The Mortality Effects of Antenatal Testing Laws [℘]

Winnie Fung
Wheaton College, IL

Omar Robles
U.S. Department of Labor

April 2014

Preliminary draft. Please do not cite.

Abstract: Even though syphilis can be prevented effectively and treated inexpensively, it has remained a global public health problem. Untreated congenital syphilis results in neonatal death, stillbirth, preterm birth, or congenital deformities. Many developing countries have recently instituted syphilis prevention programs in antenatal care, but there has not been a systematic study of the effects of such programs. This paper is the first to study antenatal testing laws initiated in the U.S. in 1938-1947 which mandated physicians attending to pregnant women to test them for syphilis. 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 preterm birth. Using 1931-1947 NCHS Vital Statistics data, we find that these laws decreased neonatal mortality rates of nonwhites by 3.15 per 1,000 live births (a 8.6% reduction) while having no discernible impact on whites. The laws contributed to a narrowing of the white-nonwhite neonatal mortality gap by 18.0% by 1947. Using the 1950 U.S. Census data, we find that mandatory antenatal testing led to a 7.0% increase in the cohort size of nonwhite poor, which is consistent with our mortality results. We find universal antenatal testing to be very cost-effective, with a $7,600 cost per life-year saved. Applying our estimate to the 12 intensified support countries identified by the WHO to have a high syphilis burden, we estimate that universal antenatal testing can help avert over 52,000 neonatal deaths annually.

JEL Codes: I1, I18, J13
Keywords: Antenatal care, infant mortality, sexually transmitted diseases

---

[℘] All views expressed in this paper are those of the authors and do not necessarily reflect the views or policies of Wheaton College or the U.S. Department of Labor. We would like to thank Lili Mejia and Harry Mak for excellent research assistance. Special thanks go to discussants and participants at the 2013 Northeast Universities Development Consortium conference, the 2012 Economics of Global Poverty seminar at Calvin College, the 2012 American Economic Association annual meeting, the 2011 Southern Economic Association annual meeting, and the 2011 J. Dennis Hastert Center political economy seminar at Wheaton College. Financial support from the G.W. Aldeen Memorial Fund and Christian Scholars Foundation are gratefully acknowledged. All errors are the authors' own. Please direct correspondence to winnie.fung@wheaton.edu and robles.omar@bls.gov.

I. Introduction

Mother-to-child transmission of syphilis, which causes 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 cases result in neonatal death, stillbirth, preterm 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 the only neonatal infection that can be screened and treated effectively and inexpensively.[1] Many developing countries have recently initiated policy guidelines for universal antenatal syphilis screening. Such prevention programs help reduce the number of stillbirth, preterm births, and perinatal deaths and contribute to the achievement of the Millennium Development Goals on maternal and child health. However, 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. We find that these laws decreased neonatal mortality rates and deaths due to preterm birth for nonwhites while having no discernible impact on whites.

A growing body of research has documented the potential benefits of early childhood health intervention programs (Almond and Currie 2011; Currie 2011). A number of articles have focused on the health benefits of antenatal interventions. Field et al. (2009) showed that iodine supplements given to pregnant women in Tanzania led to an increase in schooling attainment for treated children. Almond and

[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).

Mazumder (2011) found that prenatal exposure to maternal fasting during the month of Ramadan resulted in lower birth weight as well as a higher likelihood of disability in adulthood. Bhalotra and Venkataramani (2012) examined the effect of the introduction of sulfa drugs on pneumonia in the U.S. in the 1930s. Pneumonia was a leading cause of death in children in the U.S. at the time. They found that cohorts born after the introduction of sulfa experienced increased schooling, income, and employment.

This is the first paper to examine the health benefits of an antenatal intervention program which targeted a sexually transmitted disease. Syphilis, unlike other sexually transmitted diseases, is transmitted from mother to child during pregnancy. Intervention in the first trimester can yield significant life-saving benefits to offspring with minimal effort and cost. Moreover, antenatal testing for syphilis may disproportionately alleviate the health disparity experienced by blacks, a disparity that results from the racially divided prevalence of sexually transmitted diseases in the U.S. As a result the health intervention may reduce the racial gap in socioeconomic outcomes such as educational attainment and labor force participation to the extent that these outcomes are influenced by physical health disparities.

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 other robustness tests and also discusses the exogeneity of the laws. 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] Unlike other sexually transmitted diseases, pregnant women 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

[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.

the second trimester, between the 16th and 28th week of gestation, but it can also occur as early as the 9th week of gestation (Berman 2004).

Studies have shown that 49%-75% of untreated syphilitic pregnancies lead to adverse pregnancy outcomes, including neonatal death, stillbirth, preterm 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, while preterm 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

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 preterm labor, stillbirth and fetal death. Twenty years ago at the Johns Hopkins Hospital, 34.4% of all

[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.
[5] As comparison, in 2011, the congenital syphilis rate was 8.5 per 100,000 live births (CDC 2011).

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 [be] 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

[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.

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 with 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 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 the 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

[8] Wisconsin does not require physicians to test for syphilis during antenatal care.

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 infected couples prior to their marriage. As a result couples may have sought treatment prior to conception or may

[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).

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]

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

[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 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.

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]

Since untreated congenital syphilis results in neonatal death and/or preterm birth, we study the effect of the antenatal testing laws on neonatal mortality rates and on infant deaths due to preterm birth. Neonatal mortality is defined as all mortality that occurs in the first 28 days of life. Preterm 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 or as early as the data was available to allow for a large pre-period 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.

[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. 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.

As a robustness check we construct a state-year panel of infant mortality (i.e. death within 1 year of live birth) and post-neonatal infant mortality (1-12 months after birth) by race to see if there is an additional effect of the laws beyond the neonatal period. As previously discussed medical research has found that the impact on mortality is limited to the perinatal period (i.e. fetal and neonatal period). A valid result will not show evidence of an effect on infant mortality beyond the neonatal period. As a preview of our results, we do not find any post-neonatal mortality effect.

In addition to neonatal and infant mortality rates, we also study deaths within 1 year due to preterm birth. As direct data on preterm birth is not available, we believe this variable is a close proxy, since a large fraction of preterm births resulted in immediate 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 from syphilis, and deaths within 1 year from congenital deformity, but these data are either not consistently available for our time period of study or the variable itself is not consistently defined across states.[18]

As a further 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.

[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 (not less) 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 antenatal laws to measure the impact on mortality using the following regression:

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

where *s* indexes states and *t* indexes years. y_{st} is the dependent variable of interest, which is the neonatal mortality rate and deaths within one year due to preterm birth in state *s* in 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* and is zero otherwise. *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* and is zero otherwise. The coefficient of interest, γ, is the average effect of mandatory antenatal testing. We expect this coefficient to be negative if antenatal testing laws decreased neonatal mortality and death due to preterm birth.

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 *state* fixed effects control for time-invariant, unobserved heterogeneity across states which may have affected birth or neonatal mortality rates. The *year* fixed effects control for national events which may have affected birth or neonatal mortality rates in any given year, such as other national health intervention programs or U.S.'s involvement in World War II. *Time* is a linear trend so that the interaction terms *state* * *time* and *state* * *time*^{2} together control for a quadratic time trend for each state. These variables capture the trend in state-level characteristics that may affect pregnancy or birth outcomes such as the number of hospitals, fertility trends due to population changes, or growth. State quadratic trends are a more flexible approach to control for the heterogeneous syphilitic infection propensity.

We estimate equation (1) separately for whites and nonwhites. 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.

We examine the robustness of our results by adding an interaction term *Antenatal Testing* * *Premarital Testing* to equation (1):

$$\begin{aligned} y_{st} = {} & \beta_0 + \gamma\, Antenatal\ Testing_{st} + \beta_1 Premarital\ Testing_{st} \\ & + \beta_2 Antenatal\ Testing_{st} * Premarital\ Testing_{st} + \beta_3 \chi_{st} + \beta_{4s} state_s \\ & + \beta_{5t} year_t + \beta_{6s} state_s * time_t + \beta_{7s} state_s * time_t^2 + \varepsilon_{st} \end{aligned} \tag{2}$$

We account for the potential confounding effect of premarital testing by including an interaction of the dummy variables for antenatal testing and premarital testing. A negative coefficient for the interaction term will suggest that the premarital testing laws had a preemptive effect on contagion which precluded fetal syphilitic infection; making the antenatal laws obsolete in some cases. As a result exclusion of the interaction term in our initial results will bias the coefficient of interest γ downward, away from zero, to the extent that the two laws may be positively correlated. However if the coefficient for the interaction term is positive then this will suggest that the laws increased out-of-wedlock births and thus made the antenatal testing laws more effective at preventing congenital syphilis. The coefficient of interest γ will be biased toward zero in our initial results.

We examine the validity of our result by estimating the effect on infant mortality using equation (2). As previously discussed, untreated maternal syphilitic infection increases the propensity for fetal mortality, neonatal mortality and preterm birth. The effect on mortality does not extend beyond the neonatal period. A valid regression estimate on the effect of antenatal testing laws on infant mortality beyond the neonatal period (1-12months) will not yield statistically significant results.

