A Shot in the Arm of Public Health: Did the 1954 Salk Polio Vaccine Field Trial Promote Vaccine Access?

Keith Meyers*

November 12, 2022

Abstract

What is the societal impact of large-scale vaccination efforts? This paper uses the largest vaccine trial in human history, the 1954 Salk polio vaccine field trial, to measure how such campaigns affect patterns in public health. This three-month trial both provided access to a novel vaccine and resulted in a large scale mobilization of medical and governmental resources for the purpose of childhood vaccination. Using differences in trial participation across counties and the timing of Federal funding for the public provision of vaccines, I present evidence that locations more exposed to the trial were more likely to host immunization programs and experienced greater access to vaccines in later years. Furthermore, trial participation is also associated with declines in both all-cause and infant mortality. These declines correspond with the availability of federal funding for public vaccine provision. Together, this evidence suggests that the transitory experience with the Salk trial led to persistent expansions in vaccine access.[1]

*1)Economist. National Highway Traffic Safety Administration. 2)Affiliated Researcher Department of Business and Economics and Danish Institute of Advanced Studies University of Southern Denmark. Campusvej 55, 5230 Odense, Denmark. meyersk@sam.sdu.dk

[1]This project has received funding from the European Union's Horizon 2020 research innovation program under grant agreement Marie Skłodowska-Curie Action 2021-2023. No. 890475. Additional support came from the U.S. social Security Administration through the National Bureau of Economic Research's Disability Research Center as part of a NBER Post-Doctoral Fellowship from 2018-2019.

Polio is highly infectious and spreads through asymptomatic carriers. These insidious characteristics contributed to frequent polio epidemics during the 20th Century. Even after the development of an effective vaccine this disease still eludes complete eradication. This paper studies how a large scale clinical trial of the Salk polio vaccine in 1954 affects subsequent polio eradication efforts in the United States. Involving over 1.8 million children ages 6-10, the 1954 Salk Vaccine Field Trial involved the widespread coordination between public schools, local departments of health, and hundreds of thousands of volunteers to administer vaccines. Salk trial provided free health services in an era when vaccines and healthcare were overwhelmingly private purchases. The trial not only provided information about the efficacy of the novel vaccine but plausibly helped create the institutional framework for subsequent vaccination efforts.

To explore how the Salk trial may have reverberated across time and had a broader impact on public health infrastructure I explore if the trial affects 1) the appearance of public vaccination programs and vaccine clinics in later years, 2) shipments of the polio vaccine, and 3) patterns in mortality when the U.S. federal government expands public health funding. I compare counties that received the trials to counties that did not receive the trial but met the criteria used by the trial organizers, the National Foundation for Infantile Paralysis (NFIP). To accomplish this investigation, I develop novel data by web-scraping Newspapers.com historical newspaper archive and exploiting unpublished archival materials on U.S.'s Public Health Service.

The privately funded Salk trial preceded the first federally funded vaccination campaign in the United States. The overwhelmingly private nature of healthcare provision in the 1950's U.S. provides the opportunity to test if such a transitory public healthcare provision effort increases the likelihood of similar interventions in the future. For many public health departments the Salk trial was the first time they performed widespread vaccination efforts and centralized locations. From 1955 to 1957 governments and the NFIP provided enough free or subsidized polio vaccine to vaccinate over 34 million people

fully (Public Health Service, 1957).[2] By studying how the Salk vaccine trial accelerated the U.S.'s own polio eradication campaign this paper shows how transitory vaccination campaigns can support subsequent vaccination efforts. This contributes to a sizable economics literature measuring the benefits of historical disease eradication efforts on human capital (Bleakley, 2007; Bleakley and Lange, 2009; Barreca, 2010; Bütikofer and Salvanes, 2020; Egedesø et al., 2020; Atwood, 2022).

Another contribution of this paper is that it shows how an initial investment in the public provision of direct health services can propagate across time and affect populations that were not initially targeted by the initial health intervention. By broadening understanding of the U.S. initial federal forays into public vaccine provision, this paper contributes to a literature studying the development of U.S. health related institutions such as public sanitation, county health departments, and federal health insurance programs of Medicaid and Medicare (Moehling and Thomasson, 2014; Anderson et al., 2019; Alsan and Goldin, 2019; Hoehn-Velasco, 2018, 2021).

Finally, by measuring the indirect social savings from the Salk vaccine trial, this paper contributes to an economics literature studying the social costs of polio epidemics. Gensowski et al. (2019) find that Danish children afflicted with paralytic polio spent more time in school and were more prone to retire early or use disability benefits. Meyers and Thomasson (2020) present evidence that school closures and quarantines during the 1916 polio epidemic led to reduced educational attainment for some persons in the 1940 Census. Research attempting to measure the long-run benefits of polio vaccination by Serratos-Sotelo et al. (2019) and Serratos-Sotelo (2020) suggests the introduction of the polio vaccine in Sweden had little effect on later life socioeconomic outcomes and that long term scarring associated with polio outbreaks was small.

[2]This is approximately 63% percent of the total amount of polio vaccine provided in those years. The Salk vaccine involved a three-dose regimen. During the trial six 10 cubic centimeter vials provided three doses for up to 20 children. From 1955-1957, 13,888,000 cubic centimeters of vaccine were provided by the National Foundation for Infantile Paralysis (NFIP), 103,146,000 cubic centimeters by public agencies, and 68,308 cubic centimeters by commercial channels (Public Health Service, 1957; Francis et al., 1957).

This paper finds that counties that received the Salk vaccine trial in 1954 were more likely to host vaccination clinics in the years immediately following the trial, more likely to report hosting a public program vaccination program in Public Health Service Records, and more likely to host vaccine clinics after the licensing of the measles vaccine in 1963. Furthermore, trial participation resulted in substantial declines in mortality that exceed what can be explained by reductions in polio mortality alone. In trial counties all-cause mortality decreased by 0.149 deaths per 1,000 from 1955 to 1962. After the federal government enacted the Vaccine Assistance Act (VAA) and provided funding for childhood vaccination on an annual basis starting in 1963, the decline in all-cause mortality increases in magnitude to 0.359 deaths per 1,000.[3] Together this evidence suggests that counties that participated in the Salk trial were better able to provide vaccines licensed in the 1960s and exploit expansions in health care access that occurred throughout the decade. The start of these declines precedes the Great Society programs and the implementation of Medicaid and Medicare.

The manuscript is organized as follows: section 1 describes the polio, the Salk trial, and vaccine provision. Section 2 describes the empirical strategy and data used in the analysis. Section 3 measures the empirical effect of trial participation on vaccine clinics in newspaper articles. Section 4 uses archival records from the Public Health Service to explore the relationship between the Salk trial and Salk vaccine provision. Section 5 analyzes the broader effects of the trial on patterns in mortality. Section 6 concludes.

1 Polio and Vaccine Policy in the United States

The Salk trial marked a turning point in disease eradication in the United States. In the early postwar era, the provision of vaccines came primarily through personal purchases

[3]Initially the VAA covered polio, diphtheria, pertussis, and tetanus. Measles was added in 1965 and coincided with the Public Health Service's measles eradication campaign starting in that year (Guyer et al. (2000), Appendix B).

through the private health care sector. President Harry Truman's push for a national health insurance policy died a legislative death in 1946, and schools provided limited direct medical services (Wyche et al., 1997). It was in this environment where the NFIP privately funded the development of the Salk vaccine and helped launch the U.S.'s polio eradication campaign. Following the trial, vaccine clinics appeared at schools and in other public locations. The NFIP provided millions of free doses in the years immediately following the trial to first and second graders. State and local government allocated funds for the public provision of vaccines, and Congress passed the Polio Vaccination Assistance Act (PVAA) providing the first federal aid for childhood vaccination in U.S. history (Public Health Service, 1957; US Senate Committee on Labor and Public Welfare , 1955).

The impetus for this large scale vaccination campaign was driven in part by the rise of polio morbidity in the United States. With increases in water quality and sanitation the main source of polio immunity, infant exposure in the virus to tainted water, disappeared (Mauricio and Noymer, 2019).[4] Polio itself is caused by the poliovirus, an enterovirus transmitted via the fecal-oral route. The disease is highly infectious in non-immune populations and spreads rapidly. In most cases, patients infected with polio are asymptomatic or experience minor symptoms that resolve in a week (including fever, sore throat, headache or nausea) (Oshinsky, 2005). In some individuals (about one in 150 persons infected), the virus can enter the bloodstream, and then invade the central nervous system, leading to the most common symptom associated with the disease, paralysis. The risk of paralysis and death in polio infections increases with age (Nathanson and Kew, 2010). Death from paralytic polio was common. Prior to the introduction of the Salk vaccine the diseased claimed a few thousand lives annually.

[4]Exposure to the polio virus early in life could confer lifelong immunity to the disease, and infections during infancy rarely resulted in paralysis. As improvements in public health and sanitation reduced the burdens of other diseases such as typhus or cholera, they also decreased the likelihood people would be exposed to the polio virus early in childhood. These improvements created populations vulnerable to the disease and this increased vulnerability manifested as paralytic polio epidemics.

Figure 1 plots out reported polio morbidity from 1930 to 1970 from data provided by Project Tycho (Van Panhuis et al., 2018). During the 1930s the number of polio cases ranged between a few thousand and almost twenty thousand cases per year. After the end of the Second World War, the number of reported acute polio cases increased with a peak in 1952 and a total of 57,159 cases. The Salk vaccine was licensed in the United States and made publicly available in April 1955. By 1957 there were only a few thousand reported cases of acute polio. Albert Sabin's live virus vaccine was first licensed in the U.S. in 1961 and quickly replaced Salk's attenuated virus vaccine by 1962 (Pearce, 2004).[5] In 1963, a single dose trivalent Sabin Oral Polio Vaccine (OPV) was licensed and greatly reduced the logistical burden of immunization. By the 1960s polio became rare in the United States and the last case of endemically transmitted polio reported in the U.S. occurred in 1979.[6]

Conduct of the Salk Vaccine Trial

The 1954 Field trial of the poliomyelitis vaccine was organized by the NFIP and evaluated independently by the Poliomyelitis Vaccine Evaluation Center at the University of Michigan. A substantial advertising campaign promoting the trial informed the public about the NFIP's plan. A Gallup poll showed that more Americans were aware of the Salk Vaccine Trial than knew the full name of the President of the United States, and one estimate suggested two thirds of Americans had donated to the March of Dimes campaign to eradicate polio (Clausen et al., 1954; Oshinsky, 2005).

[5] In the U.S. infants were given the Salk vaccine and then Sabin Oral Polio Vaccine to minimize the risk of vaccine contracted polio from the live-attenuated vaccine. The Sabin polio vaccine became the vaccine of choice after it was introduced in the early 1960s.

[6] Work on developing a vaccine to immunize the population against the ravages of polio started decades before the licensing of the Salk vaccine. In 1935 Maurice Brodie attempted to create a polio vaccine using a polio inactivated by formaldehyde. John Kollmer attempted to create a live-virus vaccine. Both attempts were unsuccessful, and it was Jonas Salk's lab that produced the first effective inactivated polio vaccine in 1953 (Pearce, 2004). Albert Sabin started development of a competing live virus vaccine in 1954 (first licensed in the U.S. in 1961). The oral polio vaccine produced by Sabin proved easier to administer and provided longer lasting immunity relative to the Salk vaccine (Pearce, 2004; Baicus, 2012).

The trial was organized by the NFIP in conjunction with local departments of health starting in the fall of 1953 and vaccines were given to students in April, May, and June of 1954. Trial counties were chosen primarily due to their population size and recent experiences with polio from 1948 to 1952. The only way to test the efficacy of the vaccine was to observe how it performed during outbreaks. Since polio outbreaks could be somewhat unpredictable and infection often asymptomatic, large numbers of participants from a wide geographic area were needed. Organizers looking at disease surveillance records concluded that counties with between 50,000 and 200,000 residents had the greatest risks of polio outbreaks and that subsequent polio outbreaks were correlated with recent years' incidences of polio.[7] Counties in the trial had on average 22% more cases of polio per capita than the average (Francis et al., 1957). Large urban areas such as New York City and some rural counties were also included. The NFIP sought to conduct the trial in all 48 continental states, since the organizers also used the trial as a promotional tool for their planned polio eradication campaign.

The evaluation program involved 211 distinct study areas in 44 states and 1,829,916 participants ages 6 to 10. The targeted groups were first, second, and third graders.[8] Figure 2 provides a map of counties participating in the trial and the counties that were in each location.[9] The Salk Vaccine Trial involved a massive logistical undertaking and involved the coordination of over 14,000 school principals, 50,000 teachers, 20,000 physicians, 40,000 nurses, and 200,000 volunteers. A two-day long workshop trained local organizers on protocols and procedures (Oshinsky, 2005).[10] In total 422,743 children

[7]State surgeon generals or equivalent health officers shorted listed the counties the NFIP chose from the UCSD Archives and Special Collections.

[8]Three trial areas in Georgia withdrew due to a sudden polio outbreak. Maryland, Arizona, and Washington DC withdrew since the school year ended before the trial would complete. Areas in Minnesota could not get legislative approval in time for the trial to be conducted (Francis et al., 1957).

