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THE EFFECT OF STATE INSURANCE MANDATES ON INFANT IMMUNIZATION RATES

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ABSTRACT

While US infant immunization rates have been increasing in the last 20 years, the cost of fully immunizing a child with all recommended vaccines has almost tripled. This is partly not only due to new additions in the list of recommended vaccines but also due to the use of new, safer, but more expensive technologies in vaccine production and distribution. In recent years, many states have mandated that recommended childhood vaccines be covered by private health insurance companies. Currently, there are 33 states with such a mandate. In this paper, I examine whether the introduction of mandates on private insurers affected immunization rates. Using state and time variation, I find that mandates increased the immunization rate for three vaccines—the diphtheria–tetanus–pertussis, polio, and measles–mumps–rubella vaccines—by about 1.8 percentage points. These results may provide a lower bound for the expected effect of the Affordable Care Act, which mandates coverage of childhood vaccines for all private insurers in the USA. I also find evidence that the mandates shifted a significant portion of vaccinations from publicly funded sources to private ones, with a decline in public health clinic visits and an increase in vaccinations at hospitals and doctor's offices. Copyright © 2015 John Wiley & Sons, Ltd.

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1. INTRODUCTION

The discovery of vaccines against infectious diseases such as polio and measles is widely regarded as one of the greatest public health achievements of the 20th century (Institute of Medicine (IOM), 2004). Children are most vulnerable to vaccine-preventable diseases, so appropriate vaccinations are especially important. Indeed, childhood immunizations are one of the most cost-effective preventative services provided in a clinical setting (Maciosek *et al.*, 2006). In the USA, infant immunizations are usually administered right after birth at the hospital and during routine well-child visits with the pediatrician, which are recommended at 2, 4, 6, 9, and 12 months after birth.[1]

The Department of Health and Human Services sets the goal of achieving 80% immunization rates for all recommended vaccines for children under 2 years of age.[2] Moreover, the distribution of vaccinated individuals must be sufficiently uniform geographically to avoid outbreaks among unvaccinated subpopulations. Despite considerable gains in vaccination rates over the last 20 years, the USA still falls short of these goals, particularly in certain states. For example, the national immunization rate for the '431 series' (four doses of

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[1]The complete schedule can be found at http://www.cdc.gov/vaccines/parents/downloads/parent-ver-sch-0-6yrs.pdf.

[2]This goal is based on studies that find a population to be protected from a disease if at least 90% of the population has been vaccinated. This is a general rule of thumb that comes from widely accepted simulation studies in the epidemiological literature. More details are available in Heathcote (1989). The full list of immunization-related goals under this initiative is available at http://www.healthypeople.gov/document/html/volume1/14immunization.htm.

diphtheria–tetanus toxoids–pertussis vaccine, three doses of poliovirus vaccine, and one dose of measles–mumps–rubella (MMR)) increased from 76.3% in 1995 to 83.9% in 2006 for children less than 3 years old. While these figures suggest an increasing national trend that is approaching the previously stated goals, substantial variation across states still exists: 91.6% of children in Massachusetts were up to date with the 431 series in 2006, compared with only 75.5% in Nevada.[3]

The increase in immunization rates has been accompanied by an increase in the cost of becoming immunized in both the private and public sectors—which includes purchases made by the government under programs such as Vaccines for Children (VFC) and Medicaid. This increase is due to not only the discovery of new vaccines that have been added to the recommended list, but also the introduction of safer but more expensive technologies in the production and distribution of vaccines.[4] Davis *et al.* (2002) found that as a result, the cost of recommended vaccines for a 2-year old before doctors' administration charges more than doubled between 1999 and 2002.

As of 2008, 33 states have legislation mandating private insurers to cover childhood immunizations; 14 have been in place since the mid-to-late 1990s. The mandates lower the price of the recommended vaccines for children who relied on private insurance that previously did not cover immunizations. The mandates could also increase immunizations by reducing time and transportation costs for those parents who, in the absence of a mandate, could visit a federally qualified health center (FQHC) or local health department (commonly known as public clinics), in addition to their source of care to obtain free vaccines. [5]

In this paper, I assess the effect of vaccination mandates on the likelihood of young children being up-to-date with the 431 series. I focus mainly on the 431 series because while there is variation in what vaccines are covered and how the mandate applies to newly recommended vaccines, all states cover the 431 series. The contribution of the paper is threefold. First, I identify the effect of mandates on states' immunization rates and consider how mandates compare to public provision, the latter of which has been studied by Rein *et al.* (2006) and Joyce and Racine (2005).

Moreover, with the enactment of the Affordable Care Act (ACA), which requires insurance coverage for childhood immunizations, this paper provides a lower-bound estimate of the effect of the ACA for states without mandates and infants covered under self-insured plans that do not have to abide by state regulations. This is because the ACA also affects overall access to health insurance.[6] Lastly, I examine whether mandates increase the proportion of children getting their vaccines at doctors' offices and hospitals versus public clinics. The shift in immunization coverage from public clinics to private insurers results in lower public expenditure for programs that purchase and distribute vaccines, with the costs being shifted to private insurers.[7] Such effects can help estimate how the ACA will affect the budgets of public vaccine purchase programs and costs for private insurers.

[3]The corresponding immunization rates are lower for the expanded 4313 and 43133 series, which include three doses of *Haemophilus influenzae* type B and an additional three doses of Hepatitis B, respectively.