We use several approaches to examine whether the timing of the antenatal testing laws is indeed exogenous. First, we modify equation (1) to identify the dynamic effects of the laws on neonatal mortality. We do not examine the dynamic effects of the laws on death due to preterm birth due to the limited sample size. We include dummy variables for the years relative to the effective date of the antenatal testing laws:

$$y_{st} = \beta_0 + \Sigma_{4\geq k\geq -4}\, \gamma_k\, Antenatal\ Testing\ in\ effect\ for\ k\ periods_{st} \qquad (3)$$
$$+\beta_1 Premarital\ Testing_{st} + \beta_2 \chi_{st} + \beta_{3s} state_s + \beta_{4t} year_t + \beta_{5s} state_s * time_t$$
$$+\beta_{6s} state_s * time_t^2 + \varepsilon_{st}$$

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 will be a discontinuity in the dynamic estimates for the years preceding the laws and the years that follow

the law. As discussed in 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 (3) enables us to study the dynamic impact of the laws while allowing the state-specific time trends to identify pre-existing trends in the dependent variable.

We perform a second test of the exogenous timing of the antenatal testing laws. We estimate a probit model to test the predictive capacity of lagged white and non-white neonatal mortality rates on the timing of the laws. The model specification is as follows:

$$timing_{st} = \delta_0 + \delta_1 N_{st-1} + \delta_2 time_t + \delta_3 time_t^2 + \delta_4 N_{st-1} * time_t + \delta_5 N_{st-1} * time_t^2 + \varepsilon_{st} \quad (4)$$

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 law was in effect. N_{st-1} is the one-year lagged white or non-white 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.

We use placebos for the laws as a third test for the validity of our results using equation (2). The placebos are similar to the *Antenatal Testing* and *Premarital Testing* dummies but take on the value of 1 exactly two years prior to the aforementioned laws. A valid regression estimate will not yield a statistically significant result for either of our dependent variables.

Lastly, we use our baseline specification (equation (1)) with population weights to estimate the effect of antenatal testing laws on the natural log of 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. We expect the results to mirror the racial disparity seen in our baseline results. In particular, the effects of the laws on the nonwhite population will be concentrated on the low income group if the results are to be consistent with our hypothesis that the antenatal testing laws may 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.

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 both measures of mortality are negative and statistically significant for nonwhites but not for whites. From columns (1) and (4), we see that the antenatal testing laws led to a decrease in neonatal mortality rate for nonwhites by 1.17 per 1,000 live births (corresponding to a decrease of 3.2%) and a reduction in deaths due to preterm birth by 1.06 per 1,000 live births (corresponding to a decrease of 6.3%).[19] The estimated effects are larger at 3.46 and 2.48 per 1,000 live-births (a reduction of 9.4% and 14.7%) when we control for state linear trends (columns (2) and (5)). The results are statistically significant at the 5% and 1% levels 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 decreases slightly to 3.15 per 1,000 live births (an 8.6% reduction), while the effect on death due to preterm birth is 2.50 per 1,000 live births (a 14.8% reduction).

Our results 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 were less likely to have access to antenatal care in general (Nakashima et al. 1996; Peterman et al. 2005;

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

Robles 2013a), or because they were 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, were more likely to receive testing as a result of the antenatal testing laws.

Table 4 presents evidence that our baseline estimates are robust to the confounding effect of premarital testing laws. The estimated effects of antenatal testing laws are greater for both dependent variables and across all specifications as compared to Table 3. The coefficients for the interaction term between antenatal testing and premarital testing are positive though far from statistically significant. The positive interaction term suggests that the antenatal testing laws were more effective at reducing mortality when states did not also mandate premarital testing. The premarital testing laws may have had some preemptive effect on syphilitic contagion (i.e. transmission of syphilis from the mother to the fetus) which would diminish the effect of the antenatal testing laws. This is consistent with the fact that the vast majority of births took place in-wedlock during the time period of study.

Table 5 presents the effects of antenatal testing laws on infant mortality rates. 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 infant 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 (3) 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) of Table 4. 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. We take the additional step of estimating the effect of the antenatal testing laws on the mortality rate for infants aged 1-12 months at the time of death. As expected, we do not find any statistically significant effect of the laws on this measure of mortality (columns (4) to (6) of Table 5).

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, we present in Table 6 the dynamic effects of the laws on nonwhite neonatal mortality estimated from equation (3). The coefficient estimates are also plotted in Figure 4. States with effective dates of antenatal and premarital testing laws after 1945 are excluded from the analysis to allow for a 4-year post-reform period of observation. The total number of state-year observations decreases from 515 to 294 as a result. From Table 6, 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

A second way to deal with the potential concern of the exogeneity of the laws is to use the probit model (equation 4) to examine the predictive ability of lagged neonatal mortality rates on the timing of the laws. Table 7 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 0.007% the following year.

4. Placebo Laws

The third approach to examine the exogeneity of the laws is to examine the effect of placebo laws, which we have defined in the same way as the *Antenatal Testing* and *Premarital Testing* dummies except that they take on the value of 1 exactly two years prior to the actual laws. The coefficients of the placebo dummies will be positive and statistically significant if states initiated the laws in response to changes in mortality rates. The results in Table 8 show that the placebo laws do not have a statistically significant effect on mortality rates.

Taking the results of Tables 6 ,7 and 8 together, we can see that the antenatal testing laws were not correlated with neonatal mortality rates. We can therefore treat the timing of the laws as exogenous within the models used in this paper.

5. Demographic Composition Effects

A separate concern may be that the change in neonatal mortality in one or a few populous 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]

6. 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 equation (1) separately for the white and nonwhite full samples, and then for the subsamples of white and nonwhite poor. We use the natural log of state-year

[20] Results available from authors.

cohort size 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 9 presents the results. We do not find any statistically significant change in cohort size for the white and nonwhite full sample (panel B), but we do find a positive and significant effect of the antenatal testing laws on the cohort size of the nonwhite poor (panel A columns (4) to (6)). The coefficients are very similar across all three specifications, and show that mandatory antenatal testing led to a 7-8% 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 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.

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 10. We first multiply our coefficient estimate for nonwhite neonatal mortality from Table 3 (3.15 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 612, or 0.32%. We then re-run our regression from Table 9 Panel A 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 141 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 0.52%.

We see that the increase in the size of the nonwhite birth cohort is of similar magnitude but slightly larger than what we can attribute solely to the reduction in nonwhite neonatal mortality. This is to be expected, 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. 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. When observed in 1950, cohorts born before the laws were inevitably older than cohorts born after the laws. We cannot rule out the possibility that there is a higher propensity for older cohorts to die and hence to exit our sample, 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 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, which we do not.

VI. Policy Implications

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

We have shown that the antenatal testing laws decreased neonatal mortality rates of nonwhites by 3.15 per 1,000 live births while having no discernible impact on whites. Using our coefficient estimate, we calculate the counterfactual state-year mortality rates for nonwhites, that is, the mortality rates if there had been no antenatal testing laws. We then compare the counterfactual weighted-average mortality rates (weighted by nonwhite births in each state) to the actual mortality rates by year. The solid line in Figure 5 shows the actual rate while the dotted line shows the counterfactual rate. Our calculations indicate that the white-nonwhite neonatal mortality gap increasingly narrowed from 1939 to 1947 as an increasing number of states initiated antenatal testing laws. The initial reduction in the gap was 1.4% in 1939 and the cumulative reduction in the gap was 18.0% by 1947. The gap is displayed in Figure 6.

2. The Cost of Saving a Baby

We use our regression estimates to conduct a cost-effectiveness analysis of the antenatal testing laws. Results are presented in Table 11. 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 $24.27 to get Column 5. $24.27 is obtained by taking the cost of syphilis testing in 1937, which was about $1.50 according to Parran (1937), and converting it to 2013 dollars using the CPI inflation calculator provided by the Bureau of Labor Statistics.[21]

We then use our regression estimates from Table 3 Panel A to calculate the number of neonatal deaths and preterm births averted (Table 11 Columns 2 and 3). To get the number of neonatal deaths averted, we multiply 3.15 per 1,000 births (from Table 3 Panel A Column 3) by the number of nonwhite births in reform states for each year. To get the number of preterm births averted, we multiply 2.50 per 1,000 births (from Table 3 Panel A Column 6) by the same number of nonwhite births in reform states for each year. Note that the number of preterm births averted is a conservative lower bound, as our 2.50 regression coefficient refers to "death within 1 year due to preterm birth." Presumably not all preterm births lead to infant deaths, so the total number of preterm 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 9.3% for neonatal death and 5.8% for prematurity or low birth weight

[21] The CPI inflation calculator is available here: http://data.bls.gov/cgi-bin/cpicalc.pl

(WHO 2012).[22] We therefore divide Column 2 by 0.093 and divide Column 3 by 0.058 and add the two numbers together to get the number of syphilitic pregnancies averted in Column 4.[23] We multiply Column 4 by the cost of syphilis treatment ($139.31, expressed in 2013 dollars) to get Column 6.[24] We then sum up Columns 5 and 6 to get the total cost in Column 7.

