State Enforcement of School Immunization Requirements and Child Vaccination Rates*

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Abstract

Child vaccination rates have fallen below the threshold for herd immunity in many states, prompting concerns over exposure to infectious disease outbreaks. In response, several states have repealed non-medical vaccine exemptions for children in school. We estimate that state repeal of non-medical exemptions raised kindergarten vaccination rates by 2 to 4 percentage points, with little substitution toward medical vaccine exemptions. We test whether state audits further increased vaccination rates using school-level data from California. We find no effect of auditing on future likelihood of audit or vaccination rates. Our results suggest that amidst growing vaccine hesitancy, state repeal of non-medical exemptions is effective at keeping vaccination rates high.

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1 Introduction

Child vaccination rates in the U.S. are on the decline (Figure 1). In 39 states, the measles vaccination rate for kindergartners has fallen below 95 percent, a commonly cited threshold for herd immunity (Fine et al. 2011). A direct result of falling vaccination rates is that young children today are increasingly vulnerable to infectious disease outbreaks (Omer et al. 2009). Despite the fact that the Centers for Disease Control and Prevention (CDC) declared measles eliminated in 2000, notable outbreaks have recently occurred in several states. In 2025, Texas witnessed the first measles death in over a decade (Shastri and Seitz 2025).

One reason that vaccination rates are declining is because more children in school are receiving vaccine exemptions. Most states allow parents to opt their children out of required vaccines on personal, philosophical, or religious grounds (Blank et al. 2013). The nationwide rate of vaccine exemptions among kindergartners rose from 1 percent in 1991 to over 3 percent in 2023 (Omer et al. 2006). This trend is consistent with rising vaccine hesitancy, particularly since the Covid-19 pandemic. According to a Gallup poll conducted in 2024, 20 percent of adults think that vaccines are more dangerous than the diseases they prevent, up from 6 percent in 2001 (Jones 2024).

In this paper, we study how state policies to enforce school vaccination requirements affect child vaccination rates. In response to rising vaccine hesitancy and several highly publicized disease outbreaks, four states repealed non-medical vaccine exemptions for schoolchildren in the last decade.[1] We use data from the CDC and an event study design to show that repeal of non-medical exemptions caused overall exemptions to fall by 4 percentage points. We observe little substitution toward medical exemptions in response to repeal. We hypothesize that state control over the issuance of medical exemptions was effective at limiting this margin of substitution.

Kindergarten vaccination rates rose within two years following non-medical exemption repeal. Results show an increase of 2 percentage points for Hepatitis B vaccination and 4 percentage points for DTaP, MMR, and Polio vaccination. We demonstrate the robustness of our results to different sample definitions, controls, and event study estimators. Effects are similar during the Covid-19 pandemic, which suggests that state exemption policy plays a critical role in keeping vaccination

[1] The states and respective years of repeal are California (2015), Connecticut (2021), Maine (2019), and New York (2019). See Appendix B for details on state legislation.

rates high. In the face of rising vaccine hesitancy, all four states that restricted exemptions in the past decade were above the 95 percent threshold for herd immunity in 2023.

While state restrictions on vaccine exemptions can compel families to vaccinate their children, state enforcement may be necessary to ensure compliance. We use the example of the California Department of Education, which began conducting immunization audits in 2021. The goal of the audits was to ensure that unvaccinated students were excluded from school attendance calculations, which can affect school funding. Audits were targeted to schools with greater than 10 percent vaccine non-compliance among kindergarten students. We explore the effects of auditing using the 10 percent threshold in a regression discontinuity (RD) design. We find no evidence of improved vaccine compliance in future years for schools at the audit threshold. We conclude that state enforcement of immunization and attendance rules, while important for proper allocation of state funding, does not raise itself raise vaccination rates.

This paper contributes to several strands of literature. Prior papers study the effects of changing state vaccination and exemption requirements (Abrevaya and Mulligan 2011; Lawler 2017; Delamater et al. 2017; Richwine et al. 2019; Carpenter and Lawler 2019; Hair et al. 2021; Correira et al. 2024). The paper most closely related to ours is Richwine et al. (2019), which examines the removal of California non-medical exemptions in 2015. Our contribution is to examine the complete set of exemption policy changes over the prior decade using CDC data and innovations in event study methodology (Callaway and Sant'Anna 2021). Furthermore, we add a novel analysis of schools audits as one component of state immunization policy.

We contribute to broader work on the take-up of preventative healthcare. In the case of rising vaccine hesitancy, more individuals may perceive the costs of vaccination as greater than the benefits conferred by immunity (Bauch and Bhattacharyya 2012). Financial incentives to become vaccinated (in the context of Covid-19 vaccination) have been shown to be ineffective (Chang et al. 2021). Vaccination recommendations can be effective in settings where new vaccines are recommended by official organizations, as was the case with the roll-out of Hepatitis A (Lawler 2017). Other studies find that recommendations are effective when they come from laypeople but not from healthcare experts (Ho et al. 2022; Alsan and Eichmeyer 2024).[2] We consider the direct approach of several

[2] For studies on behavioral approaches to increase take-up of preventative care, see Rutter et al. (2006), Loewenstein et al. (2007), Chapman et al. (2010), and Milkman et al. (2011).

states to eliminate the personal exemption entirely. Vaccination rates rise quickly following repeal, in part because medical exemptions are tightly controlled by the states.

This paper proceeds as follows. Section 2 describes the historical context and modern policy landscape for state vaccination requirements. Section 3 discusses the data sources. Section 4 provides the estimation strategy and results for the impact of non-medical exemption repeal on exemption and vaccination rates. Section 5 reports results for the effect of immunization audits in California on vaccine non-compliance. Section 6 concludes.

2 Background

2.1 Vaccine Exemptions

States have required children attending school to be vaccinated since the mid 19$^{\text{th}}$ century. The smallpox vaccine was developed in 1796, and Massachusetts began the first state to require inoculation in 1855 (Holtkamp 2020). In the early 20$^{\text{th}}$ century, as secondary schooling became widely available, public health officials were concerned with disease spread in the classroom (Duffy 1974; Meckel 2013). During this period, more state and local governments passed vaccination mandates. Enforcement of compulsory vaccination laws was held to be within the power of states to protect public health (*Jacobson v. Massachusetts 1905*). Smallpox vaccination mandates succeeded in lowering smallpox rates and improved educational outcomes (Holtkamp 2020). However, these efforts also generated short-lived anti-vaccination backlash (Brehm and Saavedra 2024).

Over the course of the 20$^{\text{th}}$ century, new vaccines were developed and added to the required immunization schedule for schoolchildren. By 1980, all states mandated vaccination, with various exemptions in place (Omer et al. 2009). The scope of these exemptions has been a constant in health policy debates (Salmon et al. 2005; Bednarczyk et al. 2019; Colgrove 2023). All states allow medical exemptions, which are meant for children with severe allergies or other conditions that make vaccination risky. Such exemptions must be signed by a licensed healthcare provider, typically a physician, nurse practitioner, or physician assistant. By contrast, there exists substantial variation in state policies regarding non-medical (personal, philosophical, or religious exemptions) exemptions. Non-medical exemptions might require parents to sign a form, obtain signatures from school officials, or watch an informational video. Blank et al. (2013) find that in states where obtaining an exemption is more difficult, exemption rates are lower. This suggests that even minor changes to the exemption process can affect vaccination coverage.

Figure 2 plots the categories of non-medical exemptions allowable for children in each state as of 2024. California, Connecticut, Maine, New York, and West Virginia do not allow any non-medical exemptions. Remaining states vary in the types of exemptions they accept. It is important to note that changes to vaccine exemption policies are frequently proposed in state legislatures, even if few are signed into law. Nearly all of the enforced changes to state policy in the period that we study (2011-2023) have made exemptions harder to obtain. Prior to our study period, in 2003, Texas and Arkansas had to revise their laws to allow personal beliefs exemptions following challenges in federal court (Salmon et al. 2005; Hair et al. 2021). In 2023, Mississippi's exemption policy was challenged and religious exemptions were allowed for the first time.[3]

In this paper, we focus on total repeal of non-medical exemptions since 2015, beginning with California. In 2015, California experienced a substantial outbreak of measles originating in Orange County, which prompted the state to repeal non-medical exemptions (Richwine et al. 2019). Since then, Connecticut, New York, and Maine have all followed suit (in 2021, 2019, and 2019, respectively).[4] We motivate our empirical strategy by showing the raw trends in non-medical exemptions in Appendix Figure A.1, Panel (a) for the 2011 to 2023 period. Following repeal, the rate of non-medical exemptions falls to zero mechanically. By plotting the trend for states that never repeal non-medical exemptions (never-treated states), we can see parallel trends in exemptions prior to repeal. In Panel (b), we show the trends for MMR vaccination. Relative to never-treated states, states that repealed non-medical exemptions see increases in MMR vaccination. Vaccination rates converge to that of Mississippi and West Virginia, two states that never allowed non-medical exemptions (plotted in black). The staggered repeal and changes in raw trends observed here motivate the empirical strategy in Section 4.

[3] Though 2023 was the first school year that religious exemptions were allowed in Mississippi, the number of religious exemptions surpassed the total number of medical exemptions (see here).

[4] We note here several other policy changes that fell short of total repeal. Washington changed its exemption policy in 2019, when it repealed the personal exemption for MMR only. In 2015, Vermont repealed philosophical exemptions, but not religious exemptions. Since these policy changes were not total repeals, we consider Washington and Vermont as "never-treated" states in Section 4.2, and show that our results are robust to excluding these two states.

2.2 State Audits

The long-run success of vaccination policy relies on continued enforcement of school vaccination requirements. Without enforcement, some schools might have high rates of vaccine non-compliance and remain well below the threshold for herd immunity. One possible enforcement mechanism is state-conducted audits.