[4]For example, using acellular compounds in the production of the pertussis vaccine and the elimination of the preservative thimerosal.

[5]Mullahy (1999) considered time costs in the own take-up of the flu shot and found that strong attachment to labor market is associated with lower likelihood of vaccination and interpreted the results because of the importance of time costs. Further exploration finds that those individuals who are more inclined to engage in preventive care do so because of the relatively high time cost of becoming sick. In the case of childhood vaccines, however, parental time costs are likely to affect take-up negatively. For a discussion of parental time costs and well-child visits, see Hamman (2011).

[6]In addition, for non-grandfathered plans, ACA stipulates that childhood immunizations will be covered without cost sharing requirements. State mandates vary on their approach to cost sharing—some do not allow deductibles, co-payments, or both, while others have no language regarding cost sharing. Analysis not reported here does not find substantial differences in immunization rates across cost sharing restrictions. This could be due to a small sample of states within each cost sharing category, or is an indication that the level of cost sharing allowed under the mandates is not prohibitive.

[7]This shift in the source of care might result in savings of time and transportation costs for those parents who, in the absence of a mandate, would visit both a doctor's office as part of a well-child visit and a public health clinic to obtain free vaccines. While most FQHCs can provide additional comprehensive services, local health department immunization clinics do not, and it is impossible to distinguish between these two with the data available. Nevertheless, this shift might be beneficial if the mandates allow patients and families to unify their site of care so that they are receiving immunizations in their health homes for the ongoing monitoring of the health of the affected children. I would like to thank an anonymous referee for pointing this out.

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2. BACKGROUND

2.1. Infant immunizations

In the USA, recommended infant vaccines are determined federally by the Advisory Committee on Immunization Practices (ACIP) and the American Academy of Pediatrics (IOM, 2004). In the mid-1980s, seven vaccines (combined into five shots) were recommended for infants under 2 years. By the mid-1990s, six additional vaccines were recommended, with a few more in 2000 and 2004 (Hinman *et al.*, 2004). Currently, children can receive up to 24 doses by age 2, with up to five shots in a single visit. Before children enter school, most states require proof of immunization.[8] Some states require proof of vaccination before entering a daycare facility (Abrevaya and Mulligan, 2011).

Over the past several decades, the cost of vaccines has increased substantially. In 1987, the cost for a full course of recommended childhood vaccines was \$116 in the private sector and \$34 in the public sector; in 1997, the cost increased to \$332 in the private sector and \$176 in the public sector (IOM, 2000).[9] Joyce and Racine (2005) estimated the public sector cost of fully immunizing a child under 2 to be \$525 in 2002. These costs are based only on the purchase price from pharmaceutical companies and do not include administration fees or other costs associated with well-child visits. The administration fee for each shot averages about \$15 per dose (IOM, 2000). Molinari *et al.* (2007) estimated out-of-pocket costs for fully immunizing an uninsured infant and find that even with free vaccines, additional administration costs average \$573 per child under 3 years old.

Public intervention and financing for vaccines is warranted because of their positive externality. As such, most developed countries use public funds for childhood immunizations or mandate coverage by private insurance companies (Salisbury, 2005; Freed, 2007). In the USA, vaccine financing and provision includes both the public and private sectors. Public vaccine financing is split among the federal and state governments and involves various programs, such as VFC, Medicaid, Children Health Insurance Program (CHIP), and Section 317 funding. Established in 1994, the VFC program serves, through private providers such as doctors' offices and hospitals, children who are either eligible for Medicaid, uninsured, Native American, or Alaskan Native, or receive medical services at a public clinic (IOM, 2000). VFC covers the cost of the vaccine but not the administration fee. Under VFC, the federal government, through the Centers for Disease Control and Prevention (CDC), negotiates yearly vaccine prices with pharmaceutical companies and then states order their required quantity at the contracted price. Overhead distribution costs of VFC vaccines are usually covered by Section 317 funding allocated to each state (Miller, 2000). [10]

The VFC program covers the underinsured—children who have health insurance that does not cover immunizations—but does so only in public clinics. Some states have expanded VFC and use state funds to purchase vaccines for the underinsured and provide vaccines at the doctor's office. Such states have a so-called 'universal VFC' program (IOM, 2004). Lee *et al.* (2007) find that in practice, the underinsured are rarely provided with all recommended immunizations even at public clinics and especially for newly recommended vaccines. State insurance mandates thus bridge the coverage gap for previously underinsured children who do not qualify for public assistance and cannot get vaccines in public clinics because of limited supply or high time costs.[11]

[8]Most states allow parents to waive this requirement on religious grounds. Some states also permit 'philosophical' exemptions. For religious exemptions, most states require proof of religious affiliation, while for philosophical exemptions, parents are only required to sign a form stating their opposition to their child getting one or more vaccines.

[9]The price difference between the public and private sectors mainly reflects the cost savings to the federal government because of large volume purchases for VFC, Medicaid, and other programs. The public share of total vaccine purchases is between 52% and 55%, and on average, the federal government pays roughly half the price paid in the private market (IOM, 2004). The ratios of private to public prices vary by year and vaccine and can be found at the CDC website: www.cdc.gov.

[10]States are nevertheless responsible for covering the vaccine administration fee for Medicaid recipients, as well as the purchase and the administration of vaccines for CHIP beneficiaries if the CHIP program was set up as a separate program from Medicaid.

