Three Essays in Health Economics

By

Brandyn F. Churchill

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Approved:
Christopher S. Carpenter, Ph.D.
Lesley J. Turner, Ph.D.
Analisa Packham, Ph.D.
Carolyn J. Heinrich, Ph.D.

To Evelyn and Kenneth, whose love continues to inspire

and

To Sophie, who made this possible

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction

Human papillomavirus (HPV) is the most common sexually transmitted infection in the United States and the single biggest cause of cervical cancer, as well as certain cancers of the head and throat, anus, vulva, vagina, and penis. Between 2008 and 2012 nearly 40,000 people annually were diagnosed with an HPV-related cancer. Despite these staggering numbers and the existence of a highly effective vaccine, HPV vaccination rates remain low. In the first two chapters of this dissertation, I examine several policies intended to increase vaccine take-up. In the third chapter, I more generally examine the relationship between labor market opportunities and health insurance coverage.

Recent increases in vaccine-preventable diseases have led policymakers to reconsider the scope of vaccine requirement exemptions. Yet eliminating these provisions is politically difficult. In the first chapter, *How Important is the Structure of School Vaccine Requirement Opt-Out Provisions? Evidence from Washington, DC's HPV Vaccine Requirement*, I study how moving from a one-time opt-out form to an annual opt-out requirement effected vaccine take-up. Beginning in 2009, sixth grade girls in Washington, DC were required to receive the HPV vaccine or submit a one-time opt-out form. In 2014, the requirement was expanded to all students grades 6-12, and those not vaccinating were required to opt-out annually. I show that the movement from a one-time opt-out provision to an annual requirement increased the probability that teen girls in Washington, DC initiated HPV vaccination by 11 percentage points. Teen boys were 20 percentage points more likely to be vaccinated. Back-of-the-envelope calculations suggest 7 fewer cases of cervical cancer and 41 fewer cases of oropharyngeal cancer for the 33,000 enrolled during the 2017/2018 year. Using the initial value of cancer care and the value of a statistical life year, my estimates imply nearly $36 million in savings compared to $1.5 million spent on vaccination. In generalizing these results to other states, effect sizes even one-tenth the size of my most conservative estimate would imply meaningful reductions in the nationwide incidence of HPV-related cancers.

In the second chapter, *Insurance Coverage, Provider Contact, and Take-Up of the HPV Vaccine*, I show that state Medicaid expansions as part of the Affordable Care Act were associated with a 3-4 percentage point increase in the probability that a teenager initiated the HPV vaccine. This relationship appears to have been driven in part by increases in Medicaid coverage, the probability of having a recent check-up, and knowledge about the HPV vaccine. Supporting this pathway, I also show that Medicaid expansion states saw increased Google searches for "pediatrician," "Gardasil" (a trade name of the HPV vaccine), and "HPV Cancer." Importantly, teen insurance eligibility was largely unaffected by the ACA Medicaid expansions, so this chapter highlights the importance of parental engagement with the health care system in affecting teen health behaviors and outcomes.

In the third chapter, *E-Verify Mandates and Unauthorized Immigrants' Health Insurance Coverage*, I study state policies requiring employers to electronically verify (E-Verify) the work eligibility of their new hires. These policies are intended to disrupt unauthorized immigrants' access to the formal labor market. E-Verify mandates previously enjoyed bipartisan support, and GOP leaders have identified a nationwide E-Verify mandate as a policy priority in working with the Biden administration towards comprehensive immigration reform. I show in this paper that state E-Verify mandates are associated with a 5-percentage point reduction in the probability that likely unauthorized immigrants are employed and a 2-percentage point reduction in the probability that they have employer-sponsored insurance. However, these changes are limited to one period after implementation. In all remaining periods, the relationships are not distinguishable from zero. I show that this pattern can be explained by selective outmigration of otherwise unemployed and uninsured likely unauthorized immigrants. By preventing unauthorized immigrants from moving to a more favorable policy environment, a nationwide E-Verify mandate would likely further limit unauthorized immigrants' access to private health insurance.

CHAPTER 1

How Important is the Structure of School Vaccine Requirement Opt-Out Provisions? Evidence from Washington, DC's HPV Vaccine Requirement[1]

"*Research is needed to investigate the extent to which different forms of opt-out provisions may contribute to or detract from vaccination*."—Calo et al. (2016)

1.1. INTRODUCTION

Seventy-nine million Americans are infected with human papillomavirus (HPV) making it the most common sexually transmitted infection in the United States (CDC 2017). Approximately 80 percent of sexually active people will contract HPV during their lives (Cleveland Clinic 2018). HPV is a group of more than 200 related viruses (National Cancer Institute 2020a), and HPV types 16 and 18 are responsible for 66 percent of all cervical cancers in the US (CDC 2018). Over 40,000 people annually are diagnosed with an HPV-related cancer (Van Dyne et al. 2018). Approximately 11 million men are currently thought to have oral HPV (Deshmukh et al. 2017), and the incidence of male oral cancer exceeds the incidence of cervical cancer in women (Mourad et al. 2017).

Unlike most cancers, there is a highly effective vaccine that provides near complete protection against some of the most dangerous strains of HPV (Villa et al. 2005; Villa et al. 2006). Yet in 2018, only 68 percent of teens had initiated HPV vaccination and only 55 percent were fully vaccinated.[2] Over the last decade, more than 40 states have introduced legislation on HPV vaccination, many of which sought to leverage the success of other school-entry vaccine

[1] A version of this chapter is in press as "How Important is the Structure of School Vaccine Requirement Opt-Out Provisions? Evidence from Washington, DC's HPV Vaccine Requirement" at Journal of Health Economics. It is reproduced here in accordance with the rights retained by the author.

[2] In November of 2016, the Advisory Committee on Immunization Practice (ACIP) began recommending a 2-dose series for full protection (Meites, Kempe and Markowitz 2016). Prior to that it was a 3-dose series.

requirements by mandating HPV vaccination (Barraza et al. 2016). However, these mandates have proven politically difficult. For example, the New York state Parent Teachers Association announced opposition to a recent bill which would require middle school students to receive the HPV vaccine, despite re-expressing its support for other mandated vaccinations (Times Herald-Record 2020). Only three states and the District of Columbia have successfully adopted HPV vaccine school requirements, and vaccination proponents argue that their broad opt-out provisions limit their efficacy (Reynolds 2012).[3]

In this paper, I provide the first causal evaluation of how Washington, DC's 2014 HPV vaccine school requirement affected vaccine coverage. I find that the requirement increased the probability that a teen was fully vaccinated against HPV by nearly 20 percentage points—a 71 percent increase over the 2013 vaccination rate. I use an event study specification to show that this increase was not driven by pre-existing trends in vaccination. The use of placebo permutation tests confirms that the increase is larger than would be expected by chance. I also show that the estimate is robust to employing a synthetic control design. Back-of-the-envelope calculations imply that this requirement will directly result in 7 fewer cases of cervical cancer and 41 fewer cases of oropharyngeal cancer for the 33,000 students enrolled in Washington, DC schools during the 2017/2018 academic year. After accounting for the initial costs of cervical and oropharyngeal cancer care, as well as the statistical value of the life years lost, my estimates imply nearly $36 million dollars in reduced cancer savings compared to the $1.5 million it cost to vaccinate these students.

