Antenatal Testing Laws and Neonatal Mortality Reductions [℘]

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Abstract: Even though syphilis can be prevented effectively and treated inexpensively, syphilis has remained a global public-health problem, with an estimated 2 million pregnant women infected each year, causing 1.2 million cases of congenital syphilis in newborns. Untreated congenital syphilis results in neonatal death, stillbirth, premature birth, or congenital deformities. Many countries have only recently instituted syphilis prevention programs in antenatal care, but there has not been a systematic study of the effects of such programs. This paper looks at antenatal testing laws initiated in the U.S. in 1938-1947 which mandated physicians attending to pregnant women to test them for syphilis while also making the tests free in nearly all the reforming states. We use the variation in the timing of state antenatal testing laws to estimate the laws' effect on neonatal mortality rates and deaths due to premature birth. We find that these laws decreased neonatal mortality rates of nonwhites by 3.85 per 1,000 live births (10.5%) while having no discernible impact on whites. As a result the white-nonwhite neonatal mortality gap decreased 41% during this time period. We also find that mandatory antenatal testing led to a 13-16% increase in the cohort size of nonwhite poor. As the syphilis rate and level of antenatal care in the U.S. are comparable to those observed in African and Latin American countries today, we apply the estimates of our findings to the 10 countries that account for over 40% of the global burden of pregnancies and newborns affected by syphilis and discuss the implications of our findings.

JEL Codes: I1, I18, J13

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I. Introduction

Mother-to-child transmission of syphilis, or congenital syphilis, has been documented since the 15th century (Shafti et al. 2008), yet it continues to account for substantial neonatal mortality and morbidity around the world today (WHO 2007). The World Health Organization (WHO) estimates that 12 million people are infected with syphilis each year, including 2 million pregnant women (WHO 2007). About 1.2 million of these pregnant women transmit the infection to their fetus, causing congenital syphilis. Approximately 80% of untreated congenital syphilis results in neonatal death, stillbirth, premature birth, or congenital deformities (Fiumara et al. 1952; Ricci et al. 1989; Ray 1995). Untreated maternal syphilis is estimated to cause similar, if not higher, neonatal mortality compared to other important infections during pregnancy such as HIV, neonatal tetanus, or malaria (WHO 2002).

Despite the global burden of syphilis, it is a disease that can actually be screened and treated effectively and inexpensively.[1] However, many countries have only recently instituted syphilis prevention programs in antenatal care, and there has not been a systematic study of the effects of such programs. To the best of our knowledge, this paper is the first systematic, population-wide study of the effects of such antenatal programs. We examine antenatal testing laws initiated in the U.S. in 1938-1947 which mandated physicians attending to pregnant women to test them for syphilis while also making the tests free in nearly all the reforming states.

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The rest of the paper is structured as follows: Section II discusses the background on syphilis and antenatal testing laws. Section III describes the data and Section IV discusses the empirical strategy. Section V presents the results and also discusses the exogeneity of the laws and other robustness tests. Section VI discusses policy implications and Section VII concludes.

II. Syphilis, Testing, and Treatment

1. Background about Syphilis

Syphilis is a sexually transmitted disease caused by the spirochete bacterium *Treponema pallidum*.[2] Pregnant women who are infected with syphilis can transmit the infection to their fetus, causing congenital syphilis. The likelihood of transmission can be as high as 80% in cases of early maternal infection (Berman 2004). Transmission typically occurs during the second trimester, between the 16th and 28th week of gestation, but it can also occur as early as the 9th week (Berman 2004).

Studies have shown that 49%-75% of untreated syphilitic pregnancies lead to adverse pregnancy outcomes, including neonatal death, stillbirth, premature birth, low birth weight, or infant disorders such as deafness, neurologic impairment, and bone deformities. Among these untreated syphilitic pregnancies, perinatal deaths (stillbirths and early neonatal deaths) occur in 10%-23% of the cases,

[1] Rapid testing for syphilis can be performed through primary care or antenatal care at a procurement cost of less than US$ 1 per person (WHO 2010). A dose of penicillin, which is used to prevent congenital syphilis, costs only US$ 0.50 (WHO 2010).

[2] More information about syphilis can be found from the Centers for Disease Control and Prevention (CDC): http://www.cdc.gov/std/syphilis/stdfact-syphilis.htm.

while premature births occur in 20%-33% of the cases (Harman 1917; Hira et al. 1990; WHO 2002; Watson-Jones et al. 2002). These adverse pregnancy outcomes are preventable if the infection is detected and treated before mid-second trimester (WHO 2006).

Despite the high global burden of syphilis, it is actually relatively easy and inexpensive to diagnose and treat. Syphilis is commonly diagnosed using a blood test. Shortly after infection, the body produces antibodies that can be detected by an accurate, safe, and inexpensive blood test (CDC 2013). There are two kinds of blood tests used today: a non-specific (non-treponemal) test and a specific (treponemal) test. A non-treponemal test costs about US$ 0.50, while a treponemal test costs about US$ 0.55-$3.00 (WHO 2007). For the period under study in this paper, the Hinton test developed by William A. Hinton was the most common blood test used by the U.S. Public Health Service starting in 1934 (Hinton 1936).

Once detected, pregnant women with syphilis can be treated with penicillin. At present, treatment via penicillin during pregnancy is completely effective in treating the mother, preventing infection of the baby, as well as treating an infected fetus (Norwitz 2009). For the period under study in this paper, however, penicillin was not yet discovered or identified as an effective treatment. Before the advent of penicillin, treatments for syphilis included mercury, organic arsenical compounds, and bismuth (Sartin and Perry 1995). Penicillin, discovered in 1928, was first used to treat syphilis successfully in 1943 (Mahoney et al. 1943). It was then approved by the U.S. Public Health Service for the treatment of syphilis and other diseases in 1947[3], and became the treatment of choice even to this day given its effectiveness and its widespread manufacture after World War II. To reduce confounding by the introduction of penicillin, we focus on the period 1931 to 1947 in our analysis.

It should be noted that syphilis testing and treatment in 1931-1947 were more time consuming, less effective, and carried more health risks compared to the screening and treatment options today (Sartin and Perry 1995). As a result, the effects of the antenatal testing program in the U.S. in the 1930s and 1940s that we estimate in this paper may serve as a lower bound estimate of the potential effects of current antenatal programs.

When studying the effects of syphilis testing and treatment, it is also important to identify the populations that are at risk. In the U.S., syphilis has been documented to disproportionately affect racial and ethnic minority populations (CDC 2011; Robles 2013a). Data on national syphilis rates in the U.S. was available beginning in the 1940s, and it has been shown that nonwhites have always had higher syphilis and congenital syphilis rates than whites (STD Surveillance Reports 2011).[4] This health disparity between whites and nonwhites has not disappeared over time. In 1993, the black-to-white ratio of congenital syphilis rates was 56.5 (see Figure 1). Even as recently as 2011, blacks had 7.0 times the reported syphilis rates of whites (CDC 2011). This phenomenon motivates our hypothesis that antenatal testing laws benefitted nonwhites disproportionately more than whites.

2. Antenatal Testing Laws

[3] Penicillin had been approved earlier by the U.S. War Production Board to treat U.S. soldiers during World War II (Parascandola 1980).

[4] Before the 1980s, data was collected in white versus nonwhite categories.

Syphilis rose to epidemic proportions in the U.S. in the early 20th century as shown in Figure 2. In 1941, the first year that data on syphilis rates was recorded, the congenital syphilis rate was 651.1 per 100,000 live births (CDC 2011).[5] As a study in 1941 points out, "[Syphilis] was the largest single cause of premature labor, stillbirth and fetal death. Twenty years ago at the Johns Hopkins Hospital, 34.4% of all stillbirths and neonatal deaths were due to this cause… Even now 10% of all such deaths at this hospital are due to syphilis." (Peckham 1941)

Faced with the syphilis epidemic, U.S. Surgeon General Thomas Parran initiated a syphilis control campaign in 1936 which encouraged states to adopt antenatal blood test requirements for syphilis (Shafer 1954). The purpose of the campaign was to identify and treat as many syphilitic pregnancies as possible and as early in gestation as possible, in an effort to prevent syphilitic births and the irreversible congenital abnormalities which resulted from infection. The laws subsequently adopted by almost all states mandated that "a licensed physician or other persons authorized to attend to an expectant mother is required to take, or cause to be taken, a sample of blood of such woman, to be submitted to an approved laboratory for a standard test for syphilis within a specified time" (Halse and Liberti 1954). Non-compliance by an attending physician or health provider (e.g. midwife) was punishable by a misdemeanor charge although no evidence of such action is known to the authors.