[11]The extensive efforts behind the creation of VFC in the 1990s were in response to a resurgence of measles at the beginning of the decade, which resulted in 55,000 cases, 11,000 hospitalizations, and 166 deaths (CDC, 1992). The low rate of vaccination at the recommended age was the primary culprit (National Vaccine Advisory Committee, 1991).

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2.2. Insurance mandates and infant immunizations

Theoretically, whether insurance mandates affect utilization depends on how they affect insurance coverage and whether markets are imperfect because of consumer misinformation, adverse selection, etc. The empirical literature finds mixed results,[12] which are potentially due to complicating factors that result from insurance mandates often being accompanied by loopholes, exceptions, or exemptions that dilute their potential effect, resulting in small changes that are hard to quantify at the population level. For example, some mandates only require insurers to offer one type of policy that includes coverage of a service, which are less effective than those requiring coverage in all policies (Buchmueller *et al.*, 2007). Some mandates apply only to certain types of insurers and can include, exclude, or apply only to Health Maintenance Organizations (HMOs) (Schmidt, 2007). Mandate legislation can also vary by the exemptions allowed, especially with regard to firm size and potential cost increases and whether they permit yearly or lifetime caps (Gruber, 1994). Moreover, under the Employee Retirement Income Security Act (ERISA), self-insured plans are exempted from state mandates that account for the coverage of about half of employees (Laugesen *et al.*, 2006; Buchmueller *et al.*, 2007).

Importantly, infant vaccine mandates suffer much less from the problems mentioned earlier. First, of all states with mandates, only Mississippi has a mandate to offer, rather than cover, immunizations. Second, the mandates apply to all types of insurers, and no state has exceptions for firm size or future increases in costs. Third, I am able to identify one outcome—the 431 series—that is covered by all states. Finally, mandates on immunization coverage are estimated to increase insurance policy costs by less than others and are thus less likely to lead to increased insurance premiums.[13]

The increases in costs and complexity of recommended childhood vaccines highlight the importance of comprehensive pediatric care and access to health insurance. The effect of insurance on the healthcare utilization by children in general, and immunizations in particular, is well established in the literature (e.g., Lurie *et al.*, 1987; Currie and Gruber, 1996; Newacheck *et al.*, 1998; Dubay and Kenney, 2001; Smith *et al.*, 2006). Individual states appear to view coverage of childhood vaccinations as a viable policy to assure the take-up of vaccines in the face of increasing costs.[14] As of 2008, 32 states and the District of Columbia have enacted such mandates. Table I shows the time of enactment for states that introduced mandates since 1994. The first states to pass mandates did so starting in the 1980s. Two IOM (2004, 2000) reports find that between 1998 and 2000, between 5% and 13.8% of children under the age of 5 had private insurance with no immunization benefits and were thus likely to benefit from the introduction of mandates (IOM, 2004).[15]

3. DATA

The data come from the 1995–2006 National Immunization Survey (NIS), which includes yearly national samples of children aged 19–35 months. The age threshold reflects the fact that all recommended infant

[12] Pacula and Sturm (2000) and Bao and Sturm (2004) found that mental health mandates did not increase utilization, and Klick and Markowitz (2006) found that they were ineffective in reducing suicide rates. On the other hand, Liu *et al.* (2004), Harris *et al.* (2006), Schmidt (2007), Bitler and Schmidt (2012), Bitler and Carpenter (2009), and Lang (2013) all found increased utilization or better outcomes after mandates were introduced for, respectively, postpartum delivery laws, fertility treatments, mammograms, and mental health.

[13] Evidence from some states suggests that the increase in the cost of a policy after mandating coverage for all well-child benefits is at most 1 percent, while other mandates can increase cost by as much as 10 percent (Gruber, 1994; Ma, 2007).

[14] In some state legislatures the cost issue was mentioned as a primary factor in introducing the laws mandating childhood vaccine coverage; in other states, such as Illinois and North Carolina, references in the public press indicated the same.

[15] The 2000 IOM report found that prior to 1998, 8% of families with private insurance plans lacked infant immunization coverage and they estimate the underinsured rate to be about 5%. With more recent data from 2000, the underinsured rate was estimated to be 13.8%. Prior work from the CDC and IOM commissioned studies with data from before 2000 found the underinsured rate to be between 5% and 13.8% (IOM, 2004, p. 50).

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Table I. State-mandated immunization insurance coverage

State	Month-year enacted	Year coded
Delaware	Jan-99	2000
Georgia	Jul-95	1997
Illinois	Aug-99	2001
Kansas	Apr-95	1997
Mississippi	Jan-99	2000
Missouri	Oct-96	1998
Nebraska	Jan-95	1996
New Jersey	Apr-96	1998
North Carolina	Jan-96	1997
Oklahoma	Jan-98	1999
Texas	Sep-97	1999
Virginia	Jul-00	2002
West Virginia	Jul-94	1996
Wisconsin	Nov-00	2002

Arkansas, California, Colorado, Connecticut, DC, Florida, Hawaii, Louisiana, Maryland, Massachusetts, Michigan, Minnesota, Montana, New Mexico, New York, North Dakota, Ohio, Pennsylvania, and Rhode Island all enacted mandates that cover immunizations before the period in the study. *Source*: Rosenbaum *et al.* (2003) and author's findings.

immunizations should be completed by the 18th month.[16] The NIS uses random digit dialing to identify households with children of the appropriate age and surveys the most knowledgeable person about the child's immunizations and other socio-demographic information. Table II shows summary statistics for these variables. Figure 1 shows trends in immunization rates of states grouped by whether or when they introduced mandates.

