and generalized least squares (GLS). These two estimation procedures offered different approaches to addressing the issue of autocorrelation in our panel data. Without such correction, the autocorrelation problem was severe. In the OLS estimations, we calculated heteroskedasticity and autocorrelation-robust standard errors as described by Newey and West (1987). Our GLS estimates used Beach and MacKinnon's (1978) maximum likelihood procedure for regressions with autocorrelated errors. We did not include the lagged dependent variable in the GLS estimations.

RESULTS AND DIAGNOSTIC TESTS

The FUNDING coefficient was negative and significant in all three models (see Table 2) for both estimation procedures, indicating an inverse associ-

TABLE 2: Fixed Effects Estimates of Gonorrhea Incidence Rates, 1981 to 1998

	Ordinary Least Squares						*Generalized Least Squares*					
	1		*2*		*3*		*1*		*2*		*3*	
Covariates	*Coefficient*	SE	*Coefficient*	SE	*Coefficient*	SE	*Coefficient*	SE	*Coefficient*	SE	*Coefficient*	SE
FUNDING	–0.025**	0.010	–0.054***	0.021	–0.181***	0.043	–0.090**	0.040	–0.243***	0.053	–0.244***	0.060
AIDS DEATHS			0.005***	0.002	–0.005	0.005			0.024***	0.005	–0.001	0.007
YOUTH			0.023	1.100	5.408	4.235			1.905	3.053	11.50**	5.056
ROBBERY			0.001	0.012	0.068***	0.020			0.021	0.021	0.089***	0.025
CIGARETTES			0.019**	0.009	0.011	0.017			0.025*	0.013	0.007	0.014
INCOME			0.007	0.005	0.003	0.017			0.033**	0.014	0.000	0.017
POVERTY			–0.081	0.299	–0.349	0.317			–0.206	0.313	–0.224	0.331
ALCOHOL			0.124**	0.056	0.159*	0.084			0.230***	0.079	0.139	0.088
Lagged dependent variable	0.857***	0.019	0.809***	0.023	0.459***	0.038						
State trends included	No		No		Yes		No		No		Yes	
Adjusted R^2	.981		.982		.984		.978		.979		.984	
Degrees of freedom	846		839		739		847		840		740	

NOTE: The dependent variable is log (GONORRHEA). Ordinary least squares standard errors are calculated using the Newey-West (1987) procedure for autocorrelation and heteroskedasticity-robust standard errors. Each model also includes a constant and STATE and YEAR dummy variables that are not reported in the table but are available from the authors on request. Model 3 includes the STATE × TREND and STATE × TRENDSQ terms.

* $p < .10$. ** $p < .05$. *** $p < .01$.

ation between gonorrhea incidence rates in a given year and federal STD and HIV prevention expenditures in previous years.[10] Specifically, greater amounts of prevention funding in years *t*-3, *t*-2, and *t*-1 were associated with lower rates of gonorrhea in year *t*, all else being equal. We found significant residual autocorrelation in the OLS results for Model 3, but not for Models 1 and 2.[11]

These results were obtained using the log of the gonorrhea incidence rate and the actual (nonlog) value of per capita funding. Because gonorrhea incidence rates vary by state, we assumed that a given change in funding (in absolute terms) could achieve the same relative (rather than absolute) change in gonorrhea incidence rates across states. We examined the sensitivity of our findings to our choice of functional form by repeating the OLS estimates using (a) the actual gonorrhea incidence rate rather than its log value as the dependent variable and (b) the log value of all variables (except AIDS DEATHS, which was 0 for many states in the early 1980s). Again, we found a significant inverse relationship between gonorrhea incidence rates and funding amounts (see Table 3).

We also examined transformations of the key independent variable (FUNDING) by entering FUNDING and the squared value of FUNDING as independent variables. Again, we found an inverse relationship between gonorrhea incidence rates and funding amounts (see Table 3). In instances where the coefficients of the squared value of FUNDING were positive and significant, the FUNDING coefficient was negative and significant, which would be expected if there is a diminishing marginal effect of additional funding.