[9]Placebo areas randomized vaccine, placebo, and control groups across all students. Observed areas randomized placebo and vaccine only among second graders. First and third graders served as control populations.

[10]The trial was organized into two separate study areas. The first proposed by the NFIP consisted of an observed cohort control study design where only members of the second grade would be vaccinated and members of the first and third grades would serve as controls. This trial design was preferred by

completed three shots of the Salk vaccine and 201,229 completed three doses of the placebo. While institutional segregation and racial disenfranchisement was rampant within the United States during the mid-20th Century, the 1954 Salk trial did include African American children (Rogers, 2007). In total the trial involved 152,298 non-white participants or 8.3% of the trial population (Francis et al., 1957).

Licensing and distribution of the Salk polio vaccine

The Salk vaccine was approved for public use on April 12, 1955 on the tenth anniversary of Franklin D Roosevelt's death. The initial roll out of the Salk vaccine on a mass scale in 1955 experienced some obstacles. For one, the provision of Salk vaccine by private clinics was severely curtailed following an incident with an improperly inactivated strain of the virus produced by Cutter Laboratories.[11] As a result, the NFIP's program to inoculate all first and second graders was the primary source of Salk polio vaccine in 1955.[12]

The NFIP sought to provide two doses of the Salk vaccine to children in first and second grade. The NFIP provided enough vaccine to inoculate 6.7 million children twice in 1955.[13] Following the planned conclusion of the NFIP vaccination program, Congress

the NFIP for its simplicity and transparency. Transparency made it easier to convince parents to opt their children into the trial. In areas with a polio outbreak, it would be easy to distinguish vaccine recipients from non-recipients, but some public health experts warned that this knowledge could bias medical diagnoses during a disease outbreak (Meier et al., 1972). The University of Michigan team led by Thomas Francis favored a double-blind randomized placebo control trial. This would avoid potential selection effects into treatment and provide the rigor necessary to convince medical experts of the IPV's efficacy. Boxes containing three vials of the vaccine and three vials of the placebo in identical bottles with differing identification numbers were provided. Persons administering the inoculation did not know whether children would receive the Salk vaccine or sodium solution. Randomization occurred across all three grades where students were lined up and their vaccination status was determined by the place in the initial queue (Francis Jr, 1957).

[11]This tainted a batch of the vaccine resulted in numerous paralytic polio infectious and caused the Public Health Service to enact a comprehensive poliomyelitis surveillance and public relations campaign (Langmuir et al., 1956). Cutter Laboratories released approximately 401,000 cubic centimeters of vaccine in 1955, which is less than 1.5% of the total amount of vaccines shipped in 1955. The incident killed 11 children.

[12]Most of the production capacity for Salk vaccine in 1955 was purchased by the NFIP prior to the licensing of the Salk vaccine.

[13]One cubic centimeter is approximately one dose for the Salk vaccine.

sought to expand childhood vaccination and President Eisenhower felt that no child should be denied the Salk vaccine due to an inability to pay (US Senate Committee on Labor and Public Welfare , 1955).[14] Congress decided to cover populations aged 5-9 and provide funding for a third dose of the vaccine for those who participated in the NFIP program. The NFIP was able to continue their inoculation efforts since they were able to identify the tainted vaccines from Cutter. States also made public purchases of the vaccine. By May 1955, nine states appropriated funds for the purchase of the Salk vaccine and thirty more had pending legislation to finance the public provision of the Salk vaccine (Anderson, 1955a).

Federal support for Salk vaccine inoculation came from the Poliomyelitis Vaccination Assistance Act (PVAA). Congress passed this legislation in August of 1955. This was the first time the Federal government provided funding for childhood vaccinations. The PVAA initially allocated $30 million to support vaccination campaigns and subsidize the purchase of Salk vaccine. The PVAA was initially set to expire in June 1956, but it was extended to June 1957 and an additional $23.6 million was allocated to the program (Anderson, 1955b; Haldeman, 1957). It was not until 1963, after the enactment of the Vaccination Assistance Act (VAA), that Federal funds were consistently directed towards inoculation.[15] The PVAA gave states the flexibility to determine how they administered their vaccination programs. Some states, such as Florida, provided subsidized vaccines primarily through private physicians while other states such at Vermont relied primarily on centralized public vaccination clinics.

[14]The Congressional testimony on what would become the PVAA stated "These funds must be sufficient to pay the cost of vaccine for children through age 19 in low-income families. The funds would be used after the NFIP free immunization program has been completed and until December 31, 1956. These funds would be paid to States upon assurance by the State that no child within the priority age groups would be denied vaccination by reason of the cost" (U.S. Senate Committee on Labor and Public Welfare, 1955, p.11).

[15]The VAA initially provided Federal funds to support childhood vaccinations for diphtheria, pertussis, tetanus, and polio. Measles was added to the list of funded vaccines in 1965 and coincided with a 1966 Public Health Service effort to eradicate the disease. These efforts led to an expansion of state program to vaccinate children. No funding for community vaccination programs was allocated from 1969 to 1971 and many of these programs disappeared. Even after the resumption of funding many programs did not resume at the same scale until years later (Office of Technology Assessment, 1979).

Supplies were limited until 1957 since the vaccine required four months to produce and only had a six-month shelf life (Sirken and Brenner, 1960). This led the Public Health Service to manage the distribution of the Salk vaccine from 1955-1957 through a voluntary distribution program. In 1955, 13,541,000 cubic centimeters of Salk vaccine were shipped by the NFIP out of the 27,667,000 cubic centimeters of Salk vaccine available. The rest of the supply was distributed roughly equally through public agencies and commercial channels in 1955 (Public Health Service, 1957). By 1956 and 1957, public agencies were the main provisions of the Salk vaccine. Over this three-year period, the NFIP and public agencies supplied enough doses of the Salk vaccine to vaccinate 34.3 million people completely. Private commercial channels, in contrast, shipped enough doses to vaccinate 22.7 million people completely.

The provision of the Salk vaccine by the NFIP and government ran counter to the norms regarding childhood vaccination in the 1950s. The responsibility of vaccinating children came from private purchases and visits to private practitioners. The provision of direct medical services in schools, such as inoculation, were uncommon practices. A coalition of the American Medical Association, medical professional lobby, and labor unions sought to keep schools from providing direct medical services and killed a 1948 bill that would have provided Federal assistance to school health programs (Wyche et al., 1997). It was not until the 1960s and the Great Society programs of President Lyndon B Johnson that there was a renewed focus on using schools to provide direct medical services. Nevertheless, schools and other clinics outside the purview of private medical practices served as the primary source of Salk vaccine inoculations for children from lower income families (Sirken and Brenner, 1960; Sirken, 1962).

2 Empirical Strategy and Conceptual Framework

There are three aims to the econometric analysis. The first is to test if Salk trial participation resulted in vaccine provision strategies similar to the school vaccine clinics used during the trials. The second aim is to verify that participation in the trials resulted in more polio vaccine provision and public vaccination programs during the PVAA campaign using archival records. The final goal is to test if Salk trial participation had broader benefits for public health using mortality as a proxy for the overall health environment.

The first empirical analysis uses a flexible difference-in-differences approach to measure the frequency that newspapers report vaccine clinics. This tests if proximity to the Salk vaccine trial resulted in similar large scale public vaccination efforts in subsequent years. By comparing counties in the trial to those that met the population criteria for the trial, but that did not participate and by leveraging the timing of national health and vaccine related events, I test if trial participation resulted in persistent changes in vaccine provision.

Figure 3 provides a list of key innovations in vaccines and major federal public health policies. The key federal policies are the 1955-1957 PVAA and 1962 Vaccine Assistance Act. These two programs provided subsidies for childhood inoculation. The licensing of the live attenuated virus measles vaccine in 1963 also is a substantial health event. This specific vaccine is hypothesized to broadly increase immune health and reduce non-measles morbidity (Aaby et al., 2014; Benn et al., 2020). Atwood (2022) exploits this feature of the measles vaccine and finds evidence that the timing and adoption of the measles vaccine is associated with the broad reductions in infectious disease morbidity.

The subsequent analysis uses records from the Public Health Service on the PVAA in a set of cross-sectional regressions to test if trial counties were more likely than non-trial counties to have polio eradication programs and if trial participation affected shipments

of Salk vaccine per from 1955 to 1960. Finally, for the mortality analysis I employ the same flexible difference-in-differences approach used in the newspaper analysis.

2.1 Data and Descriptive Statistics

Salk Vaccine Participation Information

Information regarding the conduct of the Salk Polio Trial is sourced from the "Evaluation of the 1954 Field Trial of Poliomyelitis Vaccine" (Francis et al., 1957).[16] From this previously unused historical source, I have gathered county level information on Salk trial design, implementation, and participation.[17] The "Evaluation" volume contains information of the number of children participants in each group (vaccine, placebo, control, other) by gender and age. The volume also reports the share of parents who opted to have their children participate in the trial and the share of parents who explicitly refused to let their children participate in the vaccine trial.

Newspapers.com Records

Mentions for vaccine clinics were scraped from the Newspapers.com API. The number of newspaper pages containing a specific search string, county the newspaper was headquartered in, and year the mentioned occurred were scraped using R. The number of total newspaper pages printed for each county and year from 1946 to 1970 was also collected. The search terms included Salk clinic, polio clinic, poliomyelitis clinic, vaccine clinic, and vaccination clinic.[18]

Vaccination Polices and Programs

Governments and private organizations created programs to eradicate polio and distribute the Salk vaccine in the years after the Salk trial. These programs include the

[16]The individual vaccination records of trial participants are housed in the University of Michigan archives and will become available in 2055.

[17]Placebo areas randomized vaccine, placebo, and control groups across all students. Observed areas vaccinated only second graders. First and third graders served as control populations.

[18]In the appendix figure A1 maps the number of newspaper pages available by county from 1946 to 1970. Appendix figure A2 displays the number of newspaper pages with vaccine clinic related strings.

federally funded Polio Vaccination Assistance Act from 1955-1957, state and local programs, and the NFIP's own vaccination efforts. The Federal government helped coordinate the distribution of the vaccine and public channels were a major provider of the Salk vaccine. I collected and organized records from the U.S. Archives at College Park from *Record Group 90: Records of the Public Health Service, 1794 - 1990, Records Relating to the Polio Vaccine Distribution Program, 1954 - 1960* (National Archives at College Park). These records provide information on the shipment of vaccines over time, NFIP activities, and public provision campaigns for Salk vaccine. Additional archival information comes from the Salk papers at the University of California San Diego (UCSD Archives and Special Collections).

Mortality records

A panel containing information on population and all-cause mortality by residence is constructed from Bailey et al. (2015) *U.S. County-Level Natality and Mortality Data, 1915-2007* (ICPSR 36603). The mortality records come from two sources to this panel. County level information by cause of death for year 1950 to 1958 comes from Vital Statistics of the United States (VSUS) tables. County level deaths by cause for 1958 to 1967 come from the Multiple Cause-of-Death Mortality Data files provided by the National Vital Statistics System of the National Center for Health Statistics.

Figure 4 presents trends in the mean all cause death rate per 1,000 residents for three categories of counties. The groups presented are Salk trial counties, their candidate counterfactual counties, and all other counties in the U.S. not included in the study. In the period before 1954, both trial and candidate counties follow similar trends in mortality. Figure 5 presents trends in the mean infant death rate per 1,000 births for three categories of counties. Salk trial counties start with lower levels of infant mortality and decline at a slower rate than non-trial counties. I adjust the infant death rate for this pre-trend difference using the method described in Goodman-Bacon (2021).

3 Empirical Effects of Salk Trial on Vaccination Clinics

In the years after the 1954 trial, mass vaccination events, often referred to as vaccine clinics, appeared throughout the US. These clinics reappeared with the introduction of the licensing of the Sabin oral polio virus in the early 1960s. The NFIP was instrumental in the initial roll out of the Salk vaccine after it was licensed in April 1955.[19]

Since the Salk trial involved large scale vaccination efforts in centralized locations, I turn to newspapers to explore whether similar such vaccination strategies were employed more often in vaccine trial counties than other counties. Digitized newspaper articles provide novel means to study both the geographic and temporal extent of such a decentralized public health program. Of 168 Salk trial counties 88 to 94 counties have newspapers in the Newspapers.com archive for any given year examined.

$$m_{it} = \Sigma_{j=1946, j\neq 1953}^{1970} \theta_{j,t} * ProxSalk_i + X_{it}\beta + \alpha_i + \gamma_{r(i),t} + \epsilon_{it} \quad (1)$$

Equation 1 describes the full specification. The outcome m_{it} measures the number of pages in newspapers in a given county i that reference the terms "vaccine clinic, vaccination clinic, Salk clinic, and polio clinic" during year t. The year indicator variables for years 1946 to 1970, $\theta_{j,t}$, are interacted with the measure of proximity to a Salk trial county, $ProxSalk_i$. The omitted base year is 1953. Two measures for proximity are used in the analysis. The first is an indicator variable that denotes whether a given county the newspaper is in participated in the 1954 vaccine trial. The other measure of proximity used is the log inverse distance in kilometers between a newspaper county and the nearest Salk trial county.[20] Controls for the log number of newspaper pages printed

[19] Another reason the preexisting NFIP relationship might matter was an initial pause on polio vaccination programs in 1955. A tainted batch of the Salk vaccine produced by Cutter Laboratories and lax oversight from the Federal government resulted in approximately 200,000 children receiving an inappropriately inactivated vaccine. This event resulting in the cessation of Salk vaccine vaccination until the fall of 1955. Vaccines supplied by the NFIP were exempt from this cessation since the NFIP was able to ensure the quality and safety of the vaccine lots they distributed.