The first antenatal testing law was passed in New York state in March 1938. Just two years later, by 1940, nineteen more states had passed the laws, and during the years 1943 to 1945, eleven additional states adopted the laws.[6] The timing of the adoption of the antenatal testing laws is presented in Table 1 and Figure 3. The adoption of these laws has been termed "a legislative landslide unsurpassed in speed and scope" (ASHA 1948).

Due to the influence of Thomas Parran's campaign, the contents of the antenatal testing laws were quite consistent across states. In 34 states, a serologic test for syphilis during pregnancy was required at the first antenatal visit or first examination for pregnancy, or within fifteen days after the first examination (Halse and Liberti 1954).[7] All states required that the physician submit a blood sample of the patient to a state-approved laboratory for a standard serologic test for syphilis. In 33 states, serologic tests for syphilis were free if performed by state laboratories (Halse and Liberti 1954). In Ohio, Pennsylvania, North Carolina, and Georgia, tests were free if the patient was unable to pay and an appeal to the state was made by the physician attending to the patient. Tests were not free in California, Kansas, Massachusetts, Rhode Island, and Vermont. To this day, all states except Wisconsin maintain the antenatal testing laws as initially adopted.[8]

We would expect to see an effect from the antenatal testing laws if and only if (i) the rate of antenatal testing for syphilis was low prior to the adoption of the laws and (ii) there was a high compliance of the laws. If most pregnant women were already being tested for syphilis before the laws were adopted, then we would not expect to see much effect of the laws. Unfortunately there is no

[5] As comparison, in 2011, the congenital syphilis rate was 8.5 per 100,000 live births (CDC 2011).
[6] At present, 45 states require antenatal testing for syphilis and/or other sexually transmitted diseases (Robles 2013a).
[7] There were some exceptions: In Indiana, the law specifies that a test for syphilis be taken at the time of diagnosis of pregnancy; in Maine, at some time during the gestation period; in Rhode Island, within thirty days from the first professional visit; in Connecticut and Georgia, within thirty days after the first examination for pregnancy; in Louisiana, at the time of the first examination or as soon thereafter as possible; and in Missouri, within twenty days after the first visit to the physician.
[8] Wisconsin does not require physicians to test for syphilis during antenatal care.

information available on the rate of antenatal syphilis testing before the laws. There is anecdotal evidence, however, to suggest that a large percentage of pregnant women did not receive antenatal testing for syphilis prior to the laws. For instance, Faden, Geller, and Powers (1991) point out that prior anti-venereal disease programs only targeted prostitutes and their customers. As a result, the test for syphilis might have carried a stigma that discouraged the screening of pregnant women as part of routine obstetric care.

Whether pregnant women were being tested for syphilis also depended on whether they were receiving antenatal care. Unfortunately, there is no systematic, historical data on utilization of antenatal care by race for our period under study. There are studies that do show that nonwhite women are less likely to receive antenatal care compared to white women (Nakashima et al. 1996; Peterman et al. 2005; Robles 2013a). This suggests that nonwhite women who were not getting antenatal care would not have benefited from the antenatal testing laws. We also do not have information on the compliance rate of the laws. Ideally, we would like to know the actual number of syphilis tests performed as compared to the number of pregnancies after the laws were passed. Looking at studies done in the 1990s and early 2000s, Hossain et al. (2007) estimated that the compliance rate for syphilis screening during antenatal care visits ranged from 32% to 98%. This suggests that any effect of the antenatal testing laws that we find is likely to be a lower bound of the true treatment effect.

A causal interpretation of our results requires that, net of the control variables, the timing of the antenatal testing laws is uncorrelated with other factors that are likely to affect infant health. To our knowledge only one other national health intervention took place between 1931 and 1947, namely, the passing of premarital testing laws, which we discuss below. There were also other public health interventions but those were initiated after our 1931-1947 period of study. Penicillin was initially approved by U.S. Public Health Service for the treatment of syphilis and other diseases in 1947.[9] The beginning of modern neonatology started around 1948, when the first booklet entitled "Standards and Recommendations for Hospital Care of Newborn Infants" was published. While there do not appear to be any other national health interventions which may confound the effect of the antenatal testing laws, we do examine the exogeneity of the antenatal testing laws using regression analysis, which we describe in the empirical strategy section.

3. Premarital Testing Laws

Thomas Parran's campaign against syphilis also spawned the adoption of premarital testing laws during the same period as the antenatal testing laws.[10] The premarital testing laws mandated individuals seeking a marriage license to submit the results of a serological test for syphilis when applying for the license (Shafer 1954; Hedrich and Silverman 1958). The purpose of the premarital laws was to limit contagion to the partner and to the would-be offspring.

The potential confounding effect from premarital testing is theoretically ambiguous due to its preemptive effect on both birth rate and vertical contagion (i.e. mother-to-child transmission of disease). On one hand, premarital testing laws may have prevented contagion of offspring by alerting

[9] Before that, penicillin had been approved by the U.S. War Production Board to treat U.S. soldiers during World War II (Parascandola 1980).

[10] The correlation between the timing of the adoption of antenatal testing laws and the adoption of premarital testing laws is 63% (authors' calculation).

infected couples prior to their marriage. As a result couples may have sought treatment prior to conception or may have deferred conception past the point of vertical contagion, thereby reducing congenital syphilis rates and neonatal mortality rates. In such a case, antenatal testing would be ineffective when conception takes place after marriage, assuming the marriages are monogamous.[11]

On the other hand, premarital testing laws may have increased neonatal mortality rates by way of increasing the proportion of offspring born out-of-wedlock. Out-of-wedlock children are far more likely to experience negative outcomes, such as higher fetal and infant mortality, than children born in-wedlock. Studies have found that the 1980-2007 repeals of premarital testing laws increased marriage rates by approximately 1-3% by way of the reduced entry-cost of marriage (Buckles et al. 2011; Robles 2013b). By similar reasoning, the adoption of premarital testing laws may have discouraged some from marriage when the laws were first enacted.[12] As a result the proportion of offspring born out-of-wedlock may have increased as couples simply avoided marriage but did not preclude procreation. We examined the confounding effect of premarital testing on fertility rates in 1931-1947 and found no effect.[13]

We account for the potential confounding effect of premarital testing by including interactions of the dummy variables for antenatal testing and premarital testing. This is discussed in greater detail in the empirical strategy section.

III. Data

Information on the timing of antenatal and premarital testing laws was obtained from an editorial by the American Social Hygiene Association in the *Journal of Social Hygiene* (1948). A total of 38 states adopted laws for antenatal testing between 1938 and 1947. 31 of the 38 states adopted laws for premarital testing over the same period. The first full year in which each state's laws were adopted is shown in Table 1.[14] In most cases the effective date of the law took place midway through the prior year, except for four states (IN, NJ, NC, WA) which had effective dates on or around January 1st of the year listed in the table. One state (SC) had an effective date prior to the approval date of the antenatal legislative act, in which case the latter was taken as the true effective date.

We use the first full year of the law rather than the effective year to account for the lag between the observed birth outcomes and the timing of treatment in the first trimester. Since the laws in most of the states took effect on or around July 1st, a pregnancy that was treated soon after the effective date while still being sufficiently early to avert adverse birth outcomes would not come to fruition until the beginning of the following year.[15]

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[11] Of course, this would not be the case for births occurring outside of marriage.

[12] Robles (2013b) argued that much of the effect on marriage rates was due to the non-linear effect of the waiting period. Therefore states which previously required a waiting period will have experienced a smaller reduction in marriage rates.