The California Department of Education began conducting audits in 2021. The purpose of these audits was not necessarily to improve vaccine compliance, but to ensure schools were properly reporting student attendance. The relevant measure of attendance for school funding allocation in California is average daily attendance (ADA). ADA is calculated as the total days of student attendance divided by the total number of instruction days. Students that are not compliant with state immunization requirements must be excluded from ADA, and California conducts audits to ensure that this exclusion is taking place. The potential punishment for schools over-reporting student attendance is that school funding payments may be withheld or rescinded.[5] We hypothesize that audits may prompt schools to prevent future audits by increasing vaccination rates.

3 Data Sources

3.1 State Vaccine Exemption Laws

We identify changes to state exemption laws using LexisNexis (via the National Conference of State Legislatures).[6] We examine each state's legislative text to verify the provisions of new laws and we report these details in Appendix B. We are primarily concerned with changes concerning non-medical vaccine exemptions since 2015, including complete repeal, partial repeal, or other modifications.

3.2 State Vaccination and Exemption Rates

We obtain state vaccination and exemption rates from the CDC's National Center for Immunization and Respiratory Diseases (CDC 2024).[7] States report vaccination rates to the CDC for children in kindergarten, a common checkpoint that states use to enforce school immunization requirements.

[5] See here for details from the California Department of Public Health.
[6] See information on exemptions provided by NCSL here.
[7] See the CDC's webpage here.

States differ in how they measure vaccination and exemption rates, with some states using a full kindergarten census and others using various sampling procedures. The benefit of CDC data is that it aggregates estimates from all states, allowing us to study vaccine policy changes across many states and years. From these data, we construct a panel of statewide kindergarten vaccination and exemption rates covering the 2011 to 2023 school years.[8]

The kindergarten data include coverage for the following vaccines: Diphtheria, tetanus, acellular pertussis (DTaP); Hepatitis B; Measles, mumps, rubella (MMR); Poliovirus (Polio); and Varicella. Coverage is defined by the states and indicates the percent of kindergarten students who are up-to-date according to state regulations.[9] We focus our analysis on DTaP, Hepatitis B, MMR, and Polio, excluding Varicella due to differences in how states report children with prior infection. The CDC data also contain overall exemptions rates, categorized into medical and non-medical exemptions.[10] Some states are partially missing outcome data for the 2011-2023 period. To construct the main analysis sample used in Section 4, we restrict the data to form a balanced panel of states for each outcome from 2011 to 2023.[11]

3.3 State and County Characteristics

We measure economic conditions using state unemployment rate, sourced from the Bureau of Labor Statistics. We measure demographics using the Surveillance, Epidemiology, and End Results (SEER) Program at the National Cancer Institute. County-level population files are used to estimate state racial composition in each year.

[8] We begin the panel in 2011 because many states are missing CDC data from 2009 and data from 2010 are unavailable. The most recent school year with available CDC data is 2023. The data also contain the CDC's national estimates of vaccine coverage, which we use to produce the time series in Figure 1.

[9] For instance, in the 2023-24 school year, kindergarten students were considered up-to-date for DTaP if they had received 3 doses in Nebraska, 4 doses in Kentucky, Maryland, Wisconsin, or Wyoming, and 5 doses in remaining states (Seither et al. 2024).

[10] Apart from vaccination and exemption, there is a third group of students that are non-compliant (not fully vaccinated with no exemption filed). Some states record these students as "provisionally enrolled" if they are on track to complete vaccination within a set time frame (also known as a grace period). A limitation is that vaccination records are reported to the CDC at a single point in time (often in the fall, but assessment dates vary across states). It is not possible to known whether students who were non-compliant at the time of assessment completed all required vaccinations or filed an exemption.

[11] We allow the set of states to vary for each outcome and subsequently verify that this does not affect our results. The final number of states included in the estimation is 38 for DTaP, 37 for Hepatitis B, 39 for MMR, 39 for Polio, 43 for overall exemptions, 42 for medical exemptions, and 43 for non-medical exemptions.

3.4 Dataset of California Schools

We construct a dataset of California schools in order to study how immunization audits affect vaccine compliance. The California Department of Education maintains a directory of schools, with information on school type, grades served, and enrollment. We merge this directory to annual school-level data from the California Department of Public Health from 2010 to 2022. This merge provides rates of vaccination, exemption, and non-compliance, as well as audits starting in 2021.

To assess the impact of audits, we construct a sample of public California elementary schools with available immunization data in both 2021 and 2022 (as far as we are aware, no private schools were audited). Schools may not have available immunization data in both 2021 and 2022. The primary reason is that immunization data for schools with fewer than 20 kindergarten students is suppressed, so many small schools are dropped from the sample. By merging this sample of schools to audit records, we can observe how the first round of audits in 2021 affected vaccine compliance and likelihood of audit in 2022. We do not currently observe data beyond the 2022 school year, nor do we observe the outcome of individual audits.

4 Non-Medical Exemption Repeal and State Vaccination Rates

4.1 Estimation Strategy

The staggered repeal of vaccine exemptions over time lends itself to an event study approach, where treated (repeal) states are compared to untreated (non-repeal) states before and after repeal. Define T_s^* as the first school year after the repeal of non-medical exemptions in state s. For instance, New York signed its exemption repeal on June 13^{th}, 2019, effective for the 2019-20 school year. Maine signed its repeal in May 2019, but the repeal did not take effect until the 2021-22 school year. We assign treatment year $T_s^* = 2019$ for both New York and Maine. This allows us to see how vaccination rates respond dynamically to the passage of legislation, even before legislation takes effect. Similarly, we assign $T_s^* = 2015$ for California and $T_s^* = 2021$ for Connecticut.[12] For additional details on state legislation, see Appendix B.

We estimate the following event study specification:

$$y_{st} = \theta_s + \delta_t + X_{st} + \sum_{e=-5}^{-2} \pi_e D_{st}^e + \sum_{e=0}^{4} \beta_e D_{st}^e + \varepsilon_{st}, \tag{1}$$

where y_{st} is the vaccination or exemption rate in state s and school year t, θ_s is a vector of state fixed effects, δ_t is a vector of school year fixed effects, X_{st} is a vector of time-varying controls, and ε_{st} is an error term. The binary indicator $D_{st}^e = \mathbf{1}[t - T_s^* = e]$ is equal to 1 when state s in year t is e years away from initial treatment year T_s^*. The coefficients π_e for $e \in \{-5, -2\}$ measure whether treated states trended differently than untreated states two to five years prior to treatment. Similarly, the coefficients β_e for $e \in \{0, 4\}$ measure the treatment effect e years after treatment. The π_e and β_e coefficients are relative to $e = -1$. We estimate equation (1) with and without controls for state unemployment rate, percent Hispanic, and percent Black. For inference, we report standard errors clustered at the state level.

Recent literature has emphasized several concerns with the event study approach in equation (1), also known as a dynamic two-way fixed effects (TWFE) specification. Much of the concern revolves around how to construct a relevant comparison group for treated units, how to interpret estimates in the presence of dynamic and/or heterogeneous treatment effects, and how to test for parallel trends.[13] Our approach is to estimate equation (1) using the methodology of Callaway and Sant'Anna (2021). We report results using never and not-yet treated states as controls and show the sensitivity of our estimates to alternative approaches. In addition, rather than reporting a single TWFE estimate that aggregates across periods, we prefer to report the full set of dynamic effects.

[12] To obtain unbiased estimates, difference-in-differences requires a "no anticipation" assumption (Baker et al. 2025). In our setting, this requires that families did not change vaccination behavior prior to the passage of the law. We find this assumption plausible given the short time frame of vaccine legislation. California's bill was introduced in February of 2015 and signed in June, leaving no scope for families to respond prior to the 2015 school year (which we code as the first post-treatment year). Likewise, Connecticut's bill was introduced in February of 2021 and signed in April, Maine's bill was introduced in February of 2019 and signed in May, and New York's bill was introduced in January of 2019 and signed in June.

[13] See, for instance, de Chaisemartin and D'Haultfœuille (2020), Goodman-Bacon (2021), Sun and Abraham (2021), Roth (2022), and Borusyak et al. (2024).

4.2 Results: Exemption Rates

We start by plotting how exemption rates respond to legislation. Figure 3, Panel (a) plots estimates of β_e, the effect of state repeal on the rate of total vaccine exemptions in each post-repeal school year e (in red). The removal of non-medical exemptions caused the rate of exemptions among kindergartners to drop by 4 percentage points (statistically significant at the 95-percent confidence level). Pre-treatment coefficients π_e show no evidence of a differential pre-trend in treated states prior to repeal (in black). Since non-medical exemptions make up the majority of exemptions, this drop is largely mechanical. As shown in Figure 3, Panel (b), the decline in non-medical exemptions mirrors the decline in total exemptions. In Appendix Figure A.2, we report event study estimates by group following Callaway and Sant'Anna (2021). In our setting, groups are defined as states treated in different years. We report results for states treated in 2015 (California), 2019 (Maine and New York), and 2021 (Connecticut). The effect of exemption repeal is similar across groups despite differences in treatment timing and state characteristics.

In some states, repeals were not immediately enforced. For instance, in Maine, non-medical exemptions were repealed in 2019 ($e = 0$ in our specification) but the law did not take effect until 2021 ($e = 2$). This explains the increasing magnitude of the exemption coefficients observed in Figure 3, Panels (a) and (b). We can see further evidence of these dynamics in Appendix Figure A.2. Panel (a) shows that non-medical exemptions didn't fall until 2016 when California's law took effect. Similarly, Maine's 2019 law didn't take effect until 2021, which explains the increase in magnitude of treatment effects observed in that year in Panel (c). In 2021 (Panel (e)), Connecticut's law took effect immediately, but allowed families flexibility when complying with state requirements.

Medical exemptions are still allowable in all states as of 2024. As discussed in Richwine et al. (2019), if medical and non-medical exemptions are easily substituted, we might observe a rise in medical exemptions once non-medical exemptions are repealed. We examine this hypothesis in Figure 3, Panel (c). Following the repeal of non-medical exemptions, we observe some degree of substitution toward medical exemptions. Several coefficients are positive and statistically significant post-repeal, however, the magnitudes are small (less than 0.5 percentage points). In Appendix Figure A.2, we see that these effects are driven by California's 2015 repeal (Panel (a)). Notably, at the start of 2021, California ruled that all medical exemptions must be issued and reviewed via the centralized California Immunization Registry (CAIR). In the 2021 school year, the coefficient on medical exemptions is no longer statistically significant.