[20] Log inverse distance is measured as ln(1/(km+1), where km is the closest trial county. Counties in the trial were given a distance of zero. County centroids are used to denote distance between two areas.

in a given county year, white share of the population, share of the population with a high school degree, share of the county population that is urban, and median household income are represented by X_{it}. County fixed effects are denoted by α_i and region by year fixed effects are denoted by $\gamma_{r(i),t}$. Standard errors clustered at the county level are denoted by ϵ_{it}.

Coefficients of the interactions of the year indicator variables with an indicator of Salk vaccine trial participation are in figure 6. Coefficients interacting year indicators with the log inverse distance to the nearest Salk trial county are in figure 7. Flexible differences in differences using all county newspapers appear in the appendix and reveal a more statistically significant relationship between trial participation and mentions of vaccine clinics. Both figures suggest that mentions of vaccine clinics in local newspapers are higher in counties more proximate to the Salk trial areas. There are notable statistically significant increases in newspaper pages mentioning vaccine clinics in 1954-1958 and 1963. In 1963, with the passage of the Vaccine Assistance Act, counties that participated in the Salk trial in 1954 had more frequent mentions of vaccine clinics.

To provide a more tractable interpretation on the effects, I regress the number of newspaper page mentioning vaccine clinic terms on interactions using pooled year coefficients. The excluded reference period are the years 1946 to 1953 that occurred prior to the Salk trial. The Salk trial and years where PVAA funding was available, 1954 to 1957, are pooled together. The period of 1958 and 1962 covers the years between the PVAA lapsing and the enactment of the VAA. Finally, the years of 1963 to 1970 consist of years when the VAA was in effect. Tables 2 and 3 report the regression coefficients using the Salk trial participation indicator variable and distance to nearest Salk trial participating county interacted with the three pooled year coefficients. Specifications (1) to (3) use newspapers from Salk trial participating counties and counties with populations that put them in consideration for Salk trial participation by trial organizers. Specification (4) includes all counties with newspapers during this period. The results find large increases

in the number of mentions. In specification (3), the coefficients measuring the effect of proximity to the trial on mortality are statistically significant at the 5% level for both 1954-1957 and 1963-1970 bins. Table 2 suggests if a county participates in the Salk trial, then 12.209 additional newspaper pages are printed referencing vaccine clinics each year between 1954 and 1957. The statistically significant effect reemerges with VAA funding ands suggest an additional 4.556 references per year between 1964-1970. Table 3 provides statistically significant coefficients of 2.743 and 0.987 for the 1954-1957 and 1963-1970 bins respectively. These coefficients suggest a one standard deviation increase in log inverse distance to nearest Salk trial county, 2.319, results in 6.361 additional references to vaccine clinics between 1954 and 1957 per year. It also suggests 2.288 additional vaccine clinic mentions in newspapers every year after 1963.

4 Empirical Effects of Salk trial on Vaccine Campaigns

Granular information on vaccination rates and government efforts to provide and provide vaccines is limited even today.[21] Using information collected from archives, I provide insight into how participation in the Salk trial relates to subsequent polio eradication efforts and uptake of vaccines. This section also shows how differences in trial participation at the state level affects the number of vaccines administered pr shipped. This section also provides direct evidence that participation in the Salk trial increases the likelihood a county hosted a public polio vaccination program in 1957.

Direct Evidence that Salk Vaccine Trial affected Polio Eradication Programs

Using unpublished manuscripts from the Public Health Service, I present direct evidence that Salk trial participation is associated with a greater likelihood that a given county hosts a polio eradication program in 1957. In 1957 the Public Health Service audited

[21] The first national survey on vaccination rates was conducted in 1957 through the Current Population Survey.

states and counties to ascertain what polio eradication efforts were being undertaken. This was the last year PVAA funding was provided and many states had exhausted much of the funds allotted to them. If trial counties hosted polio eradication programs in 1957 it would suggest that their public health interventions with respect to polio were more persistent.

$$p_c = \alpha_s + \theta proximity_c + \epsilon_c \tag{2}$$

Equation 2 describes how either county participation in the 1954 trial or the log inverse distance to the nearest trial county, $proximity_c$, affects the probability a county reported hosting a Salk vaccine campaign in 1957. Only 133 out of 3,101 counties, or 4.27%, reported having such a program. State fixed effects α_s ensures comparisons are made between counties within the same state and controls for the effect that some states administered their own Salk vaccine campaigns. Standard errors, ϵ_c, are clustered at the state level.

Table 4 presents a positive and statically significant relationship between proximity to a trial location and the likelihood a county has an Salk vaccine program in 1957. This relationship persists even when restricting the sample to trial counties and those in the population range considered by trial organizers. Across all counties in the U.S., trial participation increases the probability of a county program by 10.1% relative to other counties within the same state. Similarly, being 10% closer to a trial county increases the probability of having a program by 0.2%. These results are statistically significant at the 1% level. This evidence corroborates the evidence from newspaper articles and confirms that places that participated in the Salk polio vaccine trial in 1954 had more active polio eradication efforts.

Relationship between Salk Vaccine Trial and vaccine shipments

$$y_s = \alpha_{r(s)} + \theta intensity_s + \epsilon_s \tag{3}$$

Equation 3 describes the cross sectional regression that look at various outcomes reported at the state level in the archival records. Outcome y_s represents per capita outcomes of interest. The denominator is the number of children ages 5-10 in 1954 in a given state.[22] This is the initial target group for the Salk vaccine campaigns starting in 1955. The outcomes include the number of shots administered per capita in 1955, the cumulative amount of vaccine shipped by the PVAA/NFIP per capita, PVAA funding per capita, and total vaccine shipments per capita. The measures of Salk trial participation used is denoted by $intensity_s$ and represents the share of children ages 5-10 that participated in the program or were fully vaccinated in a given state. All regressions control for four Census region fixed effects $\alpha_{r(s)}$), and I use robust standard errors to adjust for heteroskedasticity in ϵ_s.[23] Descriptive statistics for these variables is in table 1. At the state level approximately 10 percent of children ages 5 to 10 participated in the trial and 2.4 percent received three full doses of the Salk vaccine.

Table 5 presents the relationship between the trial and NFIP vaccinations per capital. I find a statistically significant relationship at the 1% level that suggests that greater trial participation resulted in the NFIP providing more polio vaccine by 1960. A one standard deviation increase in trial vaccination coverage is associated with the NFIP sending another dose of vaccine, one cubic centimeter, for every 22 children by 1960. While shots and Salk vaccine shipments in 1955 are positively related with trial participation, the results suggest that early NFIP activities targeting all first and second graders in the U.S. did not disproportionately focus on trial areas. The relationship between trial participation and NFIP vaccine shipments and shots administered reveal

[22]This value was constructed from age tables in the 1950 Census and aged forward. Not all ages were represented as single year bands

[23]In the appendix specifications using natural logs and controlling for log population are reported for tables A1, A2, and A3. The results are comparable.

that trial increased private provision of subsidized vaccines.

While the NFIP activities were privately funded, PVAA activities were publicly funded. Evidence from PVAA activities in table 6 suggest that Federal funding targeted states that had not participated in the trial and that there is a statistically significant and negative relationship between PVAA funding and PVAA provided Salk vaccine and trial participation. One goal of the PVAA campaign was to ensure that children would have access to the Salk vaccine regardless of their inability to pay. Since the trial occurred primarily in the north relative to the poorer regions of the U.S., this result suggests that the PVAA tried to rectify a vaccine provision deficit.

In contrast, table 7 shows that total vaccine shipments per capita are positively related with greater shares of the population participating in the Salk trial. In 1955 supplies were limited and Salk vaccine doses were shipped primarily via the NFIP. In 1956 there were still shortfalls in production. By 1957 bottlenecks in production had disappeared and supply of the Salk vaccine exceeded demand. In states where a greater share of children was inoculated in 1954 the cumulative Salk vaccine shipments per child in 1956 and 1960 increased. This relationship is statistically significant at the 10% level in 1956 and 5% level by 1955. A one standard deviation increase in children being vaccinated in 1954 increases cumulative shipments per capita by 0.7 cc's by 1956 and 5.05 cc's per capita by 1960. The results for the PVAA vaccine shipments and total vaccine shipments suggest that states with greater trial participation in 1954 had greater polio vaccine access (and plausibly uptake). Furthermore, this abundance of vaccines was not driven by federal policy.

5 Empirical Effects of Trial Participation on Mortality

The main analysis uses a flexible differences in differences design studying the evolution of VSUS mortality from 1946 to 1970 and compares the effect of Salk trial participation

in a county (first difference) over time (second difference). Key timing events include the 1955-1957 PVAA, the licensing of live-virus vaccines starting in 1961, and the VAA which provided funding starting in 1963.

The counties I compare with the Salk counties are those considered by the trial organizers to be candidate counties. The comparison counties consist of counties with population sizes between 50 and 200 thousand residents in 1950 that did not predicate in the trial.[24] These are counties that the trial organizers described as being the primary candidates in Francis et al. (1957).[25] I construct a fully balanced panel of 438 counties from 1946 to 1970, 164 trial counties and 274 non-trial counties.[26] Descriptive statistics for this balanced sample are presented in table 8.

$$m_{ct} = \Sigma_{j=1946, j\neq 1953}^{1970}\{\phi_j SalkTrial_c 1[j=t]\} + + X_{ct}\beta + \alpha_c + \gamma_{R(c)t} + \epsilon_{ct} \qquad (4)$$

In equation 4 the mortality rate per 1,000 residents and per 1,000 births for infant mortality, m_{ct}, in county c in year t is regressed on interactions of a Salk trial county indicator and year indicator variables. I use total deaths by residence since county death rates by races are not available at the county level until 1959. The $SalkTrial_c 1[j=t]$ take the value one if county c participated in the trial and if year t equals j. The analysis uses all-cause mortality and infant mortality as a time consistent measures of mortality.

[24]County population in 1950 was the primary criteria for inclusion in the trial and polio morbidity from 1948 to 1952. The trial organizers also wanted to include counties from all states in the trial for geographic coverage and deviated from these criteria. I do not have access to the county level morbidity data the organizers used. I am currently in the process looking through archives for more information on the selection of counties into the trial.

[25]The trial organizers sought to conduct the trial in counties with populations between fifty and two hundred thousand people according to the 1950 U.S. Census. Their primary justification for this is that these counties had the greatest prevalence of polio infections on average and that these counties would have sufficient public health infrastructure to conduct the inoculations. Some exceptions were made to include a few rural and highly urban counties in the vaccine trial (e.g. New York City). The trial organizers planned on including all states in the study but only forty-four participated. I plan future archival work to identify the set of locations that applied to participate in the Salk vaccine trial.

[26]Massachusetts is excluded from the sample since U.S. vital statistics excludes deaths by residence for some years in the 1950s due to poor data quality. New York City reports deaths by occurrence for some years rather than residence and is also exclude from the panel.

Deaths from non-natural causes (suicide, homicide, accidents, and motor deaths) serve as a falsification exercise.

The coefficients ϕ_j trace out the effects of trial participation on mortality relative to the omitted year, 1953. A set county level of time varying controls from U.S. Census records including interpolated log median income, share white, share with high school degree, and share urban from U.S. Censuses are denoted by X_{ct}.[27] County fixed effects, α_c, control for time invariant factors specific to counties. Census region by year fixed effects $\gamma_{R(c)t}$ control common annual shocks shared across census regions. Standard errors are clustered at the county level to account for county specific heteroskedasticity. The regression equation is weighed by county population. Identification of the regression above comes from comparisons of death rates of residents between counties within the same region around the timing of the event.

All-cause mortality

The results from the flexible differences in differences framework suggest that mortality in Salk trial counties declined faster in the years after the trial than counties considered by trial organizers to be comparable. Figure 8 presents the coefficients on the year interactions with Salk trial participation. The base year for mortality is the year prior to the trial, 1953. Statistically significant declines at the 5% level start in 1959. Widespread availability of the Salk vaccine did not meet demand until 1957. The deadline for states to use allocated funds from the Polio Vaccine Assistance Act (PVAA) was extended in 1956 (Commerce, 1956). The 1959 decline coincides with subsequent waves of the H2N2 Asian Flu and the availability of an effective influenza vaccine (Davenport, 1958; Lackman et al., 1959).

There is a sharp decline in all cause deaths after the licensing of the live trivalent OPV and measles vaccines in 1963. This decline also coincides with adoption of the VAA.

[27] Regressions with infant death rates control for the general fertility rate for women ages 15 to 44.