We also checked for influential observations. First, we repeated our basic analysis after deleting observations in which the residual was larger than 2 standard errors. About 50 observations were omitted in each of the three models, and the relationship between funding and gonorrhea incidence rates remained significant (see Table 3). We found similar results when using 1 standard error as the cutoff (rather than 2), which resulted in the omission of about 200 observations (results not shown). We also checked for influential observations by repeating our basic analysis, deleting all observations from 10 states (the 5 states with lowest and highest gonorrhea incidence rates, based on rankings in 1981). In doing so, we found an even stronger inverse association between funding and gonorrhea incidence rates (see Table 3). Even when omitting all observations from 20 states (the 10 lowest and 10 highest as of 1981), we found a significant inverse relationship between funding and gonorrhea incidence rates (results not shown).

TABLE 3: Summary of Robustness Tests

		Model 1		Model 2		Model 3	
Robustness Test	*Description of Coefficient and Standard Errors Shown to Right*	*Coefficient*	SE	*Coefficient*	SE	*Coefficient*	SE
Testing alternative function forms							
Using actual gonorrhea rates (not in log form) as dependent variable	OLS estimates of FUNDING when GONORRHEA was the dependent variable	–68.88***	15.16	–47.19***	16.65	–99.30***	37.40
Using log form of gonorrhea rates and all independent variables including FUNDING	OLS estimates of FUNDING (log) when GONORRHEA (log) was the dependent variable	–0.171***	0.025	–0.142***	0.029	–0.199***	0.045
Using log form of gonorrhea rates, and including FUNDING and $FUNDING^2$ as independent variables	OLS estimates of FUNDING and $FUNDING^2$, respectively, when GONORRHEA (log) was the dependent variable	–0.116*** 0.008***	0.026 0.002	–0.111*** 0.006	0.032 0.002	–0.245*** 0.009	0.073 0.006
Using actual gonorrhea rates (not in log form) of gonorrhea rates and including FUNDING and $FUNDING^2$ as independent variables	OLS estimates of FUNDING and $FUNDING^2$, respectively, when GONORRHEA was the dependent variable	–41.48** -2.868	18.20 2.277	–21.61* -2.626	12.35 1.909	9.093 –14.72**	27.31 5.997
Testing for influential observations							
Omitting outliers	OLS estimates of FUNDING when deleting observations with residuals greater than 2 standard errors	–0.028***	0.009	–0.035**	0.017	–0.175***	0.032
Omitting states with highest and lowest gonorrhea rates	OLS estimates of FUNDING when deleting observations from five states with highest gonorrhea rates and five states with lowest gonorrhea rates as of 1981	–0.133***	0.023	–0.171***	0.035	–0.344***	0.067

NOTE: OLS = ordinary least squares.
* $p < .10$. ** $p < .05$. *** $p < .01$.

ADDITIONAL RESULTS: ROBUSTNESS CHECKS

The results presented thus far show a significant inverse relationship between funding amounts and gonorrhea incidence rates at the state level across a range of model specifications. These findings, however, should be considered in light of three main limitations.

First, because the degree of underreporting of gonorrhea incidence rates might vary by state, comparisons of reported STD rates across states should be interpreted with caution. However, because surveillance activities remain relatively stable from one year to the next, comparisons of trends in STD rates across states should be minimally affected by differences in surveillance activities across states (Division of STD Prevention 2001). Second, estimation of dynamic fixed effects models is potentially biased (Nickell 1981; Hsiao 1986; Baltagi 1995; Kennedy 1998).[12] Third, we did not include prevention funding from sources other than the CDC. To address these and other potential limitations, we examined the robustness of our findings to a wide range of alternative approaches.[13]

The marginal impact of CDC prevention funding may vary across states depending on how much funding is available for STD and HIV prevention in that state from sources other than the CDC. To address this issue, we allowed the FUNDING coefficient to vary by state by multiplying the FUNDING coefficient by the STATE dummy variables. We found that the sum of these 51 estimated FUNDING coefficients was negative and statistically significant and that the average magnitude of these coefficients was consistent with our findings when the FUNDING coefficient is not varied by state (results not shown).[14]

In our basic analysis, and in a series of robustness tests, we found a significant inverse relationship between funding and gonorrhea incidence rates in subsequent years. If this association were spurious, we might also expect funding to be associated with factors that are correlated with STD rates, such as robbery rates and/or cigarette consumption. As an additional test, we repeated the analysis using ROBBERY and CIGARETTES as dependent variables rather than GONORRHEA.[15] Although cigarette consumption and the robbery rate were inversely associated with lagged funding amounts in Model 1, this association did not hold in the models that included additional sociodemographic variables (results not shown). In contrast, as we have reported in this study, we found a strong inverse association between prevention funding and gonorrhea incidence rates across a range of model specifications and estimation procedures. Thus, our models predicted an effect of prevention funding on gonorrhea incidence rates but did not predict an implausible effect of STD and HIV prevention funding on cigarette smoking or robbery rates.