To summarize the event study results, Table A.1 reports coefficients from equation (1) for overall, non-medical, and medical exemption rates (columns (1)-(3)). We observe insignificant pretrends in exemptions prior to state law passage, followed by a drop in non-medical exemptions as the laws take effect. Relative to the mean exemption rate in treated states, repeal of non-medical exemptions causes the overall exemption rate to fall to nearly zero. The slight uptick in medical exemptions is statistically significant and large relative to baseline. However, as shown in Appendix Figure A.2, this effect is driven by California and does not persist after six years.

We assess the robustness of the event study results in several ways. We first examine robustness to different event study estimators. In Appendix Figure A.3, we show that our results are similar using a variety of different approaches developed in Sun and Abraham (2021), Borusyak et al. (2024), and de Chaisemartin and D'Haultfœuille (2020). We also show that (potentially biased) estimates from a standard TWFE event study are highly similar to our main results. This suggests that the potential issues with staggered treatment adoption are not substantial in our setting. In Appendix Figure A.4, we explore whether our main event study estimates are sensitive to the weighting scheme, sample definition, or controls used. Adding population weights slightly shrinks the magnitude of the treatment effects. Similarly, when we restrict the sample to a uniform set of states across all outcomes, the relative decline in exemptions is smaller. This is consistent with the presence of several small states in the control group that report high exemption rates and are dropped from the uniform sample. The addition of time-varying controls does not change the estimates. Finally, we restrict the set of comparison states in multiple ways. We estimate equation (1) and only include "never-treated" states. We drop partially treated states (Washington and Vermont), which restricted exemptions during the sample period but stopped short of a full repeal (see Appendix B). As a final check, we note that all treated states consistently align with the Democratic party in presidential elections. We restrict to Democrat-leaning states (defined as states that voted for Hillary Clinton in the 2016 presidential election). In all of these robustness checks, we find event study estimates that are similar to our main results in terms of magnitude and statistical significance.

4.3 Results: Vaccination Rates

Figure 4 plots estimates of β_e for several vaccination outcomes. Results in Panel (a) show that following the repeal of non-medical exemptions, DTaP vaccination among kindergartners increased by 4 percentage points relative to comparison states. We observe similar effects for Hepatitis B, MMR, and Polio vaccination (Panels (b)-(d), respectively).[14] Note that while the effect size for Hepatitis B is smaller, the baseline vaccination rate against Hepatitis B is highest among the vaccines that we consider (Figure 1). We account for the fact that the state of Washington repealed exemptions for MMR in 2019. For MMR only, we add Washington to the set of treated states to ensure that we capture the effects of this reform. Similar to the exemption results, we observe no pre-treatment trend in vaccination rates. Event study coefficients are statistically significant at the 95 percent level for all four vaccines.

We conduct the same set of extensions as in Section 4.2. We verify that effects look similar by treatment year (Appendix Figure A.2, Panels (b), (d), and (f)). In California, the anticipation of state enforcement in 2016 raised vaccination rates in the 2015 school year by 1 to 2 percentage points. Similar to the exemption results, the coefficients increase in size as state enforce their exemption repeals. To summarize these results, we report coefficients from equation (1) in Table A.1. We observe insignificant pretrends in vaccinations prior to state law passage, followed by an increase in vaccinations as the laws take effect. Note that we do not observe vaccine-specific exemptions in the CDC data. However, the results imply that most children who were receiving non-medical exemptions in the pre-period were exempt from all vaccines. Exemption repeal therefore increased vaccination rates similarly across the different vaccines. Finally, we show in Appendix Figures A.5 and A.6 that the vaccination results are robust to changing the event study estimator, sample definition, weighting scheme, and controls used.

Our results show that state repeal of non-medical vaccine exemptions has significantly raised vaccination rates among kindergartners.[15] However, in several cases, legislation was passed in

[14] Maine does not require vaccination for Hepatitis B, so we drop Maine from the Hepatitis B sample.

[15] So far, we have focused on students entering kindergarten as the population of interest. In analysis not shown, we test whether state repeal of non-medical exemptions increased vaccination rates for older children. We find no evidence that DTaP, Hepatitis B, MMR, or Polio vaccination rates rose among children ages 13-17. This is likely due to several factors. First, children with pre-existing non-medical exemptions were typically allowed to keep them (see Appendix Section B for details by state). This means that most older children were unaffected by the law changes, and only children newly enrolled in kindergarten are likely to show increased vaccination rates.

response to notable outbreaks of measles (*e.g.*, in California and New York). Oster (2018) and Schaller et al. (2017) show that parental vaccination behavior responds to broader incidence of infectious disease. This behavioral response might be driving a portion of our results. We note that Connecticut did not experience an infectious disease outbreak prior to repeal, and effects for Connecticut are similar to other treated states (Appendix Figure A.2, Panels (e) and (f)). Oster (2018) also shows that parents respond most to outbreaks when their children are very young or about to enter kindergarten. Rather than the observed effects becoming smaller as memory of the outbreak fades, the effects grow and persist for many years. Finally, we might expect the largest behavioral response from parents to be measles vaccination, yet we observe statistically similar effects for DTaP and polio vaccination. In summary, we do not find evidence that suggests our results are driven by parental response to disease outbreak.

We also look for simultaneous policy changes that would complicate the interpretation of our results (Hoehn-Velasco et al. 2024). Mandates for Tdap vaccination in middle school were mostly passed prior to 2015 (Carpenter and Lawler 2019). We find it unlikely that mandates for older children would influence vaccination of children entering kindergarten. Hepatitis A mandates for young children were also passed in many states prior to 2015, and Lawler (2017) finds no evidence of spillover effects on take-up of other vaccines. Importantly, our sample period overlaps with the Covid-19 pandemic and corresponding state Covid-19 policies, which can pose a challenge for difference-in-differences approaches in general (Goodman-Bacon and Marcus 2020). In our context, routine child vaccinations fell during the pandemic as a direct result of pandemic restrictions and the shift to remote instruction (DeSilva et al. 2022). It is possible that the states that repealed exemptions in 2019 would have experienced even larger treatment effects absent the Covid-19 pandemic (see Appendix Figure A.2, Panel (d)). Given that we observe similar treatment effects for California's exemption repeal in 2015, we emphasize that our results generalize beyond the pandemic period.

Second, the vaccination rates for older children come from the National Immunization Surveys (NIS-Teen). See the CDC's TeenVaxView here. These data are generated from phone surveys, so estimates of teen vaccination rates are far noisier than the measured vaccination rates for students in kindergarten. These data also do not contain information on school vaccine exemptions, which limits our ability to understand outcomes for this age group.

5 State Enforcement via Audits

In this section, we explore whether school audits in California since 2021 have increased vaccine compliance beyond the effects of the legislation passed in 2015. We use the structure of audits to identify whether schools that were audited exhibit higher vaccine compliance in future years. The state audited schools with a non-compliance rate greater than 10 percent in 2021. Figure 5 shows the sharp discontinuity in auditing for schools at the 10 percent threshold. The distribution of non-compliance rates is smooth around the threshold, which lies in the upper tail of the distribution. Given that 2021 was the first year of audits, there was little scope for schools to anticipate the audit threshold. Rounding in the public data causes some unaudited schools to appear at or above the threshold. Rather than use a fuzzy regression discontinuity design, we reassign the unaudited schools above the 10 percent audit threshold to just below the threshold. This is equivalent to assuming that California correctly audited all schools and that a sharp regression discontinuity design is appropriate in this setting.

Specifically, we compare schools that were audited (non-compliance greater than 10 percent) with schools that were just below the audit threshold (non-compliance of 10 percent or less):

$$y_s = \gamma_0 + \gamma_1 \mathbf{1}(NC_s > 10) + \gamma_2(NC_s - 10) + \gamma_3 \mathbf{1}(NC_s > 10)(NC_s - 10) + \nu_s, \tag{2}$$

where y_s is the outcome for school s in 2022, $\mathbf{1}(NC_s > 10)$ is an indicator for whether school s was above the audit threshold of 10 percent vaccine non-compliance in 2021, and $(NC_s - 10)$ is the distance of school s from the audit threshold. We include the interaction term $\mathbf{1}(NC_s > 10)(NC_s - 10)$ to allow for a linear relationship between the running variable and the outcome that varies on either side of the threshold.

Figure 6 plots the running variable (non-compliance in 2021), the binned outcome (non-compliance in 2022), and a linear fit above and below the audit threshold. The outcome shows no discontinuity in 2022, which suggests that the audits did not raise vaccine compliance. We test several other outcomes, including likelihood of audit and vaccination rates in 2022. To construct point estimates, we implement equation (2) using optimal bandwidth selection with a triangular kernel (Calonico et al. 2014, 2017). These results are reported in Table A.2. We do not find evidence of a significant difference at the audit threshold for any outcome.

While these results show that immunization audits in California did not raise future vaccine compliance, we do not conclude that the audits were ineffective. The goal of the audits was to enforce proper school enrollment reporting for unvaccinated students. Furthermore, we note several reasons why we might not identify statistically significant effects. Our causal evidence is limited to RD estimates at the audit threshold in 2022, which leaves us with very little effective sample size. It remains a possibility that the threat of audit shifted the entire distribution of schools toward improved compliance. We also note that even if schools try to avoid a future audit, they may have little scope to improve vaccine compliance for incoming kindergarten students.

6 Conclusion

The decline of child vaccination rates has the potential to cause an uptick in cases and deaths from preventable infectious diseases. In this paper, we examine state actions that enforce school vaccination requirements, including the removal of non-medical exemptions and school audits in the state of California. We find robust evidence that the repeal of non-medical vaccine exemptions increased vaccination rates by 2 to 4 percentage points. This effect is sizable enough to keep overall vaccination rates above the commonly cited 95 percent immunity threshold in repeal states. The addition of school immunization audits in California in 2021 did not further raise vaccine compliance.