Lastly, we divide the total cost in Column 7 by the number of neonatal deaths averted in Column 2 to get the cost per neonatal death averted in Column 8. From Column 8, we see that the cost of saving a baby is around $84,000–$141,000. The average across the 1939-1947 period is about $96,000.

Our estimated cost of saving a baby is clearly an upper-bound estimate. We have ignored all the cost savings associated with treating an adverse birth outcome resulting from a syphilitic pregnancy, for instance, a preterm birth, a low birth weight baby, or a baby with congenital deformities. According to WHO (2012), the medical costs associated with an infected infant are $182–$243, costs associated with prematurity or low birth weight are $366–$1464, and costs associated with perinatal death are $893–$3571. Given that these are current costs, we expect the medical costs to be even greater back in the 1930s and 1940s. By testing and treating syphilitic pregnancies, we were able to save on these medical costs, which means the cost of saving a baby is much lower than $96,000.

Moreover, the cost of syphilis testing and treatment is much lower today than in the 1930s and 1940s. The WHO (2012) estimates the cost of syphilis testing today to be $1.83–$2.30 and the cost of syphilis treatment to be $3.72–$3.79. If we use the $2.30 and $3.79 figures for our cost-effectiveness calculation in Table 11, we would find that the cost of averting a neonatal death is around $7,700–$13,100. The average cost would be $8,900. We believe this $8,900 figure more accurately reflects the order of magnitude of the cost of saving a baby if high syphilis burden countries today are to implement universal syphilis testing for pregnant women.

---

[22] The actual percentage of adverse pregnancy outcomes might be higher in the 1940s than these current estimates.
[23] The estimated number of syphilitic pregnancies averted in Column 4 may be a higher estimate, given that Column 3 corresponds to deaths from preterm 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 preterm births in Column 3 is definitely a lower bound for the actual number of preterm births.
[24] According to Parran (1937), the cost of syphilis treatment was $8.60 back then. We use the CPI inflation calculator provided by the Bureau of Labor Statistics to convert it to 2013 dollars, giving $139.13.

Using our cost estimate of $96,000 per neonatal death averted, if we assume each infant lives to age 52, which was the life expectancy at birth for nonwhite males born in 1939-1941, then the cost per discounted life-year would be $7,600 (assuming a 5% discount rate).[25] This is way below the value of a healthy life-year, which Cutler and Meara (1999) estimate to be $75,000–$150,000. Clearly, the antenatal testing laws are very cost-effective in terms of life-year saved. The cost of $7,600 per life-year saved is also comparable to the cost of other infant health interventions in the U.S. Cutler and Miller (2005) show that sanitation improvements in the U.S. in the early 20th century cost $500 per life-year. Watson (2006) shows that sanitation improvements on U.S. Indian reservations cost $7,000 per life-year. Currie and Gruber (1996) find that offering public health insurance to the poor improves infant survival at a cost of $45,000 per life-year.

3. Implications for High Disease Burden Countries

What are the implications of our findings for today, especially for countries that still suffer from a high burden of syphilis? U.S. in the 1940s looked fairly similar to some of the high disease burden countries today, in terms of the syphilis rate and the level of antenatal care. In 1941, U.S. had a syphilis rate of 51.6 per 100,000 population and a congenital syphilis rate of 651.1 per 100,000 live births (CDC 2011). These numbers are likely a lower bound estimate. Given that the U.S. population in 1941 was 133, 402,471 and that the total live births was 2,513,427, the CDC prevalence rates translate to 68,836 adult cases and 16,365 congenital cases. Parran (1937), however, argues that the conservative estimate of syphilis cases in the late 1930s should be about 683,000 per year. This would give a rough estimated rate of 512 per 100,000 population. Such prevalence rate is still low compared to that in high disease burden countries today. WHO (2012) has identified 12 intensified support countries that have a high syphilis burden but are committed to implement initiatives to eliminate mother-to-child transmission of syphilis. These intensified countries have a syphilis prevalence rate of 0.4% (China) to 10.0% (Central African

[25] Life expectancy information is obtained from: http://www.infoplease.com/ipa/A0005140.html

Republic).[26] As this prevalence rate is measured by the percentage of antenatal care attendees who were tested positive for syphilis (the only kind of prevalence data available in these countries), it is most likely a lower bound of the true prevalence, as not every pregnant woman will obtain antenatal care, and not every antenatal care attendee will be tested for syphilis.

Given the WHO's push for eliminating mother-to-child transmission of syphilis, we are interested in asking: If all countries today mandate antenatal testing for syphilis, how many neonatal deaths will be averted? We first apply our coefficient estimate of 3.15 neonatal deaths averted per 1,000 live births to all countries. We assume that the 3.15 effect found in the U.S. corresponded to a 4.07% syphilis prevalence rate (Parran 1937). We then calculate the number of neonatal deaths averted for all countries using this formula: Number of live births in country *i* * 0.00314 * syphilis prevalence rate in country *i* / 0.0407. This assumes that the effect of syphilis testing on neonatal deaths can be scaled linearly by the syphilis prevalence rate. The number of live births is obtained for year 2008, from the United Nations Population Division (UNPD) World Population Prospects (WPP) tables. The syphilis prevalence rate, again, is the percentage of antenatal care attendees who were tested positive for syphilis in 2008, obtained from Newman et al. (2013). Table 12 shows the estimates grouped by WHO regions. Column 1 gives the number of live births in each region in 2008, and Column 2 gives the estimated number of neonatal deaths averted if all countries implement universal antenatal testing. The operating assumption for Column 2 is that countries do not have any antenatal testing in place yet. Since this is an oversimplified assumption, we further adjust our estimate in Column 3, by applying the 3.15 effect only to those countries that have less than 30% of antenatal care attendees being tested for syphilis as of 2008-2011 (obtained from Newman et al. (2013)). Column 3 shows that if we implement universal antenatal testing in Africa and South-East Asia, we would be able to avert 34,332 and 22,934 neonatal deaths each year respectively. The total neonatal deaths averted each year will be 68,553 globally. Our estimate is very similar to that in the literature. Column 4 shows the estimate by Newman et al. (2013), who estimate that the WHO initiative to get at least 90% of pregnant women tested for syphilis and at least 90% of

[26] The mean prevalence rate for these 12 intensified support countries is 3.6%.

seropositive women treated will help avert a total of 63,451 neonatal deaths globally. If each life is valued at $3 million (Cutler 2004), our estimate of 68,553 neonatal lives saved will translate to $205 billion in value of statistical life (VSL).

Finally, we apply our estimate to the 12 intensified support countries and estimate that universal antenatal testing will help avert a total of 52,074 neonatal deaths annually (see Table 13), which is already 76% of the global estimate of 68,553 averted neonatal deaths. Just focusing on these 12 countries is going to cost $17.4 million over the next four years according to WHO (2012), but compared to $156 billion ($3 million * 52,074) of VSL saved, it is clearly very cost-effective. Our results provide additional support for the push for global elimination of mother-to-child transmission of syphilis.

VII. Conclusion

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 preterm birth. Historical congenital syphilis data is not available but neonatal mortality and preterm birth are common symptoms of syphilitic pregnancies. We find that these laws decreased neonatal mortality rates of nonwhites by 3.15 per 1,000 live births (a 8.6% reduction) while having no discernible impact on white neonatal mortality. As a result, the white-nonwhite neonatal mortality gap decreased by 18.0% during this time period. We also find that mandatory antenatal testing led to a 7.0% increase in the cohort size of the nonwhite poor, which is consistent with our mortality estimates. Again, we find no evidence of a change in the cohort size of whites. Back-of-the-envelope calculations show that universal antenatal testing was very cost-effective, and our results provide strong support for implementing universal antenatal testing particularly in countries with high syphilis burdens.

References

Almond, D. and Currie, J. (2011). "Killing Me Softly: The Fetal Origins Hypothesis." *Journal of Economic Perspectives*. 25(3): 153-72.

Almond, D. and Mazumder, B. (2011). "Health Capital and the Prenatal Environment: The Effect of Ramadan Observance during Pregnancy." *American Economic Journal: Applied Economics* 3(4): 56-85.

American Social Hygiene Association (1948). "Editorial: Premarital and Antenatal Examination Laws in Review." *Journal of Social Hygiene* 34(8).

Bartlett, J. and Galant, J. (2003). *Medical Management of HIV Infection* Baltimore: Johns Hopkins University School of Medicine.

Bateman, D.A., Phibbs, C.S., Joyce, T., Heagarty, M.C. (1997). "The Hospital Cost of Congenital Syphilis." *Journal of Pediatrics* 130(5): 752-758.

Berman, S.M. (2004). "Maternal Syphilis: Pathophysiology and Treatment." *Bull World Health Organ* 82: 399-478.