The NIS dataset is most appropriate, as it has a sufficiently large sample size that allows state-year comparisons. In addition, because NIS surveys actual providers of the children's immunizations, the data are very reliable. An important drawback, however, is that it does not ask about health insurance coverage. I address this shortcoming by estimating public insurance eligibility, including information on children's uninsurance rate by state-year from the Current Population Survey (CPS) (US Census Bureau, 2010), and making use of the sampling framework that accounts for lack of insurance within the strata.[17]

Children with complete provider information are more likely to be white, have better educated parents, and live in households with higher incomes than those without provider data. In my analysis, I use controls and stratification weights that adjust for these factors. I also use CPS data on unemployment to account for private insurance availability, general effects of economic conditions on infants' health, and time costs.[18]

4. EMPIRICAL STRATEGY

Following the standard approach in the immunization literature, I define the main outcome as the fraction of children up-to-date with the 431 series. Immunization status is usually evaluated at the series level rather than with individual doses because an additional dose has a different marginal effect on building immunity.

[16]The only exception is the Hepatitis A vaccine, for which a second dose should be completed by 24 months of age.
[17]In the CPS, children's insurance status can only be determined for those younger than 18 years of age. Smith *et al.* (2001) described the NIS dataset in greater detail.
[18]Dehejia and Lleras-Muney (2004) found that parental characteristics and infants' health outcomes vary depending on the unemployment rate at the time of conception.

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Table II. Summary statistics

	No mandates	Old mandates	New mandates
431 immunization rate	80.29%	80.91%	80.36%
Number children in household			
1 child	27.22%	27.81%	27.66%
2 or 3 children	59.43%	59.52%	60.29%
4 or more	13.35%	12.67%	12.05%
Male	51.12%	51.37%	50.91%
Race/ethnicity			
White	73.02%	57.75%	62.55%
Black	7.30%	15.34%	16.96%
Hispanic	12.60%	17.47%	14.54%
Other	7.08%	9.44%	5.95%
Age in months			
19–23	29.81%	29.46%	29.89%
24–29	34.85%	35.54%	34.71%
30–35	35.34%	35%	35.40%
Moved from state of birth	12.02%	10.09%	10.02%
Number providers per child			
One provider	80.57%	84.74%	82.07%
Two providers	17.37%	13.95%	16.33%
Three or more providers	2.06%	1.31%	1.60%
Provider type			
Public	21.49%	16.89%	21.89%
Hospital	6.29%	9.11%	8.23%
Private	59.94%	64.27%	58.25%
Military	2.58%	2.67%	2.24%
Mixed	9.70%	7.06%	9.39%
Mother's marital status			
Single mother	16.90%	22.08%	19.81%
Married mother	74.01%	69.76%	71.38%
Widow, separated, or divorced	9.09%	8.16%	8.81%
Mother's education			
College degree	27.28%	31.38%	29.09%
High school or more	58.93%	54.22%	54.72%
Less than high school	13.79%	14.40%	16.19%
Income			
Income less than 20K	26.07%	28.09%	28.68%
Income between 20K and 50K	43.42%	37.10%	38.60%
Income more than 50K	30.51%	34.81%	32.72%
Poverty	21.50%	23.90%	24%
Urban	6.98%	9.29%	7.98%
Medicaid/CHIP eligibility	43.21%	42.10%	41.36%
Unemployment	4.78%	5.07%	4.75%
Uninsurance	11.40%	11.45%	11.83%
Section 317 funding in 000$	4,778	10,741	10,138
HMO penetration rate	14.24%	25.73%	14.35%
State/year cells	216	228	168

National Immunization Survey provider weights and strata information used in the aggregation to state/year cells. Unemployment and children's uninsurance data come from the historical reports of the Current Population Survey. Section 317 funding data come from The Centers for Disease Control and Prevention's administrative data; Health Maintenance Organization (HMO) penetration rates by state come from Interstudy. No mandates refer to states that never passed a mandate, old mandates to states that passed such legislation prior to 1994, and new mandates to states passing mandates since 1994. CHIP stands for The Children Health Insurance Program.

I use a difference-in-difference estimator and estimate the following model:

$$\mathrm{Imm}Rate_{\mathrm{st}} = \beta_1 mandate_{\mathrm{st}} + \delta' X_{\mathrm{st}} + \gamma_1{}' state_{\mathrm{s}} + \gamma_2{}' year_{\mathrm{t}} + \varepsilon_{\mathrm{st}}, \tag{1}$$

where $ImmRate_{\mathrm{st}}$ is the state-year immunization rate with the 431 series, $mandate_{\mathrm{st}}$ is a dummy variable that takes on a value of 1 if a state had a mandate on a given year, and X_{st} is the vector of controls composed of state-year data aggregated from individual NIS data and other variables mentioned earlier. I include state and

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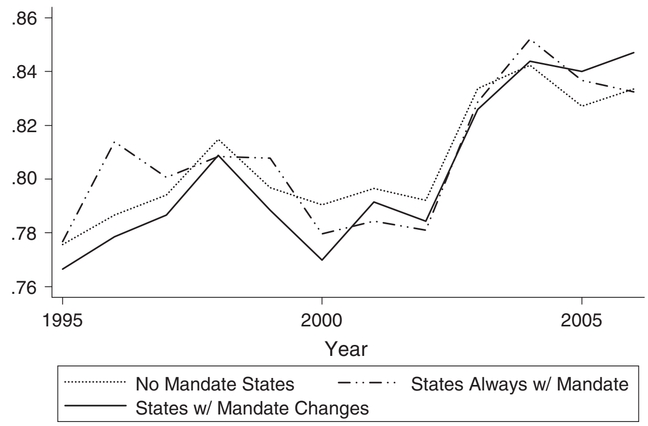

Source: Author's tabulations from NIS data

Figure 1. Trends in immunization rates by state group

year fixed effects to capture unobserved, fixed state characteristics affecting immunizations and trends in vaccine take-up, vaccine prices, and federal policies that are common to all states. The controls are listed in Table II. I report standard errors that are robust to heteroskedasticity and clustered at the state level to account for state correlation over time.