We highlight several limitations and avenues for future work. Our primary estimates are based on CDC data, which limits our ability to speak to dimensions like disparities in vaccination by race and socioeconomic status. Our audit results are based on only one state, and state efforts that more directly target vaccine non-compliance might be more effective at increasing vaccination rates. We focus primarily on the direct effect of state policy action, however, backlash against legislation might also occur.[16] It is an open question whether families are responding to changing state education and health policy by moving states or choosing to homeschool their children. In the face of rising vaccine hesitancy, state compulsion to vaccinate might strengthen the messaging of anti-vaccination groups. We leave these questions for future research.

[16] In the context of the Covid-19 pandemic, several studies examine the (possibly unanticipated) costs to vaccine mandates (Bardosh et al. 2022; Colgrove 2023; Ferranna et al. 2023; Abouk et al. 2024; Gandhi et al. 2024).

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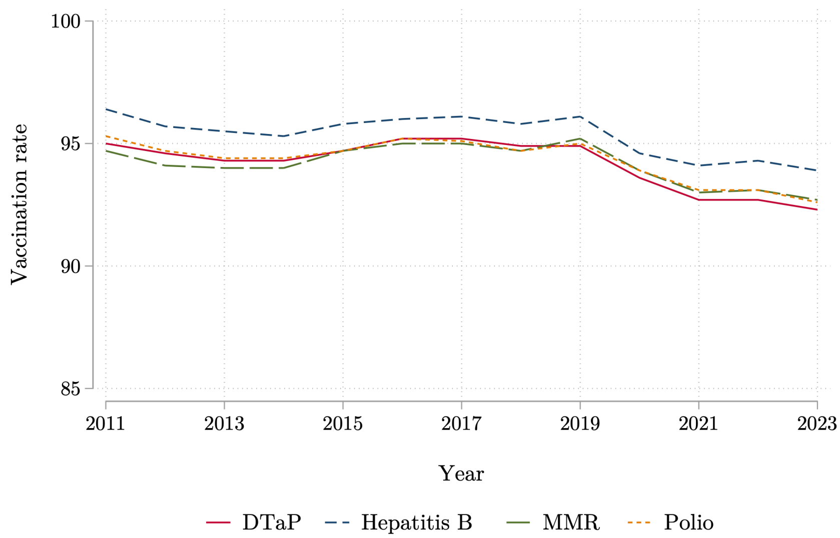
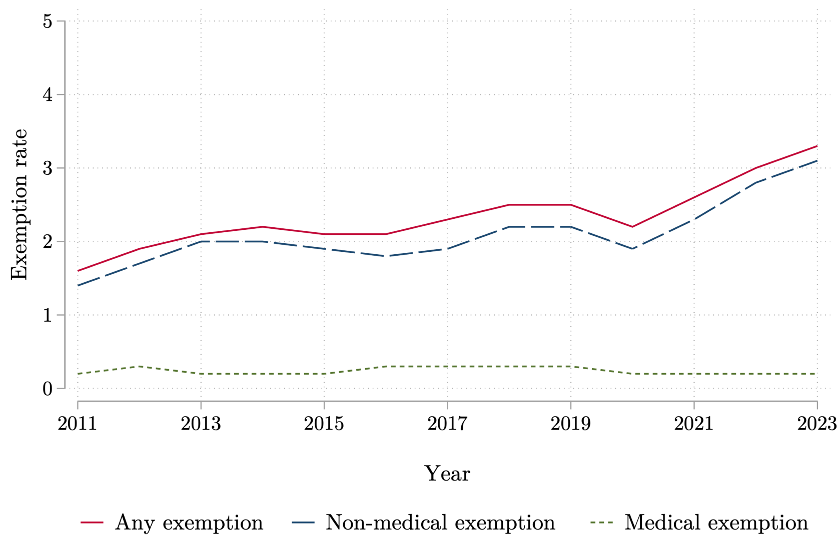
7 Figures

Figure 1: Trends in kindergarten vaccination and exemption rates

(a) Vaccination rates

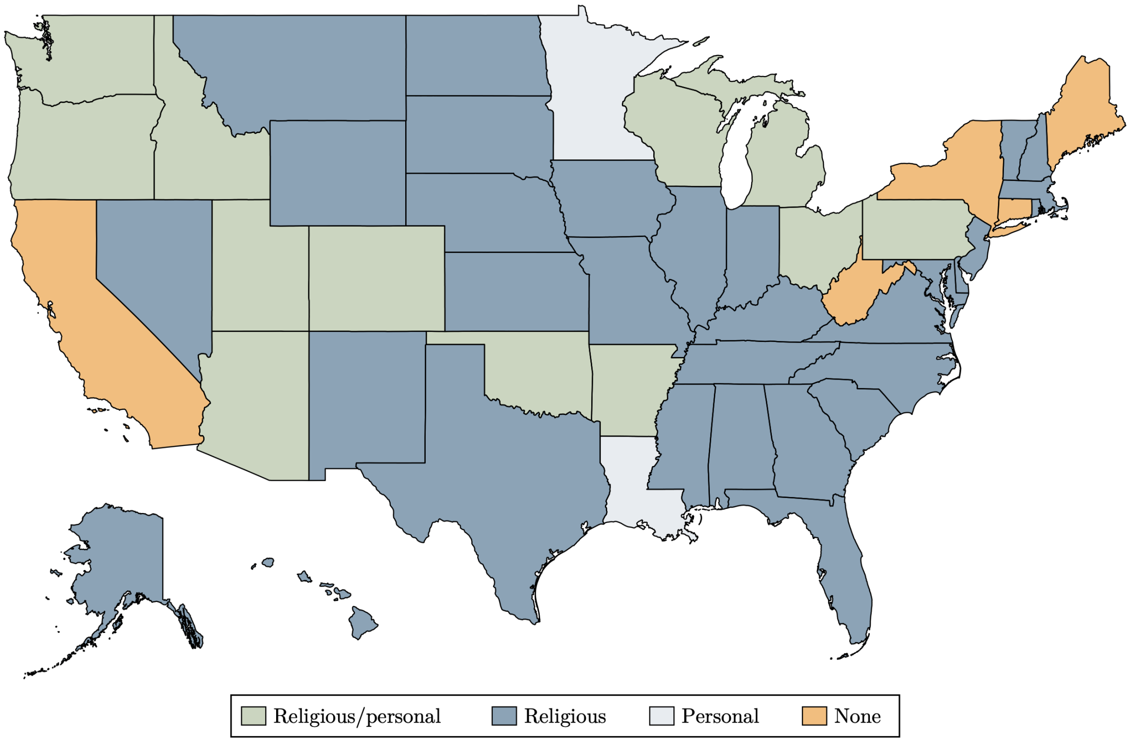


(b) Exemption rates



Notes: Figure shows national trends in vaccination and exemption rates for children entering kindergarten from 2011 to 2023. Vaccination rates are shown for DTaP, HepB, MMR, and Polio. Exemption rates are shown as the total exemption rate and the subcategories of non-medical and medical exemptions. Data are sourced from the CDC (see Section 3.2 for details).

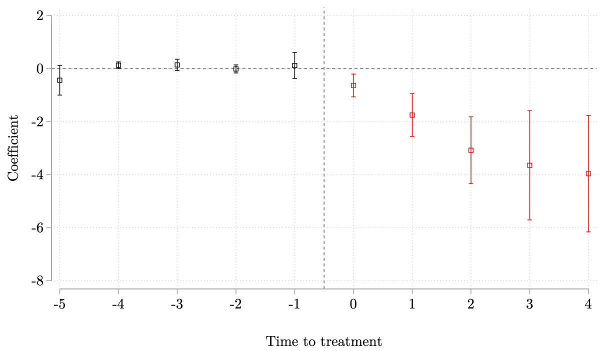
Figure 2: Map of non-medical exemptions



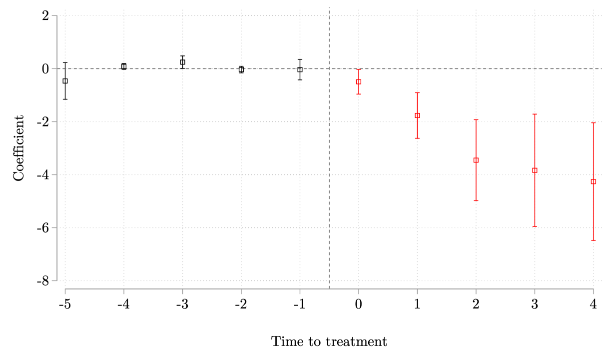
Notes: Figure shows a map of state non-medical vaccine exemptions for children entering kindergarten as of 2024. Exemption laws are sourced from LexisNexis via the National Conference of State Legislatures.