[13] The results of the fertility rate regressions are available upon request from the authors. We used a state-year panel of aggregate fertility rates and the regression specification in equation (1).

[14] There is a total of 43 states listed in Table 1. States that are not listed in the table did not have antenatal or premarital testing laws prior to 1948. These states are included as part of the control group in our regressions.

[15] Mother-to-child transmission of syphilis may occur in the first trimester but neonatal mortality does not occur until the end of gestation which can be 6-7 months after the point of infection. While treatment on or before the penultimate month of gestation will cure the mother and the fetus, it will not reverse any physiological damage.

Since untreated congenital syphilis results in neonatal death or premature birth, we study the effect of the antenatal testing laws on neonatal mortality rates and on infant deaths due to premature birth. Neonatal mortality is defined as all mortality that occurs in the first 28 days of life. Premature birth is defined as all births that occur before 37 weeks of gestation. These birth outcomes are clearly and consistently defined across states and across years and the data are available for the entire period that the antenatal testing laws were enacted.

Data on neonatal mortality by state of occurrence was gathered from the 1931-1947 National Center for Health Statistics (NCHS) Vital Statistics Mortality Reports.[16] We started with 1931 to allow for a pre-period of at least 8 years of observed mortality rates to account for pre-existing trends. We examine the effect on neonatal mortality separately for whites and nonwhites due to the disparate prevalence of syphilis by race.[17] State-year mortality rates are calculated as the total number of deaths divided by the live-birth count in each state-year cell. Live-birth counts were obtained from the 1931-1947 NCHS Vital Statistics Nativity Reports.

We also construct a state-year panel of infant mortality (i.e. death within 1 year of live birth) by race to see if there is an additional effect of the laws beyond the neonatal period. As a preview of our results, we find no post-neonatal mortality effect, which is consistent with medical evidence that the adverse mortality outcome of congenital syphilis is mostly concentrated in the neonatal period.

In addition to neonatal and infant mortality rates, we also study deaths within 1 year due to premature death. As direct data on premature birth is not available, we believe this variable is a close proxy, since a large fraction of premature births resulted in deaths given the lack of medical care available to preterm births in the 1930s and 1940s. We also looked into data on fetal mortality, deaths within 1 year due to syphilis, and deaths within 1 year due to congenital deformity, but these data are either not consistently available for our time period of study or the variable itself is not consistently defined.[18]

As a robustness check, we complement our main regression analysis by studying the effect of antenatal testing laws on cohort size. Data on cohort size by state, year, and race (white and nonwhite) was obtained from the 1% sample of the 1950 U.S. Census, available through the Integrated Public Use Microdata Series (IPUMS-USA). Individuals are grouped into state-year-race cells corresponding to their state of birth, year of birth, and race. Each cell is weighted by person-weights to take into account how many persons in the U.S. population are represented by a given person in the 1% sample. Since we are using the 1950 Census, the 1931-1947 birth cohorts in our study were aged 3 to 19 when observed in 1950. The 1950 Census is better than later censuses for our purpose since the 1931-1947 cohorts would be older when observed in later censuses, and there may be cohort attrition that may confound the effects of congenital syphilis or antenatal testing laws.

Only treatment which occurs shortly after mother-to-child transmission will avert the adverse birth outcomes that we observe.

[16] Data on neonatal mortality by state of residence is not available until 1947 in the Vital Statistics Mortality Reports.

[17] Mortality data in 1931-1947 is not available by detailed categories of race. The nonwhite category refers to all races other than white.

[18] For instance, states used inconsistent determinants to classify deaths as fetal deaths or miscarriages. Currently it is standard practice to report a fetal death as a death that occurs after 20 weeks of gestation and a miscarriage as a death prior to 20 weeks of gestation.

Another advantage of using the cohort size data from the 1950 Census is that we can make use of the poverty measure in the Census data to study the effect of the laws on the poor. One may expect the antenatal testing laws to have had a larger impact on lower income women as they may have been less likely to get tested before the laws were passed or they may have had a higher incidence of syphilis to begin with. In the Census data, the variable POVERTY ranges from 1 to 501, with 1 referring to individuals at 1% or less of the poverty threshold, and 501 referring to individuals at 501% or more of the poverty threshold. For our analysis, we define the "poor" as those at 100% or less of the poverty threshold. We examine the effect of the antenatal testing laws on both the white and nonwhite poor.

Table 2 shows the summary statistics. From panel A, we see that nonwhites had higher neonatal and infant mortality rates than whites on average. The average neonatal mortality rate is 37.54 per 1,000 live births for nonwhites and 27.71 per 1,000 live births for whites. From panel B, we see that the average cohort size in each birth state and birth year cell is 47,954 for whites and 6,999 for nonwhites. For those who are at 100% or less of the poverty threshold, the average cohort size is 5,962 for whites and 2,362 for nonwhites.

IV. Empirical Strategy

We use state-year panel datasets combined with the variation in the timing of the adoption of state laws to measure the impact on neonatal mortality using the following regression:

$$y_{st} = \beta_0 + \gamma Antenatal\ Testing_{st} + \beta_1 Premarital\ Testing_{st} * Antenatal\ Testing_{st} + \beta_2 Premarital\ Testing_{st} + \beta_{3st}\chi_{st} + \beta_{4s} state_s + \beta_{5t} year_t + \beta_{6st} state_s * time_t + \beta_{7st} state_s * time_t^2 + \varepsilon_{st} \quad (1)$$

where *s* indexes states and *t* indexes years. y_{st} is the dependent variable of interest, which includes the neonatal mortality rate, deaths within 1 year due to premature birth, and infant mortality rate in state *s* at year *t*. *Antenatal Testing*$_{st}$ is a dummy variable which takes on the value of 1 when antenatal testing is required in state *s* for the entire year *t*. The coefficient γ is the average effect of mandatory antenatal testing. *Premarital Testing*$_{st}$ is a dummy variable which takes on the value of 1 when premarital testing is required in state *s* for the entire year *t*. We also include the interaction *Premarital Testing * Antenatal Testing* to control for the separate effect of antenatal testing when premarital testing is also mandated.

The state- and time-varying covariates (χ_{st}) include variables that are commonly linked to neonatal and infant mortality: fraction of first time live-births and fraction of live-births by women outside of age 17-35. The *year* fixed effects control for national events which may have affected birth or neonatal mortality rates in any given year, such as national health intervention programs or U.S.'s involvement in World War II. The *state* fixed effects control for stable unobserved heterogeneity across states which may have affected birth or neonatal mortality rates. *Time* is a linear trend so that the interaction terms *state * time* and *state * time*^{2} control for a quadratic time trend for each state. These variables capture the trend in state-level characteristics that may affect birth outcomes such as the number of hospitals, fertility trends due to population changes, or growth. State quadratic trends are a more flexible approach of controlling for the heterogeneous syphilis infection propensity.

All regressions are weighted by state-year live-birth totals to reflect the underlying micro-data. We cluster the standard errors at the state level in all regressions to account for the possibility of serial correlation within a state. As noted by Bertrand et al. (2002), failing to account for serial correlation when computing standard errors may lead to over-rejection of the null hypothesis.

To examine whether the timing of the antenatal testing laws is indeed exogenous, we modify equation (1) to identify the dynamic effects of the laws on the dependent variables. We include dummy variables for the years relative to the effective date of the antenatal testing laws:

$$y_{st} = \beta_0 + \sum_{4\geq k\geq -4} \gamma_k \, Antenatal\ Testing\ in\ effect\ for\ k\ periods_{st} + \sum_{k\geq 0} \beta_{1k}\, Premarital\ Testing_{st} * Antenatal\ Testing\ in\ effect\ for\ k\ periods_{st} + \beta_2 Premarital\ Testing_{st} + \beta_{3st}\chi_{st} + \beta_{4s} state_s + \beta_{5t} year_t + \beta_{6st} state_s * time_t + \beta_{7st} state_s * time_t^2 + \varepsilon_{st} \quad (2)$$

The coefficient estimates γ_k are grouped together in two-year periods for the years preceding the laws and are presented annually thereafter for years 1 to 4. If the timing of the laws is exogenous, there should be a discontinuity in the dynamic estimates for the years preceding the laws and the years that follow the law. As pointed out by Wolfers (2006), a major difficulty in difference-in-difference analyses involves separating out pre-existing trends from the dynamic response of a policy shock. Our estimation equation (2) enables us to study the dynamic impact of the laws while allowing the state-specific time trends to identify pre-existing trends in the outcome variables.