I conduct the analysis at the state-year aggregate level for several reasons. First, mandate status varies only by state-year, and using individual level data might result in overestimating the statistical significance of the mandates because of the pitfalls discussed in Moulton (1990). Second, in 2005 and 2006, NIS introduced new survey strata. This makes it difficult to analyze individual level data while taking into account the survey sampling design, particularly because the weights account for the likelihood of having insurance. Finally, while the number of observations used in aggregate varies from 95 to 2498, on average, it is still relatively large at 595 observations across all states and years.

To account for access to vaccines through public insurance, I control for the proportion of children eligible for Medicaid and CHIP. However, since the take-up is much less than 100% (see Currie and Gruber, 1996 and Gruber and Simon, 2008), controlling for the proportion of children eligible for public assistance is likely to underestimate the mandate effect, as some eligible but unenrolled children have private insurance and are likely to benefit from the mandates.[19] Moreover, Joyce and Racine (2005) found that the introduction of CHIP did not affect the take-up of vaccines compared with those unlikely to be eligible for CHIP.

In group average regressions, it is common to weigh by cell size. I use the test proposed in Dickens (1990) and find that weighting by sample size introduces more heteroskedasticity, likely because the state level error component is larger than the sample average estimation error. In this case, simple Ordinary Least Squares estimation with heteroskedasticity robust standard errors is preferable, and these are reported here.[20]

I consider a mandate to be 'in effect' after a full year since enactment. For mandates enacted on or before June of a given year, the following year is taken to be the mandate year. For mandates enacted after June of a given year, the mandate year is taken to be 2 years hence.[21] The results are similar if I define the mandate

[19] I estimate Medicaid/CHIP eligibility using cut-off rules for each state and year for 1–5 year olds based on LoSasso and Buchmueller (2004). I only observe income categories, so I assign to each household either the income for the midpoint in their category or the 75th percentile. The findings are similar across both definitions of income.

[20] Alternative weights in a weighted least squares framework that account for the state average component and the different sample sizes provide similar results to those presented here and are available upon request.

[21] In Delaware, for instance, the mandate was enacted in January 1999, so 2000 is coded as the first year the mandate was in effect. In Georgia, the mandate was enacted in July 1995, so 1997 is coded as the first year with a mandate in effect.

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Table III. Mandate effect

	Panel A		Panel B	
	(1)	(2)	(3)	(4)
	All states	No old mandate states	All states	No old mandate states
Mandate	0.0180** [0.0074]	0.0156** [0.0077]	–	–
1–2 years after	–	–	0.0181** [0.0078]	0.0089 [0.0081]
3 or more years after	–	–	0.0165* [0.0082]	0.0210** [0.0086]
State Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Observations	612	384	612	384

National Immunization Survey provider weights used in the aggregation. Analysis conducted at the state/year level. Panel A considers the overall effect of the mandates on the percentage of children up to date with the 431 immunization series (four doses diphtheria–tetanus toxoids–pertussis, three doses of polio, and one dose measles-mumps-rubella). Panel B considers the dynamics over time and separates the immediate and the longer term effect of the mandate. In parenthesis are reported heteroskedasticity robust standard errors clustered at the state level.
*denotes significance at 10%,
**significance at 5%.

to be in effect the year after its enactment without consideration to month. To examine dynamics, I allow for short-term and long-term effects by separating the first 2 years after enactment.

5. RESULTS

5.1. Baseline results

Panel A of Table III shows the results from estimating Equation (1). Column 1 reports results using the 431 immunization rates for all states, and Column 2 drops states that had mandates introduced prior to when the data became available.[22] Panel B shows the results of estimating a dynamic version of Equation (1). The results suggest that the introduction of a mandate increased immunization rates on average by 1.8 percentage points, and the effect is significant at the 5% level. The effect appears to be strongest in the first 2 years for all states, and it persists as indicated in Panel B, with an increase of 1.65 percentage points. Among states that introduced mandates more recently, it appears that effects were concentrated in the latter period.

These results are substantial given that the population likely to be affected consists of between 5% and 13.8% of all children. Because about half of all employees had coverage through self-insured plans that, under ERISA, do not have to comply with state regulations, these results become even more economically significant, even though the 1.8 percentage point effect may seem small from an overall population standpoint.

Naturally, it would be impossible to link this effect with the actual incidence of 431-series-related diseases because of the overall low population incidence among infants. However, from a public health perspective, it now appears evident that low vaccination rates among subgroups can trigger outbreaks, thus putting the overall population at greater risk. Such is the case with the recent outbreaks of measles and pertussis (CDC, 2014a, 2014b, 2014c). Such incidents, of course, emphasize the general importance of vaccines as an overall public

[22]In addition, to account for the fractional nature of the dependent variable, I estimate Equation (1) using a fractional Probit model in a quasi-maximum likelihood framework following Papke and Wooldridge (2008) and find similar effects—the mandate effect is estimated to be 0.0184 with standard error 0.0067 and significant at the 1% level.