Figure 3: Exemption repeal and state exemption rates

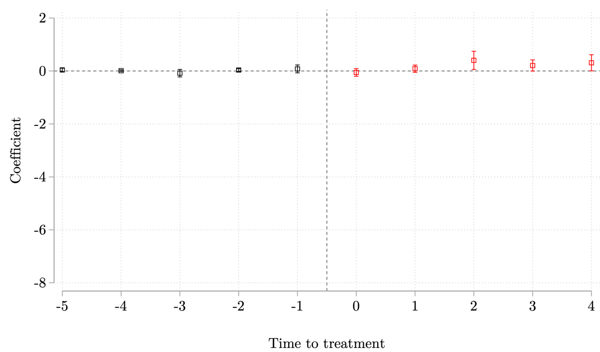
(a) All exemptions



(b) Non-medical exemptions

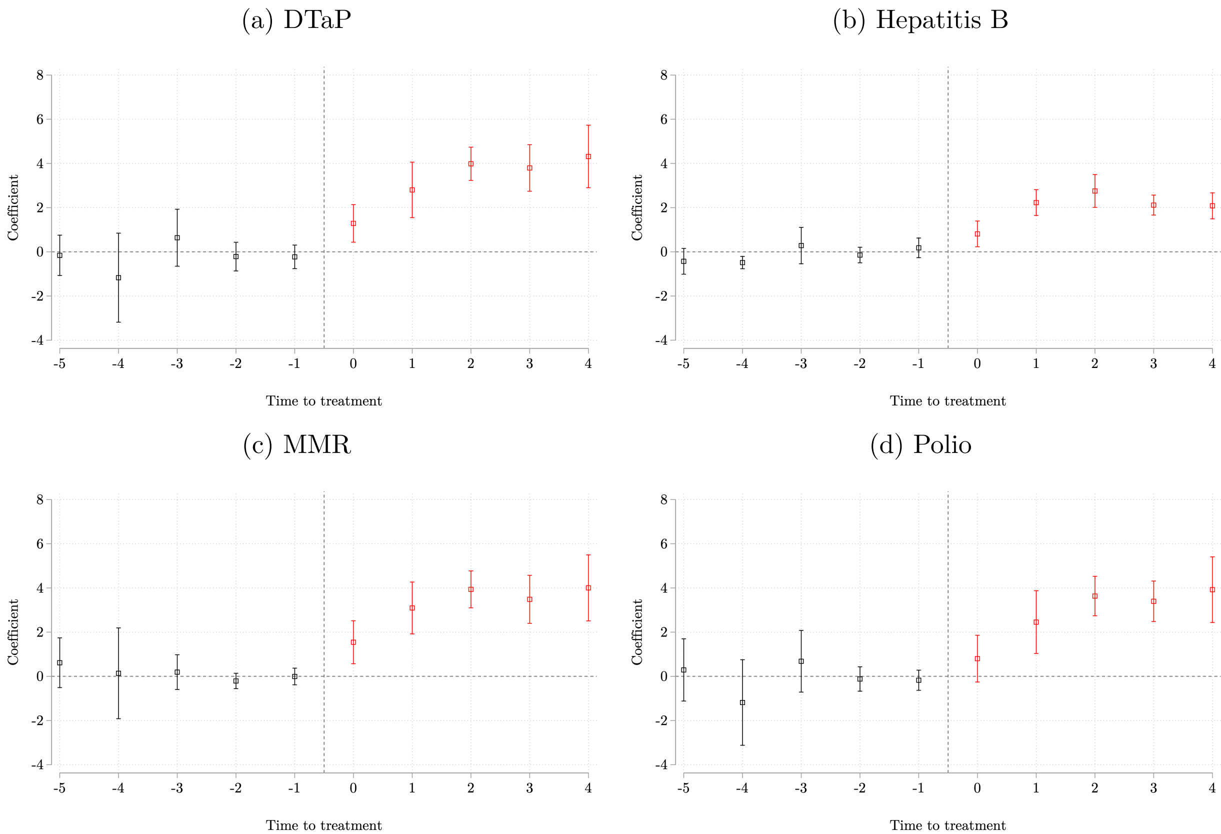


(c) Medical exemptions



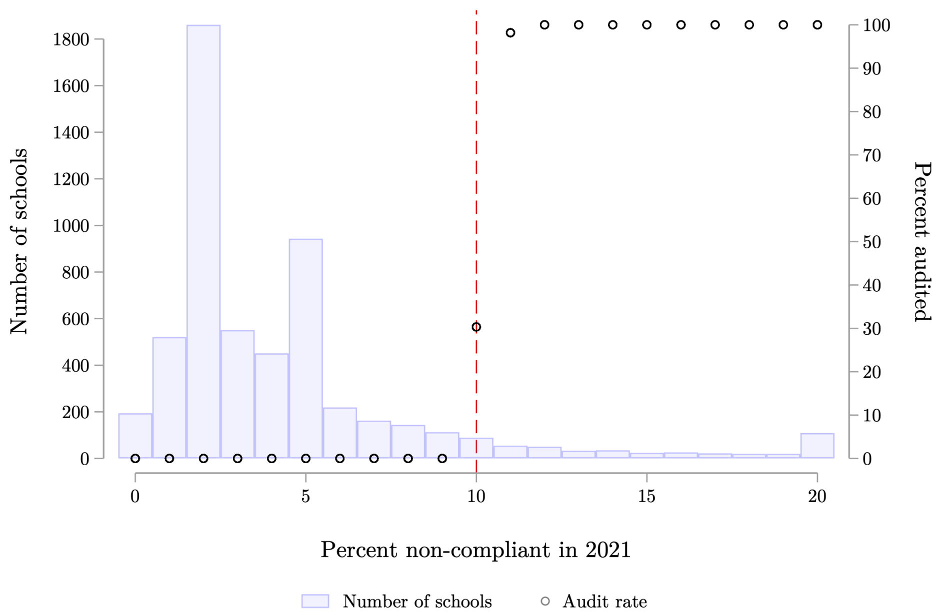
Notes: Figure shows event study coefficients from equation (1). Each panel plots the π_e coefficients on the pre-treatment years in black and the β_e coefficients on the post-treatment years in red. Coefficients are estimated using the event study methodology of Callaway and Sant'Anna (2021). 95 percent confidence intervals are shown with standard errors clustered at the state level. The dependent variable in Panel (a) is the rate of children entering kindergarten receiving any vaccine exemption. Results for the two subcategories of exemptions, non-medical and medical, are shown in Panels (b) and (c). Data are sourced from the CDC (see Section 3.2 for details).

Figure 4: Exemption repeal and state vaccination rates



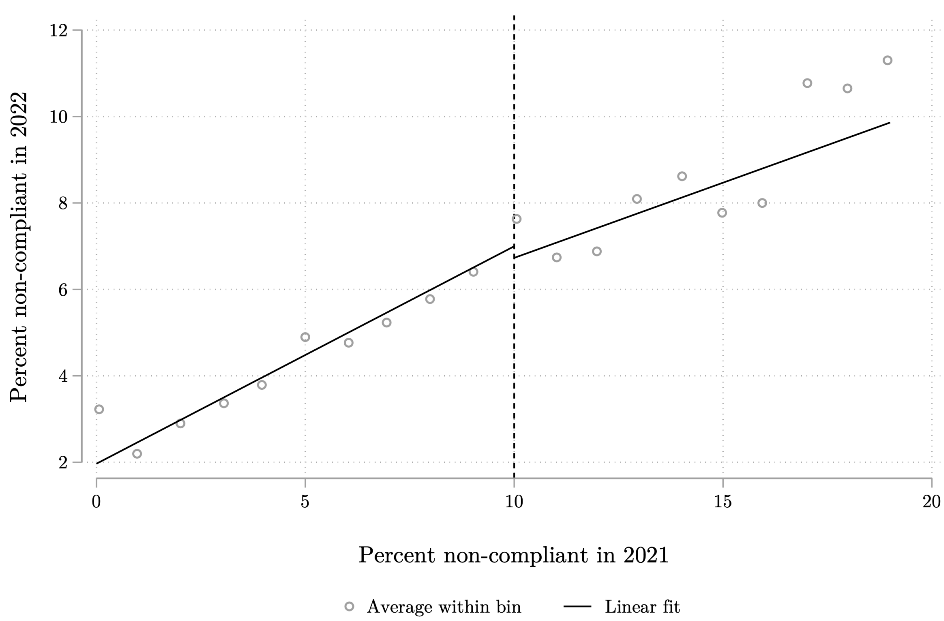
Notes: Figure shows event study coefficients from equation (1). Each panel plots the π_e coefficients on the pre-treatment years in black and the β_e coefficients on the post-treatment years in red. Coefficients are estimated using the event study methodology of Callaway and Sant'Anna (2021). 95 percent confidence intervals are shown with standard errors clustered at the state level. The dependent variable in Panel (a) is the DTaP vaccination rate for children entering kindergarten. Results for Hepatitis B, MMR, and Polio are shown in Panels (b), (c), and (d). Data are sourced from the CDC (see Section 3.2 for details).

Figure 5: Non-compliance rates in 2021



Notes: Figure shows a histogram of vaccine non-compliance rates in California schools in 2021. Left y-axis shows the number of schools. Right y-axis shows the percent of schools in each bin that were audited in 2021. See Section 5 for details.

Figure 6: Percent of vaccine non-compliance in 2022 at the 2021 audit threshold

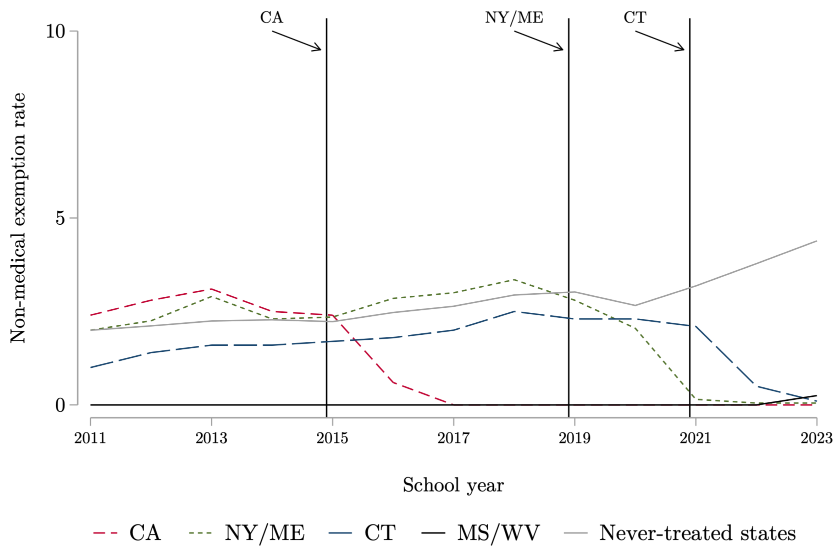


Notes: Figures shows the relationship between vaccine non-compliance in 2021 (x-axis) and 2022 (y-axis). Schools to the right of the audit threshold (10 percent non-compliance) were audited. See Section 5 for details.