Bhalotra, S. and Venkataramani, A. (2012). "Shadows of the Captain of the Men of Death: Early Life Health Interventions, Human Capital Investments, and Institutions." Mimeo.

Billings, F. and Irons, E. (1919). *Forchheimer's Therapeusis of Internal Diseases*. D. Appleton and Company: New York. Page 430.

Brady, W. (1948). "Penicillin for Syphilis." *Pittsburgh Post-Gazette*. May 4, 1948. Page 24.

Buckles, K., Guldi, M., and Price, J. (2011). "Changing the Price of Marriage: Evidence from Blood Test Requirements." *Journal of Human Resources* 46(3): 539-567.

Center for Disease Control and Prevention (1983). *Venereal Disease Statistical Letters*. US Department of Health and Human Services, Public Health Service.

Centers for Disease Control and Prevention (1988). "Policy Guidelines for the Prevention and Control of Congenital Syphilis." MMWR 37: 1-13.

Centers for Disease Control and Prevention (1993-2010). *STD Surveillance Reports for Minorities*. U.S. Department of Health and Human Services, Public Health Service.

Centers for Disease Control and Prevention (2011). *2011 Sexually Transmitted Diseases Surveillance*. U.S. Department of Health and Human Services, Public Health Service.

Centers for Disease Control and Prevention (2013). "Syphilis — CDC Fact Sheet." http://www.cdc.gov/std/syphilis/STDFact-Syphilis.htm. Accessed September 10, 2013.

Cole, H.N., Ayres, S., Barr, J.H., Genatios, T., Held, B., Murphy, W.W., Printz, D.R., Strauch, J., Binkley, G.W., Colimodio, S., Driver, J.R., Kile, R.W., Rauschkolb, J. (1946). "Use of Penicillin in the Treatment of Syphilis in Pregnancy." *Arch Derm Syphilol* 54(3): 255-64.

Currie, J. (2011). "Inequality at Birth: Some Causes and Consequences. *American Economic Review* 101(3): 1-22.

Dayan, L. and Ooi, C (2005). "Syphilis Treatment: Old and New." *Expert Opinion on Pharmacotherapy* 6(13).

Faden, R.R., Geller, G., Powers, M. (1991). *AIDS, Women and the Next Generation: Towards a Morally Acceptable Public Policy for HIV Testing of Pregnant Women and Newborns.* Oxford University Press.

Field, E., Robles, O., Torero, M. (2009). "Iodine Deficiency and Schooling Attainment in Tanzania." *American Economic Journal: Applied Economics* 1(4): 140-69.

Fitzgerald, D.W., Behets, F.M., Lucet, C., Roberfroid, D. (1998). "Prevalence, Burden and Control of Syphilis in Haiti's Rural Artibonite Region." *International Journal of Infectious Diseases* 2(3): 127-131.

Fiumara, N.J., Fleming W.L., Downing J.G., Good F.L. (1952). "The Incidence of Antenatal Syphilis at the Boston City Hospital." *New England Journal of Medicine* 247(2): 48-52.

Fonck, K., Claeys, P., Bashir, F., Bwayo, J., Fransen, L., Temmerman, M. (2001). "Syphilis Control During Pregnancy: Effectiveness and Sustainability of a Decentralized Program." *Am J Public Health* 91: 705-707.

Furstenberg, F. (1987). "Race Differences in Teenage Sexuality, Pregnancy, and Adolescent Childbearing." *The Millbank Quarterly* 65(S2): 381-403.

Global Business Coalition on HIV/AIDS (2004). "The Need to Know: Accelerating Access to Testing." http://www.gbcimpact.org/documents/media/publications/archive/Accelerating_access_to_testing_05_20_04.pdf. Accessed September 10, 2013.

Halse, L.M. and Liberti, D.V. (1954). "Prenatal Health Examination Legislation: History and Analysis." *Public Health Reports* 69(2): 105-110.

Harman, N. (1917). *Staying the Plague*. London: Methuen.

Harris, A., Rosenberg, A.A., Riedel, L.M. (1946). "A Microflocculation Test for Syphilis Using Cardiolopin Antigen: Preliminary Report." *J Vener Dis Inform* 27: 159-72.

Hedrich, A.W. and Silverman, C. (1958). "Should the Premarital Blood Test be Compulsory?" *American Journal Public Health Nations Health* 48(2): 125-32.

Hinton, W.A. (1936). *Syphilis and Its Treatment*. New York: The Macmillan Company.

Hira S.K., Bhat, G.J., Chikamata, D.M. Nkowane, B., Tembo, G., Perine, P.L. (1990). "Syphilis Intervention in Pregnancy: Zambian Demonstration Project." *Genitourin Med.* 66: 159-164.

Hossain, Mazeda, Nathalie Broutet, Sarah Hawkes. (2007). "The Elimination of Congenital Syphilis: A Comparison of the Proposed World Health Organization Action Plan for the Elimination of Congenital Syphilis with Existing National Maternal and Congenital Syphilis Policies." *Sexually Transmitted Diseases* 34(7): S22-S30.

Jenniskens, F., Obwaka, E., Kirisuah, S., Moses, S., Yusufali, F.M., Achola, J.O. (1995). "Syphilis Control in Pregnancy: Decentralization of Screening Facilities to Primary Care Level, a Demonstration Project in Nairobi, Kenya." *Int Journal of Gynaecolory and Obstetrics* 48: 121-128.

Kamb, M.L., Newman, L.M., Riley, P.L., Mark, J., Hawkes, S.J., Malik, T., Broutet, N. (2010). "A Road Map for the Global Elimination of Congenital Syphilis." *Obstetrics and Gynecology International* Vol. 2010, Article ID 312798.

Kantner, J.F. and Zelnik, M. (1972). "Sexual Experience of Young Women in the United States." *Demography* 25: 189-204.

Lim, C.T., Koh, M.T., Sivanesaratnam, V. (1995). "Early Congenital Syphilis – a Continuing Problem in Malaysia." *Medical Journal of Malaysia* 50: 131-135.

Mahoney J. F., Arnold R. C., Harris A. D. (1943). "Penicillin Treatment of Early Syphilis." *Am. J. Public Health* 33: 1387–1391.

Moore, K.A. and Simms, M.C. and Betsey, C.L. (1986). *Choice and Circumstance: Racial Differences in Adolescent Sexuality and Fertility.* New Brunswick, CT. Transaction Books.

Nakashima, A.K., Rolgs, R.T., Flock, M.L., Kilmarx, P. and Greenspan, J.R. (1996). "Epidemiology of Syphilis in the United States 1941-1993." *Sexually Transmitted Diseases* 23: 16-23.

National Center for Health Statistics. (1931-1947). Vital Statistics Reports.

Norwitz, E.R. (2009). *Syphilis in Pregnancy*. www.uptodate.com. Accessed September 10, 2013.

Parascandola, J. (1980). *The History of Antibiotics: a Symposium*. American Institute of the History of Pharmacy, No. 5.

Peckham Jr., C.H. (1941). "Legal and Therapeutic Aspects of Syphilis and Pregnancy." *J Am Med Assoc*. 117(22): 1863-1868.

Peterman, T.A., Heffelfinger J.D., Swint, E.B., Groseclose, S.L. (2005). "The Changing Epidemiology of Syphilis." *Sex Transm Dis* 32: S4-S10.

Ray, J.G. (1995). "Lues-Lues: Maternal and Fetal Considerations of Syphilis." *Obstetrical and Gynecological Survey* 50(12): 845-850.

Ricci, J.M., Fojaco, R.M., O'Sullivan, M.J. (1989). "Congenital Syphilis: The University of Miami/Jackson Memorial Medical Center Experience 1986-1988." *Obstetrics and Gynecology* 74(5): 687-693.

Robles, O. (2013a). "The Health Consequences of Repealing Premarital Blood Testing Requirements." Mimeo.

Robles, O. (2013b). "The Effect of Premarital Law Reforms on Marriage, Divorce, and Fertility?" Mimeo.

Ruggles, S., Alexander, J.T., Genadek, K., Goeken, R., Schroeder, M.B., and Sobek, M. (2010). *Integrated Public Use Microdata Series: Version 5.0*. Minneapolis: University of Minnesota.

Sartin J. S. and Perry H. O. (1995) "From Mercury to Malaria to Penicillin: the History of the Treatment of Syphilis at the Mayo Clinic." ***J. Am. Acad. Dermatol.*** 32: 255-261.

Schulz, K.F., Cates, W., O'Mara, P.R. (1987). "Pregnancy Loss, Infant Death, and Suffering: Legacy of Syphilis and Gonorrhea in Africa." *Genitourin Med.* 63: 320-325.

Shafer, J.K. (1954). "Premarital Health Examination Legislation: History and Analysis." *Public Health Reports* 69(5): 487-493.

Shafti, T., Radolf, J.D., Sanchez, P.J. (2008). "Congenital Syphilis," in *Sexually Transmitted Diseases*, K. K. Holmes, et al., Ed., chapter 82, pp. 1577-1612, McGraw Hill, New York, NY, USA, 4th edition.