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Table IV. Policy endogeneity

	(1)	(2)
Mand	0.0182*	–
	[0.0099]	
Lead_Mand	−0.0046	–
	[0.0090]	
$T-3$ years or more before the mandate	–	−0.0065
		[0.0140]
$T-1$ and $T-2$ years before the mandate	–	0.0128
		[0.0080]
$T+2$ and $T+3$ years after mandate	–	0.0208**
		[0.0081]
$T+4$ years after the mandate enactment	–	0.0193**
		[0.0080]
State Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Controls	Yes	Yes
Observations	612	612

National Immunization Survey provider weights used in the aggregation. Analysis conducted at the state/year level. Column (1) estimates Equation (1) by adding a lead_mandate variable that turns one the year before the mandate was enacted. Column (2) estimates an event study type of model, and the excluded categories are the year the mandate was enacted and the year immediately prior and states that never had a mandate. In parenthesis are reported heteroskedasticity robust standard errors clustered at the state level.
*denotes significance at 10%,
**significance at 5%.

health intervention, but they also underscore that risks to overall public can be mitigated by policies that target subgroups (the underinsured, in our case).

It is likely that the children affected would eventually receive a full course of vaccinations, especially before enrolling in school. However, before then, they would have a higher risk of contracting a disease, the effect of which is much more severe at younger ages. Splitting the sample by the three available age groups, the increase is found to be 3.05 percentage points for 19–23 month olds, and 2 percentage points for 24–29 month olds, both of which are significant at 5%. For the oldest group, there is a small and insignificant effect. Hence, the effect of the mandate is mainly concentrated among younger children.

5.2. Policy endogeneity

A usual concern when analyzing the effect of a policy change is that it might have been enacted in response to abnormally low level pre-policy, and so any observable improvements might be a natural response. To address this type of endogeneity, I test whether states enacted mandates in response to low immunization rates by first including a 1-year lead of the mandate in Equation (1). If the policy was adopted in response to low rates in the previous year, the lead indictor would be negative and statistically significant. Column 1 of Table IV shows the results and while the lead mandate indicator coefficient is negative, it is not significantly different from zero.[23]

I also conduct an event-study type of analysis by adding indicators for 2, 3, or 4 or more years after the mandate, as well as 1 to 2 years and 3 or more years prior to the mandate. The excluded category is the year of and immediately following enactment.[24] I find that the leads of the mandate are all insignificant, suggesting that the enactment does not result from previously low immunization rates. Other sources of endogeneity can possibly be caused by state-level unobservables, and I address some of the more serious ones in the following section.

[23]The excluded category includes states that never had a mandate. Dropping such states and limiting the excluded category to only the 'before' period for states enacting a mandate gives similar results.
[24]Years before and after the enactment are grouped into two in order to increase sample size.

5.3. Robustness checks

The main results could be biased if the timing of the mandates coincided with other state changes. This problem is exacerbated by the fact that with the available data, I do not observe the population likely to be affected by such mandates (i.e., children with private insurance coverage). To address this, I implement robustness checks that account for other changes in the policy environment related to childhood vaccinations.

VFC. VFC was implemented in 1995 at the beginning of the study period, but there is no reason to expect states participated equally or enrolled providers with the same speed. This heterogeneity, which is not captured in the model earlier, might account for the positive results. Because of data limitations on the number of VFC providers by state and year (reliable data on VFC participation from NIS exist only after 2005), I cannot directly account for VFC expansions in the main specification. By eliminating states that had the more generous 'universal VFC' program, however, it may be possible to account for this indirectly because such states are more likely to have a larger proportion of immunizations delivered by VFC providers (IOM, 2004).[25] Table V column 1 reports the results after dropping VFC states and the estimate declines minimally. Because of the generosity of the universal VFC program, we would also expect the mandates to not have an important effect in VFC states. Column 2 confirms this, although with a sample size of only 96 observations, there may be low statistical power, thus limiting the ability to draw inferences.

ERISA. Self-insured plans do not have to comply with state mandates, so we should expect states with a higher proportion of such enrollees to have a lower mandate effect. Using the Medical Expenditure Panel Survey data on percentage of enrollees by state in the year 1996, I split the sample into states that had self-insurance enrollment above the US average of 46%, those below, and those that could not get individual estimates because of sample size. This last group of states had 34.5% self-insurance, so we should expect a similar effect as the below average group. Table V columns 3, 4, and 5 present the results confirming the previous hypotheses.