We also perform a second test of whether the timing of the antenatal testing laws was independent of the neonatal mortality trends. We estimate a probit model to test the predictive capacity of lagged neonatal mortality rates on the timing of the laws. The model specification is as follows:

$$timing_{st} = \delta_0 + \delta_1 N_{st-1} + \delta_2 time_t + \delta_3 time_t^2 + \delta_4 N_{st-1} * time_t + \delta_5 N_{st-1} * time_t^2 + \varepsilon_{st} \quad (3)$$

where $timing_{st}$ is a dummy variable that equals 1 if state *s* instituted an antenatal testing law in year *t* and 0 otherwise. States exit our sample the year after the effective year. N_{st-1} is the one-year lagged state neonatal mortality rate while $N_{st-1} * time_t$ and $N_{st-1} * time_t^2$ give the state-specific quadratic trend in neonatal mortality rate.

Lastly, we use equation (1) to estimate the effect of the laws on birth cohort size. We run the regressions separately for the white and nonwhite full samples, and then for the subsamples of white and nonwhite poor.

V. Results

1. Mortality Effects of Antenatal Testing Laws

Table 3 shows the estimated effects of the antenatal testing laws on mortality rates. For each dependent variable, we present results for three empirical specifications, first with state and year fixed effects, then adding state linear trends, and finally adding state quadratic trends. All three specifications

control for state- and time-varying covariates as described in the previous section. We refer to the third specification as our main results.

Comparing the results across panel A (nonwhites) and panel B (whites), we see that the estimated effects of the laws on all measures of mortality are negative and statistically significant for nonwhites but not for whites. From columns (1) and (4), we see that mandatory antenatal testing decreased neonatal mortality rate for nonwhites by 2.04 per 1,000 live births (corresponding to a decrease of 5.6%) and decreased deaths due to premature birth by 1.33 per 1,000 live births (corresponding to a decrease of 7.9%).[19] The estimated effects are larger at 4.70 and 2.60 per 1,000 live-births (a reduction of 12.8% and 15.4%) when we control for state linear trends (columns (2) and (5)). The results are statistically significant at the 1% and 5% level respectively. The larger coefficient estimates suggest that there may be a confounding effect of an upward trend in state mortality rates, which we now control for with the state linear trends. When we include the state quadratic trends (columns (3) and (6)), the effect on neonatal mortality decreased slightly to 3.85 per 1,000 live births (a 10.5% reduction), while the effect on death due to premature birth increased to 3.08 per 1,000 live births (a 18.2% reduction).

Columns (7) to (9) present the coefficient estimates for infant mortality. As discussed earlier, medical studies have shown that maternal syphilitic infection will increase neonatal and fetal mortality but there is no medical evidence that post-neonatal mortality is affected. Our results are consistent with the medical literature in that we do not find any reduction in infant mortality that exceeds the reduction in neonatal mortality. Specifically, column (9) shows that the nonwhite infant mortality rate decreased by 3.90 per 1,000 live births, which is almost entirely accounted for by the 3.85 per 1,000 reduction in nonwhite neonatal mortality rate shown in column (3). The fact that we do not find an impact on infant mortality beyond the direct effect on neonatal mortality suggests that the estimated effect on neonatal mortality is indeed due to an increase in the screening and treatment of maternal syphilis rather than an increase in antenatal care per se.

In sum, the results in Table 3 suggest that antenatal testing laws benefited nonwhites but had little to no effect on whites. There are two main reasons for the racial disparity. First, the prevalence of sexually transmitted diseases has historically been higher among the nonwhite population. Second, nonwhite women may have pursued syphilis testing less frequently than white women prior to the laws, either because they are less likely to have access to antenatal care in general (Nakashima et al. 1996; Peterman et al. 2005; Robles 2013a), or because they are less likely to pay for the testing (given that there are a larger proportion of nonwhites who have a lower socioeconomic status compared to whites). Since antenatal testing laws require physicians to test for syphilis regardless of the patient's ability to pay, those unable to pay, specifically nonwhites, are now more likely to receive testing as a result of the laws.

2. Dynamic Effects on Neonatal Mortality

In giving a causal interpretation of our results, one may be concerned that there were trends in mortality rates that were correlated with the timing of antenatal testing laws. In other words, one may worry that the timing of the laws may not be exogenous. We deal with this concern in two ways. First,

[19] We calculate the percentage change by dividing the coefficient estimates by the four-year preceding average, which is calculated as the population-weighted average over the four years prior to the effective year of the antenatal testing laws in each state.

we present in Table 4 the dynamic effects of the laws on nonwhite neonatal mortality estimated from regression model (2). The coefficient estimates are also plotted in Figure 2. States with effective dates of antenatal and premarital testing laws after 1944 are excluded from the analysis to allow for a 4-year post-reform period of observation. This explains why the total number of state-year observations decreases from 515 to 294. From Table 4, we see that the coefficient estimates for the four years preceding the laws are negative but insignificantly different from zero, whereas the estimates after testing is mandated are negative, large, and statistically significant across all three specifications. This shows that the results in Table 3 are not simply picking up a downward trend in nonwhite neonatal mortality rates that preceded the antenatal testing laws. This suggests that the timing of antenatal testing laws is exogenous to the baseline rate of neonatal mortality.

3. Timing of Antenatal Testing Laws

The second way to deal with the potential concern of the exogeneity of the laws is to use the probit model (Equation (3)) to examine the predictive capacity of lagged neonatal mortality rates on the timing of the laws. Table 5 shows that there is no evidence that the lagged neonatal mortality rates or the state-specific trends in neonatal mortality predict the passing of the laws. All coefficients are insignificant for the nonwhite neonatal mortality rates. The coefficient on the first lag of white neonatal mortality rates is statistically significant at the 10% level, but the marginal effect is negative (as opposed to positive if one expects the law to be a reaction to higher congenital syphilis or neonatal mortality rates) and the magnitude is practically insignificant. The results indicate that an increase in the white neonatal mortality rate decreases the propensity of initiating an antenatal testing law by 0.006% the following year.

Taking the results of Tables 4 and 5 together, we can see that the antenatal testing laws were not correlated with neonatal mortality rates. We can treat the timing of the laws as exogenous within the models used in this paper.

4. Demographic Composition Effects

A separate concern may be that the change in neonatal mortality in one or a few states is driving our results due to the population weights. For instance, the geographic concentration of nonwhites in the southern states may introduce a regional bias to our national estimates if the change in neonatal mortality varies by geographic region. Alternatively, a more forceful public health campaign or venereal disease control program in populous states such as New York or California may bias our estimates towards a larger coefficient if the change in neonatal mortality is less aggressive in all other states. We examine the robustness of our estimates by regenerating Table 3 and excluding each state one at a time. The results do not appear sensitive to the exclusion of any particular state.[20]

5. Cohort Size Effects

As a further robustness check we examine the effects of antenatal testing laws on birth cohort size using data from the 1950 Census. We estimate regression model (1) separately for the white and nonwhite full samples, and then for the subsamples of white and nonwhite poor. We use the natural log

[20] Results available from authors.

of the cohort $size_{st}$ as the dependent variable, where *s* indexes the birth state and *t* indexes the birth year. Similar to our previous state-year mortality panel, we limit our data to those born between 1931 and 1948.

Table 6 presents the results. We do not find any statistically significant change in cohort size for the white and nonwhite full sample (panel A), but we find a positive and strongly significant effect of the laws on the cohort size of the nonwhite poor (panel B columns (4) to (6)). The coefficients are very similar across all three specifications, and show that mandatory antenatal testing led to a 13-16% increase in the cohort size of nonwhite poor. Consistent with our mortality results in Table 3, the antenatal testing laws benefitted the nonwhites but had no effect on whites. In particular, the effects on the nonwhite population are concentrated on the low income group. This is consistent with our hypothesis that the antenatal testing laws may have a larger impact on lower income women as they may be less likely to get tested before the laws were passed or they may have a higher incidence of syphilis to begin with.