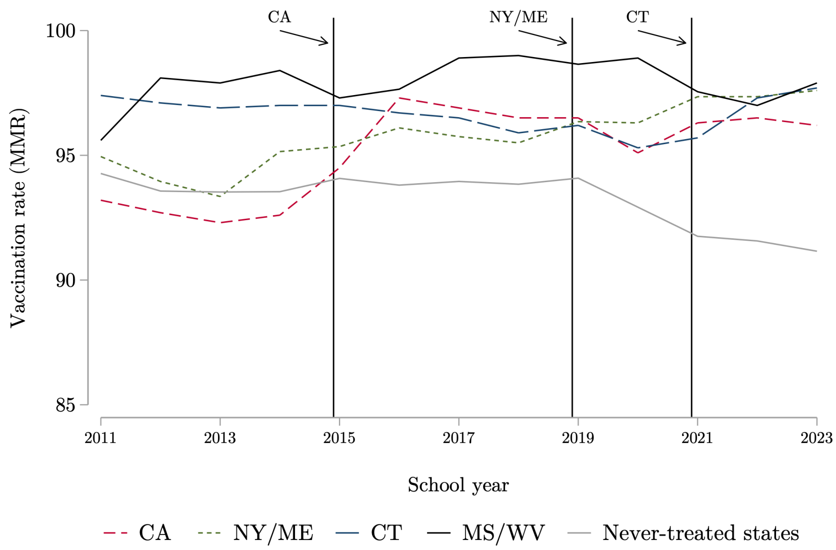
A Appendix Tables and Figures

Figure A.1: Trends by treatment year

(a) Non-medical exemptions

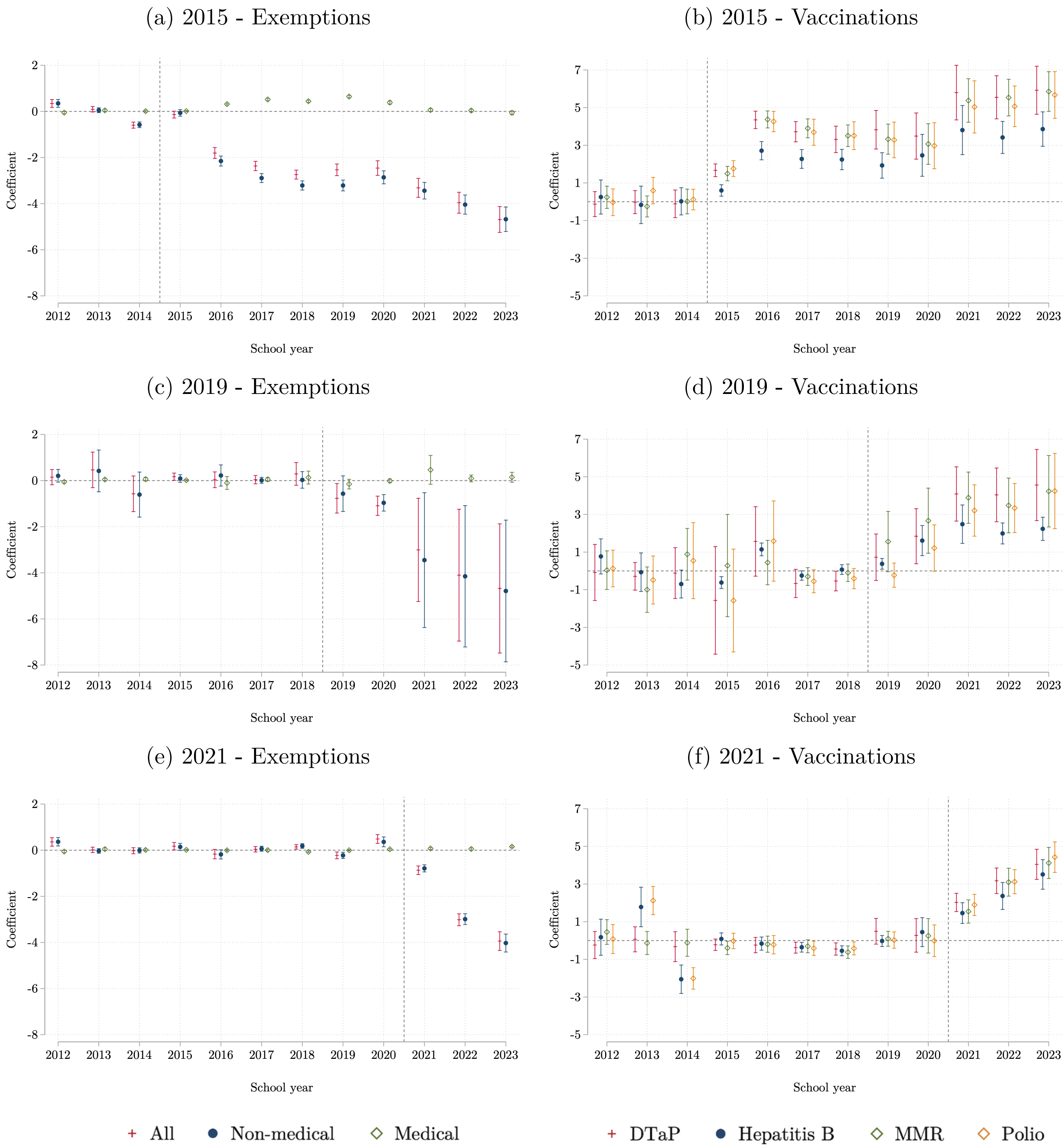


(b) Vaccinations (MMR)



Notes: Figure shows trends in non-medical exemption rates and vaccination (MMR) rates in panels (a) and (b). Data are measured for children entering kindergarten from 2011 to 2023. Trend lines are plotted separately for states that repealed non-medical exemptions in different years. Vertical lines indicate the year that the law was passed. The groups of states that never allowed non-medical exemptions (Mississippi and West Virginia) and all other states are plotted in black and gray. Data are sourced from the CDC (see Section 3.2 for details).

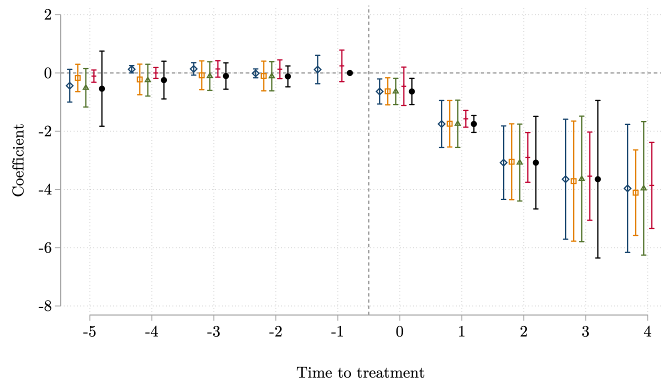
Figure A.2: Exemption repeal: Estimates by treatment year



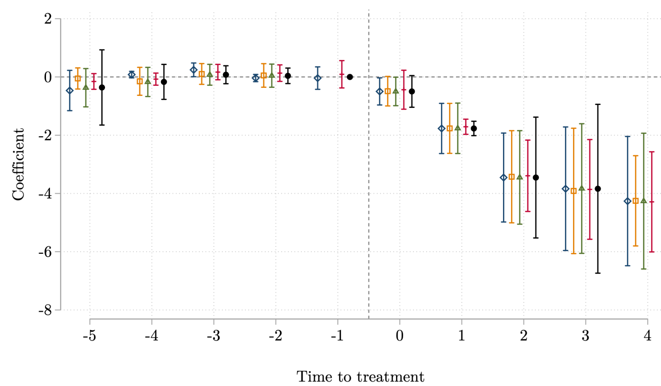
Notes: Figure shows event study coefficients from equation (1) for states treated in 2015, 2019, and 2021. Coefficients are estimated using the event study methodology of Callaway and Sant'Anna (2021). 95 percent confidence intervals are shown with standard errors clustered at the state level. The x-axis is displayed in school years. Results are shown for states treated in 2015 in Panels (a) and (b), 2019 in Panels (c) and (d), and 2021 in Panels (e) and (f). The dependent variables are exemption and vaccination rates for children entering kindergarten (see legend). Data are sourced from the CDC (see Section 3.2 for details).

Figure A.3: Exemption repeal and state exemption rates: Robustness to different estimators

