Technical Appendix

Relative Impact of Different Strategies for Allocating Federal Funds for Syphilis Prevention

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The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention.
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Details of methods

We used the following expression to estimate the relative reduction in each district’s syphilis rate due to the supplemental funding for syphilis prevention activities: Relative reduction = \( \exp(-2.79 \times F) - 1 \), where \( F \) is the change in the district’s per capita supplemental funding for the syphilis prevention from the previous year and \( \exp \) is the base of the natural logarithm.

Overview

This formula was derived from an analysis of state-level syphilis elimination funding allocations,\(^1\) which estimated that each 1-dollar increase in funding per capita was associated with a reduction of 2.79 in the natural log of the early syphilis rate. The 2.79 value was derived by adjusting the published coefficient of -3.35 to 2016 dollars. Our adaptation of the published regression model follows the adaptation of other regression models of reported STI case rates,\(^2,3\) except that we included additional simplifications in this adaptation as discussed below.

Regression equation on which our model equation is based

The published analysis of historic syphilis case rate data and syphilis elimination funding used the following regression equation:

\[
R_{i,t} = \alpha + \beta_1 R_{i,t-1} + \beta_2 A_{i,t-1} + \beta_3 A_{i,t-2} + \beta_4 A_{i,t-3} + \gamma X_{i,t} + S_i + Y_t + M_{i,t} + \varepsilon_{i,t},
\]

where the dependent variable \( R_{i,t} \) is the log of the reported early syphilis rate (new cases of P&S and early latent syphilis per 100,000 people) in state \( i \) in year \( t \).\(^1\) The independent variables are as follows. The constant term is denoted by \( \alpha \). The lagged value of the dependent variable was included as an explanatory variable (that is, the term \( R_{i,t-1} \) represents the log of the early syphilis rate in state \( i \) in year \( t-1 \)). The term \( A_{i,t} \) is the allocation of syphilis elimination funding in state \( i \) in fiscal year \( t \), and 3 lagged values of this term (\( A_{i,t-1}, A_{i,t-2}, \text{and} A_{i,t-3} \)) were included to account for the effects of syphilis elimination funding beyond one year. The term \( X_{i,t} \) is a vector of state-level socio-demographic variables for state \( i \) in year \( t \). The sociodemographic variables were: the percentage of the population who are black, the percentage of the population who are aged 15 to 24 years, the robbery rate, and the percentage of the population below the poverty line. State and year dummy variables (\( S \) and \( Y \), respectively) were
included, along with a state-specific trend variable denoted by M (M was an interaction between the state dummy variables and “trend”, where “trend” was set to 1 in 1997, 2 in 1998, 3 in 1999, and so on through 2005). The error term is denoted by ε.¹

**Our adaptation of the published equation**

For our adaptation of the regression model from the published study, we made numerous simplifications. The basic approach was to use the information from the funding coefficients (β₂, β₃, β₄) to estimate the impact of the supplemental federal funds for syphilis prevention. We assumed that in the absence of the supplemental federal funds for syphilis prevention, syphilis rates in a given district would be constant from one year to the next. Rather than including 3 lags of the syphilis funding variable as in the published regression model, we instead assumed all impacts of the supplemental syphilis funding would occur in the year in which the funding was applied and that these impacts would not persist into the next year. The sum of the funding coefficients was -0.335 in the published regression model, in which funding was entered as dimes per capita.¹ For funding to be expressed as dollars per capita, the funding coefficient would be -3.35. The published regression analysis used 2005 dollars, so when updated for inflation to 2016 dollars the new coefficient becomes -2.79. We used the personal consumption expenditures (PCE) price index:


As noted above, we assumed that the change in a given district’s syphilis rate from one year to the next depends only on changes to the amount of supplemental funding allocated to the district for syphilis prevention (when there is no supplemental funding, then supplemental funding = $0). Thus, for each district, the relative change in syphilis rates from year t-1 to year t can be approximated as noted above (Relative reduction = \( \exp^{(-2.79F)} - 1 \)), where the value -2.79 is the sum of the funding coefficients from the published regression and F is the change in the supplemental syphilis funding per capita from year t-1 to year t. For example, if a district receives $0.20 per capita in the first year of the supplemental syphilis funding program, then the change in syphilis incidence from the baseline ($0.00 per capita of supplemental syphilis funding) to the first year of supplemental syphilis ($0.20 per capita of funding) is approximated as: = \( \exp^{(-2.79 \times 0.2)} - 1 \) = \( \exp^{(-0.558)} - 1 \) = 0.572 – 1 = -0.428. In this example, a district that receives $0.20 per capita in supplemental funding will have a decline in syphilis of 42.8% relative to a scenario of no supplemental funding ($0.00 per capita of funding). In this simple approach, increases in funding and decreases in funding have symmetric effects, and the function describing the relationship
between funding and incidence is smooth and continuous. In reality, the effects of funding changes are likely not continuous, due to a wide range of factors, such as “friction costs” associated with increasing or decreasing the size of the workforce.

Exclusion of terms from the published equation

Most of the terms from the published regression equation were dropped in our application of the equation because of our isolation of the effect of the supplemental syphilis prevention funding and our assumption that syphilis rates would be constant from one year to the next in the absence of the supplemental syphilis prevention funding.

The assumption of constant syphilis rates in the absence of supplemental syphilis prevention funding allowed us to drop the year dummy variables and the trend variables. In assuming the districts did not vary in any way except by population size and initial syphilis rate (and in some scenarios the effectiveness of the syphilis prevention activities), we were able to delete the state dummy variables. The assumption that districts did not vary allowed us to drop the sociodemographic variables from the model. Finally, because we focused on the relative change in syphilis rates from one year to the next, we did not need to include the constant term in our calculations.

Exclusion of the lagged dependent variable

We included the additional simplification of dropping the lagged dependent variable in our application of the model. In doing so, we varied our approach from that of other adaptations of regression models of reported STI case rates. In these other adaptations, the lagged dependent variable is accounted for, and thus the impacts of prevention funding extend beyond one year and transmission dynamics are more realistically approximated. For ease of illustration, however, we omitted the lagged dependent variable. This omission follows from our assumptions that the supplemental syphilis funds are used in the same year they are awarded and that all impacts of the supplemental syphilis funding would occur in the same year and not persist into the next year. Had we allowed the impacts to persist beyond one year, however, the estimated effects of the supplemental syphilis prevention funding would be greater than we estimated when limiting the effects to one year.
Examples of calculations

This section provides additional details of the calculations in Table 1, Table 2, and Table 3. Specifically, the calculations for District 1 (the top row of results in each table) are explained. The calculations for the other districts were performed in an analogous manner.

Table 1 calculations
Population size and baseline syphilis incidence rate

The values for population size and baseline syphilis incidence rate were assumed for each district. District 1 was assumed to have a population of 6 million and a syphilis incidence rate of 5 per 100,000.

Number of incident infections
The number of incidence infections in District 1 was calculated by multiplying the population (6 million) by the rate (5/100,000), which yielded 300 cases.

Population-based funding allocation
District 1’s population-based funding allocation was calculated by multiplying District 1’s share of the total population (6 million / 324 million) by the total amount of funding ($64.8 million), which is 0.01851852 x $64.8 million, or $1,200,000.

Rate-based funding allocation
District 1’s syphilis incidence rate at baseline is 5 per 100,000. The sum of the incidence rates in all districts is 270. That is, there are 6 districts with a rate of 5, 6 districts with a rate of 15, and 6 districts with a rate of 25. This works out to a sum of (6 x 5) + (6 x 15) + (6 x 25), or 30 + 90 + 150, or 270. District 1’s rate-based allocation was calculated by dividing District 1’s incidence rate by the total of the incidence rates (5/270) and multiplying by the total amount of funding ($64.8 million). This can be written as 0.01851852 x $64.8 million, or $1,200,000.

District 1’s population-based allocation and rate-based allocation are the same, because the district’s population as a percentage of the total population (6 million / 324 million) is the same as the district’s rate as a percentage of the sum of rates (5 / 270).
Case-based funding allocation

District 1’s case-based funding allocation was calculated by multiplying District 1’s share of the total incident infections (300/48,600) by the total amount of funding ($64.8 million), which is 0.00617284 x $64.8 million, or $400,000.