The VAA authorized Section 317 of the Public Health Service Act to form the National Immunization Program at CDC (1963) (Guyer et al., 2000). These live-virus vaccines are associated with reductions in mortality and morbidity for infectious diseases not targeted by the vaccines. The phenomenon is termed *non-specific effects* in the clinical literature. I explore this mechanism further when analyzing the effects of the Salk trial on infant mortality. Finally, the coefficients for the placebo interactions show that the Salk trial had no statistically significant effect on all cause deaths. This result is consistent with the pre-trends presented in figure 4 and is consistent with the parallel trends assumption holding between Salk trial and candidate counties.

Non-specific effects and infant mortality

In the clinical literature there is evidence that live virus vaccines, such as measles and OPV, may increase protection against pathogens in children. Live virus vaccines such as BCG, the Sabin OPV, and measles vaccine are associated with reductions in neonatal and early childhood mortality (Benn et al., 2020).[28] Smallpox vaccination (Vaccinia) is associated with protections against measles, scarlet fever, and syphilis (Mayr, 2004; Sørup et al., 2011). After the introduction of the BCG vaccine in Sweden researchers found reductions in infant mortality that could not be explained by the vaccine itself (Naeslund, 1932). Randomized controlled trials in Guinea-Bissau and Senegal find that the standard live measles vaccine and live BCG vaccine induce beneficial health effects in young children (Benn et al., 2013). [29]

The flexible differences in differences for infant mortality per 1,000 births in figure 9

[28]There is also some evidence that vaccinations against smallpox using live vaccines affects mortality risks later in adulthood. Rieckmann et al. (2016) use the phase out of mandatory smallpox and tuberculosis vaccines to study the effects of childhood vaccination on adult mortality. Using a cohort of Copenhagen students born between 1965 and 1976, they find reductions in age specific mortality risk that cannot be explained by vaccine specific protections.

[29]Within the context of the COVID-19 pandemic, researchers have hypothesized that the BCG vaccine might reduce suggestibility to the coronavirus (Miller et al., 2020). These observations may be due to spuriously correlated factors that affect pandemic transmission and research using migration flows in Germany suggest that BCG coverage does not affect COVID-19 transmission (Bluhm and Pinkovskiy, 2020).

does not find strong relationship between Salk trial participation and reductions in infant mortality in the 1950s. Infants were inoculated against polio and other pathogens during this period. This includes both the Salk vaccine and OPV. I find there are statistically significant declines in infant mortality starting in 1963. The dip in 1963 coincides with VAA funding becoming available. This decline in infant mortality persists for the rest of the 1960s and intensifies with the enactment of Medicaid in 1965.[30] Even with the pretrend correction, infant mortality in Salk counties appear to be lower on average than in non-Salk counties and 1952 stands out in particular.

Together, the flexible differences in differences support the hypothesis that counties that experienced the Salk trial had greater vaccine uptake of subsequent vaccines introduced in the 1950s and early 1960s. The decline in all cause deaths and influenza/pneumonia mortality during the subsequent waves of the H2N2 epidemic suggests greater resilience towards the disease. Since an effective H2N2 vaccine was available in these later years, it is plausible that Salk trial counties had greater influenza vaccine coverage than non-trial counties. Similarly, the sharp decline in all cause deaths in 1963 suggests that Salk trial counties were better able to utilize Federal VAA funding and had greater coverage of trivalent OPV and measles vaccines.

Non-natural deaths

Since deaths from suicides, homicides, vehicle accidents, and other accidents should not be associated with Salk trial participation, I repeat analysis using deaths from non-natural causes in figure 10 as a falsification exercise. Furthermore, deaths from these causes should be relatively unaffected by subsequent immunization campaigns, changing behaviors towards preventative health care, and subsequent expansions in public health care under President Johnson. There appears to be no discernible difference in the evolution of non-natural mortality for trial and non-trial counties. This evidence lends

[30]State adoption of the Medicaid program started in 1966. By 1972 all states except Arizona had adopted Medicaid.

credibility to the main results and suggests that trial participation is not associated with underlying trends in mortality.

Alternative specifications and polio mortality

In this section I perform a set of difference in difference regressions using either 1955 or 1963 as the years the difference indicator for Salk trial participation turns on. Table 9 presents the effect of trial participation on all-cause mortality per 1,000 residents. Specifications (1) through (3) measure the post 1954 effect of participation on deaths and highlights a negative effect, specifications (4) through (6) present the effect using a post 1962 indicator, specifications (7) through (9) include both indicators flexibly as an additive spline. The coefficients range between -0.138 and -0.154 of the post 1954 effect and is statistically significant at the 10% level. Most of the reductions in mortality coincide with the post 1962 indicator and the coefficients range between -0.155 and -0.219 and are statistically significant at least at the 5% level.

This reduction in all-cause mortality parallels the results in the flexible difference in difference regression. All-cause mortality in trial counties began trending downward starting in 1957. There is a discrete drop in mortality starting in 1963. This gap continues to widen as Great Society programs expand access to medical care starting in the mid-1960s. Taking the most restrictive specification, specification (9), I add the two coefficients together, -0.149 and -0.211, and multiply them by the underlying county population in trial counties for each year from 1962-1970. Summing these values across trial counties and years suggests that trial counties experienced 109,530 fewer deaths from 1963 to 1970 than would have otherwise occurred.[31]

The Salk trial themselves shifted and expanded the provision of medical services. Areas touched more by this NFIP effort shifted more toward public provision of medical services. Declines in mortality coincide with subsequent expansions in health care access

[31]The cumulative population of trial counties in 1950 was approximately 25.1 million and non-trial counties was 24.9 million. Using the 1950 baseline for the population the deaths prevented is 72,230.

in the 1960s. The magnitude of total mortality reduction is substantial and greatly exceeds the number of deaths from polio experienced in these counties prior to the vaccine. In an average year from 1946 to 1953, trial counties experienced approximately 363 polio deaths. Trial counties were more likely to host polio clinics in 1957. States where more of the population participated in the trial had more NFIP and total Salk vaccine provided by 1960. Newspapers in trial counties were more likely to report the presence of vaccine clinics both under the PVAA and the first year of the VAA. Finally, the experiences with the Salk trial may have affected both the provision and uptake of live virus vaccines that have broad non-specific effects on immunity such as the measles vaccine and OPV.

Repeating this exercise for infant mortality in table 10 reveals similar results. Reduction in infant mortality per 1,000 births (by residence) decreases after the licensing of live virus vaccines in 1962 and enactment of the VAA. Specification (9) suggests that trial participation results in 1.253 fewer deaths per 1,000 births after 1962. Parents vaccinating infants with the OPV and measles vaccines could in part explain this result. Summing the effect up over years suggests that from 1963 to 1970, trial participation reduced the number of infant deaths in trial counties by approximately 7,400. The results for deaths by non-natural causes in table 11 did not find a statistically significant relationship.

Polio deaths are available in U.S. Vital Statistics at the county level from 1946 to 1957. In table 12 I regress the outcomes of polio deaths per 1,000 residents and the probability a county experiences a polio death on post 1954 trial participation indicator variable. Trial participation reduced the number of polio deaths in trial counties by approximately 0.004 deaths per 1,000 residents. For the probability of a polio death there are negative but no statistically significant coefficients.

6 Conclusion

The Salk vaccine trial preceded the first Federal intervention in childhood inoculation and Great Society programs such as Medicaid or Medicare. The trial was unique in that they provided hundreds of thousands of children protective shots against a potentially crippling infectious disease. This trial was not only an experiment seeking to study the efficacy of a novel vaccine but was also a major public relations campaign for the National Foundation for Infantile Paralysis polio eradication campaign. This paper finds that Salk trial participation is associated with declines in mortality greater than what can be explained by reductions in polio infections alone.

The declines in mortality associated with the Salk trial coincide with the availability of new vaccines. These include i) the H2N2 influenza vaccine first introduced in late 1957, ii) the live OPV vaccines of 1961/1963, and iii) the live measles vaccine of 1963. The first decline in mortality occurs during the subsequent waves of the H2N2 Asian influenza pandemic. The second decline in mortality coincides with the single dose trivalent OPV, measles vaccine, and Federal funding for childhood inoculation. This result corroborates the clinical literature on the non-specific effects of live virus vaccines.

The Salk vaccine trial took place during a period when the role governments played in providing direct medical services was limited. Six years prior, the American Medical Association and trade unions stopped a legislative effort to create a national public health insurance program. This meant that medical services were the purview of the private sector. The NFIP upended this trend with its trial. It mobilized hundreds of thousands of volunteers, coordinated with public health departments, and used public schools as a mechanism to deliver direct medical services to the public. These efforts changed the role governments played in the provision of medical services and allowed trial counties to take greater advantage of subsequent interventions and expansions in public health. Counties that participated in the 1954 Salk trial were more likely to host Salk vaccine

clinics and large-scale vaccination programs. These efforts involved the coordination and cooperation of governmental entities and civic organizations. Locations closer to trial locations also reported increased public provision of vaccines. States with greater rates of participation in the trial also reported more vaccine shipments and shots administered per capita. These effects appear to persist as trial counties experience greater declines in mortality than their peer counties after Federal programs expanding access to medical care reappears and new novel vaccines are introduced in the 1960s.

The results of this paper reveal that large scale vaccination campaigns can have lasting public health effects and affect how medical services are provided. The Salk polio vaccine trial in 1954 involved a first-of-its-kind collaboration between schools and county health boards to deliver thousands of vaccines. The experiences and infrastructure from the trial may have had lasting effects on public vaccine provision in an era when vaccination was a private personal purchase. Furthermore, the trial may have increased trust in vaccines and caused people to adopt new vaccines more rapidly once they were introduced. These potential mechanisms require further research and examination. As governments work to distribute massive quantities of novel COVID-19 vaccines, there is an opportunity to use these vaccination campaigns to build trust in preventative medicine and combat the growing problem of vaccine hesitancy. Evidence from the US's polio eradication campaign highlights how successful public health interventions can enhance the success of subsequent public health interventions and reduce mortality.

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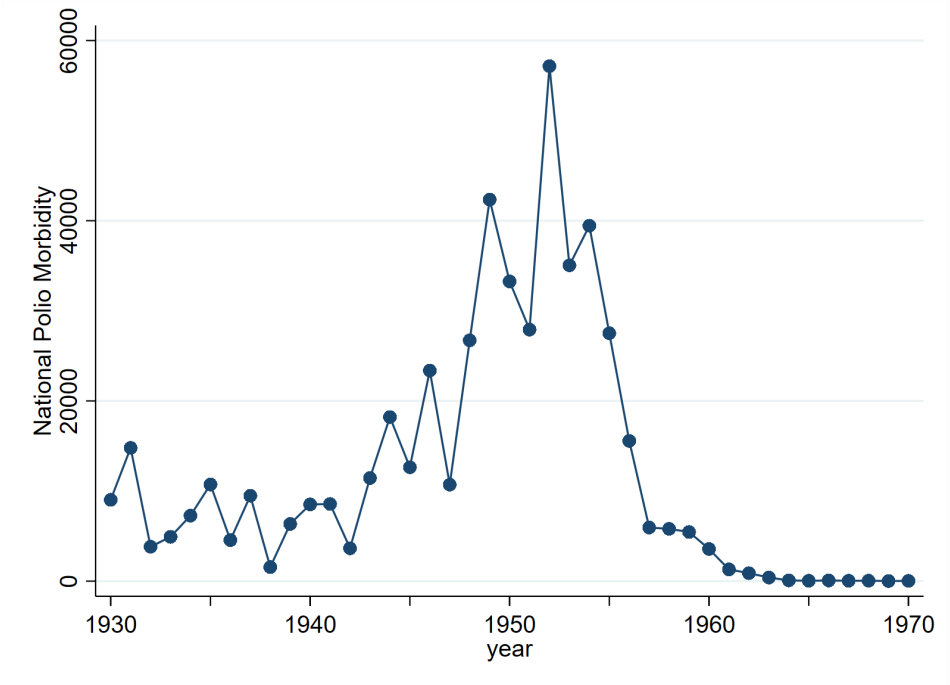

Figure 1: Polio morbidity in the US. Source: Author's tabulation of Project Tycho data