[3] These states are Hawaii, Rhode Island, and Virginia, though Hawaii's requirement did not take effect until the 2020/2021 school year. In 2007, then-governor Rick Perry issued an executive order requiring that 6th grade girls in Texas be vaccinated against HPV. The order was vacated by the legislature, and the issue was used against Perry during a debate when he ran for the Republican presidential nomination (NPR 2011).

While important for policymakers, generalizing these estimates to the broader US requires caution. For one, the HPV vaccine initiation rate in the US in 2018 was higher than Washington, DC's initiation rate immediately prior to the policy change (68 percent vs. 62 percent). Moreover, vaccine initiation rates between girls and boys have converged. In 2018, 70 percent of girls and 67 percent of boys had received at least one shot of the HPV vaccine. As a result, school requirements may no longer induce larger increases in take-up for teen boys than teen girls. Yet even subject to these caveats, considering how these estimates could generalize is a useful exercise. There are 30 million 6-12th grade students in the US (National Center for Education Statistics 2018). Applying my most conservative estimated increase in vaccine initiation (10.9 percentage points) still yields approximately 3.27 million more vaccinated students and over 6,000 fewer cases of cervical cancer.

In addition to learning about ways to improve HPV vaccination, the Washington, DC policy change offers broader insights into the importance of how vaccine mandates are implemented. While respondents view vaccine school requirements more favorably if they contain opt-out provisions, these provisions likely reduce the mandates' efficacy (Calo et al. 2016). Indeed, there is a positive association between the ease of opting-out of vaccination and the number of exemptions granted in a state (Blank et al. 2013) and repealing non-medical vaccine exemptions is associated with greater vaccine coverage (Nyathi et al. 2019; Richmine, Dor, and Moghtaderi 2019). Beginning in 2009, sixth grade girls in DC were required to (i) receive the HPV vaccine or (ii) submit a one-time opt-out form. In 2014, the requirement was expanded to 6th grade boys and all students up through 12th grade. Additionally, all those not vaccinated were required to opt-out annually. As such, the treatment for teen girls was not a movement from "no requirement" to an

"HPV vaccine requirement," but rather a change from a one-time opt-out in 6th grade to an annual opt-out requirement all the way through 12th grade.

For teen girls, I find a 11-percentage point increase in HPV vaccine initiation and a 20-percentage point increase in vaccine completion. This pattern suggests that the annual reminder induced girls who had previously opted-out of HPV vaccination to receive their first shot, while also encouraging girls who had initiated vaccination to complete the vaccine series. In support of this pathway, I show that DC's 2014 HPV vaccine requirement reduced the probability that a teen girl had initiated but not completed the HPV vaccine. Additionally, I find that the 2014 requirement increased the probability that teen girls completed HPV vaccination within the recommended timeframe conditional on initiation. In contrast to these results for teen girls, I find that the increase in vaccine completion for teen boys is fully explained by an increase in vaccine initiation.

In Section 2, I discuss the history of the HPV vaccine, state HPV vaccine school requirements, and the existing literature on policies promoting HPV vaccination. In Section 3, I provide an overview of the NIS-Teen data and show descriptively that DC experienced a dramatic increase in HPV vaccination in the post-school requirement period. I then discuss my identification strategies, as well as the difficulties of conducting statistical inference with a single treated unit. In Section 4, I show that DC's 2014 HPV vaccine school requirement led to a large statistically significant increase in HPV vaccination, and I explore how the relationship varied by sex, grade level, race/ethnicity, and mother's educational attainment. In Section 5, I use my estimates to project the number of cancers prevented due to the 2014 mandate, and I estimate the cost savings associated with these reductions. Finally, I conclude in Section 6 by discussing the policy implications of my estimates and areas for future research.

1.2. POLICY BACKGROUND & EXISTING LITERATURE

In this section, I provide a history of the HPV vaccine within the United States. I discuss when various age and sex groups were eligible to receive the vaccine, as well as state HPV vaccine school requirements. Next, I summarize the literature on vaccine mandates with a focus on the structure of these requirements. Finally, I discuss existing work on ways to improve HPV vaccination.

1.2.1. Policy Background

Gardasil—the trade name of the HPV vaccine—was approved for girls ages 9-26 in June 2006.[4] Initially, the Advisory Committee on Immunization Practices (ACIP) recommended a 3-dose vaccination series for 11- and 12-year-old girls (FDA 2006), and that unvaccinated 13-26 year old females catch-up on vaccination (Meites et al. 2019). While several states have enacted legislation to educate the public about the HPV vaccine (NCSL 2020), only three states and DC require HPV vaccination for school attendance.

In April of 2007, Virginia began requiring that girls initiate HPV vaccination prior to entering 6th grade starting in the 2008/2009 academic year.[5] Similarly, DC Law 17-10 included an HPV vaccine school requirement for teen 6th grade girls starting in the 2009/2010 school year. Notably, this order applied to all girls, including those in private and parochial school, and I show in Figure 1 that the share of teenage girls in DC initiating the HPV vaccine rose by approximately

[4] Between 2009 and 2016, a variant of the HPV vaccine was sold in the US under the trade name Cervarix. It left the US market due to low demand (FDA 2009; GSK 2016).

[5] Because the National Immunization Survey-Teen begins in 2008, I am unable to leverage identifying variation from Virginia's requirement. I opt to focus on the DC requirement instead of including Rhode Island for two reasons. First, Rhode Island had the highest HPV vaccination rate in the US prior to its school requirement, while the nationwide HPV vaccination rate in 2018 was similar to Washington, DC's prior to DC's HPV mandate (68 percent vs. 62 percent). Because of this, my results may be more generalizable to other settings. Additionally, because DC had already implemented an HPV vaccine requirement in 2009, the 2014 policy change provides insights into the importance of having annual opt-out form relative to a one-time option that cannot be measured in Rhode Island.

20-percentage points following the first mandate. However, after viewing an information sheet about HPV shown in Figure A1, parents had broad latitude to opt out of vaccination "for any reason." Since then, only two other states adopted HPV vaccine school requirements. In 2015, Rhode Island began requiring all middle school students, regardless of sex, to receive the HPV vaccine, and Hawaii began requiring HPV vaccination starting in the 2020/2021 academic year (NCSL 2020).[6]

During the same month that DC's 2009 mandate went into effect, Gardasil was approved for teen boys and young men (FDA 2009). However, DC's requirement was not expanded to include teen boys until the 2014/15 school year. At this point, the policy was also modified so that parents choosing not to vaccinate their children became required to opt-out annually (American Academy of Pediatrics DC Chapter 2015; Ko et al. 2020). I summarize these policy changes and the students bound by the requirements in Table 1.[7]

1.2.2. Vaccine Mandates

In addition to the protection provided to the vaccinated person, immunization offers social benefits by lowering the probability that others contact an infected person. Because these social benefits are not internalized, coverage rates remain below the social optimum. Accordingly, policymakers have explored methods of improving vaccination, including mandating immunization for school

[6] In 2007, then-governor Rick Perry signed an executive order requiring that Texas 6th grade girls receive the vaccine (Tanne 2007). The legislature passed a bill overruling the executive order and it was never implemented (NPR 2011).
[7] The DC Immunization Program received Prevention and Public Health Funding Awards through the CDC in 2013, 2016, and 2017 (American Academy of Pediatrics DC Chapter 2015) totaling $2,251,008 in additional funding to help implement the expanded school vaccine requirement. In Appendix B, I provide a month-by-month granular breakdown of how this funding was spent, as obtained from the Department of Health and Human Services.

attendance (Orenstein and Hinman 1999). While several papers have studied whether these requirements increase immunization (Abrevaya and Mulligan 2011; Ward 2014; Carpenter and Lawler 2019; Luca 2020), less attention has been paid to the structure of these mandates. Yet recent outbreaks of vaccine-preventable diseases have increased interest in exemptions allowing individuals to remain unvaccinated (Olive et al. 2018), with authors finding that vaccination falls when it is easier to obtain an exemption (Blank et al. 2013; Nyathi et al. 2019; Richmine, Dor, and Moghtaderi 2019).