From columns (4) to (6) in panel B, we see that the premarital testing laws, same as the antenatal testing laws, have a positive and statistically significant effect on the cohort size of the nonwhite poor, while the interaction term between antenatal testing and premarital testing is negative, statistically significant, and of similar magnitude as the positive coefficient on antenatal testing alone. This means that for states that have passed premarital testing laws, the average effect of antenatal testing laws is close to zero (as the positive coefficient on antenatal testing is offset by the negative coefficient on the interaction term). This result is slightly different from the results for mortality rates in Table 3. In Table 3, we see that the coefficients on premarital testing and on the interaction term between antenatal and premarital testing are statistically insignificant.

How does the magnitude of the cohort size results compare to the magnitude of the neonatal mortality results? We show a calibration of the increase in cohort size in Table 7. We first multiply our coefficient estimate for nonwhite neonatal mortality from Table 2 (3.85 per 1,000 live births) by the number of live births in the reform states in the year prior to the effective year of antenatal testing laws (194,184 live births). The imputed increase is 748, or 0.39%. We then re-run our regression from Table 6 Panel B Column 6 but with the dependent variable being the cohort size of nonwhite poor (instead of the natural log of cohort size). The coefficient estimate is 235 and we divide this by the cohort size of nonwhite poor for the reform states in the year prior to the effective year of antenatal testing laws (27,351). The imputed increase is 0.86%.

We see that the increase in the size of the nonwhite birth cohort is of similar magnitude but larger than what we can attribute solely to the decrease in nonwhite neonatal mortality. This is not surprising, as the passing of antenatal testing laws should also avert fetal deaths that will be reflected in the cohort size but will not be captured by the neonatal mortality reduction. Moreover, mandatory antenatal testing may have an impact on cohort survival beyond the neonatal period of 28 days.[21] Another reason why we may get a larger estimate for the birth cohort size is that we may be introducing some upward bias when using the 1950 Census data to construct our cohort size. Cohorts born before the laws were inevitably older than cohorts born after the laws when observed in 1950. We cannot rule out the possibility that there is a higher propensity for older cohorts to perish, though this should be small as our 1931-1948 cohorts were still relatively young by 1950 (they would be 2 to 19 years old). We

[21] On the other hand, our infant mortality results in Table 3 seem to indicate that most of the effects of the laws are concentrated in the neonatal rather than post-neonatal period.

also cannot rule out the possibility that subsequent health interventions were able to benefit the survival of younger cohorts disproportionately more than that of the older cohorts. For instance, the advent of penicillin in 1947 or influenza vaccine in 1945 may have disproportionately benefited the survival rates of younger cohorts more, since the older cohorts may have been exposed to the illnesses at the same age but before the discoveries of the drug and vaccine. However, it is important to note that such alternative explanations for the increase in birth cohort size require that there be a systematic benefit which is both limited to nonwhites and correlated with the timing of antenatal testing laws. If the systematic benefit was solely correlated with the timing of the antenatal laws then we should observe an increase in the white cohort size as well.

VI. Implications

1. Contribution of Antenatal Testing Laws to Narrowing of White-Nonwhite Mortality Gap

[We estimate that these laws decreased neonatal mortality rates of nonwhites by 3.9 per 1,000 live births (10.5%) while having no discernible impact on the neonatal mortality rates of whites. As a result the neonatal mortality gap between nonwhites and whites decreased 41.4%.] [more here]

2. The Cost of Saving a Baby

We use our regression estimates to conduct a cost-benefit analysis of the antenatal testing laws. Results are presented in Table 8. For each year from 1939 to 1947, we total the number of births in the states that mandate antenatal testing using data from NCHS Vital Statistics (column (1)). For instance, in 1939, three states (NJ, NY, RI) have mandated antenatal testing, and the total number of white and nonwhite births in these three states is 254,752. Assuming the total number of syphilis testing during antenatal care visits is the same as the total number of births, we multiply column (1) by $2.30 to get column (5). $2.30 is the cost of syphilis testing (including both supplies and labor cost) according to WHO (2012).[22]

We then use our regression estimates from Table 3 Panel A to calculate the number of neonatal deaths and premature births averted (columns (2) and (3)). To get the number of neonatal deaths averted, we multiply 3.85 per 1,000 births by the number of nonwhite births in reform states for each year. To get the number of premature births averted, we multiply 3.08 per 1,000 births by the same number of nonwhite births in reform states for each year. Note that the number of premature births averted is a conservative lower bound, as our 3.08 regression coefficient refers to "death within 1 year due to premature birth." Presumably not all premature births lead to infant deaths, so the total number of premature births averted as a result of the laws should be even higher than that reported in column (3).

Since we do not have information on the actual prevalence of maternal or congenital syphilis, we use parameters from the literature to estimate the number of syphilitic pregnancies. According to the synthesis of existing medical studies, the estimated percentage of adverse outcomes in untreated pregnancies affected by syphilis is 9% for neonatal death and 6% for prematurity or low birth weight (WHO 2012). We therefore divide column (2) by 0.09 and divide column (3) by 0.06 and add the two

[22] WHO (2012) estimates the cost of syphilis testing to be $1.83 – $2.30. We take the higher cost estimate to make our cost-benefit calculation more conservative. Ideally, we would like to use the cost figures for the 1940s, but such data is not available.

numbers together to get the number of syphilitic pregnancies averted in column (4).[23] We multiply column (4) by the cost of syphilis treatment ($3.79) to get column (6). As we do not have information on the cost of syphilis treatment back in the 1940s, we use the current cost as estimated by WHO (2012). Based on anecdotal evidence, we expect the historical cost and current cost of syphilis treatment to be of similar magnitude.

If maternal and hence congenital syphilis is averted, there will be cost savings from no longer needing to treat an adverse birth outcome, for example, a premature birth, or a low birth weight baby, or a baby with congenital deformities. We take this cost savings into account in column (7), which we calculate by multiplying the number of premature births in column (3) by $366, which is the direct cost of medical care for each premature birth.[24] The cost savings number is clearly a lower bound of all possible medical cost savings.[25] We sum up columns (5) through (7) to get column (8).

Finally, we divide the total cost in column (8) by the number of neonatal deaths averted in column (2) to get the cost per neonatal death averted in column (9). From column (9), we see that the cost of saving a baby is around $6000-$10,500. The average across the 1939-1947 period is about $7,000.

[compare to the cost of other infant health interventions]

3. Implications for High Disease Burden Countries

[Just 10 countries account for over 40% of the global burden of pregnancies and newborns affected by syphilis (WHO 2010). We apply our U.S. estimate to these 10 countries.]

VII. Conclusion

[23] The estimated number of syphilitic pregnancies averted in column (4) may be a higher estimate, given that column (3) corresponds to deaths from premature birth, and some of these deaths are already accounted for in the neonatal death numbers in column (2). On the other hand, the number in column (4) may be a lower estimate given that the number of premature births in column (3) is definitely a lower bound for the actual number of premature births.

[24] WHO (2012) estimates the cost of prematurity or low birth weight to be $366 – $1464. We take the lower cost estimate to make our cost-benefit calculation more conservative.

[25] Indeed, Bateman et al. (1997) estimate that the hospital cost per newborn infant with congenital syphilis is $5,000 higher than the hospital cost per uninfected infant, using data from an inner-city hospital in New York City in 1989.