Section 317 funding. In the 1990s, in addition to the introduction of VFC, there was an expansion in Section 317 funding, which has been found to increase immunizations (Rein *et al.*, 2006). In the main analysis, I do not control for Section 317 funding because this information is only available from 1998 to 2004. Table V column 6 reports the results from estimating Equation (1) with the sample restricted to those years for which data are available. The estimated mandate effect is now no longer statistically significant, which could be due to halving of the effective sample. Adding lagged Section 317 funding allocations to the main specification for the 1999–2005 subsample, it appears that a $100 per capita increase in Section 317 funding results in roughly a one percentage point increase in the 431 immunization rate, which is comparable to the 1.6 percentage point effect of Rein *et al.*[26]

HMO penetration. The IOM (2004) report finds that children in HMOs are more likely to be up-to-date with their immunizations.[27] NIS does not have information on whether a provider is part of an HMO. However, data on HMO penetration rates by state and year are available from other sources from 1995–2000 and 2002–2006.[28] Using the 1996–2001 and 2003–2006 sub-periods, I estimate the effect of the mandate with and without the previous years' HMO penetration rate as a control. Table V columns 8 and 9 show the results. The effect of the mandate is found to be smaller at 1.56% but is still significant at the 10% level. However, contrary to expectations, the HMO penetration rate is significantly negatively associated with 431 take-up. A potential explanation for this negative effect could be related to the HMO backlash and

[25]Using the most recent information from 2004, there are eight states with universal VFC programs: Alaska, Idaho, Maine, Massachusetts, New Hampshire, New Mexico, Rhode Island and Washington. In 2006, 87% of children had all their vaccines in a VFC participating provider in states with universal VFC, while in the remaining states this figure was only 78%, with outliers going as low as 42%.
[26]Rein *et al.* used different vaccine series as their outcome of interest.
[27]This is probably because HMOs need to report immunization rates for their enrollees as a measure of their service quality.
[28]HMO penetration rates are missing for a few years for the District of Columbia.

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Table V. Robustness checks

	(1) No universal VFC	(2) Universal VFC states only	(3) Self-Insurance Enrollment Above US Average	(4) Self-Insurance Enrollment below US average	(5) Self-Insurance Not Available
Mandate	0.0179**	0.0992	0.0164*	0.0262**	0.0310***
	[0.0073]	[0.0902]	[0.008]	[0.0115]	[0.0087]
Observations	516	96	336	144	132

	(6) Sect 317	(7) Same sample as (6)	(8) HMO (1996–2001 and 2003–2006)	(9) Same sample as (8)	(10) 43 series
Mandate	0.0134	0.0128	0.0156*	0.0165**	0.0147**
	[0.0082]	[0.0081]	[0.0082]	[0.0067]	[0.0074]
Section 317	0.009*	–	–	–	–
(100$ per capita)	[0.005]				
HMO penetration rate	–	–	−0.0413*	–	–
			[0.0232]		
Observations	357	357	508	508	612
State Fixed Effects	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes

National Immunization Survey provider weights used in the aggregation. Column 1 shows the results of estimating Equation (1) without states that had a universal Vaccines for Children (VFC) program enacted. Column 2 uses only these states. Columns 3, 4, and 5 split the states by their self-insurance enrollment relative to the US average. Column 5 controls for total Section 317 funding assigned to each state. In Column 6, I use the same sample as in column 5 but no longer control for Section 317 funding. In Column 8, I control for the states' Health Maintenance Organization (HMO) penetration rate based on Interstudy data, and in Column 9, I estimate the mandate effect with the same sample available as column 8 but no longer control for HMO penetration rate. Column 10 considers the take-up of the 43 series. Robust standard errors reported and clustered at state level.
*denotes significance at 10%,
**significance at 5%, and
***significance at 1%.

changes in the composition of private versus Medicaid HMO participants that occurred in the late 1990s, but especially after 2001, as documented in Cooper *et al.* (2006) and Marquis *et al.* (2004)).[29]

Autism. The 431 vaccination series includes the MMR vaccine, the take-up of which was likely affected by the controversy that followed the publication of Wakefield *et al.* (1998) that alluded to a link between MMR and autism (Anderberg *et al.*, 2011). Because the timing of the controversy partially overlaps with the introduction of mandates in some states, the results could underestimate the mandate effect. As a robustness check, I consider the effect of the mandates on the take-up of the '43' series without any consideration to the MMR shot. As reported in Table V column 10, the results are not very different. [30]

Varicella vaccine and daycare vaccination requirements. Abrevaya and Mulligan (2011) found that the introduction of daycare requirements for the newly recommended varicella vaccine strongly affected its take-up. Daycare requirements began in the USA in the late 1990s and early 2000s. Although the timing does not

[29]In the latter time period, during the backlash, many privately insured HMO participants switched to other non-HMO plans. At the same time, HMOs were expanding into the Medicaid population. Indeed, Marquis *et al.* (2004) found that the remaining population of HMO beneficiaries was disproportionally concentrated (and growing) among Medicaid plans. So, the composition of HMO participants shifted towards the Medicaid population, who on average have lower infant immunization rates (in my sample, the Medicaid-eligible have a 75.8% take-up of the 431 series, versus 82.2% for those not eligible). Thus, the negative association may be a reflection of lower immunization rates among Medicaid beneficiaries.

[30]There was likely a spillover effect due to the autism controversy on other vaccines as well, but this would further bias downward the mandate effect.