While broad exemptions may undermine the efficacy of vaccine mandates, it is worth noting that these policies may still improve coverage by signaling the importance of vaccination. For example, Lawler (2017) used the 2003-2013 NIS-Child to show that while state hepatitis A mandates increased vaccine take-up by 8 percentage points, ACIP recommendations increased vaccination by 20 percentage points. Similarly, Lawler (2020) found that meningococcal vaccine recommendations increased vaccine take-up among the targeted population by 133 percent relative to the baseline mean.

1.2.3. HPV Vaccination

I am unaware of any economics study which has attempted to determine the causal effect of state HPV vaccine school requirements. Instead, the existing work on these policies in the public health literature is largely based on correlational comparisons. Perhaps most related to this project, Ko et al. (2020) used the 2017 NIS-Teen to compare HPV vaccine initiation rates in areas with HPV vaccine school requirements (DC, Virginia, and Rhode Island) to non-treated areas. The authors then used the 2008-2017 NIS-Teen to perform a difference-in-differences style analysis.

Ko et al. (2020) found a positive association by comparing DC's pre- and post-policy vaccination rates to the change experienced by a composite region generated from Delaware, Maryland, Pennsylvania, and West Virginia. For teen girls, the authors used 2008 as the pre-period and 2009-2017 as the post period, thereby precluding the 2014 policy change from separately affecting girls. They found a 15 percent increase in the likelihood that teen girls were vaccinated, though the result was statistically insignificant. For teen boys, they used 2008-2013 as the pre-period and 2014-2017 as the post-period, and the authors reported a statistically significant 94 percent increase in vaccination. However, they did not probe whether their result could be attributable to a pre-existing trend in vaccination. Nor did they control for time-varying state-level policies—such as DC's grant to promote HPV vaccination— which could bias their estimate upwards. Finally, the authors did not adjust their standard errors to account for the fact that there was only one treated unit in each analysis.

Thompson et al. (2018) examined the relationship between Rhode Island's 2015 HPV vaccine school requirement—which applied to both girls and boys—and parental-reported vaccination using the 2010-2016 NIS-Teen data. Using a triple-difference style specification, the authors documented an 11-percentage point increase in the likelihood that boys were vaccinated; the estimate for girls was statistically insignificant. In a subsequent paper, Thompson et al. (2020) documented a 13-percentage point increase for teen boys using provider-verified data, and they reported finding no meaningful increase when examining DC's mandate. In both cases, the authors failed to control for other vaccine-related policies or adjust their standard errors to account for having only one treated unit.

With so few states requiring HPV vaccination, researchers have examined other policies which may improve coverage. Lipton and Decker (2015) used the 2008-2012 National Health

Interview Survey to show that the Affordable Care Act's dependent coverage provision increased the probability that a 19- to 25-year-old woman was vaccinated for HPV by 8 percentage points compared to a control group of 18- and 26-year-olds. Churchill (2020) found that the ACA Medicaid expansions were associated with increased Medicaid coverage and HPV vaccination for both teen boys and teen girls, with the largest effects for poorer teens, non-white teens, and teens whose mothers lacked college degrees.

Other research has demonstrated the important role of physician contact in vaccination. Carpenter and Lawler (2019) found that middle school Tdap booster requirements increased HPV vaccination by 4-5 percentage points. Because the Tdap booster and HPV vaccine are both recommended for 11- to 12-year-olds (CDC 2020a), the authors argued that the effect was due to the requirements increasing age-appropriate teens' contact with vaccine providers. This pattern is consistent with Moghtaderi and Adams (2016), who found that NIS-Teen respondents who were more likely to encounter physicians for reasons aside from vaccination—such as for mandatory wellness checks or previous asthma diagnoses—were more likely to receive the HPV vaccine.

1.3. DATA & METHODOLOGY

In this section, I describe the specifics of the NIS-Teen data. I show descriptively that the share of DC teens vaccinated against HPV increased dramatically concurrent with the 2014 HPV vaccine school requirement. The average vaccination rate in all other states was unchanged. I then describe my two empirical strategies intended to test whether this is a causal effect—difference-in-differences and synthetic control.

1.3.1. Data: National Immunization Survey-Teen

I obtain HPV vaccination data from the 2008-2018 National Immunization Survey (NIS)-Teen which contains individual-level, provider-verified, state-representative vaccination data on teenagers ages 13-17. The NIS-Teen is administered by the Centers for Disease Control and Prevention (CDC) in two parts. First, the CDC uses telephone surveys to collect demographic information about eligible teens and their parents and guardians. Survey interviewers ask parents which vaccines their teen has received, and whether they may contact the vaccine provider(s). As a follow-up, paper questionnaires are mailed to each provider to obtain provider-verified information on each vaccination, including the number of doses and dates of administration. To guard against the possibility that DC's HPV vaccine school requirement changed the probability that parents reported vaccination without affecting vaccine take-up, I utilize the provider-verified immunization data and restrict my sample to teens with adequate provider information.[8]

I show in Figure 2 that DC and the rest of the United States had similar rates of HPV vaccination prior to 2014. In 2013, 26 percent of DC teens had completed the HPV vaccine (22nd highest in the nation), which was identical to the average vaccination rate throughout the rest of the country. By 2018, the share was nearly 20 percentage points higher in DC than the rest of the country (74 percent vs. 55 percent), and DC had the second highest HPV vaccination rate in the US.[9] Similarly, I show in Table 2 that the average HPV vaccine completion rate was 17 percent for both DC and the rest of the country during the 2008-2013 period (columns 2 and 5 row 1), and

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[8] In 2018, 71.9 percent of eligible households completed the phone survey, and 58.2 percent of these respondents granted permission for the surveyors to contact their teen's vaccination providers. Of these questionnaires, 92.5 percent were returned. Overall, 48.3 percent of teens with completed household interviews had adequate provider information.

[9] Rhode Island, Delaware, Connecticut, Maine, New York, New Mexico, Vermont, Pennsylvania, California, North Carolina, New Hampshire, Nebraska, Arizona, Louisiana, Massachusetts, Washington, Iowa, Texas, West Virginia, Oklahoma, and Oregon all had higher vaccination rates in 2013. By 2018, only Rhode Island had a higher rate of vaccine completion. As mentioned previously, Rhode Island adopted an HPV vaccine mandate in 2015.

only around 30 percent of teens had received at least one dose of the vaccine (columns 2 and 5 row 2). Throughout the post-period, DC's average vaccination rate was considerably higher columns 3 and 6 row 1).

It is worth noting that DC experienced a demographic change throughout this period. From 2008-2013, over 70 percent of teens were identified as black (column 2 row 11). In the post-period, 66 percent of DC teens were identified as black (column 3 row 11). At the same time, the share of teens whose mothers lacked a high school degree fell (18 percent vs. 13 percent) and the share living in households earning less than $20,000 a year fell (31 percent vs. 25 percent). To the extent that white teens, teens with more educated mothers, and wealthier teens were more likely to receive the HPV vaccine, it is possible that these composition changes could bias my estimates. However, I show in Figure A2 that these changes were part of a smooth trend and did not occur concurrent with the 2014 school requirement. Additionally, white teens throughout the rest of the US had a lower vaccination rate than non-white teens (27 percent vs. 34 percent), so the direction of any potential bias is unclear.