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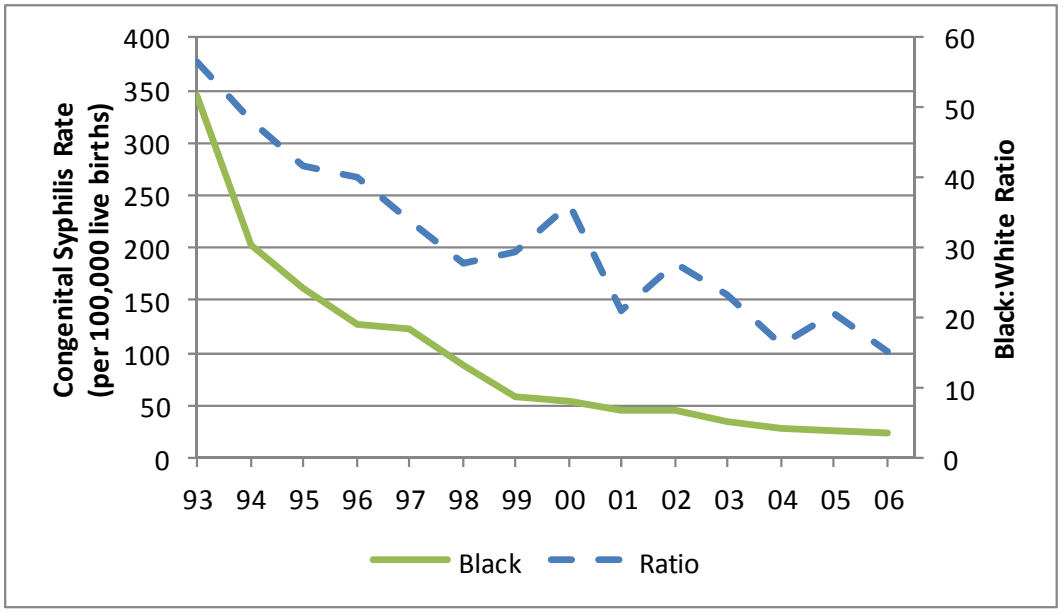
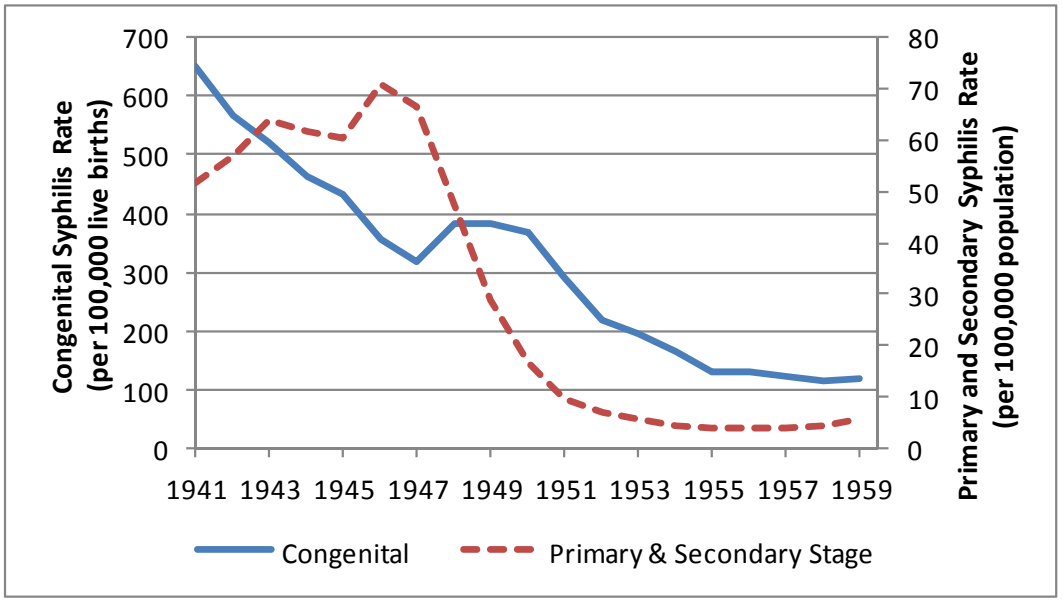
Figure 1: Congenital Syphilis Rates by Race



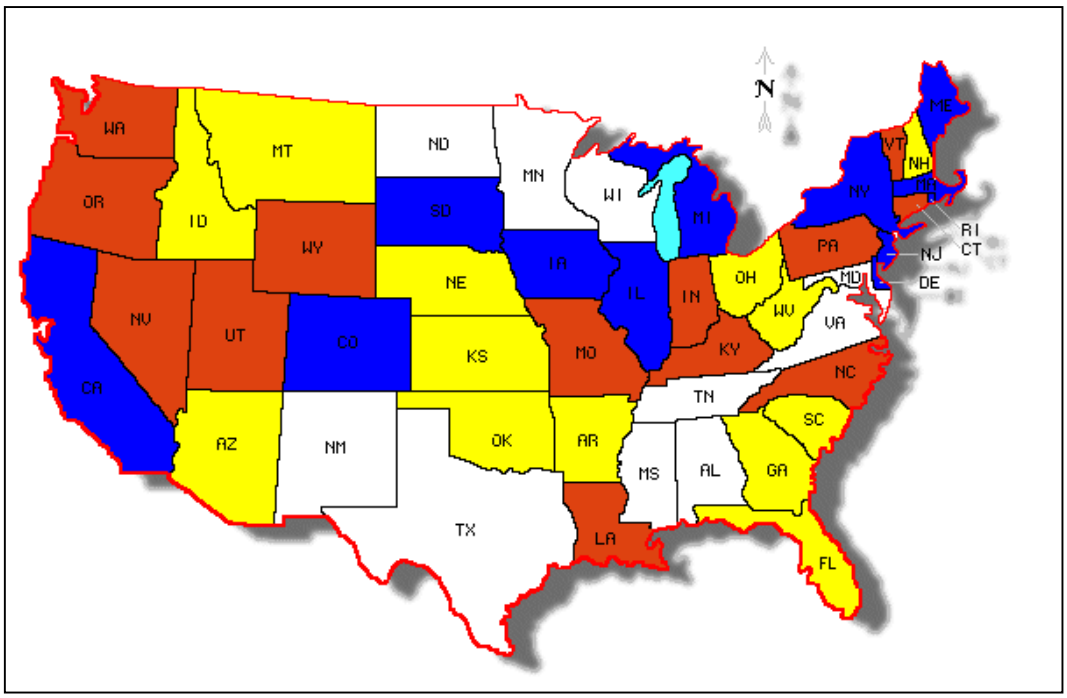
Source: STD Surveillance Reports 1993-2009.

Figure 2: Historical Congenital and Adult Syphilis Rates



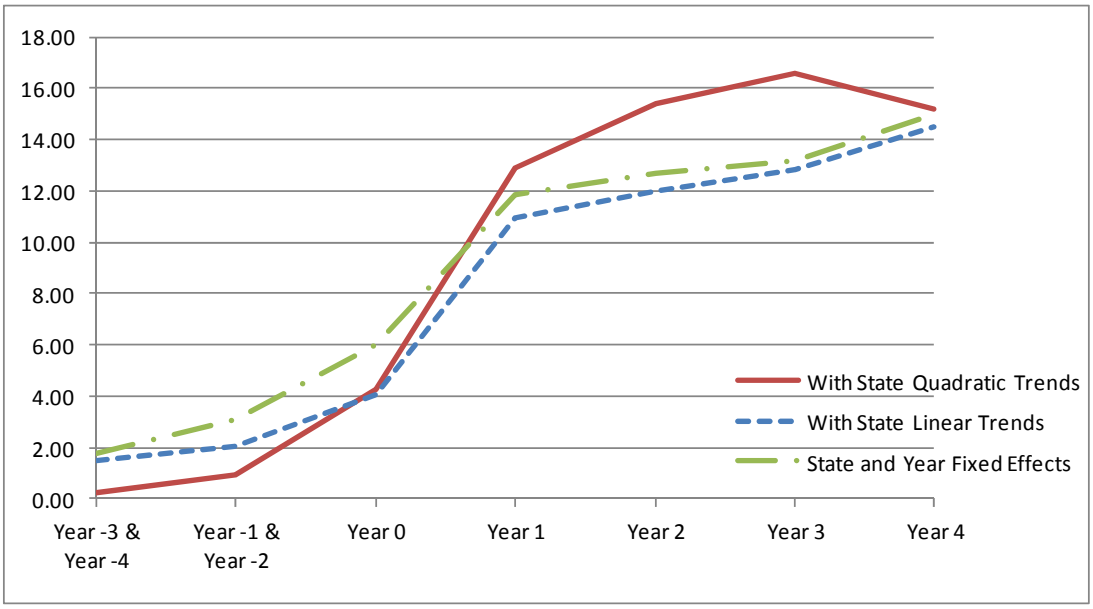
Source: STD Surveillance Reports 1993-2009.