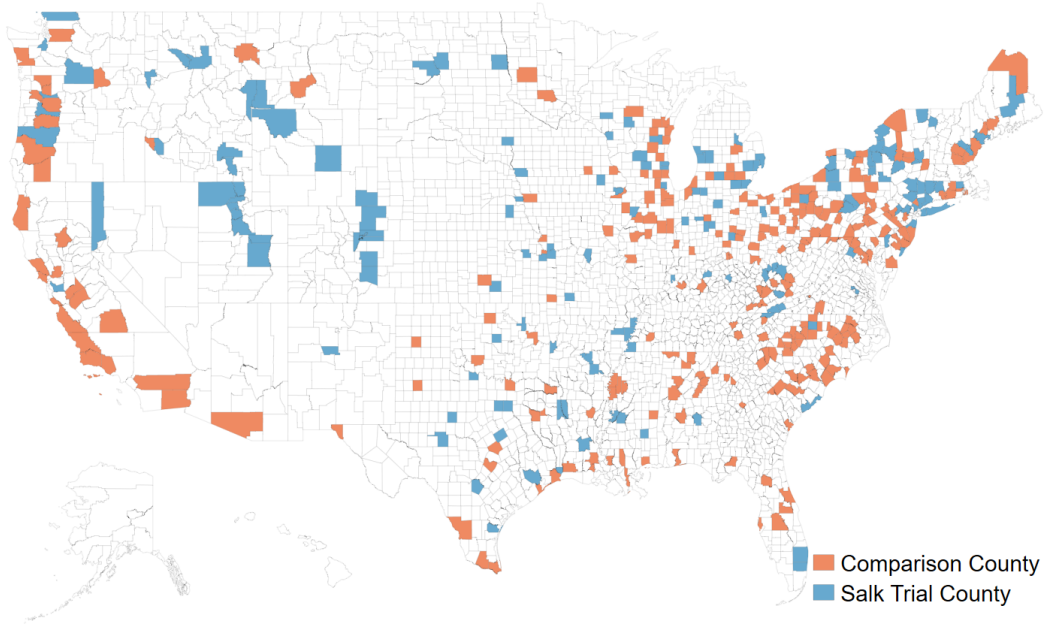

Figure 2: Salk trial and comparison counties. Source: Author's tabulation of (Francis et al., 1957)

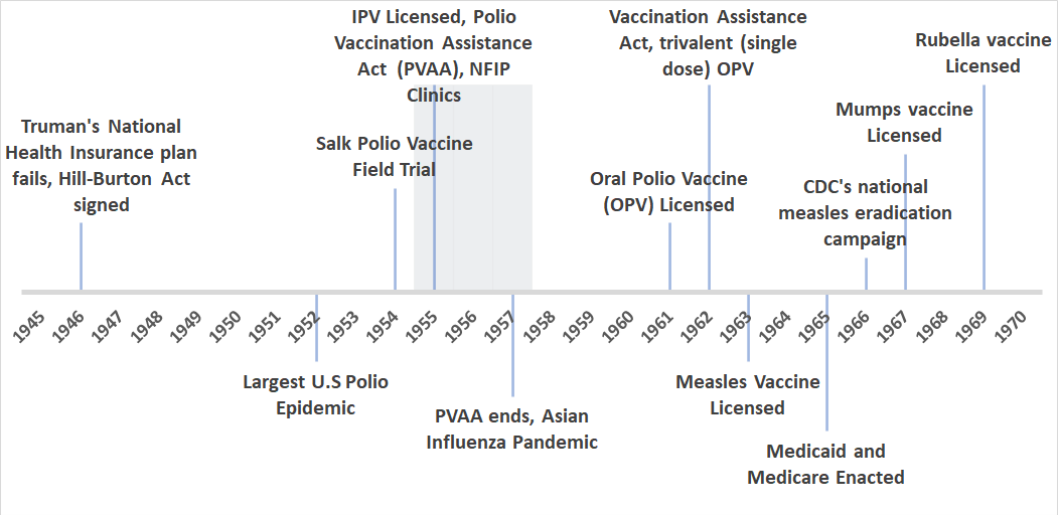

Figure 3: Timeline of key vaccine and health events, 1945-1970

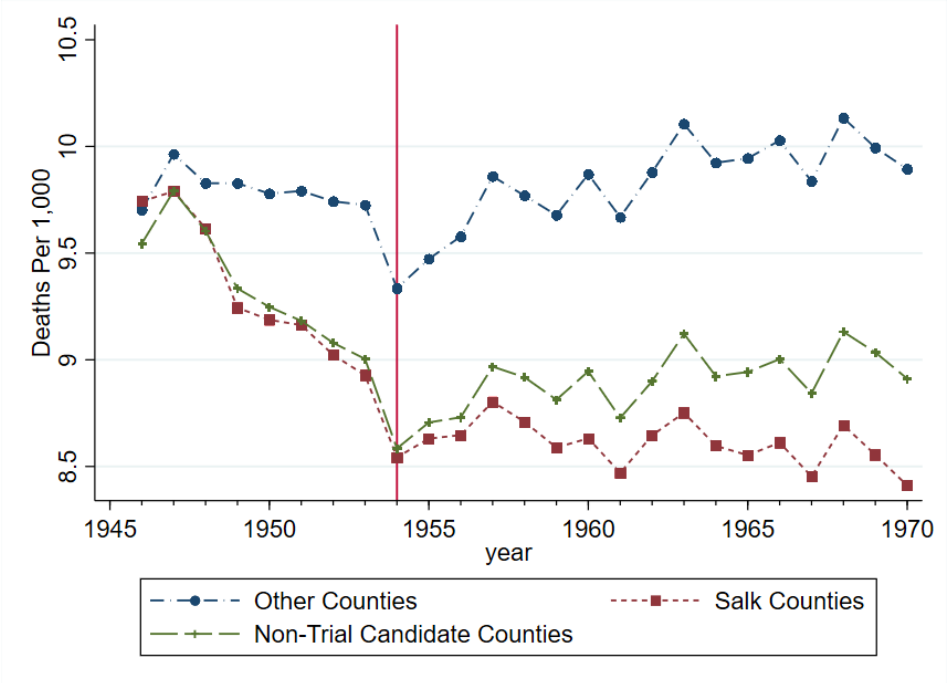

Figure 4: Average annual all cause death rate per 1,000, 1946-1970 by Salk trial participation status

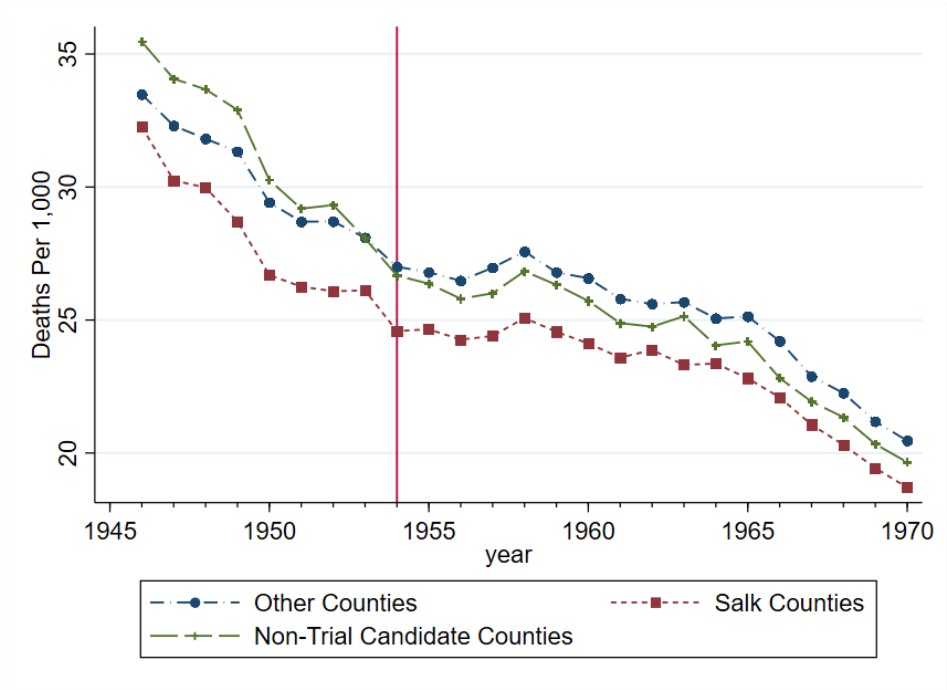

Figure 5: Average annual infant death rate per 1,000 births, 1946-1970 by Salk trial participation status

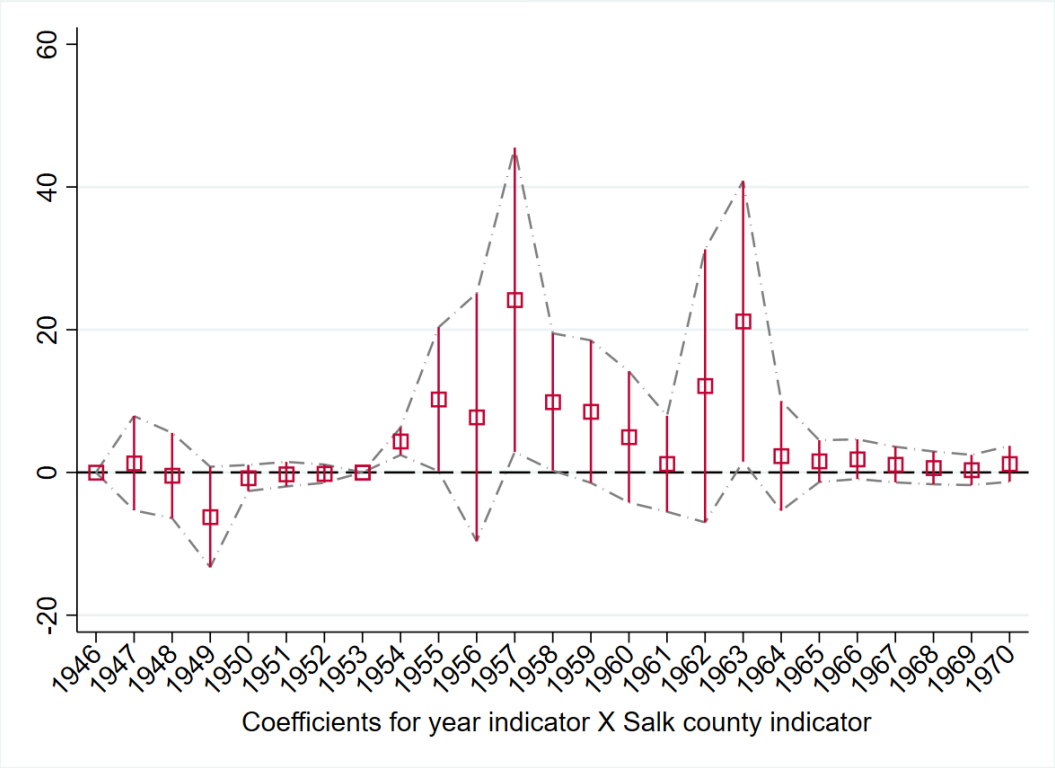

Figure 6: Flexible differences in differences coefficients, regression coefficients and 95%CI, newspaper page mentions of terms related to vaccine clinics and Salk trial participation, 1950-1970. Trial and candidate counties.

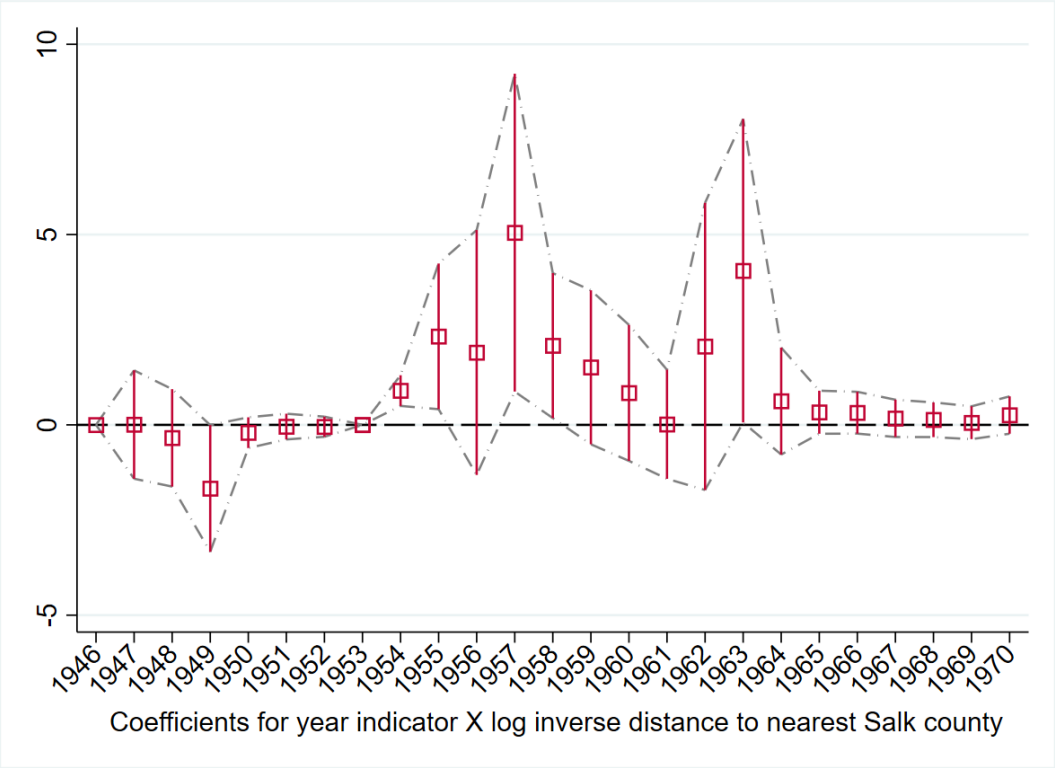

Figure 7: Flexible differences in differences coefficients, regression coefficients and 95%CI, newspaper page mentions of terms related to vaccine clinics and log distance to the nearest Salk trial county, 1950-1970. Trial and candidate counties.