1.3.2. Methodology: Difference-in-Differences with Randomization Inference

While the descriptive statistics in Figure 2 indicate an increase in DC's HPV vaccination rate after the school requirement was implemented in 2014, I formally test this relationship using the following linear probability model:

$$\text{VACC}_{ist} = \alpha + \beta \cdot \mathbf{1}\{s = \text{DC}\} \cdot \mathbf{1}\{t \geq 2014\} + \mathbf{X'}_{ist}\boldsymbol{\gamma} + \mathbf{B'}_{st}\,\boldsymbol{\delta} + \theta_s + \tau_t + \varepsilon_{ist} \qquad (1)$$

where VACC is an indicator for whether the teen, *i*, in state, *s*, was fully vaccinated against HPV in year *t*. The coefficient of interest, β, measures how much more likely a teen in DC was to be vaccinated against HPV after the implementation of the 2014 school HPV vaccine requirement.

To account for the fact that DC's demographic composition was changing throughout the sample period in a way that may have been correlated with vaccination, I include a vector of individual-level characteristics, **X**. These includes indicators for the teen's sex (male, with female omitted), the teen's age (13, 14, 15, 16, with 17 omitted), the teen's grade level (6-8th, 9-12th, high school graduate, with "unenrolled" omitted), and the teen's race/ethnicity (white, black, Hispanic, with "other" omitted). The vector also includes indicators for mother's age (≤ 34, 35-44, with 45+ omitted), mother's educational attainment (less than high school, high school graduate, some college, with college omitted), and household income (less than $20K, $20-30K, $30-40K, $40-50K, with $50K+ omitted).

I account for state-level time-varying characteristics related to HPV vaccination. The vector **B** includes indicators for Washington, DC's 2009 HPV vaccine requirement, whether the vaccine was approved by the FDA and/or recommended by ACIP for the teen. It also includes indicators for other vaccine mandates, including a Tdap booster requirement (Carpenter and Lawler 2019), a meningococcal booster mandate, post-secondary school meningococcal education mandate, a secondary school meningococcal education mandate, and a post-secondary meningococcal vaccine mandate (Lawler 2020). It also includes indicators for whether a pharmacist has prescriptive authority for the HPV vaccine, whether a pharmacist has general authority for the HPV vaccine, whether the pharmacist has patient-specific authority for the HPV vaccine, whether some minors can consent to any medical procedure, and whether some minors can consent to receive the HPV vaccine.[10]

[10] I am grateful to Emily C. Lawler for providing me with these policy variables.

To account for access to the vaccine, the vector **B** also includes an indicator for whether the state purchases the HPV vaccine for all children through a universal purchase program, Mulligan et al. 2018), as well as state requirements that the HPV vaccine be covered by private health insurance (Hoss, Meyerson, and Zimet 2019). The vector also controls for whether the state received National Cancer Institute (NCI) or National Association of County and City Health (NACCHO) HPV vaccine grants, as well as the real value of CDC grants issued per person that year for HPV vaccination (American Academy of Pediatrics DC Chapter 2015). Finally, I include time-invariant state fixed effects, θ, and location-invariant year fixed effects, τ.

To conduct inference, I employ the variant of Fisher's (1935) permutation test used by Buchmueller, DiNardo, and Valleta (2011) and Cunningham and Shah (2018).[11] First, I estimate equation (1) an additional 50 times iteratively assuming that each of the control states was treated in 2014. I then compare the $\hat{\beta}$ for the actual 2014 DC treatment to the placebo distribution. To achieve 10 percent statistical significance using a two-tailed test, DC's coefficient must be larger (or smaller) than all but two states. Similarly, 5 percent statistical significance requires the coefficient to be at the top of the placebo distribution. As such, this is a demanding statistical test.

It is possible that DC's HPV mandate had differential effects depending on the teen's grade level, race/ethnicity, and/or maternal education. I test this possibility by interacting an indicator for being a member of the group of interest with the independent variable, every control variable, the state fixed effects, and the year fixed effects using the triple-difference specification in equation (2):

[11] With the traditional "clustering" framework, the underlying assumption necessary for the asymptotic approximations is that the number of individuals within a state grows larger. This assumption is not satisfied with one treated state.

$$VACC_{ist} = GROUP_{ist} \times (\alpha + \beta \cdot \mathbf{1}\{s=DC\} \cdot \mathbf{1}\{t \geq 2014\} + \mathbf{X'}_{ist}\boldsymbol{\gamma} + \mathbf{B'}_{st}\,\boldsymbol{\delta} + \theta_s + \tau_t\,) + \varepsilon_{ist} \qquad (2)$$

To interpret β as the causal effect of DC's school HPV vaccine requirement on vaccination, I must assume that vaccine coverage would have evolved similarly to the rest of the United States had it not been for the mandate. While this assumption is fundamentally untestable, I explore whether vaccination was trending differently from the rest of the country prior to the requirement using the following event study framework:

$$VACC_{ist} = \alpha + \sum_{j=2008,\, j\neq 2013}^{2018} \beta^j \cdot \mathbf{1}\{s=DC\} \cdot \mathbf{1}\{t=j\} + \mathbf{X'}_{ist}\boldsymbol{\gamma} + \mathbf{B'}_{st}\,\boldsymbol{\delta} + \theta_s + \tau_t + \varepsilon_{ist} \qquad (3)$$

where β^j is allowed to vary with each year. For ease of comparison, I use 2013—the year prior to the mandate—as the reference year. Equation (3) allows me to test for parallel trends in the pre-period and capture whether the relationship between DC's school requirement and immunization varied over time.

As with equation (1), traditional methods of inference are invalid. Instead of testing whether the pre- and post-implementation coefficients are different from zero (and each other), I again follow Cunningham and Shah (2018) and construct 95 percent placebo intervals for each β^j. As I will show in the results section, the interpretation of this event study specification differs from that typically seen in empirical work. To interpret the school requirement as having a causal effect on immunization, the estimated coefficients should be near zero and bounded within the 95 percent placebo intervals during the pre-period. In the post-period, the estimated coefficients should exceed the placebo-generated intervals.

1.3.3. Methodology: Synthetic Control Analysis

I also explore the robustness of the estimates to using a synthetic control framework (Abadie and Gardeazabal 2003; Abadie et al. 2010), which is intended to alleviate concerns that the rest of the

US is not necessarily an appropriate control for DC. First, I aggregate the variables of interest to the state-year-level. I then construct a "Synthetic DC" from the subset of the control states that best approximates DC's HPV vaccination rates in the pre-period. This Synthetic DC serves as the counterfactual for how the vaccination rate would have evolved in absence of the school requirement.

The synthetic counterfactual is constructed by assigning non-negative weights to the 50 potential donor states to minimize equation (4):

$$(VACC_{DC} - VACC_{SC}W)'V\,(VACC_{DC} - VACC_{SC}W) \qquad (4)$$

where $VACC_{DC}$ is a (K x 1) vector of outcome variables from the pre-period, $VACC_{SC}$ is a (K x J) matrix of the same variables for every other state, W is a (J x 1) vector of weights that sum to 1, and the diagonal matrix V contains the "importance weights" assigned to each variable in VACC. I construct Synthetic DC by matching on three lagged values of the dependent variable (2009, 2011, and 2013), though I show in the appendix that the results are robust to choosing alternative years or simply matching on the average vaccination rate from 2008-2013. I conduct inference using the placebo technique proposed by Abadie et al. (2010).