St. Lawrence, J., Montano, D.E., Kasprzyk, D., Phillips, W.R., Armstrong, K., Leichliter, J. (2000). "National Survey of U.S. Physicians' STD Screening, Testing, Case Reporting, Clinical and Partner Notification Practices." Presented at the 2000 National STD Prevention Conference, Milwaukee, Wisconsin.

Terris-Prestholt, F., Watson-Jones, D., Mugeye, K., Kumaranayake, L., Ndeki, L., Weiss, H. (2003). "Is Antenatal Syphilis Screening Still Cost Effective in Sub-Saharan Africa." *Sex Transm Infect* 79: 375-381.

Watson-Jones, D., Gumodoka, B., Weiss, H. Changalucha, J. Todd, J., Mugeye, K. (2002). "Syphilis in Pregnancy in Tanzania. The Effectiveness of Antenatal Syphilis Screening and Single-Dose Benzathine Penicillin Treatment for the Prevention of Adverse Pregnancy Outcomes." *Journal of Infectious Disease* 186: 948-957.

Wolfers, Justin. (2006). "Did Unilateral Divorce Raise Divorce Rates? A Reconciliation and New Results." *American Economic Review,* 96(5): 1802-1820.

World Health Organization (2002). *World Health Organization Global Burden of Disease Report*. Geneva, Switzerland.

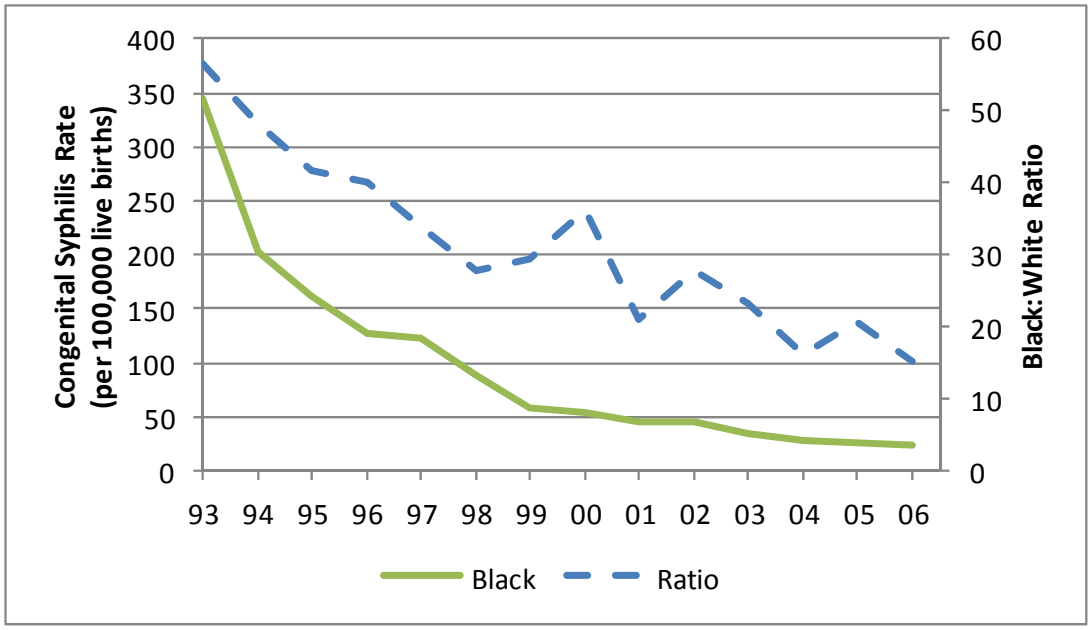
World Health Organization (2006). "The Use of Rapid Syphilis Tests." http://www.who.int/reproductivehealth/publications/rtis/TDR_SDI_06_1/en/index.html. Accessed September 10, 2013.

World Health Organization (2007). "The Global Elimination of Congenital Syphilis: Rationale and Strategy for Action." http://www.who.int/reproductivehealth/publications/rtis/9789241595858/en/index.html. Accessed September 10, 2013.

World Health Organization (2010). "Advancing MDGs 4, 5 and 6: Impact of Congenital Syphilis Elimination." http://www.who.int/reproductivehealth/publications/rtis/rhr_hrp_10_01/en/index.html. Accessed September 10, 2013.

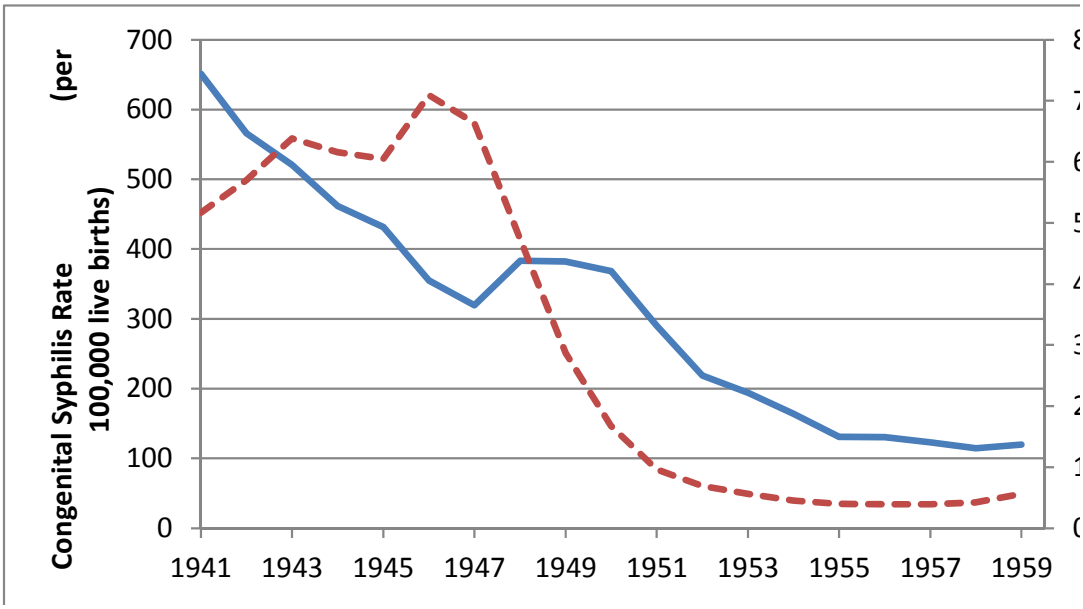
World Health Organization (2012). “Investment Case for Eliminating Mother-to-Child Transmission of Syphilis.” http://www.who.int/reproductivehealth/publications/rtis/9789241504348/en/index.html. Accessed September 10, 2013.

Figure 1: Congenital Syphilis Rates by Race, 1993-2006



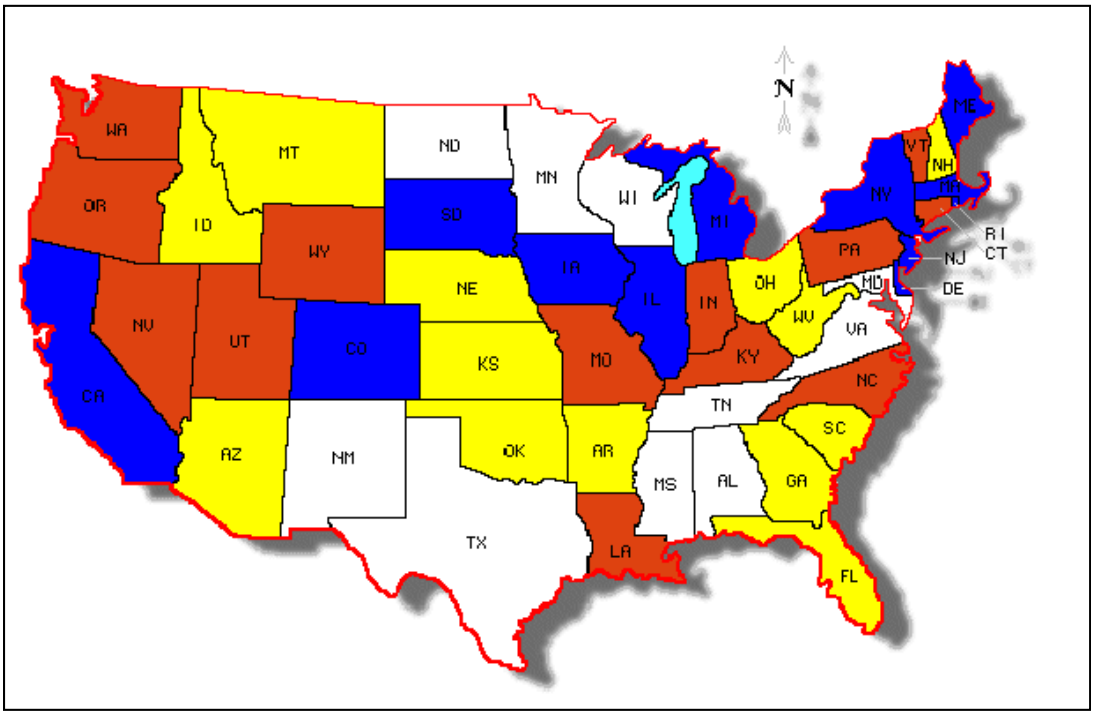
Source: STD Surveillance Reports 1993-2009.