DISCUSSION AND CONCLUSIONS

Our study offered evidence that greater amounts of STD and HIV prevention funding in a given year are followed by reductions in reported gonorrhea incidence rates at the state level in subsequent years. The estimated coefficients of the funding variable (–.025 to –.244 in our basic analyses) suggest that a one-unit increase in the FUNDING variable (average dollars per capita in prevention funding in *t*-3, *t*-2, and *t*-1) is associated with a decrease in gonorrhea incidence rates in year *t* of about 2.5% to more than 20%.

If we accept the funding coefficient at face value and assume the effects on gonorrhea incidence rates are generalizable to other STDs, the estimated magnitude of the effect of funding on STD incidence rates is substantial. For example, if we assume that each one-unit increase in funding decreases all STD rates by 10% (the approximate midpoint of the estimated effects in the basic results), then STD rates with a constant funding level of $0.76 per capita (the mean value in our sample) would be 7.6% lower in a given year than would be expected if there had been no prevention funding. Furthermore, because STD rates in a given year are correlated with rates in previous years, the actual effect of prevention funding could compound over time and could be several times greater than 7.6% annually. However, with the direct medical costs of STDs (including HIV) at $9.3 to $15.5 billion annually (2000 dollars; see Siegel 1997 and American Social Health Association 1998), even a 7.6% decrease in STD rates could save far more in medical costs than the $0.76 per capita spent for prevention.

The estimated magnitude of the association may not be particularly meaningful, however, because we did not have information on prevention funding from sources other than the CDC, a fact that could bias the interpretation of the FUNDING coefficient. Furthermore, as mentioned in the introduction, there are many reasons that an association between funding and gonorrhea might not be detected at the state level, and these factors could bias the interpretation of the FUNDING coefficient as well.

Nonetheless, to our knowledge, this study is the first to demonstrate an association between federal STD and HIV prevention expenditures and reductions in gonorrhea incidence rates at the state level over time. Our findings of an association between prevention funding and gonorrhea rates at the state level are consistent with previous literature documenting the effectiveness of various HIV and STD prevention activities to which state-level prevention funding is allocated. We conclude that federally funded STD and HIV prevention activities, on the whole, appear to have a discernable effect on gonorrhea incidence rates at the state level. Because gonorrhea is a marker for risky sexual behavior, these findings are likely generalizable to some degree to other STDs, including HIV.

NOTES

1. The Centers for Disease Control and Prevention's (CDC's) allocation for HIV prevention activities, for example, represents an estimated 87% of overall federal spending for HIV prevention, based on 1999 allocations (Foster et al. 1999).

2. Of the funds distributed externally for HIV prevention activities by the CDC's Division of HIV/AIDS Prevention, about two thirds are distributed through awards to state and local health departments, based on 1999 allocations (Institute of Medicine 2001). As for external distribution of sexually transmitted disease (STD) prevention funds, awards to state and local health departments comprise about 87% of the overall budget of the CDC's Division of STD Prevention, based on 1995 allocations (Institute of Medicine 1997).

3. An informal CDC survey of state and local health departments suggested that state and local funding accounts for about 58% of combined federal, state, and local funding for STD prevention activities, although this estimate varied across states from 0% to 90% (Institute of Medicine 1997). Unpublished reports from 40 states to the CDC in 2000 indicated that state and local funding accounts for about 40% of the combined state, local and federal funding for HIV prevention activities, with a range across the states from 0% to 74%.

4. See Holtgrave et al. (1995); Oakley, Fullerton, and Holland (1995); Stephenson, Imrie, and Sutton (2000); HIV/AIDS Prevention Research Synthesis Project (1999); Mullen et al. (2002); Semaan et al. (2002); Johnson et al. (2002); and Neumann et al. (2002) for reviews of this literature.

5. Because observed gonorrhea incidence rates are incomplete and subject to measurement error (owing to underreporting), and because random factors can influence gonorrhea incidence rates at the state level, we considered this data not to be a population but a representative sample that is redrawn from state-level gonorrhea rates over time and with error. The gonorrhea incidence rate was unavailable for 1 of the 918 observations.