Table 2 calculations

Number of incident infections with population-based allocation of funding

District 1’s population-based allocation of $1.2 million, given their population of 6 million, works out to $0.20 per capita in supplemental funding. At baseline, there is no supplemental funding, or $0.00 per capita. The change in funding per capita is $0.20 - $0.00, or $0.20. The resulting change in the syphilis incidence rate is calculated as: $\exp(-2.79 \times 0.20) - 1$, or $\exp(-0.558) - 1$, or 0.5724 - 1, or -0.4276.

At baseline, the rate is 5 per 100,000. The new rate is 5 + (-0.4276)*5, or 2.862 per 100,000. For a population of 6 million, this rate corresponds to 171.7 incident infections, which is rounded to 172 in Table 2.

Number of incident infections with rate-based allocation of funding

District 1’s rate-based allocation of $1.2 million is the same as their population-based allocation as described above, and thus also yields 172 incident infections as described above for the population-based allocation.

Number of incident infections with case-based allocation of funding

District 1’s case-based allocation of $400,000, given their population of 6 million, works out to $0.067 per capita in supplemental funding. The change in funding per capita is $0.067 - $0.00, or $0.067. The resulting change in the syphilis incidence rate is calculated as: $\exp(-2.79 \times 0.067) - 1$, or $\exp(-0.186) - 1$, or 0.8303 -1, or -0.1697.
At baseline, the rate is 5 per 100,000. The new rate is 5 + (-0.1697)*5, or 4.151 per 100,000. For a population of 6 million, this rate corresponds to 249.1 incident infections, which is rounded to 249 in Table 2.

**Table 3 calculations**

**Scenario of no supplemental funds**

These values are the same as listed in Table 1. For District 1, there are 300 incident infections at baseline in the absence of supplemental funding.

**First phase of supplemental funds: Population-based allocation**

As described above in the Table 2 example, District 1’s population-based allocation of supplemental funding is $0.20 per capita. The resulting change in the syphilis incidence rate is calculated as described above, except the additional factor 1.9 is applied because District 1 is a high efficacy district. Instead of the formula used above: \( \exp(-2.79*0.20) - 1 \), this scenario uses \( \exp(-2.79*0.20*1.9) - 1 \), or \( \exp(-1.0602) - 1 \), or 0.3464 - 1, or -0.6536.

At baseline, the rate is 5 per 100,000. The new rate is 5 + (-0.6536)*5, or 1.732 per 100,000. For a population of 6 million, this rate corresponds to 103.9 incident infections, which is rounded to 104 in Table 3.

**First phase of supplemental funds: Rate-based allocation**

As described above in the Table 2 example, District 1’s rate-based allocation of $1.2 million is the same as their population-based allocation as described above, and thus also yields 104 incident infections in Phase 1 as described above for the population-based allocation.

**First phase of supplemental funds: Case-based allocation**

As described above in the Table 2 example, District 1’s case-based allocation of $400,000, given their population of 6 million, works out to $0.0667 per capita in supplemental funding. The change in funding per capita is $0.0667 - $0.00, or $0.0667. The resulting change in the syphilis incidence rate is calculated as described above, except the additional factor 1.9 is applied because District 1 is a high efficacy
district. Instead of the formula used above: \( \exp^{(-2.79*0.0667)} - 1 \), this scenario uses \( \exp^{(-2.79*0.0667*1.9)} - 1 \), or \( \exp^{(-0.3534)} - 1 \), or 0.7023 - 1, or -0.2977.

At baseline, the rate is 5 per 100,000. The new rate is 5 + (-0.2977)*5, or 3.5115 per 100,000. For a population of 6 million, this rate corresponds to 210.7 cases, which is rounded to 211 in Table 3.

Second phase of supplemental funds: Population-based allocation

The populations of the districts are assumed to remain constant over time. District 1’s population-based allocation of supplemental funding therefore remains at $0.20 per capita. Thus, the change in funding per capita from Phase 1 to Phase 2 is $0.00. That is, $0.20 - $0.20 = $0.00. The resulting change in the syphilis incidence rate is calculated as: \( \exp^{(-2.79*0^1.9)} - 1 \), or \( \exp^{(0)} - 1 \), or 1 - 1, or 0.00.