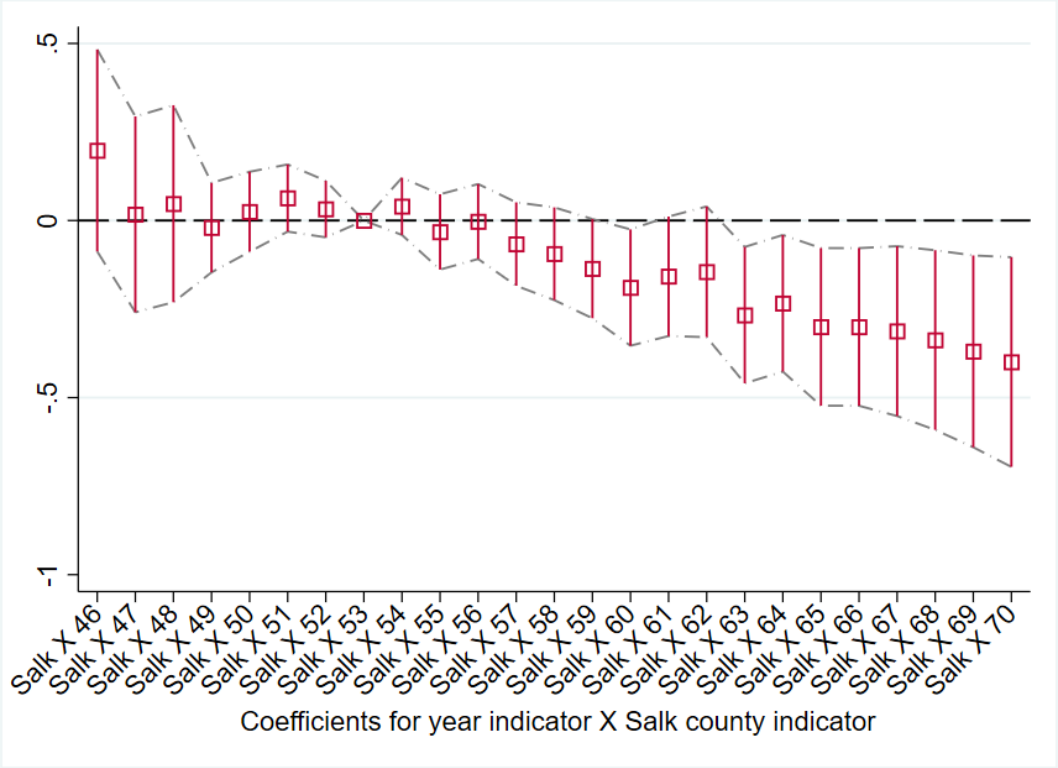

Figure 8: Effect of Salk trial participation on all cause death rate per 1,000, regression coefficients and 95%CI

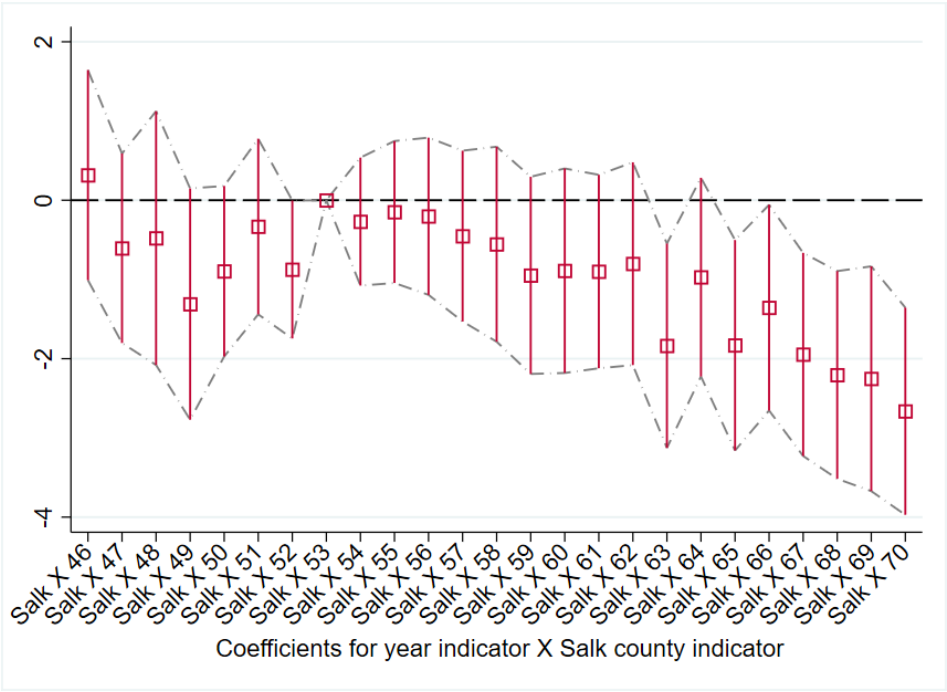

Figure 9: Effect of Salk trial participation on infant deaths per 1,000 births, regression coefficients and 95%CI

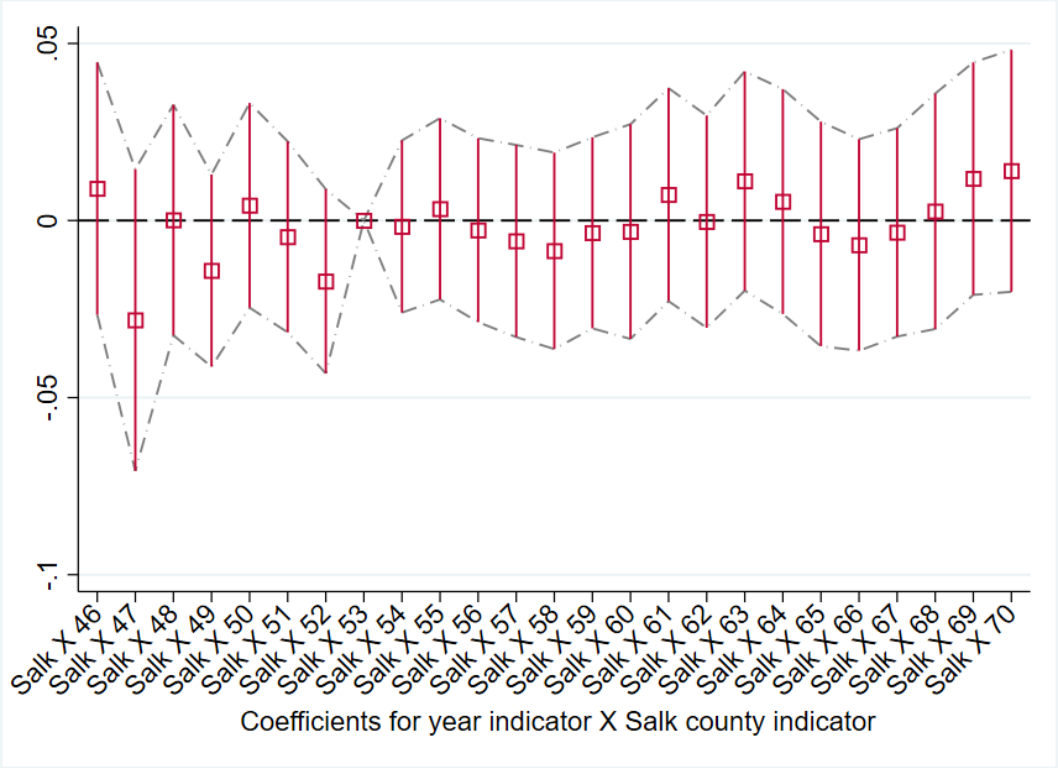

Figure 10: Effect of Salk trial participation on non-natural death rate per 1,000, regression coefficients and 95%CI

Table 1: Summary statistics, newspapers and vaccination programs

Variable	Mean	Std. Dev.	Min.	Max.	N
Newspapers.com Records					
# of mentions	11.209	37.203	0	882	5063
number of pages	18937.563	19928.46	1	155594	5063
ln(inv. dist. to nearest trial)	-2.657	2.319	-6.533	0	5063
State level Salk trial participation measure					
% age 5/10 vaccinated, 1954	0.025	0.023	0	0.111	49
% age 5/10 in trial, 1954	0.109	0.097	0	0.403	49
NFIP programs, per child					
vaccine injections, Dec 31, 1955	0.948	0.289	0.332	1.596	47
vaccine shipped cc, Dec 31, 1955	0.404	0.126	0.123	0.739	49
vaccine shipped cc, Sept 30, 1960	0.789	0.288	0.381	2.124	49
PVAA programs, per child					
vaccine shipped cc, Nov 4, 1955	1.616	0.368	1.09	2.8	49
vaccine shipped cc, Nov 30, 1956	2.811	0.734	0.384	5.003	44
PVAA expend., Dec 31, 1955	0.326	0.243	0	1.121	43
PVAA expend., 1957	2.738	0.812	0.358	5.003	44
Total vaccine shipments, per child					
Total vaccine shipped cc, Dec 31, 1955	1.439	0.303	0.674	2.003	47
Total vaccine shipped cc, Nov 30, 1956	4.135	0.728	2.785	6.266	49
Total vaccine shipped cc, Sept 30, 1960	16.528	4.045	9.975	28.818	49

Table 2: Newspaper page mentions of terms related to vaccine clinics and Salk trial participation, 1946-1970

	(1)	(2)	(3)	(4)
salkX1[1954-1957]	14.5205**	12.2153**	12.2094**	13.6441***
	(6.0778)	(5.4962)	(5.5021)	(4.8319)
salkX1[1958-1962]	10.6038*	7.9109	7.9289	7.0091
	(5.4045)	(4.8083)	(4.8421)	(5.1759)
salkX1[1963-1970]	6.1320**	4.6543**	4.5561**	4.8759**
	(2.4556)	(2.1786)	(2.2632)	(2.0051)
Observations	5069	5063	5063	16246
Adjusted R^2	0.362	0.410	0.411	0.353
county FE	yes	yes	yes	yes
year FE	yes	no	no	no
regionXyear FE	no	yes	yes	yes
census controls	no	no	yes	yes

Specifications (1) to (3) include on Salk trial counties and counties not in the trial but with populations between 50,000 and 200,000 residents in 1950. Specification (4) includes all counties with newspapers in the Newspapers.com archives for the 1950 to 1970 time period. All standard errors are clustered at the county level. $*p \leq 0.1, **p \leq 0.05, ***p \leq 0.01$.

Table 3: Newspaper page mentions of terms related to vaccine clinics and log inverse distance to the nearest Salk trial county, 1946-1970

	(1)	(2)	(3)	(4)
ln(inv. dist.)X1[1954-1957]	3.5100***	2.7441**	2.7433**	2.8631***
	(1.2233)	(1.0620)	(1.0644)	(0.8488)
ln(inv. dist.)X1[1958-1962]	2.2889**	1.4964	1.4974	0.4841
	(1.1358)	(0.9594)	(0.9674)	(1.4799)
ln(inv. dist.)X1[1963-1970]	1.4604***	0.9849**	0.9863**	1.0378***
	(0.5192)	(0.4372)	(0.4539)	(0.3586)
Observations	5069	5063	5063	16246
Adjusted R^2	0.363	0.411	0.411	0.353
county FE	yes	yes	yes	yes
year FE	yes	no	no	no
regionXyear FE	no	yes	yes	yes
census_controls	no	no	yes	yes

Specifications (1) to (3) include on Salk trial counties and counties not in the trial but with populations between 50,000 and 200,000 residents in 1950. Specification (4) includes all counties with newspapers in the Newspapers.com archives for the 1950 to 1970 time period. All standard errors are clustered at the county level. $*p \leq 0.1, **p \leq 0.05, ***p \leq 0.01$.

Table 4: County polio programs, effect of trial participation on local vaccination programs in 1957

	(1) program	(2) program	(3) program	(4) program
trial county	0.068*	0.101***		
	(0.037)	(0.031)		
ln(inv. dist.)			0.014*	0.019***
			(0.008)	(0.006)
Observations	448	3101	448	3101
Adjusted R^2	0.190	0.229	0.188	0.228
mean dependent	0.138	0.043	0.138	0.043
mean independent	0.388	0.057	-2.732	-4.435
std. dev. independent	0.488	0.233	2.246	1.265

The outcome of interest is a binary variable denoting whether a county reported hosting county/city level vaccination programs in 1957. Specifications (1) and (2) measure the effect of 1954 trial participation on the probability of a county hosting a program in 1957. Specifications (3) and (4) use the log inverse distance to the nearest Salk vaccine trial county to measure the effect. All regressions control for state fixed effects and cluster standard errors at the state level. Specifications (2) and (4) include all counties. Specification (1) and (3) limit the sample to trial counties and those with populations between 50,000 and 200,000 residents in 1950. $*p \leq 0.1, **p \leq 0.05, ***p \leq 0.01$.