6. We examined a variety of funding-related records. Records of HIV prevention funding appearing separately from STD prevention were available for all years after 1984. HIV prevention funding in 1985 was obtained from the list of AIDS HTLV-III Cooperative Agreement Awards. HIV prevention funding in 1986 was obtained from records of funds obligated for AIDS counseling and testing and for AIDS capacity and augmentation. HIV prevention funding from 1987 to 1998 was obtained from annual listings of HIV/AIDS Prevention Obligations. We did not attempt to exclude HIV funding targeted to reduce nonsexual transmission of HIV. STD prevention funding from 1981 to 1996 was obtained from annual listings of Venereal Disease Grant Obligations, which, beginning in 1985, were called "Sexually Transmitted Disease Control Grant Obligations." These STD control awards included financial assistance (dollars) and direct assistance (personnel, etc.) for STD prevention. For 1997 and 1998, Sexually Transmitted Dis-

ease Control Grant Obligations records were not available. For these years, STD prevention awards were calculated as the sum of direct assistance (the base amount of funding listed in records labeled "Comprehensive STD Prevention Services Funding Recommendations") and indirect assistance (based on available records of indirect assistance). In addition to these general STD prevention awards, our estimates of STD prevention funding also included infertility prevention awards (which began in 1994) and syphilis elimination awards (which began in 1998).

7. These lagged effects would be expected if prevention efforts have long-term benefits. For example, preventing gonorrhea in one person today might prevent gonorrhea in that person's subsequent sex partner or partners, in their subsequent sex partners, and so on. Using the 3-year average amount of funding also mitigates any bias created by (a) our use of fiscal-year funding records to approximate calendar-year funding or (b) by the carrying over of funds by state from one year to the next.

8. Our approach was similar to other models used in the analysis of panel data, such as Friedberg (1998) and Baughman et al. (2001).

9. Including a variable for percentage of state population that is African American had no substantial effect on the results.

10. When using syphilis rather than gonorrhea as the dependent variable, the FUNDING coefficients and p values were as follows: for the ordinary least squares (OLS) Model 1, –.070 (p = .052); for OLS Model 2, –.007 (p = .925); for OLS Model 3, –.231(p = .071); for generalized least squares (GLS) Model 1, –.118 (p = .158); fpr GLS Model 2, .071 (p = .600); and for GLS Model 3, –.159 (p = .356).

11. We regressed the residual on the lagged residual and all other explanatory variables and tested the significance of the coefficient of the lagged residual (Kennedy 1998).

12. We note, however, that Baltagi and Griffin (1997) found that least squares fixed effects models with lagged dependent variables perform well in Monte Carlo exercises when compared to alternative instrumental variable methods.

13. We performed numerous other estimations in addition to those reported in the main text. First, we found similar results when we used two-stage least squares, an instrumental variable technique (Wooldridge 2002). This approach was analogous to (a) regressing the lagged dependent variable on the second lag of the dependent variable and all of the other independent variables and (b) estimating the original models using the predicted (rather than actual) value of the lagged dependent variable. Second, we examined the sensitivity of our findings to changes in the number of lags included in the funding variable. We found similar results when applying a 1-year moving average and a 5-year moving average. Third, because the marginal impact of CDC funding on gonorrhea incidence might vary over time, we allowed the FUNDING coefficient to vary by year. The sum of the YEAR × FUNDING coefficients was negative and significant in all three model specifications. Finally, we abandoned the state fixed-effects approach and instead examined the relationship between changes in prevention funding and changes in STD rates. Specifically, we repeated the OLS estimations, entering each variable in terms of its percentage change from the previous year. Because each variable (except the constant, YEAR, STATE-trend interaction terms, and AIDS mortality) was entered as a percentage change, we did not include state dummy variables. Percentage changes in funding were inversely associated with percentage changes in gonorrhea incidence rates, a finding consistent with our fixed-effects results.

14. Specifically, we used the t statistic calculated as the sum of the coefficients divided by the standard error.

15. For consistency with our original analysis, the dependent variable and its lagged value were both in log form, and we substituted GONORRHEA in place of ROBBERY (CIGARETTES) as an independent variable when ROBBERY (CIGARETTES) was the dependent variable.

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