1.4. RESULTS

In this section, I show that DC's 2014 HPV vaccine school requirement led to a large increase in the probability that teens were vaccinated against HPV. Using an event study specification, I show that this relationship was not driven by a pre-existing trend in immunization. I also document an increase in HPV vaccine initiation, intentions to vaccinate, and the likelihood of having been recommended the vaccine. Finally, I show that this pattern is robust to utilizing a synthetic control framework.

1.4.1. Vaccine Completion

I first show in Table 3 that the 2014 school requirement was associated with a 22-percentage point increase in the likelihood that teens were fully vaccinated against HPV (column 1).[12] As I show in Figure 3, the estimated increase is well outside of the 95 percent placebo interval (Panel A) and is over twice the size of the largest placebo coefficient (0.22 vs. 0.09). Moreover, this increase is large relative to the pre-period mean; between 2008-2013 only 17 percent of students were fully vaccinated against HPV, and only 26 percent were vaccinated as of 2013.[13]

Next, I use the event study specification from equation (3) to test whether HPV vaccination was trending differentially in DC prior to the 2014 requirement. In Figure 3, I show that DC teens were no more likely to be vaccinated against HPV than their counterparts throughout the rest of the US (Panel B). Indeed, the pre-period coefficients are all within the 95 percent placebo interval. However, after the requirement was implemented in 2014, the probability of complete vaccination increased by approximately 20 percentage points. Each of the coefficients from the post-period is outside of the placebo distribution, indicating that the increase was unlikely to have been from chance.

Because teen girls were already bound by the 2009 HPV vaccine school requirement, I next test whether girls and boys were differentially affected by the 2014 policy change. In Figure 4, I show that the 2014 school requirement was associated with a 20-percentage point increase in

[12] Coefficients and standard errors for the covariates are reported in Table A1. In Figure A3, I show that my results are robust to including observations from Rhode Island and Virginia.

[13] As mentioned previously, the number of doses required for full coverage changed from 3 shots to 2 shots in late 2016. In Table A2, I show that my estimate is robust to restricting the sample to years 2008-2016 (column 1) and to recoding complete coverage as requiring 3 shots for the full sample period (column 2). Additionally, the NIS-Teen moved from being a landline phone survey to including cellphone respondents in 2011, and the survey underwent a redesign in 2014. I show that my estimate is robust to whether I utilize the sample weights (column 3). I also show that the estimate is robust to dropping 2013 (column 4) when some teens may have begun vaccinating in anticipation of the 2014 requirement, and the estimate is robust to controlling for only state and year fixed effects (column 5).

complete vaccination for teen girls (Panel A) and similarly a 23-percentage point increase for teen boys (Panel B). While the point estimate for teen boys is larger, these estimates are statistically indistinguishable from each other when I use the triple-difference specification from equation (2). In Table 3, I am unable to reject that the additional 3 percentage point increase experienced by teen boys was attributable to chance (column 2).

In the remaining columns of Table 3, I use the triple-difference specification to test for heterogeneity by grade level (column 3), race/ethnicity (column 4), and mother's educational attainment (column 5).[14] While the point estimates suggest larger increases for older and non-white teens, the differences are statistically insignificant.[15] However, I do detect a statistically significant 9-percentage point larger increase for teens whose mothers lacked college degrees. Prior to the 2014 mandate, teens in DC with college educated mothers were 8 percentage points more likely to be fully vaccinated compared to teens whose mothers lacked college degrees (22 percent vs. 14 percent). In the post-period, teens in both groups were similarly likely to be fully vaccinated (56 percent vs. 55 percent), suggesting that the 2014 requirement may have helped close the education gap for HPV vaccination.

In Figure 5, I explore whether the increase in HPV vaccination was driven by more general changes in immunization behaviors. First, I show that the 2014 HPV vaccine school requirement

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[14] Unfortunately, the NIS-Teen does not contain information on urban vs. rural status, so I cannot compare Washington, DC to other metropolitan areas. However, it is worth noting that I find identical estimates for white and non-white teens. In addition to being an interesting heterogeneity exercise, limiting my sample to non-white teens may provide me with a better counterfactual for teens in Washington, DC, given that 80 percent of the city is non-white.

[15] It is worth noting that between 2008-2013 in DC, 52 percent of non-white girls had initiated HPV vaccination compared to 63 percent of white girls. Similarly, only 25 percent of non-white girls were fully vaccinated compared to 47 percent of white girls. So, while I cannot conclude that non-white teens experienced a larger percentage point increase in vaccination, the point estimate represents a larger increase from the pre-period mean for non-white teens. This suggests that the 2014 HPV vaccine school requirement may have been more salient for non-white teens and could possibly help close the racial gap in HPV-related cancer incidence.

was unrelated to the probability that a teen received a Tdap booster. When I use the two-way fixed effects specification from equation (1), the point estimate is negative and statistically insignificant (Panel A). Nor is there a noticeable change concurrent with the 2014 policy when examining the descriptive trends (Panel B). Similarly, the point estimate for meningococcal vaccination is negative and within the 95 percent placebo interval, though the estimate is statistically significant at the 10 percent level (Panel C). However, rather than the 2014 policy increasing the share of teens receiving the meningococcal vaccine, the descriptive statistics indicate that the relationship is due to growth in the share of immunized teens in the control states, while DC's rate remained unchanged (Panel D).

Finally, I explore whether DC's 2014 HPV vaccine school requirement affected the likelihood that teens received the influenza vaccine. Unlike the HPV vaccine, Tdap booster, and meningococcal vaccination, the influenza vaccine is administered each flu season, and the 2008-2017 NIS-Teen data contain information on whether the teen received the flu vaccine during the prior three years. For example, the 2017 data reports vaccination for the 2015/16, 2016/17, and 2017/18 flu seasons. Because I do not know the exact date of the survey, individuals in the 2017 data may be interviewed prior to the 2017/18 flu season which stretched from September 1st, 2017 through January 31st, 2018.[16] As a result, I utilize data on influenza vaccination for the two flu seasons prior to the survey year. I find suggestive evidence that DC's 2014 HPV vaccine school requirement increased the likelihood that teens received the flu vaccine by almost 6 percentage points (Panel E), though the change appears to have happened over time rather than immediately with the policy change (Panel F).

[16] Fewer than 5 percent of respondents are listed as being up to date for the 2017/18 flu season.

1.4.2. Vaccine Initiation

In the prior section, I showed that DC's 2014 HPV vaccine school requirement led to a large increase in the probability that teens were fully vaccinated against HPV. I next explore whether the requirement increased the probability that teens received *any* shots of the vaccine. This measure is important because medical research indicates that even a single shot offers considerable protection from HPV (Kreimer et al. 2020). Consistent with the prior estimates, I show in Figure 3 that the school requirement was associated with a 20-percentage point increase in the probability of vaccine initiation (Panel C). The point estimate is well outside of the placebo interval and over 2.4 times larger than the largest placebo estimate (0.20 vs. 0.08). Furthermore, I show that the probability of vaccine initiation was near zero and within the placebo distribution during the pre-period and that it jumped by nearly 20 percentage points in the post-period (Panel D).