Figure 2: Historical Congenital and Adult Syphilis Rates, 1941-1959



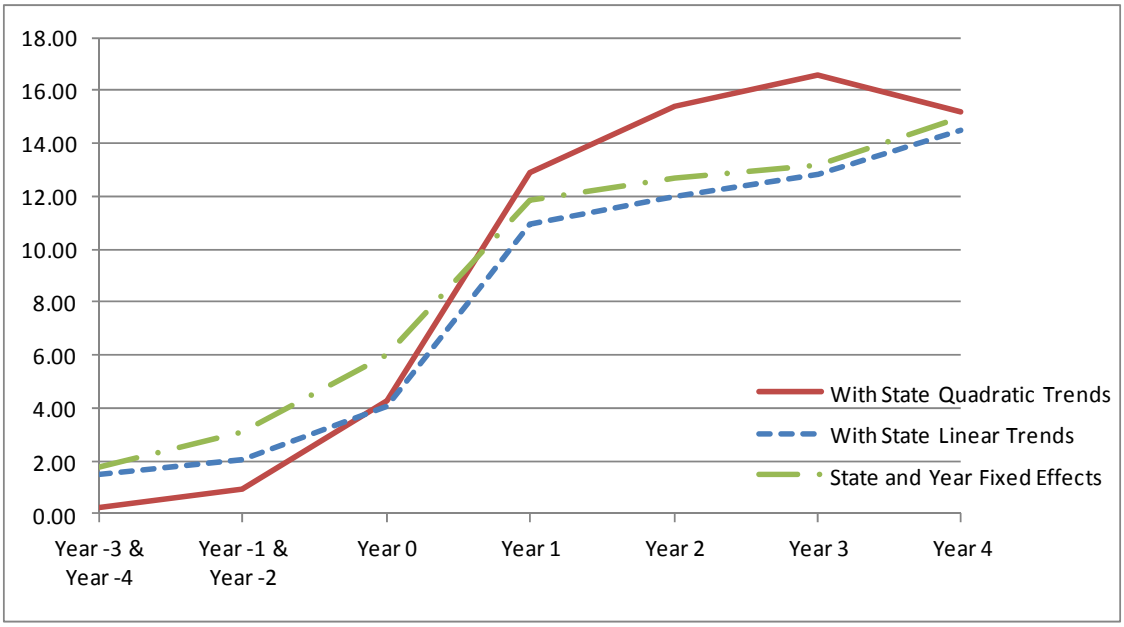
Source: STD Surveillance Reports 1993-2009.

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



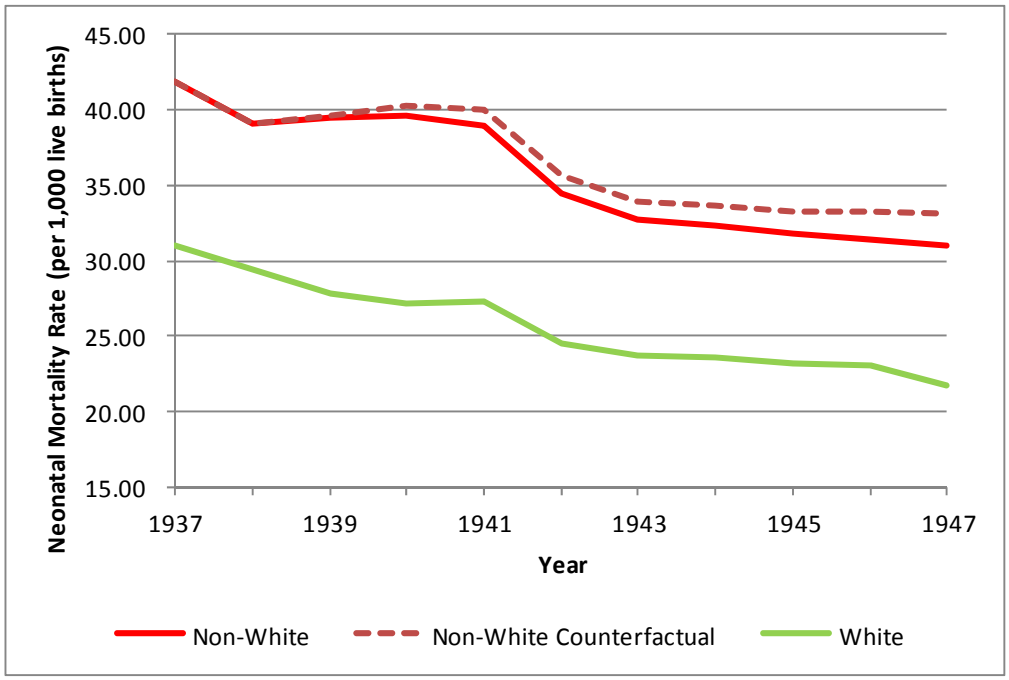
Group I [Blue]: 1938-1939; CA, CO, DE, IA, IL, MA, ME, MI, NJ, NY, OK, RI, SD
Group II [Orange]: 1940-1941; CT, IN, KY, LA, MO, NC, NV, OR, PA, UT, VT, WA, WY
Group III [Yellow]: 1943-1947; AZ, AR, FL, GA, ID, KS, MT, NE, NH, OH, OK, SC, WV
Group IV [White]: Post-1947 Unknown Date; AL; MD; MN; MS; ND;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

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



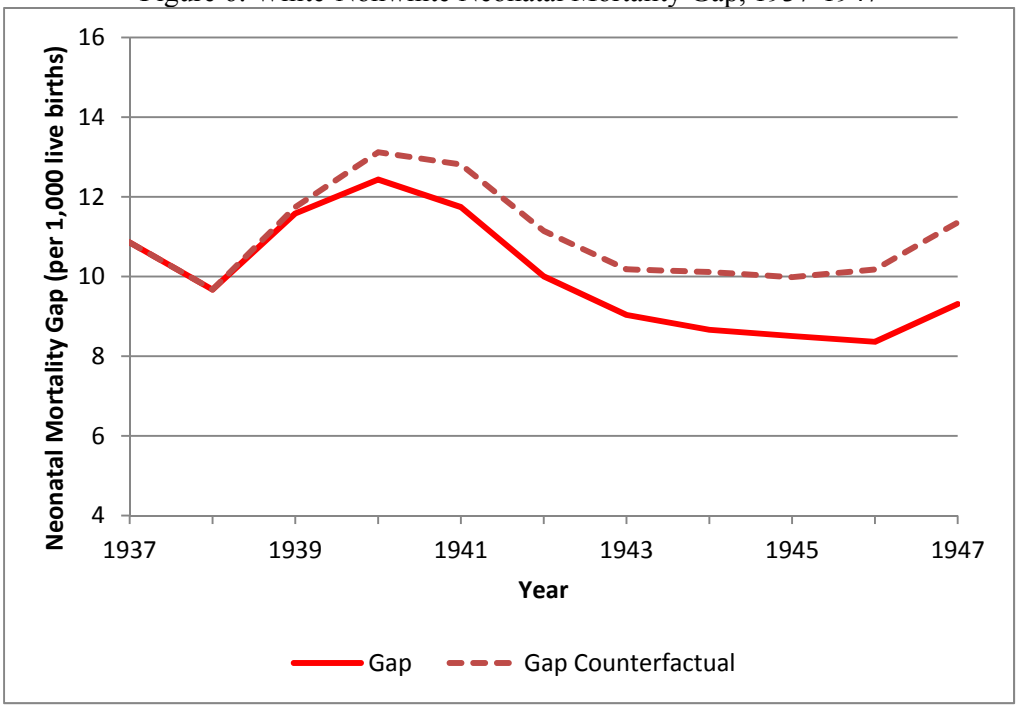
Source: Table 6.

Figure 5: Nonwhite Counterfactual Mortality Rates, 1937-1947



Source: Calculated from Table 3 estimates.

Figure 6: White-Nonwhite Neonatal Mortality Gap, 1937-1947



Source: Figure 5.

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)
Deaths Due to Preterm 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. Neonatal Mortality refers to death within 28 days of birth. Deaths due to Preterm Birth refers to death within one year of birth where the cause of death is identified as premature birth. Infant Mortality refers to death within one year of birth. All mortality rates are calculated as the number of deaths per 1,000 live births. Average cohort size is population-weighted. The Poverty Subsample refers to the subsample of individuals from the 1950 Census who are at 100% or less of the poverty threshold. Mortality rates are calculated using NCHS Vital Statistics Reports. Cohort sizes are calculated using the 1950 Census based on individuals born between 1931 and 1947.