Table 5: NFIP vaccination program: relationship between trial participation rates and privately provided Salk vaccine per capita

	(1) # shots 1955	(2) cc NFIP 1955	(3) cc NFIP 1960	(4) # shots 1955	(5) cc NFIP 1955	(6) cc NFIP 1960
% vaccinated, 1954	3.548*	0.561	3.777***			
	(2.093)	(0.574)	(1.347)			
% in trial, 1954				1.004**	0.132	0.906***
				(0.488)	(0.132)	(0.252)
Observations	46	48	48	46	48	48
Adjusted R^2	0.000	0.232	0.025	0.039	0.232	0.031

All variables are rates per the number of persons ages 5 to 10 in 1954. This was the initial target group for the Salk vaccine during polio eradication campaign starting in 1955. All regressions include four Census region fixed effects and include robust standard errors. Outcome (1) and (4) reports the cumulative number shots administered per capita in a given state in 1955. Outcomes (2),(3), (5) and (6) report the cumulative cc's per capita of Salk vaccine supplied by the NFIP. $*p \leq 0.1, **p \leq 0.05, ***p \leq 0.01$.

Table 6: PVAA vaccination program: relationship between trial participation rates and federally supported activities per capita

	(1) cc PVAA 1955	(2) cc PVAA 1957	(3) PVAA $ 1955	(4) PVAA $ 1957	(5) cc PVAA 1955	(6) cc PVAA 1957	(7) PVAA $ 1955	(8) PVAA $ 1957
% vaccinated, 1954	-4.308*	-6.533*	0.723	-6.651*				
	(2.320)	(3.859)	(0.912)	(3.645)				
% in trial, 1954					-1.180**	-1.719*	0.095	-1.716**
					(0.541)	(0.935)	(0.225)	(0.848)
Observations	48	44	42	44	48	44	42	44
Adjusted R^2	0.416	0.114	0.107	0.000	0.444	0.127	0.103	0.010

All variables are rates per the number of persons ages 5 to 10 in 1954. This was the initial target group for the Salk vaccine during polio eradication campaign starting in 1955. All regressions include four Census region fixed effects and include robust standard errors. Outcome (1) and (5) reports the cumulative cc's of Salk vaccine per capita supplied by the PVAA in 1955. Outcome (2) and (6) denote the value for 1957, the last year PVAA funding was provided. Outcome (4) and (7) denote PVAA expenditures per capita in 1955 and outcome (4) and (8) denote the final expenditures per capita in 1957. $*p \leq 0.1, **p \leq 0.05, ***p \leq 0.01$.

Table 7: Total Salk vaccine shipments: relationship between trial participation rates and cc of total vaccine per capita

	(1) cc IPV 1955	(2) cc IPV 1956	(3) cc IPV 1960	(4) cc IPV 1955	(5) cc IPV 1956	(6) cc IPV 1960
% vaccinated, 1954	0.413	7.241*	52.122**			
	(1.926)	(3.818)	(22.678)			
% in trial, 1954				0.197	1.508	13.055**
				(0.467)	(1.010)	(5.256)
Observations	46	48	48	46	48	48
Adjusted R^2	0.017	0.252	0.360	0.021	0.243	0.379

All variables are rates per the number of persons ages 5 to 10 in 1954. This was the initial target group for the Salk vaccine during polio eradication campaign starting in 1955. All regressions include four Census region fixed effects and include robust standard errors. Outcomes denote the total cumulative cc's of Salk vaccine per capita shipped to a state in 1955, 1956, and by 1960. $*p \leq 0.1, **p \leq 0.05, ***p \leq 0.01$.

Table 8: Summary statistics, VSUS sample

Variable	Mean	Std. Dev.	Min.	Max.	N
all cause deaths per 1k	8.897	1.878	3.31	21.182	10950
non natural deaths per 1k	0.702	0.19	0	5.005	10947
polio deaths per 1k	0.011	0.017	0	0.439	5256
probability of polio death	0.579	0.494	0	1	5256
infant deaths per 1k births	25.077	6.943	0	107.216	10950
births per 1k women 15-44	108.576	36.816	50.955	1203.266	10938
log median income	8.436	0.515	5.07	9.724	10900
percent pop white	0.673	0.323	0.004	1.39	10950
percent pop with hs degree	0.441	0.113	0.098	0.796	10950
percent pop urban	0.722	0.204	0	1	10950
share requesting participation in trial	0.272	0.295	0	0.931	10950
share vaccinated in trial	0.119	0.121	0	0.388	10950

All values are weighted by county population except for the general fertility rate and infant death rate which are weighted by number of births. Log median income is extrapolated out from the 1946 to 1950 based on slope between 1950 and 1960 due to the 1940 Census missing median income data.

Table 9: Difference in differences estimates of Salk trial participation on all cause mortality

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	all cause deaths per 1,000 residents								
salk X post 1954	-0.2711**	-0.2200**	-0.2603**				-0.1544*	-0.1375*	-0.1485*
	(0.1055)	(0.1043)	(0.1013)				(0.0831)	(0.0799)	(0.0784)
salk X post 1962				-0.2915***	-0.2193**	-0.2799***	-0.2187***	-0.1545**	-0.2108***
				(0.0964)	(0.0971)	(0.0946)	(0.0732)	(0.0735)	(0.0728)
Observations	10950	10950	10950	10950	10950	10950	10950	10950	10950
Adjusted R^2	0.857	0.868	0.881	0.858	0.868	0.882	0.858	0.868	0.882
sample	1946/70	1946/70	1946/70	1946/70	1946/70	1946/70	1946/70	1946/70	1946/70
county FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
year FE	yes	no	no	yes	no	no	yes	no	no
regionXyear FE	no	yes	yes	no	yes	yes	no	yes	yes
census ctrls.	no	no	yes	no	no	yes	no	no	yes

Specifications (1) to (3) use a post trial indicator variable that turns on starting in 1955. Specifications (4) to (6) use an indicator variable that turns on in 1963, which coincides with the availability of VAA funding. Specifications (7) to (9) include both indicators in a spline regression. All regressions are weighted by county population. County controls include interpolated log median income, share white, share with high school degree, and share urban from U.S. Censuses. All standard errors clustered by county. $*p \leq 0.1, **p \leq 0.05, ***p \leq 0.01$.

Table 10: Difference in differences estimates of Salk trial participation on infant mortality

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	infant deaths per 1,000 births								
salk X post 1954	-0.0627	-0.5950	-0.7096				0.3472	-0.0808	-0.1225
	(0.6728)	(0.5911)	(0.6556)				(0.6060)	(0.5291)	(0.6047)
salk X post 1962				-0.7067	-1.1291***	-1.3105***	-0.8708***	-1.0909***	-1.2532***
				(0.4755)	(0.4296)	(0.4449)	(0.2745)	(0.2600)	(0.2641)
general fertility rate	0.0074**	0.0119***	0.0139***	0.0076**	0.0121***	0.0141***	0.0075**	0.0121***	0.0141***
	(0.0032)	(0.0033)	(0.0036)	(0.0032)	(0.0032)	(0.0035)	(0.0031)	(0.0031)	(0.0034)
Observations	10938	10938	10938	10938	10938	10938	10938	10938	10938
Adjusted R^2	0.706	0.720	0.859	0.707	0.721	0.860	0.707	0.721	0.860
sample	1946/70	1946/70	1946/70	1946/70	1946/70	1946/70	1946/70	1946/70	1946/70
county FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
year FE	yes	no	no	yes	no	no	yes	no	no
regionXyear FE	no	yes	yes	no	yes	yes	no	yes	yes
census ctrls.	no	no	yes	no	no	yes	no	no	yes

Specifications (1) to (3) use a post trial indicator variable that turns on starting in 1955. Specifications (4) to (6) use an indicator variable that turns on in 1963, which coincides with the availability of VAA funding. Specifications (7) to (9) include both indicators in a spline regression. All regressions are weighted by the number of births and control for the general fertility rate of women between 15 and 44. A pre-trend for years before 1954 is fit to the model for trial counties following the methods described in Goodman-Bacon (2021). County controls include interpolated log median income, share white, share with high school degree, and share urban from U.S. Censuses. All standard errors clustered by county. $*p \leq 0.1, **p \leq 0.05, ***p \leq 0.01$.

Table 11: Difference in differences estimates of Salk trial participation on non-natural mortality

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	non natural deaths per 1,000 residents								
salk X post 1954	0.0001	0.0080	0.0071				0.0006	0.0039	0.0041
	(0.0095)	(0.0090)	(0.0087)				(0.0084)	(0.0081)	(0.0082)
salk X post 1962				-0.0006	0.0095	0.0075	-0.0009	0.0077	0.0056
				(0.0095)	(0.0087)	(0.0080)	(0.0087)	(0.0078)	(0.0073)
Observations	10947	10947	10947	10947	10947	10947	10947	10947	10947
Adjusted R^2	0.663	0.681	0.686	0.663	0.681	0.686	0.663	0.681	0.686
sample	1946/70	1946/70	1946/70	1946/70	1946/70	1946/70	1946/70	1946/70	1946/70
county FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
year FE	yes	no	no	yes	no	no	yes	no	no
regionXyear FE	no	yes	yes	no	yes	yes	no	yes	yes
census ctrls.	no	no	yes	no	no	yes	no	no	yes

Specifications (1) to (3) use a post trial indicator variable that turns on starting in 1955. Specifications (4) to (6) use an indicator variable that turns on in 1963, which coincides with the availability of VAA funding. Specifications (7) to (9) include both indicators in a spline regression. Non-natural deaths are defined as those resulting from suicides, homicides, and accidents inclusive of car accidents. All regressions are weighted by county population. County controls include interpolated log median income, share white, share with high school degree, and share urban from U.S. Censuses. All standard errors clustered by county. $*p \leq 0.1, **p \leq 0.05, ***p \leq 0.01$.

Table 12: Difference in differences estimates of Salk trial participation on polio mortality, 1946-1957

	(1)	(2)	(3)	(4)	(5)	(6)
	polio deaths per 1,000 residents			polio death indicator		
salk X post 1954	-0.0037**	-0.0044***	-0.0037***	-0.0539	-0.0269	-0.0285
	(0.0015)	(0.0013)	(0.0013)	(0.0627)	(0.0589)	(0.0586)
Observations	5256	5256	5256	5256	5256	5256
Adjusted R^2	0.187	0.222	0.223	0.295	0.314	0.314
county FE	yes	yes	yes	yes	yes	yes
year FE	yes	no	no	yes	no	no
regionXyear FE	no	yes	yes	no	yes	yes
census ctrls.	no	no	yes	no	no	yes

This sample uses data from U.S. Vital Statistics tables for polio deaths of residents of counties. By 1958 polio deaths had declines so much that these deaths were no longer reported at the county level. All regressions are weighted by county population. County controls include interpolated log median income, share white, share with high school degree, and share urban from U.S. Censuses. All standard errors clustered by county. $*p \leq 0.1, **p \leq 0.05, ***p \leq 0.01$.

Table 13: Relationship between county characteristics in 1950 and pre-trial polio mortality and selection in to Salk trial

	(1)	(2)	(3)	(4)
	Probability in Salk Polio Vaccine Trial			
polio deaths per capita, 1948-1952	0.4015	0.4812	0.0572*	0.0455
	(0.3604)	(0.3294)	(0.0315)	(0.0311)
log population		0.1495***		0.0790***
		(0.0543)		(0.0117)
log median income		0.0753		-0.0222
		(0.1562)		(0.0161)
percent white		-0.1798		-0.0036
		(0.1714)		(0.0201)
percent high school degree		0.0076**		0.0044***
		(0.0037)		(0.0009)
percent urban		-0.2065		-0.0045
		(0.1513)		(0.0284)
Constant	0.3369***	-1.9476	0.0488***	-0.6767***
	(0.0293)	(1.1680)	(0.0029)	(0.1685)
Observations	433	433	3038	3038
Adjusted R^2	0.247	0.290	0.065	0.208

Specifications (1) and (2) restrict the sample to trial counties and those with populations between 50,000 to 200,000. Specifications (3) and (4) include all counties. All regressions control for state fixed effects and standard errors clustered by state. $*p \leq 0.1, **p \leq 0.05, ***p \leq 0.01$.