Figure 3: Timing (Effective Date) of Antenatal Testing Laws



Group I [Blue]: 1938-1939; CA, CO, DE, IA, IL, MA, ME, MI, NJ, NY, OK, RI, SD
Group II [Orange]: 1940-1941; CT, IN, KY, LA, MO, NC, NV, OR, PA, UT, VT, WA, WY
Group III [Yellow]: 1943-1947; AZ, AR, FL, GA, ID, KS, MT, NE, NH, OH, OK, SC, WV
Group IV [White]: Post-1947 Unknown Date; AL; MD; MN; MS; ND; NM; WI; VA; TN; TX
Source: Table 1 for more detailed information.

Figure 4: Dynamic Effects of Antenatal Testing Laws on Nonwhite Neonatal Mortality



Source: Table 4.

Table 1: Timeline of Antenatal and Premarital Testing Laws for Syphilis 1936-1948

State	Antenatal Testing	Premarital Testing	State	Antenatal Testing	Premarital Testing
Alabama		1948	Nebraska	1944	1944
Arizona	1946		Nevada	1942	
Arkansas	1948		New Hampshire	1948	1939
California	1940	1940	New Jersey	1939	1939
Colorado	1940	1940	New York	1939	1939
Connecticut	1942	1936	North Carolina	1940	1940
Delaware	1940	1948	North Dakota		1940
Florida	1946	1946	Ohio	1946	1942
Georgia	1944		Oklahoma	1946	1946
Idaho	1944	1944	Oregon	1942	1939
Illinois	1940	1938	Pennsylvania	1941	1941
Indiana	1940	1941	Rhode Island	1939	1939
Iowa	1940	1942	South Carolina	1947	
Kansas	1944	1948	South Dakota	1940	1940
Kentucky	1941	1941	Tennessee		1942
Louisiana	1941		Utah	1942	1942
Maine	1940	1942	Vermont	1942	1942
Massachusetts	1940	1944	Virginia		1941
Michigan	1940	1938	Washington	1940	
Missouri	1942	1944	West Virginia	1946	1940
Montana	1946	1948	Wisconsin		1938
			Wyoming	1942	1944

Note: Above dates pertain to first full year of effective legislation. In most cases the true effective year is midway through the prior year except for states in which the effective date occured on or around January 1st of the above-stated year (IN; NJ; NC; WA) or the stated effective date was prior to the approval date (SC) in which case the latter was taken to be the true effective date. Source: *Editorial* in vol 34, no. 8, *Journal of Social Hygiene* .

Table 2: Summary Statistics

Panel A: Mortality Rates (per 1,000 live births)	All	White	Nonwhite
Neonatal Mortality	28.82	27.71	37.54
	(6.55)	(5.39)	(8.07)
Death Due to Premature Birth	13.75	13.44	16.20
	(3.16)	(2.70)	(4.97)
Infant Mortality	46.70	43.12	72.50
	(16.58)	(11.96)	(21.68)
Number of State-Year Observations	715	715	689
Panel B: Cohort Size	**All**	**White**	**Nonwhite**
Full Sample	54,954	47,954	6,999
	(46,706)	(43,917)	(8,549)
Number of State-Year Observations	774	774	770
Poverty Subsample	7,251	5,962	2,362
	(3,864)	(3,345)	(1,285)
Number of State-Year Observations	774	774	674

Note: Standard deviation in parentheses. Average cohort size is population-weighted.
Source: NCHS Vital Statistics; U.S. 1950 Census

Table 3: Effects of Antenatal Testing Laws on Mortality Rates (per 1,000 live births)

Panel A: Nonwhites	Neonatal Mortality			Death due to Premature Birth			Infant Mortality		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Antenatal Testing	-2.04 +	-4.70 **	-3.85 +	-1.33 +	-2.60 *	-3.08 **	-2.65	-6.39 *	-3.90 +
	(1.12)	(1.70)	(2.07)	(0.75)	(1.10)	(0.94)	(1.86)	(3.24)	(2.27)
Premarital Testing	0.43	0.86	1.13	-0.66	0.03	-0.19	-3.54 +	-0.30	-1.60
	(0.99)	(1.46)	(1.28)	(0.66)	(1.20)	(1.37)	(2.11)	(2.68)	(2.33)
Antenatal Testing	1.87	3.38	1.89	0.61	0.35	1.98	1.37	12.21 *	3.90
x Premarital Testing	(1.95)	(2.31)	(2.86)	(1.09)	(1.73)	(2.03)	(2.95)	(4.87)	(3.61)
Percentage Change	-5.6%	-12.8%	-10.5%	-7.9%	-15.4%	-18.2%	-3.8%	-9.2%	-5.6%
Observations		515			442			689	
Mean		36.71 per 1,000			16.92 per 1,000			69.67 per 1,000	
Years		1931-1947			1931-1947			1931-1947	
Panel B: Whites									
Antenatal Testing	-0.84	-0.61	-0.40	-0.90 *	-0.49	-0.34	-0.09	0.31	0.60
	(0.59)	(0.61)	(0.38)	(0.39)	(0.33)	(0.29)	(1.32)	(1.25)	(0.76)
Premarital Testing	-1.20 *	-0.49	-0.54	-0.94 **	-0.38	-0.25	-0.56	-0.15	-0.11
	(0.51)	(0.64)	(0.51)	(0.30)	(0.39)	(0.31)	(0.98)	(1.17)	(0.66)
Antenatal Testing	1.13 +	1.17	0.63	0.69 +	0.51	0.23	0.68	1.19	-0.64
x Premarital Testing	(0.65)	(0.81)	(0.62)	(0.39)	(0.49)	(0.39)	(1.49)	(1.47)	(0.74)
Observations		715			715			715	
Mean		27.41 per 1,000			13.54 per 1,000			42.20 per 1,000	
Years		1931-1947			1931-1947			1931-1947	
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State Linear Trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State Quadratic Trends	No	No	Yes	No	No	Yes	No	No	Yes

Note: Standard errors are clustered by state and reported in parentheses. Significance is indicated by + 10%; * 5%; **1%. The dependent variables are rates of mortality which are taken as the total count of mortality divided by the number of live-births in state s at year t. Neonatal mortality refers to mortality within 28 days of live birth. Death due to premature birth refers to death within 1 year where the cause of death is identified as premature birth. Infant mortality refers to mortality within 1 year of live-birth. Antenatal Testing is a dummy variable for mandatory prenatal testing for syphilis. Premarital Testing is a dummy variable for mandatory premarital testing for syphilis. All regressions include controls for risk factors associated with neonatal and infant mortality: fraction of first time live-births and fraction of live-births by women outside of age 17-35. Regressions are weighted by state live birth counts for the respective race. The means provided are population-weighted averages for the 4 years prior to enactment of the antenatal testing laws.

Table 4: Dynamic Effects of Antenatal Testing Laws

	Nonwhite Neonatal Mortality		
	(1)	(2)	(3)
Years -3 & -4	-1.74	-1.51	-0.23
	(1.44)	(0.99)	(1.23)
Years -1 & -2	-3.07	-2.04	-0.97
	(3.28)	(2.25)	(2.58)
Year 0	-6.00	-4.06	-4.29
	(5.04)	(3.26)	(4.04)
Year 1	-11.84 +	-10.92 *	-12.86 *
	(6.10)	(4.56)	(5.41)
Year 2	-12.69 +	-11.97 +	-15.38 *
	(7.20)	(6.03)	(6.62)
Year 3	-13.19 +	-12.82 +	-16.58 **
	(6.90)	(5.56)	(6.15)
Year 4+	-14.99 *	-14.47 *	-15.21 *
	(6.89)	(5.53)	(6.77)
Year 1 x Premarital	2.47	4.81	5.11
Testing	(1.78)	(2.45)	(2.53)
Year 2 x Premarital	2.21	5.15	5.11
Testing	(3.16)	(3.94)	(3.96)
Year 3 x Premarital	1.05	4.52	2.89
Testing	(2.15)	(2.53)	(2.69)
Year 4+ x Premarital	2.2	6.03 *	-0.69
Testing	(2.40)	(2.48)	(3.73)
Observations		294	
Years		1931-1947	
Year Fixed Effects	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes
State Linear Trends	No	Yes	Yes
State Quadratic Trends	No	No	Yes

Note: Standard errors are clustered by state and reported in parentheses. Significance is indicated by + 10%; * 5%; **1%. Antenatal Testing is a dummy variable for mandatory antenatal testing for syphilis. Premarital Testing is a dummy variable for mandatory premarital testing for syphilis. *Year #* refers to the year before (negative)or after (positive) the antenatal laws took effect. States with effective antenatal testing laws after 1945 were excluded from the analysis to allow for a 4 year post-reform balanced panel. Regressions are weighted by state live birth counts for nonwhites.