In contrast to the relationship with HPV vaccine completion, I do detect a statistically significant sex-specific difference in vaccine initiation. In Figure 4, I show that the 2014 policy change increased the likelihood teen girls received the first HPV shot by 11 percentage points (Panel C), while teen boys' vaccine initiation increased by 26 percentage points (Panel D). In Table A4, I use the triple-difference specification from equation (2) and confirm that these estimates are statistically different from each other.

These patterns suggest that the 2014 requirement induced teen boys to both initiate and complete the vaccination. Meanwhile, it induced a smaller number of teen girls to initiate the vaccine, while also encouraging girls who had previously initiated vaccination to complete the vaccine series. In support of this possibility, I show in Table 4 that the 2014 school requirement reduced the likelihood that a teen girl had initiated but not yet completed vaccination by 9 percentage points (column 3). In contrast, the point estimate for boys was smaller in magnitude, positive, and statistically insignificant (column 4). Additionally, I show that the 2014 requirement increased the probability that teen girls completed the series on time.[17]

The 2014 policy change expanded the requirement to include all teens grades 6-12 to increase vaccination among older teens. Consistent with this goal, in Table 5 I document a 7-percentage point larger increase in vaccine initiation for students in grades 9-12 (column 1). However, I do not detect a statistically significant difference for non-white teens relative to white teens (column 2). Nor do I detect a statistically significant difference in vaccine initiation by maternal education (column 3), despite having found a maternal education-specific difference in vaccine completion. However, while teens with more educated mothers had higher rates of vaccine completion in the pre-period relative to those with less educated mothers, they were similarly likely to initiate vaccination. In fact, DC teens whose mothers had college degrees were *less* likely to initiate vaccination (34 percent vs. 36 percent), suggesting that the annual requirement may have helped remind less educated mothers that their teen needed to finish the series.

[17] I compare the age at which teens received the first shot to the age at which they received the final shot (the third shot prior to 2016 and the second shot thereafter). Because the shots are intended to be given within 6-12 months of each other, I consider a teen as having received the full dose in the appropriate time frame if the final shot was administered at the same age or within one year. Unfortunately, I do not have information on the exact date of administration.

As an example, a teen receiving the first shot at 14 would need to have completed the vaccine by 15 to be classified as receiving it on time. Because the number of shots needed for complete vaccination was adjusted from 3 to 2 shots in November of 2016 (Meites, Kempe, and Markowitz 2016), in Table A5 I restrict the sample period to 2008-2016. The results are robust to this restriction.

1.4.3. Vaccination Intentions & Physician Recommendations

I next explore whether the 2014 HPV vaccine school requirement improved awareness about the HPV vaccine. First, I present descriptive statistics in Figure 6 showing that parents were 23 percentage points more likely to report that they intended to have their child vaccinated within 12 months of the interview date after the policy change.[18] Using equation (1), I show in Table 6 that the 2014 requirement increased the probability that parents reported an intent to vaccinate by 17 percentage points (column 1).

Next, I show that the requirement led to a 9.2 percentage point increase in the likelihood that parents reported that their teen had been recommended the HPV vaccine by a health care provider (column 2). This suggests that some physicians would not recommend vaccination in absence of the school requirement. In a survey of physicians, Gilkey et al. (2015) found that 26 (39) percent of respondents reported that they did not deliver timely recommendations about the HPV vaccine to teen girls (boys), 27 percent did not strongly endorse HPV vaccination, and 32 percent reported that discussing sexually transmitted infections made conversations about the vaccine uncomfortable.[19]

Finally, I examine whether the 2014 requirement increased parental reported HPV vaccination. I show that parents were nearly 15 percentage points more likely to report that their

[18] This question has only been asked since 2010.

[19] In Table A5, I examine the top 5 reasons given for why parents will not have the child vaccinated against HPV in the subsequent 12 months. The point estimate suggests that parents opting not to vaccinate were 3 percentage points more likely to state that they did not believe that the HPV vaccine was needed (column 1), though the estimate is statistically insignificant. At the same time, these parents were 11 percentage points less likely to cite safety concerns about the vaccine as their reason for not vaccinating (column 3). Similarly, the point estimates indicate reductions in the probabilities of attributing the decision to a lack of knowledge about the vaccine (column 4), as well as a lack of recommendation (column 5). Overall, Table A5 suggests that the HPV vaccine school requirement changed the composition of parents opting to leave the child unvaccinated. These parents were more likely to believe that the vaccine was not needed. This suggests that the parents bound by the school requirement were those who had previously had safety concerns or been unaware of the vaccine.

child had received the HPV vaccine (column 3). While a sizable increase, it is smaller in magnitude than the increase using the provider-verified data. One explanation is that some parents have their child immunized for school without knowing what specific vaccines the child receives. Additionally, it is possible that parents are not always aware of what was discussed between the teen and the health care provider.

1.4.4. Robustness to Synthetic Control Strategy

In this section, I test the robustness of my estimates to the synthetic control identification strategy proposed by Abadie and Gardeazabal (2003) and Abadie et al. (2010). Rather than use the rest of the US as a control group, I select a weighted combination of states which best matches DC's vaccination rate in the pre-period. In this case, every state contributes a positive weight to constructing "Synthetic DC," and I report the exact breakdown in Table A6. As shown in Figure 7, Synthetic DC matches DC's HPV vaccination rate in the pre-period (Panel A). However, the two series diverge considerably in the post-requirement period. On average, there is a 20-percentage point difference between DC and Synthetic DC in the post-period.[20]

Next, I run the placebo tests proposed by Abadie et al. (2010) and plot the true effect, as well as the 48 placebo effects. Consistent with the results from the prior sections, I find that the estimated increase in HPV vaccination experienced by DC was larger than all the placebo treatment effects (Panel B). The corresponding p-values for each post-period are shown in Figure A4, and I reject the null hypothesis that the post-period estimates are jointly equal to zero ($p<0.01$).

[20] The pre-period root mean squared prediction error—the metric used to judge the quality of the match—is 0.73. I report the exact post-period coefficients in Table A7. I show in Table A8 that the results are robust to constructing the synthetic control by matching on lagged values from years 2008, 2010, and 2012. In Table A9, I show that the results are robust to matching on the average vaccination rate between 2008 and 2013.

As such, both estimation strategies indicate that DC's HPV vaccine school requirement was associated with a large and statistically significant increase in vaccination.

1.5. IMPLIED REDUCTIONS IN CANCER AND HEALTH CARE COSTS

To conceptualize the economic and public health benefits of the HPV vaccine school requirement, it is worth considering how many cases of cancer this policy change may have prevented. The American Cancer Society (2020a) indicates that the lifetime risk of developing cervical cancer is 0.63 percent, and the CDC (2020b) estimates that HPV may be responsible for more than 90 percent of these cancers.[21] The average age of cervical cancer diagnosis is 50 (ACS 2020b), the initial cost of cervical cancer care is $45,174 (Mariotto et al. 2011), cervical cancer has a 5-year survival rate of 66 percent (ACS 2020c), and the average cervical cancer death results in 26.1 lost life years (NCI 2020b).[22] Finally, the Department of Health and Human Services estimates the value of a statistical life year (in 2018 dollars) as falling between $244,000 and $1.3 million depending on the choice of discount rate and the baseline value of a statistical life (Aldy and Viscusi 2008; US Department of Health and Human Services 2016; Kniesner and Viscusi 2019).