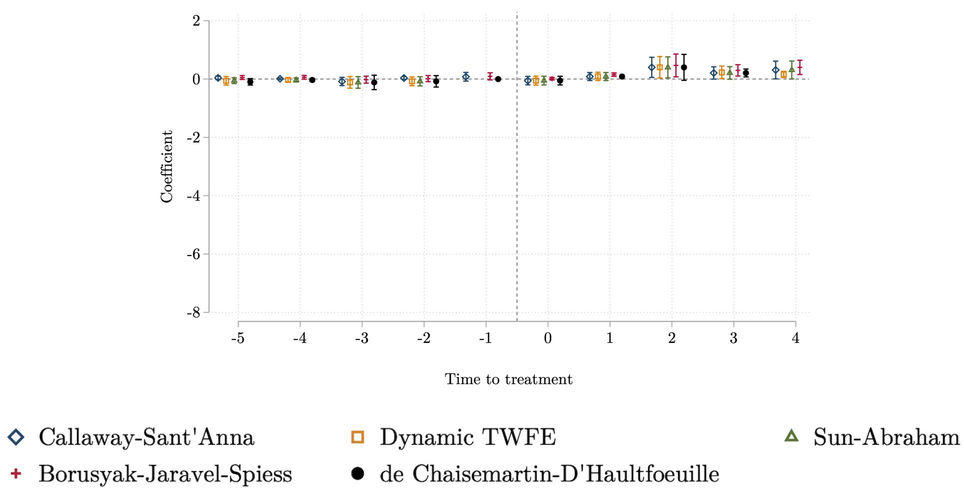
(a) All exemptions



(b) Non-medical exemptions



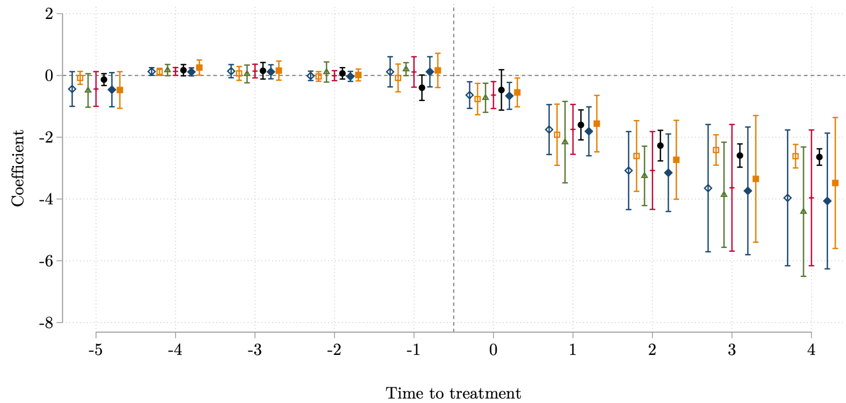
(c) Medical exemptions



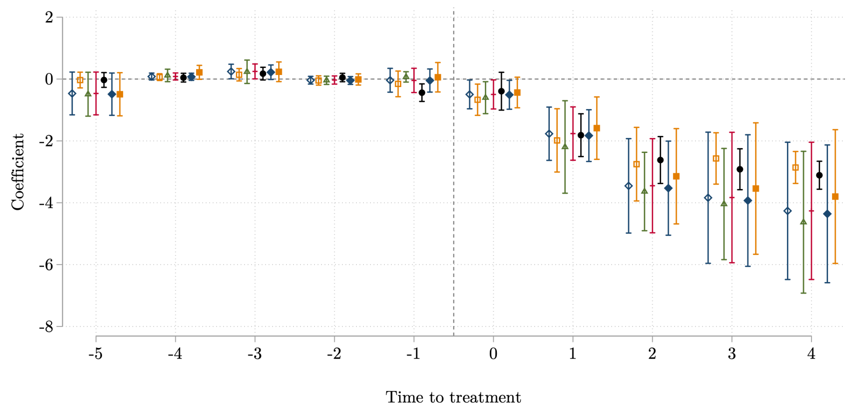
Notes: Figure shows robustness of event study results to different estimators. The outcomes in Panels (a), (b), and (c) are the overall exemption rate, the non-medical exemption rate, and the medical exemption rate. Event study estimators are sourced from Borusyak et al. (2024), de Chaisemartin and D'Haultfœuille (2024), Callaway and Sant'Anna (2021), and Sun and Abraham (2021). The dynamic two-way fixed effects approach is estimated using the *xtevent* package (Freyaldenhoven et al. 2021).

Figure A.4: Exemption repeal and state exemption rates: Additional robustness checks