Table 3: Effects of Antenatal Testing Laws on Mortality Rates

Panel A: Nonwhites	Neonatal Mortality			Deaths due to Preterm Birth		
	(1)	(2)	(3)	(4)	(5)	(6)
Antenatal Testing	-1.17	-3.46 *	-3.15 *	-1.06 +	-2.48 **	-2.50 **
	(1.00)	(1.49)	(1.44)	(0.61)	(0.84)	(0.81)
Premarital Testing	1.20	2.16	1.88	-0.41	0.18	0.76
	(0.97)	(1.44)	(1.43)	(0.62)	(0.96)	(0.96)
Percentage Change	-3.2%	-9.4%	-8.6%	-6.3%	-14.7%	-14.8%
Adjusted R^2	0.83	0.87	0.87	0.84	0.88	0.88
Observations		515			442	
Mean		36.71 per 1,000			16.92 per 1,000	
Years		1931-1947			1931-1947	
Panel B: Whites	Neonatal Mortality			Deaths due to Preterm Birth		
	(1)	(2)	(3)	(4)	(5)	(6)
Antenatal Testing	-0.11	0.09	-0.08	-0.45 +	-0.19	-0.23
	(0.32)	(0.63)	(0.45)	(0.25)	(0.35)	(0.24)
Premarital Testing	-0.79 +	-0.09	-0.30	-0.68 **	-0.21	-0.17
	(0.41)	(0.50)	(0.36)	(0.24)	(0.30)	(0.23)
Adjusted R^2	0.86	0.92	0.95	0.83	0.89	0.92
Observations		715			715	
Mean		27.41 per 1,000			13.54 per 1,000	
Years		1931-1947			1931-1947	
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%. The dependent variables are rates of mortality which are taken as the total count of deaths divided by the number of live-births in state *s* in year *t*. Neonatal Mortality refers to death within 28 days of live birth. Deaths due to Preterm Birth refers to death within one year of birth where the cause of death is identified as premature birth. Antenatal Testing is a dummy variable for mandatory antenatal 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 mortality: the fraction of first time live-births and the fraction of live-births by women outisde of age 17-35 in state *s* in year *t*. Regressions are weighted by state live-birth counts for the respective race. The means provided are live-birth-weighted averages for the the 4 years prior to enactment of the antenatal testing laws.

Table 4: Robustness of Mortality Effects

Panel A: Nonwhites	Neonatal Mortality			Deaths due to Preterm Birth		
	(1)	(2)	(3)	(4)	(5)	(6)
Antenatal Testing	-2.04 +	-4.70 **	-3.85 +	-1.33 +	-2.60 *	-3.08 **
	(1.12)	(1.70)	(2.07)	(0.75)	(1.10)	(0.94)
Premarital Testing	0.43	0.86	1.13	-0.66	0.03	-0.19
	(0.99)	(1.46)	(1.28)	(0.66)	(1.20)	(1.37)
Antenatal Testing	1.87	3.38	1.89	0.61	0.35	1.98
x Premarital Testing	(1.95)	(2.31)	(2.86)	(1.09)	(1.73)	(2.03)
Percentage Change	-5.6%	-12.8%	-10.5%	-7.9%	-15.4%	-18.2%
Adjusted R^2	0.83	0.87	0.87	0.84	0.88	0.88
Observations		515			442	
Mean		36.71 per 1,000			16.92 per 1,000	
Years		1931-1947			1931-1947	
Panel B: Whites	**Neonatal Mortality**			**Deaths due to Preterm Birth**		
	(1)	(2)	(3)	(4)	(5)	(6)
Antenatal Testing	-0.84	-0.61	-0.40	-0.90 *	-0.49	-0.34
	(0.59)	(0.61)	(0.38)	(0.39)	(0.33)	(0.29)
Premarital Testing	-1.20 *	-0.49	-0.54	-0.94 **	-0.38	-0.25
	(0.51)	(0.64)	(0.51)	(0.30)	(0.39)	(0.31)
Antenatal Testing	1.13 +	1.17	0.63	0.69 +	0.51	0.23
x Premarital Testing	(0.65)	(0.81)	(0.62)	(0.39)	(0.49)	(0.39)
Adjusted R^2	0.86	0.92	0.95	0.83	0.89	0.92
Observations		715			715	
Mean		27.41 per 1,000			13.54 per 1,000	
Years		1931-1947			1931-1947	
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%. The dependent variables are rates of mortality which are taken as the total count of deaths divided by the number of live-births in state s in year t. Neonatal Mortality refers to death within 28 days of live birth. Deaths due to Preterm Birth refers to death within one year of birth where the cause of death is identified as premature birth. Antenatal Testing is a dummy variable for mandatory antenatal 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 mortality: the fraction of first time live-births and the fraction of live-births by women outisde of age 17-35 in state s in year t. Regressions are weighted by state live-birth counts for the respective race. The means provided are live-birth-weighted averages for the the 4 years prior to enactment of the antenatal testing laws.

Table 5: Effects of Antenatal Testing Laws on Infant Mortality

Panel A: Nonwhites	Infant Mortality (0-12 months)			1-12 months Mortality		
	(1)	(2)	(3)	(4)	(5)	(6)
Antenatal Testing	-2.65	-6.39 *	-3.90 +	0.14	-1.74	0.25
	(1.86)	(3.24)	(2.27)	(1.31)	(1.22)	(0.87)
Premarital Testing	-3.54 +	-0.30	-1.60	-3.04 *	-1.67	-1.57
	(2.11)	(2.68)	(2.33)	(1.43)	(1.47)	(2.03)
Antenatal Testing	1.37	12.21 *	3.90	2.13	3.84 +	2.02
x Premarital Testing	(2.95)	(4.87)	(3.61)	(1.89)	(1.98)	(2.26)
Percentage Change	-3.8%	-9.2%	-5.6%	0.4%	-5.4%	0.8%
Adjusted R^2	0.82	0.88	0.90	0.82	0.87	0.88
Observations		689			505	
Mean		69.67 per 1,000			32.40 per 1,000	
Years		1931-1947			1931-1947	
Panel B: Whites	**Infant Mortality (0-12 months)**			**1-12 months Mortality**		
	(1)	(2)	(3)	(4)	(5)	(6)
Antenatal Testing	-0.09	0.31	0.60	0.74	0.92	1.00
	(1.32)	(1.25)	(0.76)	(1.00)	(0.81)	(0.66)
Premarital Testing	-0.56	-0.15	-0.11	0.64	0.34	0.44
	(0.98)	(1.17)	(0.66)	(0.72)	(0.62)	(0.51)
Antenatal Testing	0.68	1.19	-0.64	-0.45	0.01	-1.27 +
x Premarital Testing	(1.49)	(1.47)	(0.74)	(1.09)	(0.88)	0.65
Adjusted R^2	0.92	0.93	0.96	0.83	0.86	0.92
Observations		715			715	
Years		1931-1947			1931-1947	
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%. The dependent variables are rates of mortality which are taken as the total count of deaths divided by the number of live-births in state *s* at year *t* . Infant Mortality refers to death within one year of birth. 1-12 months Mortality excludes neonatal mortality which is defined as death within 28 days of birth. Antenatal Testing is a dummy variable for mandatory antenatal 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 mortality: the fraction of first time live-births and the fraction of live-births by women outisde of age 17-35 in state s in year t. Regressions are weighted by state live-birth counts for the respective race. The means provided are live-birth-weighted averages for the the 4 years prior to enactment of the antenatal testing laws.

Table 6: Dynamic Effects of Antenatal Testing Laws

	Nonwhite Neonatal Mortality		
	(1)	(2)	(3)
Years -3 & -4	-2.01	-1.95	-0.72
	(1.51)	(1.10)	(1.16)
Years -1 & -2	-3.55	-3.01	-1.45
	(3.47)	(2.55)	(2.46)
Year 0	-6.67	-5.69	-4.21
	(5.41)	(3.99)	(3.88)
Year 1	-11.35	-11.07 *	-9.69 *
	(6.80)	(5.17)	(4.58)
Year 2	-12.14 +	-11.72 +	-10.56 *
	(7.05)	(5.81)	(4.74)
Year 3	-13.35 +	-12.81 *	-11.91 **
	(6.64)	(5.28)	(3.86)
Year 4+	-14.19 +	-13.20 *	-12.55 **
	(7.15)	(5.72)	(3.95)
Adjusted R^2	0.70	0.78	0.79
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%. Neonatal Mortality refers to death within 28 days of birth. *Year #* refers to the year before (negative) or after (positive) the antenatal testing law took effect. States with antenatal testing laws that came into effect after 1945 are excluded from the analysis to allow for a 4-year post-reform balanced panel. Regressions are weighted by state nonwhite live-birth counts.