The above figures are combined in equation (5) to estimate the present value of a prevented cervical cancer. Assuming that girls are vaccinated at 11, the initial cost of cervical cancer care should be discounted by 39 years (50 – 11 = 39). In the second part of the expression, I account

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[21] Non-white women experience a higher incidence of cervical cancer relative to white women, and DC is comprised primarily of non-white women. I show in Figure A5 that DC's age-adjusted cervical cancer rate was consistently higher than the US average from 1999-2016, though the gap has been shrinking over time. Indeed, the original 2009 HPV vaccine requirement was implemented as part of the "Human Papillomavirus and Reporting Act of 2007," which also called on the Mayor to "initiate a public information campaign…aimed at educating the public on: (1) The connection between HPV and cervical cancer; (2) The importance of protecting oneself against HPV infection; (3) The value of screening for cervical cancer through regular pap tests; and (4) The effectiveness and risks of the HPV vaccine." By using the nationwide average lifetime risk of developing cervical cancer, instead of the higher DC-specific risk, I will underestimate the number of cancers prevented and the potential cost savings.

[22] The initial cost of care is estimated to be $45,174 for women over 65 and $54,209 for those under 65. Similarly, the estimated cost of oropharyngeal cancer is $41,980 ($39,179) for women (men) over 65 and $50,376 ($47,015) for women (men) under 65 (Mariotto et al. 2011). To be conservative, I always use the smallest number.

for the fact that 44 percent of women die within 5 years after initial diagnosis and that these women lose on average 26 years of life. I use the minimum value of a statistical life year from the DHHS FDA official guidance of $244,000.

$$\text{Prevented Cervical Cancer}=\left(\frac{1}{1+r}\right)^{39}\times\$45{,}174+0.44\times\$244{,}000\times 26 \tag{5}$$

Of course, the HPV vaccine protects against more than just cervical cancer, and approximately 70 percent of oropharyngeal cancers may be linked to HPV. According to the ACS (2020a), the lifetime risk of oropharyngeal cancer is 1.66 percent for men and 0.71 percent for women. The average age of oropharyngeal cancer diagnosis is 62 (ACS 2021a), the initial cost of care is $39,179 (Mariotto et al. 2011), and the average oropharyngeal death results in 16.9 lost life years (NCI 2020b). The 5-year survival rate varies from 52 percent (floor of mouth) to 90 percent (lip), and I use the largest survival rate to provide a conservative estimate (ACS 2021b).

In equation (6), I estimate the present value of a prevented oropharyngeal cancer. I discount the initial cost of care by 51 years assuming vaccination at 11 (62-11=51).[23] In the second term, I assume the smallest mortality rate from oropharyngeal cancer (10 percent), again use the minimum value of a statistical life year as recommended by the DHHS official guidance, and account for the 16 lost years.

$$\text{Prevented Oropharyngeal Cancer}=\left(\frac{1}{1+r}\right)^{51}\times\$39{,}179+0.10\times\$244{,}000\times 16 \tag{6}$$

Using a discount rate of 3 percent (Viscusi and Hersch 2008), I estimate $2.8 million in savings for each cervical cancer prevented and over $400,000 for each oropharyngeal cancer prevented. In 2018, there were 33,614 students enrolled in public or public charter schools in

[23] By assuming that adolescents are all vaccinated at 11, I am maximizing the length of time between vaccination and what would otherwise be a cancer diagnosis. It is possible that some teens are vaccinated at later years, which would lead to less discounting. Thus, I choose 11 to increase discounting and provide a conservative estimate.

Washington, DC (DC Office of the State Superintendent of Education 2018). My estimates indicate that the 2014 HPV vaccine school requirement induced 4,336 boys (33,614×0.5×0.258) and 1,831 girls (33,614×0.5×0.109) to initiate vaccination. Sonawane et al. (2019) found that the predicted probability of HPV infection was 7.4 percent for unvaccinated women and 2.3 percent for those receiving one dose of the HPV vaccine, implying a vaccine efficacy (CDC 2012) of 69 percent ((0.074-0.023)/0.074).

Now, I multiply the number of newly vaccinated students by the lifetime risk of acquiring an HPV-related cancer, times the share of those cancers attributable to HPV, times the vaccine efficacy, to obtain the number of cancers prevented. I estimate 7 fewer cases of cervical cancer (1,831 ×0.0063 × 0.90 × 0.69) and 41 fewer cases of oropharyngeal cancer (1,831 ×0.0071 × 0.70 × 0.69 + 4,336 × 0.0166 × 0.7 × 0.69) for those 33,614 students enrolled during the 2017/18 academic year. Using the discounted values from above, this amounts to approximately $36 million in savings. With the HPV vaccine costing approximately $250 per shot (CVS 2020), my estimates imply it cost slightly more than $1.5 million to vaccinate those 6,167 teens. Therefore, the mandate appears cost effective.[24]

While I estimate that DC's 2014 HPV vaccine requirement passes a cost-benefit analysis, there are many reasons to believe that I am *underestimating* the benefits of the mandate. For one, I only account for cervical and oropharyngeal cancer, while the HPV vaccine also protects against cancers of the anus, penis, vulva, and vagina. Additionally, I only account for the initial cost of cancer care and the value of lives lost. I do not account for follow up care for those who do not

[24] Importantly, if I do not account for the value of lives lost and focus solely on the initial cost of cancer care, I still estimate $455,591 in health care savings.

die. Finally, I only account for the direct benefits to the vaccinated teen, though immunization also helps protect the vaccinated teen's subsequent sexual partners.

While important for policymakers, generalizing these estimates to the US as a whole requires caution. For one, the HPV vaccine initiation rate in the US in 2018 was higher than Washington, DC's initiation rate immediately prior to the policy change (68 percent vs. 62 percent). Moreover, vaccine initiation rates between girls and boys have converged. In 2018, 70 percent of girls and 67 percent of boys had received at least one shot of the HPV vaccine. As a result, school requirements may no longer induce larger increases in take-up for teen boys than teen girls. Yet even subject to these caveats, considering how these estimates could generalize is a useful exercise. There are 30 million 6-12th grade students in the US (National Center for Education Statistics 2018). Applying my most conservative estimated increase in vaccine initiation (10.9 percentage points) still yields 3.27 million more vaccinated students and—failing to account for any form of herd immunity—almost 6,400 fewer cases of cervical cancer. Every year, there are 13,800 new diagnosed cases of cervical cancer (American Cancer Society 2020b), so even an increase in HPV vaccine take-up half the size experienced by Washington, DC would provide dramatic public health benefits.

1.6. DISCUSSION

Throughout this paper, I have shown that Washington, DC's 2014 HPV vaccine school requirement increased the probability that a teen was vaccinated against HPV by nearly 20 percentage points. Only 28 percent of DC teens had completed the HPV vaccine in 2013, so the estimated effect is large in both absolute magnitude and as a percentage change from the pre-period level. Using an event study specification, I show that this increase was not due to pre-existing trends in the probability of vaccination, and a series of permutation placebo tests show that these increases were far larger than one would expect to obtain by chance. A synthetic control framework also supports these conclusions.

During my 2008-2018 sample period, DC's demographic composition changed considerably. The share of non-white teens fell by 10 percentage points, while the share of teens with college educated mothers rose by 12 percentage points. Critically, though, I show that my estimates do not depend on race and are in fact larger for teens whose mothers lacked college degrees. As such, it does not appear the relationship was driven by an influx of teens who were more likely to be vaccinated. I also show that while teen girls and boys experienced similar increases in the probability of vaccine completion, the point estimate for HPV vaccine initiation was larger for boys than girls. This pattern suggests that the school requirement induced some teen girls who had previously initiated vaccination to finish the vaccine series, and I show that the 2014 requirement increased the likelihood that teen girls initiating vaccination completed the series within the recommended time frame.