Table 5: Probit Model to Examine the Timing of Antenatal Testing Laws

	White		Nonwhite	
	(1)	(2)	(3)	(4)
Neonatal Mortality $_{t-1}$	-0.007 $^{+}$	-0.006 $^{+}$	-0.017	-0.016
	(0.005)	(0.005)	(0.015)	(0.015)
Neonatal Mortality $_{t-2}$		0.000		0.000
		(0.001)		(0.002)
Neonatal Mortality $_{t-3}$		0.000		-0.001
		(0.000)		(0.001)
t	-0.021	-0.019	-0.050	-0.039
	(0.015)	(0.014)	(0.155)	(0.150)
t^2	0.001	0.001	0.003	0.002
	(0.001)	(0.001)	(0.010)	(0.009)
Neonatal Mortality $_{t-1}$ *x t*	0.001	0.001	0.004	0.003
	(0.001)	(0.001)	(0.004)	(0.004)
Neonatal Mortality $_{t-1}$ *x* t^2	0.000	0.001	0.000	0.000
	(0.000)	(0.001)	(0.000)	(0.000)
Observations	352	352	174	174
Years	1932-1947	1934-1947	1932-1947	1934-1947

Note: The marginal effects, not probit coefficients, are reported. Standard errors are clustered by state and reported in parentheses. Significance is indicated by + 10%; * 5%; **1%. The dependent variable is a dummy indicator which equals to 1 for the first effective year of the antenatal testing law. States exit the sample the year after the effective year. One year lags are identified as *t-1,* two year lags are identified as *t-2,* and three year lags are identified as *t-3*.

Table 6: Effects of Antenatal Testing Laws on Birth Cohort Size by Race and Poverty Status

Panel A: Full Sample	Ln(White Cohort Size)			Ln(Nonwhite Cohort Size)		
	(1)	(2)	(3)	(4)	(5)	(6)
Antenatal Testing	0.03	-0.01	0.02	-0.01	-0.03	0.00
	(0.04)	(0.01)	(0.02)	(0.05)	(0.03)	(0.03)
Premarital Testing	-0.02	(0.01)	0.00	-0.01	-0.02	-0.02
	(0.03)	(0.02)	(0.01)	(0.04)	(0.03)	(0.02)
Antenatal Testing	0.00	0.01	-0.01	0.16 +	0.08 *	0.03
x Premarital Testing	(0.05)	(0.02)	(0.02)	(0.08)	(0.04)	(0.03)
Observations		774			770	
Panel B: Poverty Subsample	**Ln(White Poverty Cohort Size)**			**Ln(Nonwhite Poverty Cohort Size)**		
	(1)	(2)	(3)	(4)	(5)	(6)
Antenatal Testing	0.03	0.01	0.04	0.13 **	0.16 **	0.14 **
	(0.03)	(0.03)	(0.04)	(0.02)	(0.04)	(0.05)
Premarital Testing	0.00	-0.01	(0.03)	0.12 **	0.10	0.10 **
	(0.03)	(0.03)	(0.03)	(0.04)	(0.07)	(0.04)
Antenatal Testing	0.00	-0.02	-0.03	-0.15 *	-0.21 *	-0.16 +
x Premarital Testing	(0.04)	(0.03)	(0.04)	(0.07)	(0.09)	(0.08)
Observations		774			674	
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
State Linear Trends	No	Yes	Yes	No	Yes	Yes
State Quadratic Trends	No	No	Yes	No	No	Yes

Note: Standard errors are clustered by state and reported in parentheses. Significance is indicated by + 10%; * 5%; **1%. Dependent variables are the natural log of cohort size by birth year and birth state. Antenatal Testing is a dummy variable for mandatory antenatal testing for syphilis. Premarital Testing is a dummy variable for mandatory premarital testing for syphilis. Poverty is defined as those at 100 percent or less of the poverty threshold in the 1950 Census.

Table 7: Calibration of Increase in Cohort Size due to Antenatal Testing Laws

			Notes
Decrease in Nonwhite Neonatal Mortality			
Coefficient Estimate (per 1,000 live births)	3.85	a	Source: Table 3 Panel A Column 3
Number of Live Births in Prior Year	194,184	b	Number of live births in the reform states in the year prior to the effective year of antenatal testing laws. *Source: NCHS Vital Statistics*
Imputed Increase	748	c	=b*a/1000
Imputed Increase (%)	0.39%	d	=a/1000
Increase in Nonwhite Birth Cohort Size			
Increase in Birth Cohort Size	235	e	Regression specification used in Table 6 Panel B Column 6 with dependent variable "Nonwhite Poverty Cohort Size" (not natural log)
Cohort Size in Prior Year	27,351	f	Cohort size of nonwhite poor for the reform states in the year prior to the effective year of antenatal testing laws. *Source: 1950 U.S. Census*
Imputed Increase (%)	0.86%	g	=e/f
Difference in Imputed Increase (%)	0.47%		=g-d

Table 8: Cost-Benefit Analysis of Antenatal Testing

Year	Total Births in Reform States	Neonatal Deaths Averted	Premature Births Averted	Estimated Number of Syphilitic Pregnancies Averted	Cost of Syphilis Testing	Cost of Syphilis Treatment	Cost of Premature Birth Care Averted	Total Cost	Cost per Neonatal Death Averted
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1939	254,752	55	44	1,344	$ 585,930	$ 5,095	$ (16,104)	$ 574,921	$ 10,453
1940	936,195	243	193	5,917	$ 2,153,249	$ 22,424	$ (70,638)	$ 2,105,035	$ 8,663
1941	1,300,302	396	317	9,683	$ 2,990,695	$ 36,700	$ (116,022)	$ 2,911,372	$ 7,352
1942	1,651,914	444	356	10,867	$ 3,799,402	$ 41,185	$ (130,296)	$ 3,710,291	$ 8,357
1943	1,709,071	471	377	11,517	$ 3,930,863	$ 43,648	$ (137,982)	$ 3,836,529	$ 8,145
1944	1,757,182	591	475	14,483	$ 4,041,519	$ 54,892	$ (173,850)	$ 3,922,560	$ 6,637
1945	1,733,068	604	486	14,811	$ 3,986,056	$ 56,134	$ (177,876)	$ 3,864,315	$ 6,398
1946	2,457,688	817	656	20,011	$ 5,652,682	$ 75,842	$ (240,096)	$ 5,488,429	$ 6,718
1947	2,836,714	1,047	835	25,550	$ 6,524,442	$ 96,835	$ (305,610)	$ 6,315,667	$ 6,032
Total	14,636,886	4,668	3,739	114,183	$ 33,664,838	$ 432,755	$ (1,368,474)	$ 32,729,119	$ 7,011

Assumptions Used

Neonatal Deaths Averted	3.85 per 1,000 births	(from Table 3 Panel A Column 3)
Premature Births Averted	3.08 per 1,000 births	(from Table 3 Panel A Column 6)
Cost of syphilis testing	$ 2.30	(from WHO 2012)
Cost of syphilis treatment	$ 3.79	(from WHO 2012)
Cost of care for premature birth	$ 366	(from WHO 2012)