Appendix

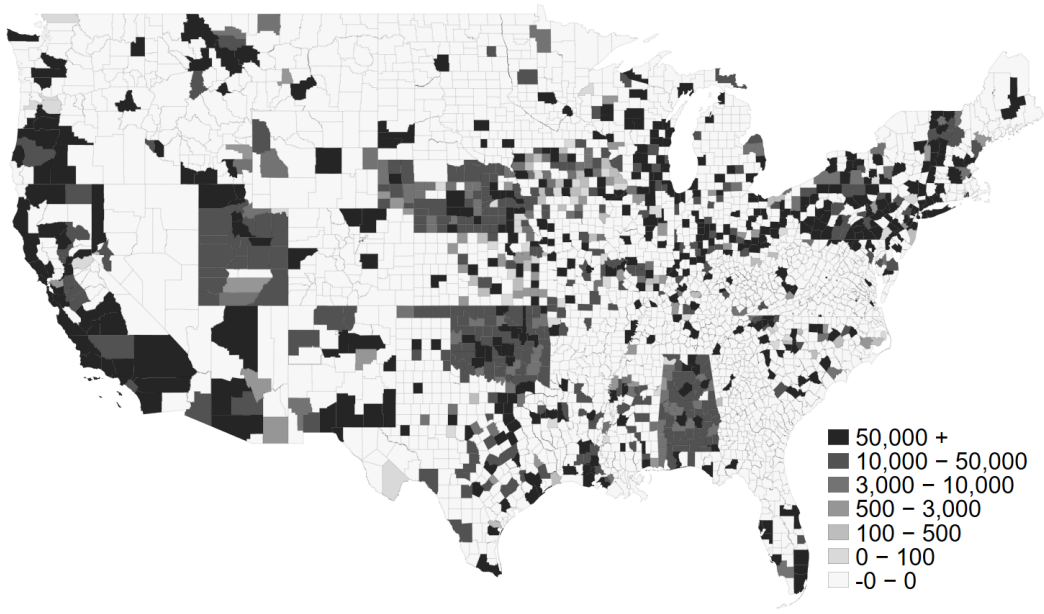

Figure A1: Number of Newspapers.com pages available from 1946-1970

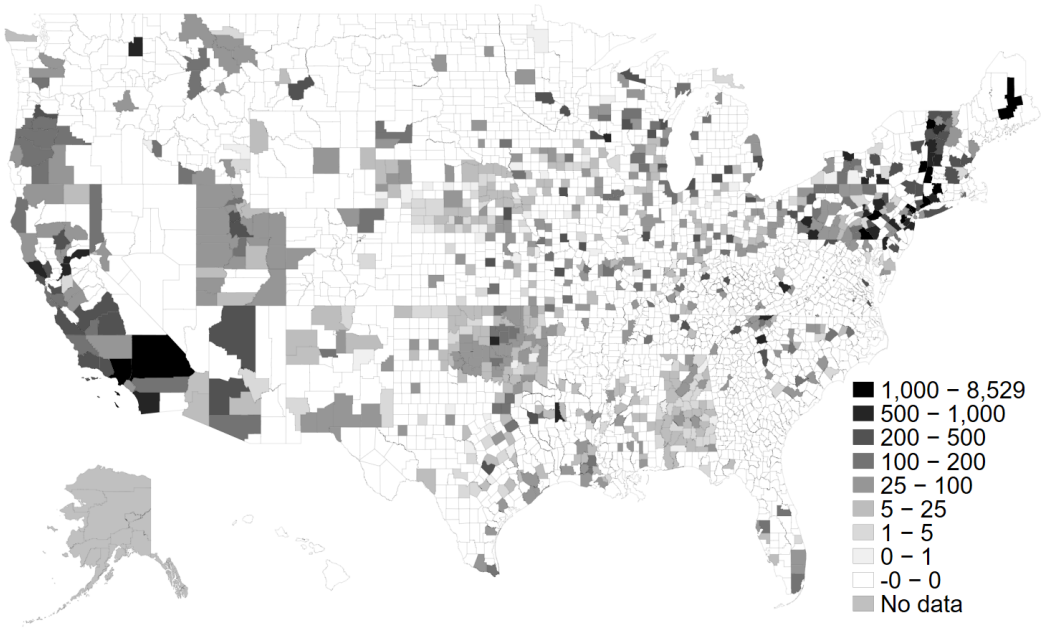

Figure A2: Number of vaccine clinic related newspaper page mentions, 1946 to 1970

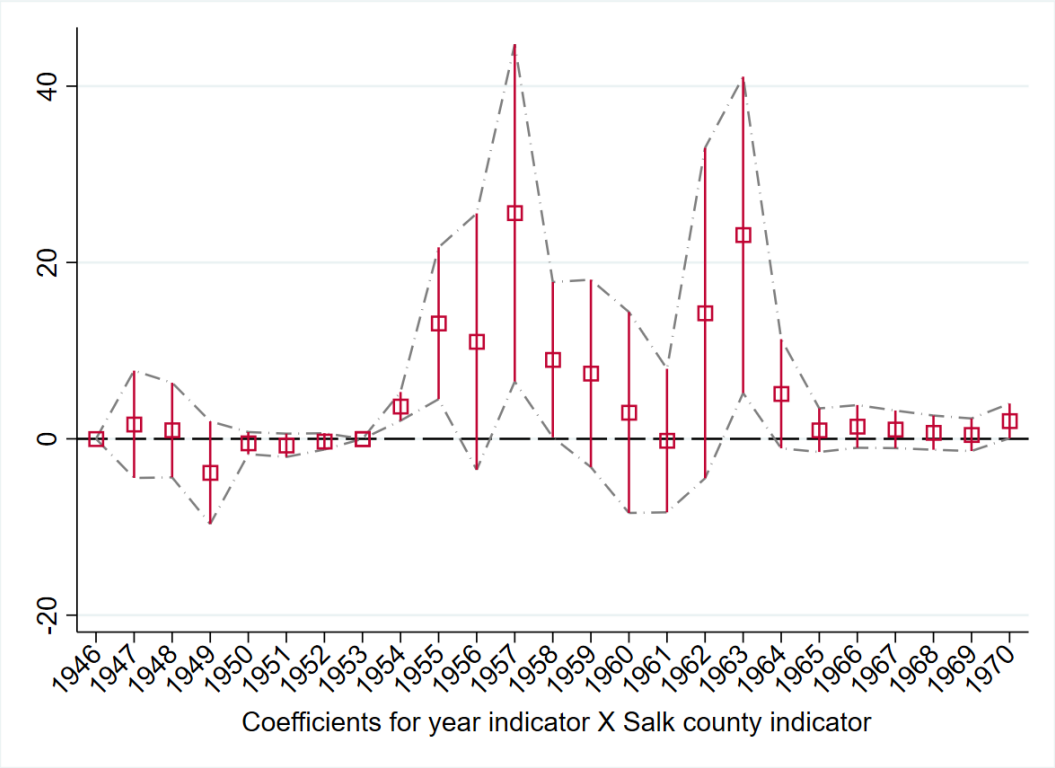

Figure A3: Flexible differences in differences coefficients, regression coefficients and 95%CI, newspaper page mentions of terms related to vaccine clinics and Salk trial participation, 1950-1970. All counties.

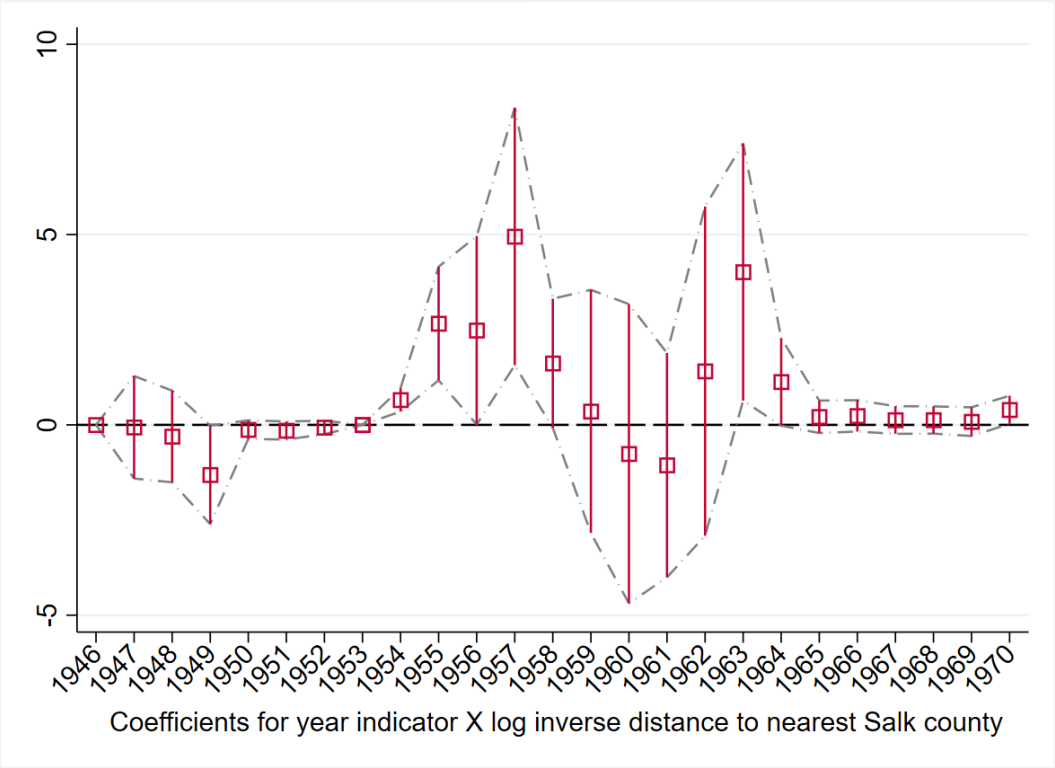

Figure A4: Flexible differences in differences coefficients, regression coefficients and 95%CI, newspaper page mentions of terms related to vaccine clinics and log distance to the nearest Salk trial county, 1950-1970. All counties.

Table A1: NFIP vaccination program: relationship between trial participation rates and NFIP provided IPV, logs

	(1) ln(shots) 1955 (1)	(2) ln(cc NFIP) 1955 (2)	(3) ln(cc NFIP) 1960 (3)	(4) ln(shots) 1955 (4)	(5) ln(cc NFIP) 1955 (5)	(6) ln(cc NFIP) 1960 (6)
% vaccinated, 1954	3.076	2.588	4.556***			
	(2.372)	(1.818)	(1.557)			
% in trial, 1954				0.857	0.614	1.020***
				(0.549)	(0.429)	(0.338)
ln(population)	0.969***	1.039***	0.949***	0.977***	1.044***	0.957***
	(0.056)	(0.056)	(0.069)	(0.055)	(0.058)	(0.071)
Observations	46	48	48	46	48	48
Adjusted R^2	0.882	0.902	0.902	0.884	0.902	0.901

All regressions control for the log number of persons ages 5 to 10 in 1954. This was the initial target group for the Salk vaccine during polio eradication campaign starting in 1955. All regressions include four Census region fixed effects and include robust standard errors. Outcome (1) and (4) reports the log cumulative number shots administered in a given state in 1955. Outcomes (2),(3), (5) and (6) report the log cumulative number cc's of Salk vaccine supplied by the NFIP.

* p 0.1 ** p 0.05 *** p 0.01

Table A2: PVAA vaccination program: relationship between trial participation rates and log PVAA activities

	(1) ln(cc PVAA) 1955	(2) ln(cc PVAA) 1957	(3) ln(PVAA $) 1955	(4) ln(PVAA $) 1957	(5) ln(cc PVAA) 1955	(6) ln(cc PVAA) 1957	(7) ln(PVAA $) 1955	(8) ln(PVAA $) 1957
% vaccinated, 1954	-3.014*	-2.157	3.744	-2.292				
	(1.543)	(1.520)	(4.722)	(1.464)				
% in trial, 1954					-0.859**	-0.555	0.428	-0.570
					(0.378)	(0.434)	(1.166)	(0.408)
ln(population)	0.955***	0.961***	0.851***	0.952***	0.946***	0.956***	0.844***	0.947***
	(0.034)	(0.031)	(0.133)	(0.029)	(0.027)	(0.029)	(0.139)	(0.029)
Observations	48	44	41	44	48	44	41	44
Adjusted R^2	0.974	0.870	0.506	0.786	0.977	0.870	0.501	0.786

All regressions control for the log number of persons ages 5 to 10 in 1954. This was the initial target group for the Salk vaccine during polio eradication campaign starting in 1955. All regressions include four Census region fixed effects and include robust standard errors. Outcome (1) and (4) reports the cumulative cc's per capita of Salk vaccine supplied by the PVAA in 1955. Outcome (2) and (5) denote the rate for 1957, the last year PVAA funding was provided. Outcome (3) and (6) denote PVAA expenditures per capita in 1955 and outcome (4) and (8) denote the final expenditures rate for 1957.
* p 0.1 ** p 0.05 *** p 0.01

Table A3: Total Salk vaccine shipments: relationship between trial participation rates and log cc of IPV

	(1) ln(cc IPV) 1955	(2) ln(cc IPV) 1956	(3) ln(cc IPV) 1960	(4) ln(cc IPV) 1955	(5) ln(cc IPV) 1956	(6) ln(cc IPV) 1960
% vaccinated, 1954	-0.095	1.746*	3.166**			
	(1.751)	(0.888)	(1.311)			
% in trial, 1954				0.023	0.383	0.845**
				(0.411)	(0.241)	(0.327)
ln(population)	0.969***	1.009***	1.033***	0.970***	1.011***	1.041***
	(0.033)	(0.022)	(0.035)	(0.034)	(0.020)	(0.029)
Observations	46	48	48	46	48	48
Adjusted R^2	0.940	0.977	0.968	0.940	0.977	0.970

All variables are rates per the number of persons ages 5 to 10 in 1954. This was the initial target group for the Salk vaccine during polio eradication campaign starting in 1955. All regressions include four Census region fixed effects and include robust standard errors. Outcomes denote the log total cumulative cc's of Salk vaccine shipped to a state in 1955, 1956, and by 1960.
* p 0.1 ** p 0.05 *** p 0.01