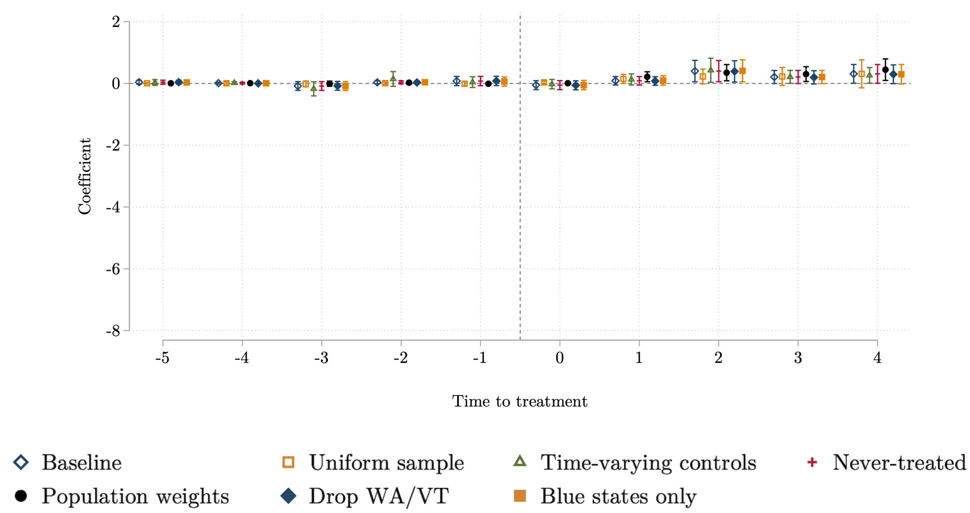
(a) All exemptions



(b) Non-medical exemptions

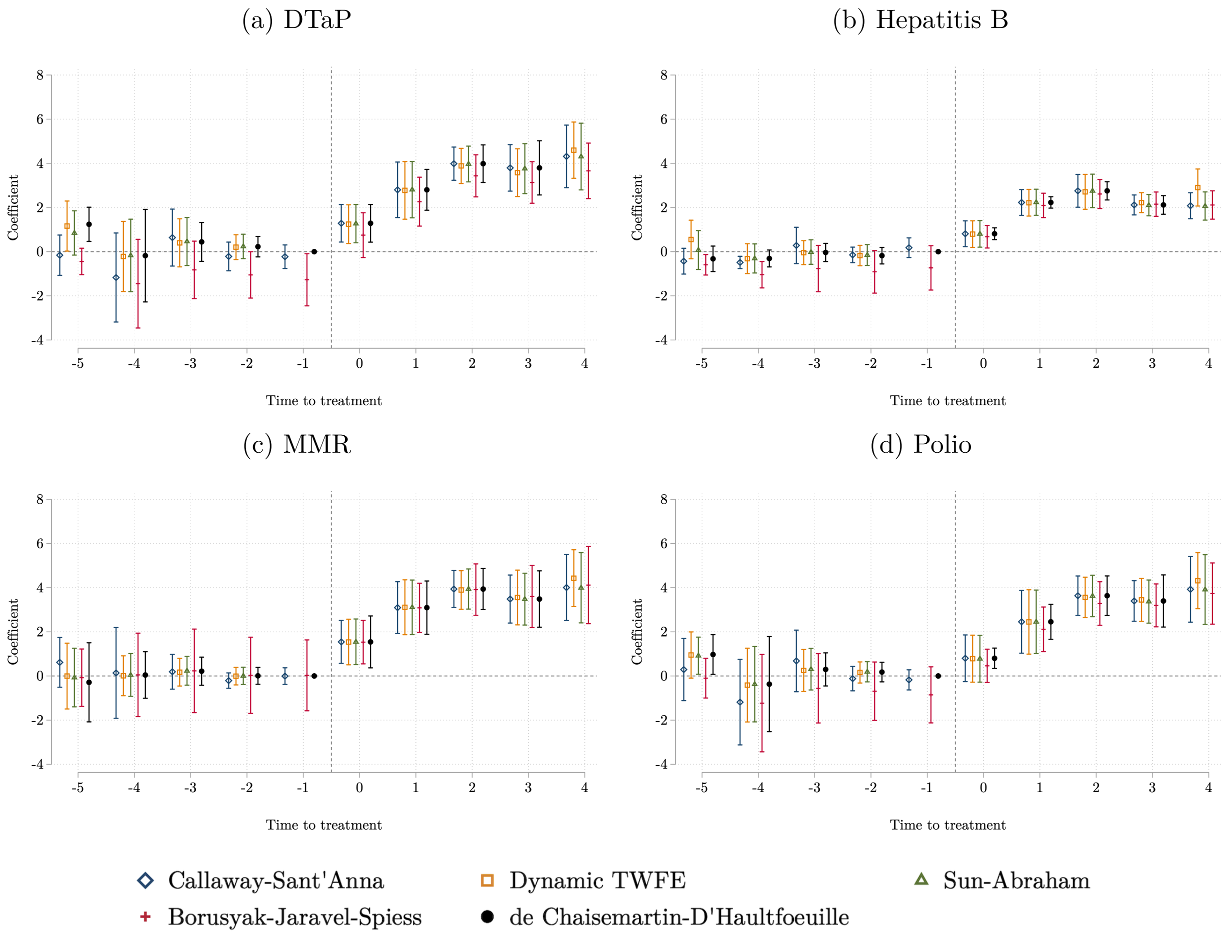


(c) Medical exemptions



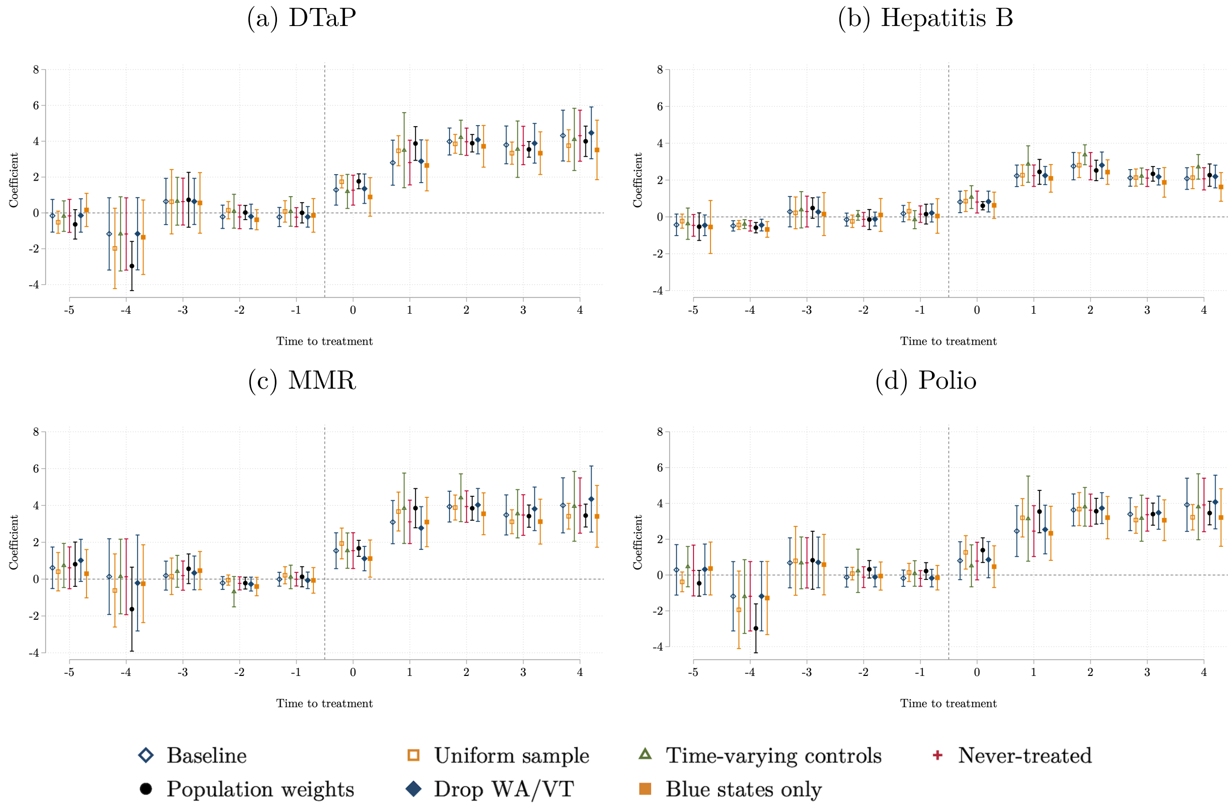
Notes: Figure reports additional robustness checks for state exemption rates. The outcomes in Panels (a), (b), and (c) are the overall exemption rate, the non-medical exemption rate, and the medical exemption rate. See Section 4.2 for a description of each robustness check.

Figure A.5: Exemption repeal and state vaccination rates: Robustness to different estimators



Notes: Figure shows robustness of event study results to different estimators. The outcomes in Panels (a), (b), (c), and (d) are the vaccination rates for DTaP, Hepatitis B, MMR, and Polio. Event study estimators are sourced from Borusyak et al. (2024), de Chaisemartin and D'Haultfœuille (2024), Callaway and Sant'Anna (2021), and Sun and Abraham (2021). The dynamic two-way fixed effects approach is estimated using the *xtevent* package (Freyaldenhoven et al. 2021).

Figure A.6: Exemption repeal and state vaccination rates: Additional robustness checks



Notes: Figure reports additional robustness checks for state vaccination rates. The outcomes in Panels (a), (b), (c), and (d) are the vaccination rates for DTaP, Hepatitis B, MMR, and Polio. See Section 4.2 for a description of each robustness check.

Table A.1: Event study coefficients: Exemption and vaccination rates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Exemption rate			Vaccination rate			
	All	Non-med	Med	DTaP	Hep B	MMR	Polio
T = -2	−0.01	−0.04	0.04	−0.22	−0.15	−0.21	−0.12
	(0.08)	(0.06)	(0.03)	(0.33)	(0.18)	(0.18)	(0.28)
T = -1	0.12	−0.04	0.08	−0.23	0.18	−0.01	−0.18
	(0.25)	(0.20)	(0.08)	(0.27)	(0.23)	(0.19)	(0.23)
T = 0	−0.64***	−0.50**	−0.05	1.29***	0.81***	1.54***	0.80
	(0.22)	(0.24)	(0.07)	(0.43)	(0.30)	(0.50)	(0.54)
T = +1	−1.75***	−1.77***	0.09	2.80***	2.23***	3.09***	2.45***
	(0.41)	(0.44)	(0.07)	(0.64)	(0.30)	(0.60)	(0.73)
T = +2	−3.08***	−3.45***	0.40**	3.99***	2.76***	3.94***	3.63***
	(0.64)	(0.78)	(0.18)	(0.38)	(0.38)	(0.43)	(0.46)
T = +3	−3.65***	−3.84***	0.21*	3.80***	2.12***	3.48***	3.40***
	(1.05)	(1.08)	(0.11)	(0.54)	(0.23)	(0.55)	(0.47)
T = +4	−3.96***	−4.26***	0.31**	4.32***	2.08***	4.00***	3.92***
	(1.12)	(1.13)	(0.15)	(0.72)	(0.30)	(0.76)	(0.76)
Mean outcome (T = -1)	3.20	2.88	0.28	94.72	96.30	93.94	94.88
State-year obs.	559	559	546	494	481	507	507

Notes: Table reports results from equation (1), estimated using the event study methodology of Callaway and Sant'Anna (2021). The outcomes are state exemption rates in columns (1)-(3) and vaccination rates in columns (4)-(7), derived from CDC data covering the 2011-2023 period (see Section 3.2). Sample is restricted in each column to a balanced panel of states. Coefficients are shown in percents and in event time for $T \in \{-2, 4\}$. Standard errors are clustered at the state level. $^*p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table A.2: Regression discontinuity estimates of audit on non-compliance and vaccination rates

	(1)	(2)	(3)	(4)	(5)	(6)
	Non-comp	Audited	DTaP	Hep B	MMR	Polio
Non-compliance > 10%	0.11	0.77	−1.34	−0.98	−0.91	−1.37
	(0.94)	(6.44)	(1.29)	(1.11)	(1.24)	(1.25)
Observations	5,543	5,543	5,543	5,543	5,543	5,543
Bandwidth	4.26	5.25	4.38	4.44	4.45	4.30
Effective obs.	880	1,804	880	880	880	880

Notes: Table reports regression discontinuity estimates for the effect of audit in 2021 on non-compliance and vaccination rates in 2022. Coefficients estimate the change in the outcome at the audit threshold of 10 percent non-compliance. Each column is a separate RD regression that uses the *rdrobust* package from Calonico et al. (2017). Outcomes are all shown in percents: Non-compliance, audit likelihood, and vaccination for DTaP, Hepatitis B, MMR, and Polio. See Section 5. Robust standard errors in parentheses. $^*p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

B State Vaccine Legislation

California

In June 2015, the California legislature passed Senate Bill 277, which repealed the personal beliefs exemption (PBE) for school-entry vaccines. The law took effect on January 1st, 2016. See the California law here. The law applies to children receiving "class-based instruction", which includes public schools and private schools. The law does not apply to children who are homeschooled.

- For students entering kindergarten, the law requires up-to-date vaccination for DTaP, MMR, Polio, Hepatitis B, and Varicella.
- Children with a PBE filed before January 2016 can keep the exemption until they reach the next vaccine checkpoint (kindergarten or 7th grade).
- Children with an Individualized Education Plan (IEP) cannot be denied special education services and may be eligible for a PBE.
- The law broadened the scope of licensed medical providers to issue a medical exemption. Effective January 1st, 2021, all medical exemptions must be issued through the California Immunization Registry - Medical Exemption (CAIR-ME) website. See the legislation here.

Connecticut

Connecticut passed Public Act No. 21-6 on April 28th, 2021. Public Act No. 21-6 repealed non-medical vaccine exemptions for children in pre K-12 schools, child care centers, group child care homes, family child care homes, and higher education institutions. See the Connecticut law here. The law took effect immediately and applies to children attending public or private schools (not children who are homeschooled).

- For students entering kindergarten, the law requires up-to-date vaccination for DTaP, MMR, Polio, Hepatitis A, Hepatitis B, and Varicella.
- Children in grades K-12 with a non-medical exemption in place prior to April 28th, 2021 can keep their exemption. However, children in pre-school with non-medical exemptions must comply with the new law. Children may be given additional time to become compliant, as long as there is written declaration from the child's physician that an alternative vaccine schedule is recommended.
- The law makes no exception for children with an Individualized Education Plan (IEP).

Maine

In February 2019, the Maine legislature introduced LD 798, a bill that proposed to repeal non-medical vaccine exemptions. The law was signed in May 2019 and took effect on September 1st, 2021. See the Maine law here. The law applies to children attending public or private schools (not children who are homeschooled).

- For students entering kindergarten, the law requires up-to-date vaccination for DTaP, MMR, Polio, and Varicella (Hepatitis B is not required).
- Children with an Individualized Education Plan (IEP) were allowed to obtain or keep a non-medical vaccine exemption, as long as the IEP was in place as of September 1st, 2021. There was no such allowance for non-IEP children.

- Medical exemptions may only be provided by a licensed physician, nurse practitioner, or physician assistant. Children may also show proof of immunity resulting from prior infection.

New York

In January 2019, the New York legislature introduced S2994A, a bill that proposed to repeal non-medical vaccine exemptions for children attending day care and public, private, or religious schools (pre-K through high school). The bill was signed into law on June 13th, 2019 and applied to the 2019 school year. See the New York law here. The law applies to children attending public, private, or parochial schools (not children who are homeschooled).

- For students entering kindergarten, the law requires up-to-date vaccination for DTaP, MMR, Polio, Hepatitis B, and Varicella.
- In practice, students are required to have the first age-appropriate dose of the required vaccines within 14 days of the first day of school or day care to remain in school. Within 30 days, parents are required to show documentation of vaccine follow-up appointments (see here).
- Children with existing non-medical exemptions are not allowed to retain them and must comply with the new law. The law makes no exception for children with an Individualized Education Plan (IEP).
- Additional vaccines are required for day care and pre-K in the state of New York, including Haemophilus influenzae type B (HiB) and Pneumococcal Conjugate Vaccine (PCV).

Washington

In May 2019, the governor of Washington signed a law that repealed personal or philosophical exemptions from the MMR vaccine. See the Washington law here. The law did not affect other vaccines, and medical and religious exemptions can still be granted for MMR. The law took effect on July 28th, 2019 and applies to children attending public or private schools (not children who are homeschooled).

Vermont

In May 2015, the governor of Vermont signed a law that repealed philosophical vaccine exemptions for children in school. See the Vermont law here. The law did not affect religious exemptions and took effect on July 1st, 2016 for children attending public or private schools (not children who are homeschooled).