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Table VI. Displacement effect and cost shifts: mandate effect on type of provider

Dependent variable: percentage of children who have completed the 431 series by setting

	(1) Public clinics	(2) Doctors' offices	(3) Hospitals	(4) Mixed	(5) Non-public
Mandate	−0.1099**	0.0822	0.1250***	0.0309**	0.0937**
	[0.0482]	[0.0578]	[0.0209]	[0.0128]	[0.0422]
State Fixed Effects	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Observations	612	612	612	612	612

National Immunization Survey provider weights used in the aggregation. Column 1 has as the dependent variable the percentage of children in each state/year that have completed the 431 series and received all eight shots at a private doctor's office. In column 2, children have obtained all the vaccine(s) at a public clinic, and in column 3, in hospitals. Column 4 refers to locations with more than one kind of provider, and non-public refers to private and hospitals only. Controls are similar to Table III but exclude type of provider and public insurance eligibility. Robust standard errors reported and clustered at state level.
*denotes significance at 10%,
**significance at 5%, and
***significance at 1%.

coincide with the introduction of state insurance mandates, there is some overlap: overall correlation between the two policies is 0.28. Adding the daycare requirements in Equation (1) slightly lowers the mandate effect, but it is still significant at the 5% level. The mandate did not seem to affect the take-up of the varicella vaccine, probably because in the majority of states, the statutes were phrased to apply to older vaccines.[31]

To account for daycare requirements, along with other state-specific differences over time, I estimate Equation (1) with state-specific time trends. I find that the effect of the mandate is now smaller at 1.55 percentage points and significant at the 10% level. Given that state-specific time trends account for much of the variation that is likely explained by the mandates, this result is broadly supportive of the previous findings.

5.4. Displacement effect and cost shifting

Aside from changes in immunization rates, another interesting question is whether insurance mandates lead to fewer immunizations being completed in public clinics. The extent to which more vaccines are being administered under private insurance rather than in public clinics represents a cost shift from the public to private sector. Because of data limitations, I cannot test directly if there are more vaccinations being paid for through private insurance. An indirect test, however, can be performed by using information on whether providers identify themselves as private, public, hospital, military, or WIC clinic.[32]

Table VI reports the results from estimating Equation (1) with the addition of five other dependent variables. The first three are the proportion of children who completed the 431 series and obtained vaccines exclusively at a public clinic, private doctor's office, or at a hospital. The last two variables indicate having more than one type of provider or having non-public providers (other than public clinics, military, and WIC clinics), respectively. As a result of the mandate, there is a shift away from public clinics towards private providers, mainly hospitals and mixed type. The mixed category includes at least one doctor's office, indicating some shifting towards doctors' offices.

There is evidence that VFC also results in a shift from public clinics to private doctors' offices (Zimmerman *et al.*, 2001). Isolating the effect of mandates by eliminating universal VFC states from the sample, I still find an

[31]An exploration of insurance mandate updates through new legislation or executive orders for newer vaccines and their effect on uptake is outside the scope of this study but remains a question for future research.

[32]Most providers fit in the first four categories; there are fewer than 0.1% of children who receive immunizations in a WIC clinic. Using a survey of New York state physicians, Szilagy *et al.* (2000) found evidence that the number of referrals to public clinics went down significantly after the introduction of the insurance mandate and VFC.

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8 percentage point decline in the proportion of children obtaining vaccines from public clinics and an almost equal increase in non-public settings, both of which are statistically significant at the 5% level.

The increase in immunizations in hospitals due to mandates can be explained by increases in the number of primary care clinics operated by hospitals and other initiatives to promote immunizations at non-traditional medical sites, such as hospitals and pharmacies (IOM, 2000). While the report goes on to state that there is ‘insufficient evidence…to support this intervention when used alone (pp. 130–31)’, a possible explanation for the increase in the 431 immunization rate is the interaction of both lower out-of-pocket and time costs due to insurance mandates in conjunction with the increase in locations supplying immunizations.[33]

To the extent that prior to the mandates, parents skipped the well-child visit at the doctor’s office and opted instead to obtain free vaccines at a public clinic, the shift away from public clinics might be a positive, if indirect and unexpected, health outcome that allows families to unify their site of care. Doctors, whether in their own offices or at the hospital, are more likely to have access to the child’s medical history, check for other conditions, and take appropriate action. The same services can be harder to obtain in some public clinics (Joyce and Racine, 2005; Lee *et al.*, 2007).

6. CONCLUSION

I find that state mandates on private insurers to cover childhood immunizations increased the immunization rate for the 431 series by 1.8 percentage points. This is a substantial effect given that around the time the mandates were introduced, the target population represented the subgroup of US children with private insurance that did not cover immunizations, representing 5% to 13.8% of 0 to 5 year olds. This effect is comparable to a $10 yearly per-capita increase in Section 317 funding as found by Rein *et al.* (2006).

The mandates also increased the proportion of children immunized at a hospital or doctor’s office, suggesting a possible shift in costs from the public sector to private insurers. The overall mandate effect is present after accounting for other concurrent changes, such as expansions in Medicaid, the introduction of CHIP, increases in Section 317 funding, and HMO penetration rates across states, as well as after indirectly accounting for the VFC program and daycare vaccination requirements.

These findings have several policy implications. The evidence suggests that part of the population is responsive to the price of immunizations. By covering immunizations in doctors’ offices and hospitals, the mandates might also lower time costs for parents without easy access to public clinics or who obtain free vaccines at a public clinic but also made separate visits to the pediatrician for checkups. The federal mandate enacted by the ACA might thus be a viable way to increase immunization rates even though the private health insurance industry has an incentive to pay for vaccines in light of their cost effectiveness, but might not do so if they are paid for through public programs. This approach would also lessen the public burden of financing VFC and eliminate inefficiencies such as the fragmentation of care and costs associated with doctor-determined eligibility (IOM, 2004). In addition, it appears that state insurance mandates can positively affect utilization if implemented without loopholes around key provisions.

CONFLICT OF INTEREST

The author reports no conflicts of interest.

[33]In addition, mandates could increase immunizations at the hospital if children who had contact with hospital staff because of other medical conditions are now more likely to complete vaccinations as part of their care.

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