Table 7: Probit Model to Examine the Timing of Antenatal Testing Laws

	Nonwhite Neonatal Mortality Rates		White Neonatal Mortality Rates	
	(1)	(2)	(3)	(4)
Neonatal Mortality $_{t-1}$	-0.077	-0.075	0.631 $^{+}$	-0.641 $^{+}$
	(0.074)	(0.076)	(0.370)	(0.367)
	[-0.017]	[-0.016]	[-0.007]	[-0.006]
Neonatal Mortality $_{t-2}$		0.003		-0.046
		(0.007)		(0.042)
		[0.000]		[0.000]
Neonatal Mortality $_{t-3}$		-0.007		0.014
		(0.007)		(0.038)
		[-0.001]		[0.000]
t	-0.233	-0.185	-2.002	-2.116
	(0.730)	-0.711	(2.064)	(2.057)
	[-0.050]	[-0.039]	[-0.021]	[-0.019]
t^2	0.014	0.010	0.065	0.067
	(0.045)	0.043	(0.102)	(0.102)
	[0.003]	[0.002]	[0.001]	[0.001]
Neonatal Mortality $_{t-1}$ *x t*	0.017	-0.185	0.090	0.094
	(0.019)	(0.711)	(0.076)	(0.075)
	[0.004]	[0.003]	[0.001]	[0.001]
Neonatal Mortality $_{t-1}$ *x* t^2	-0.001	0.010	-0.003	-0.003
	(0.001)	(0.043)	(0.004)	(0.004)
	[0.000]	[0.000]	[0.000]	[0.001]
Pseudo R^2	0.10	0.10	0.27	0.27
Observations	174	174	352	352
Years	1932-1947	1934-1947	1932-1947	1934-1947

Note: Standard errors are clustered by state and reported in parentheses. The marginal effects are given in brackets below the standard errors. Significance is indicated by + 10%; * 5%; **1%. The dependent variable is a dummy variable which equals 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* . Other independent variable definitions follow those in Table 3.

Table 8: Effects of Placebo Laws on Nonwhite Mortality Rates

	Neonatal Mortality			Deaths due to Preterm Birth		
	(1)	(2)	(3)	(4)	(5)	(6)
Antenatal Placebo	-0.71	-1.05	-0.08	-0.18	0.34	-0.43
	(1.25)	(0.65)	(0.80)	(0.70)	(1.02)	(0.85)
Premarital Placebo	0.27	1.54	0.44	-0.09	1.13	0.13
	(0.98)	(1.94)	(2.53)	(0.86)	(1.84)	(1.74)
Antenatal Placebo	-0.31	-1.82	-0.93	-1.14	-2.74	-0.81
x Premarital Placebo	(1.68)	(1.92)	(2.76)	(1.15)	(2.09)	(2.15)
Adjusted R^2	0.84	0.88	0.88	0.83	0.88	0.87
Observations		515			442	
Years		1931-1947			1931-1947	
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%. The dependent variables are rates of mortality which are taken as the total count of deaths divided by the number of live-births in state s in year t. Neonatal Mortality refers to death within 28 days of live birth. Deaths due to Preterm Birth refers to death within one year of birth where the cause of death is identified as premature birth. Antenatal Placebo is a dummy variable that takes on the value of 1 two years prior to the actual effective year of antenatal testing laws. Premarital Placebo is a dummy variable that takes on the value of 1 two years prior to the actual effective year of premarital testing laws. All regressions include controls for risk factors associated with neonatal mortality: the fraction of first time live-births and the fraction of live-births by women outisde of age 17-35 in state s in year t. Regressions are weighted by state nonwhite live-birth counts.

Table 9: Effects of Antenatal Testing Laws on Birth Cohort Size by Race and Poverty Status

Panel A: Poverty Subsample	Ln(Cohort Size of White Poor)			Ln(Cohort Size of Nonwhite Poor)		
	(1)	(2)	(3)	(4)	(5)	(6)
Antenatal Testing	0.03	0.00	0.02	0.07 +	0.08 *	0.07 +
	(0.02)	(0.02)	(0.03)	(0.03)	(0.05)	(0.04)
Premarital Testing	0.00	-0.01	-0.04	0.04	0.01	0.05
	(0.02)	(0.02)	(0.02)	(0.04)	(0.06)	(0.05)
Adjusted R^2	0.95	0.95	0.96	0.92	0.92	0.92
Observations		774			674	
Panel B: Full Sample	**Ln(Cohort Size of White)**			**Ln(Cohort Size of Nonwhite)**		
	(1)	(2)	(3)	(4)	(5)	(6)
Antenatal Testing	0.03	-0.01	0.01	0.06	-0.01	0.01
	(0.03)	(0.01)	(0.01)	(0.04)	(0.02)	(0.02)
Premarital Testing	-0.02	0.00	0.00	0.08 +	0.01	0.03
	(0.03)	(0.01)	(0.01)	(0.05)	(0.02)	(0.02)
Adjusted R^2	0.98	0.99	0.99	0.97	0.98	0.99
Observations		774			770	
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, birth state, and race. Cohort sizes are calculated using the 1950 Census based on individuals born between 1931 and 1947. The Poverty Subsample refers to the subsample of individuals from the 1950 Census who are at 100% or less of the poverty threshold. Antenatal Testing is a dummy variable for mandatory antenatal testing for syphilis. Premarital Testing is a dummy variable for mandatory premarital testing for syphilis.

Table 10: Calibration of the Increase in Cohort Size

			Notes
Decrease in Nonwhite Neonatal Mortality			
Coefficient Estimate (per 1,000 live births)	3.15	a	From 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	612	c	= a*b/1000
Imputed Increase (%)	0.32%	d	= a/1000
Increase in Nonwhite Birth Cohort Size			
Increase in Birth Cohort Size	141	e	Regression specification used in Table 9 Panel A Column 6 with dependent variable "Cohort Size of Nonwhite Poor" (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 (%)	0.52%	g	= e/f
Difference in Imputed Increase (%)	0.20%		= g-d

Table 11: Cost-Effectiveness 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	Total Cost	Cost per Neonatal Death Averted
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1939	254,752	45	36	1,105	$ 6,182,831	$ 153,678	$ 6,336,509	$ 140,811
1940	936,195	199	159	4,881	$ 22,721,453	$ 679,116	$ 23,400,569	$ 117,591
1941	1,300,302	325	256	7,908	$ 31,558,330	$ 1,100,298	$ 32,658,628	$ 100,488
1942	1,651,914	363	287	8,852	$ 40,091,953	$ 1,231,509	$ 41,323,462	$ 113,839
1943	1,709,071	384	305	9,388	$ 41,479,153	$ 1,306,104	$ 42,785,257	$ 111,420
1944	1,757,182	487	385	11,874	$ 42,646,807	$ 1,652,098	$ 44,298,905	$ 90,963
1945	1,733,068	495	393	12,098	$ 42,061,560	$ 1,683,256	$ 43,744,817	$ 88,373
1946	2,457,688	671	533	16,405	$ 59,648,088	$ 2,282,387	$ 61,930,475	$ 92,296
1947	2,836,714	854	680	20,907	$ 68,847,049	$ 2,908,782	$ 71,755,830	$ 84,023
Total	14,636,886	3,823	3,034	93,418	$ 355,237,223	$ 12,997,228	$ 368,234,452	$ 96,321

Assumptions Used

Neonatal Deaths Averted	3.15 per 1,000 births	(from Table 3 Panel A Column 3)
Premature Births Averted	2.50 per 1,000 births	(from Table 3 Panel A Column 6)
Cost of syphilis testing	$ 24.27	(from Parran 1937, expressed in 2013 dollars)
Cost of syphilis treatment	$ 139.13	(from Parran 1937, expressed in 2013 dollars)

Table 12: Region Estimates of the Effects of Universal Antenatal Testing

WHO Region	Number of Live Births	Number of Neonatal Deaths Averted (for all countries)	Number of Neonatal Deaths Averted (for countries with <30% testing currently)	Number of Neonatal Deaths Averted (Newman et al. 2013)
	(1)	(2)	(3)	(4)
Africa	27,847,697	61,479	34,332	24,278
America	15,520,318	12,548	3,901	1,509
Eastern Mediterranean	16,078,682	4,633	4,588	1,363
Europe	10,700,076	2,554	1,261	5,843
South-East Asia	38,047,410	70,071	22,934	27,625
Western Pacific	25,112,962	6,334	1,537	2,833
GLOBAL	133,307,145	157,618	68,553	63,451

Table 13: Effects of Universal Antenatal Testing for Intensified Support Countries

Country	WHO Region	Syphilis Prevalence Rate, 2010	Estimated Number of Neonatal Deaths Averted
	(1)	(2)	(3)
Honduras	Latin America	1.5	195
Uruguay	Latin America	1.3	33
Ghana	Africa	3.4	3,497
Central African Republic	Africa	10.0	902
Zambia	Africa	5.3	2,185
Tanzania	Africa	2.8	9,448
Madagascar	Africa	6.0	4,852
Mozambique	Africa	5.7	5,345
China	Asia	0.4	4,602
Myanmar	Asia	0.7	1,612
Indonesia	Asia	1.2	19,025
Papua New Guinea	Asia	4.8	378
Total			52,074

Note: Syphilis prevalence rate in column (2) obtained from WHO (2012) p.9. Estimated number of neonatal deaths averted in column (3) is from authors' calculations.