Second phase of supplemental funds: Rate-based allocation

As described above, the rate after the Phase 1 implementation of supplemental funds is 1.732 per 100,000 in District 1. This value is shown in Appendix Table 1, along with the rates for all of the other districts. The sum of the rates is 157.400.

For the second phase of the supplemental funding, District 1’s rate-based allocation was calculated by dividing District 1’s incidence rate by the total of the incidence rates (1.732/157.400) and multiplying by the total amount of funding ($64.8 million). This can be written as 0.011 x $64.8 million, or about $713,018.

District 1’s rate-based allocation of $713,018, given their population of 6 million, works out to about $0.1188 per capita in supplemental funding. The change in funding from Phase 1 to Phase 2 is $0.1188 - $0.20, or -0.08116.

The percentage change in the syphilis incidence rate when going from Phase 1 to Phase 2 is calculated as \( \exp^{(-2.79*-0.08116*1.9)} - 1 \), or \( \exp^{(0.43025)} - 1 \), or 1.5376-1, or 0.5376.

After Phase 1, the rate is 1.732 per 100,000. The new rate is 1.732 + (0.5376)*1.732, or 2.663 per 100,000. For a population of 6 million, this rate corresponds to 159.8 incident infections, which is rounded to 160 in Table 3.
Second phase of supplemental funds: Case-based allocation

As described above, the number of incident infections after the Phase 1 implementation of supplemental funds is 210.7 in District 1. This value is shown in Appendix Table 2, along with the number of incident infections for all of the other districts. The sum of incident infections is 29,620.

For the second phase of the supplemental funding, District 1’s case-based allocation was calculated by dividing District 1’s number of incident infections by the total number of incident infections (210.7/29,620) and multiplying by the total amount of funding ($64.8 million). This can be written as 0.00711 x $64.8 million, or about $460,925.

District 1’s case-based allocation of $460,925, given their population of 6 million, works out to about $0.0768 per capita in supplemental funding. The change in funding from Phase 1 to Phase 2 is $0.0768 - $0.0667, or $0.01015.

The percentage change in the syphilis incidence rate when going from Phase 1 to Phase 2 is calculated as \(\exp\left(-2.79\times0.01015\times1.9\right) - 1\), or \(\exp\left(-0.05383\right)\)-1, or 0.9476-1, or -0.0524.

After Phase 1, the rate is 3.5115 per 100,000. The new rate is 3.5115 + (-0.0524)*3.5115, or 3.3275 per 100,000. For a population of 6 million, this rate corresponds to 199.6 incident infections, which is rounded to 200 in Table 3.
Appendix Tables

Appendix Table 1: Rate of incident syphilis infections (per 100,000) by district after Phase 1 allocation of supplemental syphilis funds, when districts are assumed to differ in the effectiveness of their syphilis prevention activities

<table>
<thead>
<tr>
<th>District</th>
<th>Population-based allocation</th>
<th>Rate-based allocation</th>
<th>Case-based allocation</th>
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<tr>
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<td>1.732</td>
<td>1.732</td>
<td>3.511</td>
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<tr>
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<td>5.196</td>
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<td>5.196</td>
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<td>4.271</td>
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<tr>
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<td>1.732</td>
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Syphilis prevention activities were 90% more effective in districts 1-9 and 90% less effective in districts 10-18, respectively, than in the scenario in which all districts were assumed to have equally effective syphilis prevention activities.
Appendix Table 2: Number of incident syphilis infections by district after Phase 1 allocation of supplemental syphilis funds, when districts are assumed to differ in the effectiveness of their syphilis prevention activities

<table>
<thead>
<tr>
<th>District</th>
<th>Population-based allocation</th>
<th>Rate-based allocation</th>
<th>Case-based allocation</th>
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<tr>
<td>1</td>
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Syphilis prevention activities were 90% more effective in districts 1-9 and 90% less effective in districts 10-18, respectively, than in the scenario in which all districts were assumed to have equally effective syphilis prevention activities.
References