Overall, my results indicate that how school vaccine requirements are implemented can be as important as the mandate itself. Except for those girls entering sixth grade in 2014, all of the girls in my sample were already bound by the 2009 HPV vaccine requirement. As such, the 2014 requirement's saliency should have been limited; these girls were already supposed to be vaccinated. However, expanding the requirement to older teen girls and requiring an annual opt-out offered public health officials another chance to encourage vaccination. Because I find that the annual requirement resulted in a 11-percentage point increase in HPV vaccine initiation, it is possible that parents who were uncomfortable vaccinating their middle school daughters against an STI were more comfortable once the girls had entered high school. In estimating the future reduction in cancer incidence, my estimates imply nearly $36 million in benefits compared to the $1.5 million it cost to vaccinate these teens, indicating that the mandate was cost effective.

Of course, this study is not without limitations. For one, conclusions drawn from DC may not easily generalize to the rest of the country. Nearly 80 percent of DC teens are non-white, the entire city spans less than 70 square miles, and DC has a centralized Department of Public Health and State Board of Education. However, it is worth noting that all 50 states require at least some vaccinations for school entry (Schwartz and Easterling 2015), indicating that the logistical hurdles of an HPV vaccine school requirement are hardly insurmountable.

An additional concern common to all single-state policy evaluations is the possibility that my estimates are driven by an unaccounted-for variable which changed concurrently with the school requirement, though I have controlled for several known policies known to affect vaccine take-up. Moreover, I have not examined potential moral hazard associated with receiving the HPV vaccine, such as changes in risky sexual behaviors or preventative cancer screenings later in life. As more states enact HPV vaccine requirements, it will be important to confirm my estimates in alternative settings and to quantify potential downstream effects. Finally, because the gains from HPV vaccination may not be realized for several decades, I am unable to directly study the relationship between the school vaccine requirement and morbidity. Developing strategies to identify this latter relationship remains an important area for future research.

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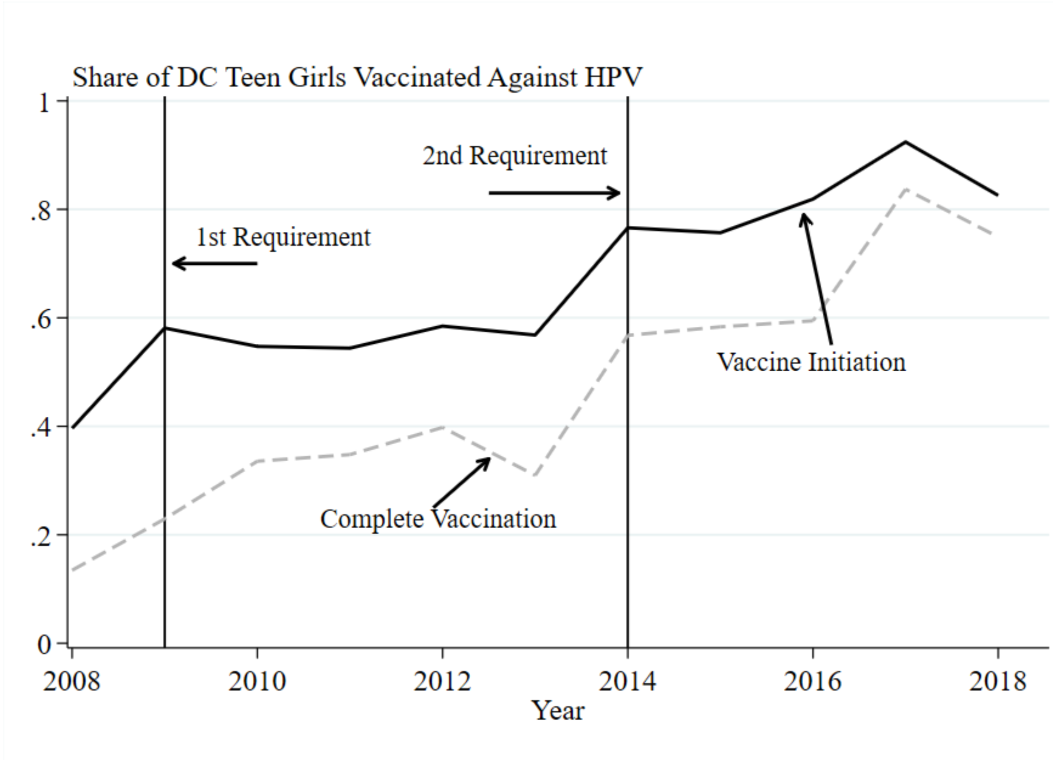
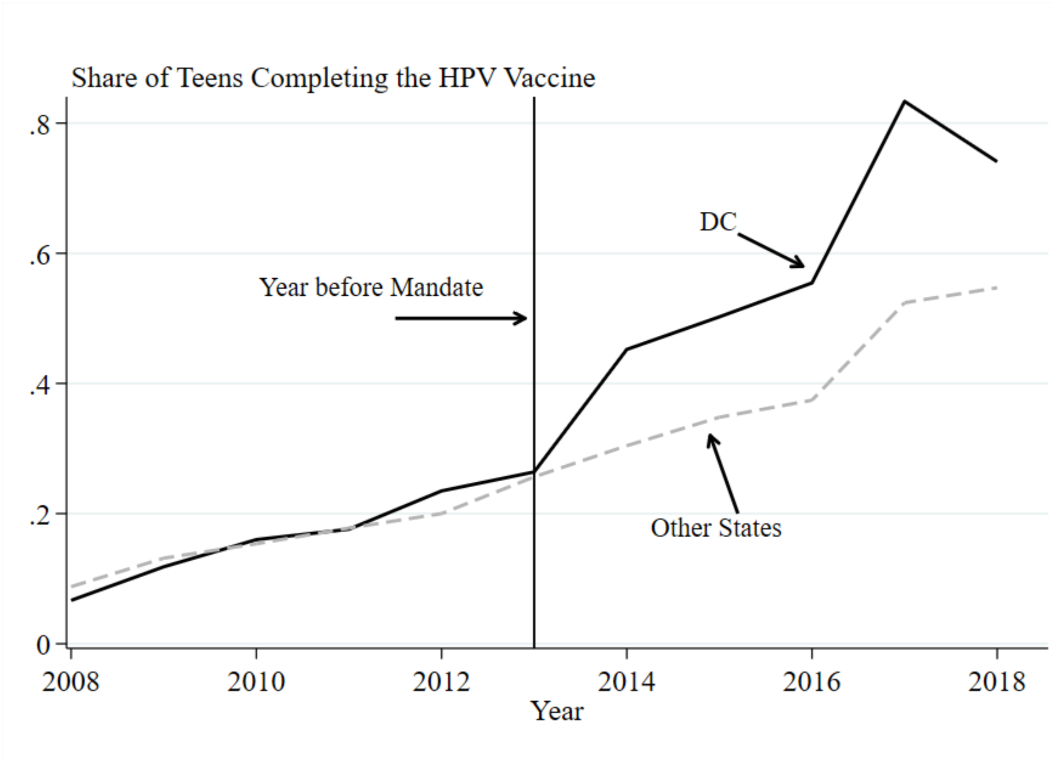
Figure 1: Share of teen girls in Washington, DC vaccinated against HPV



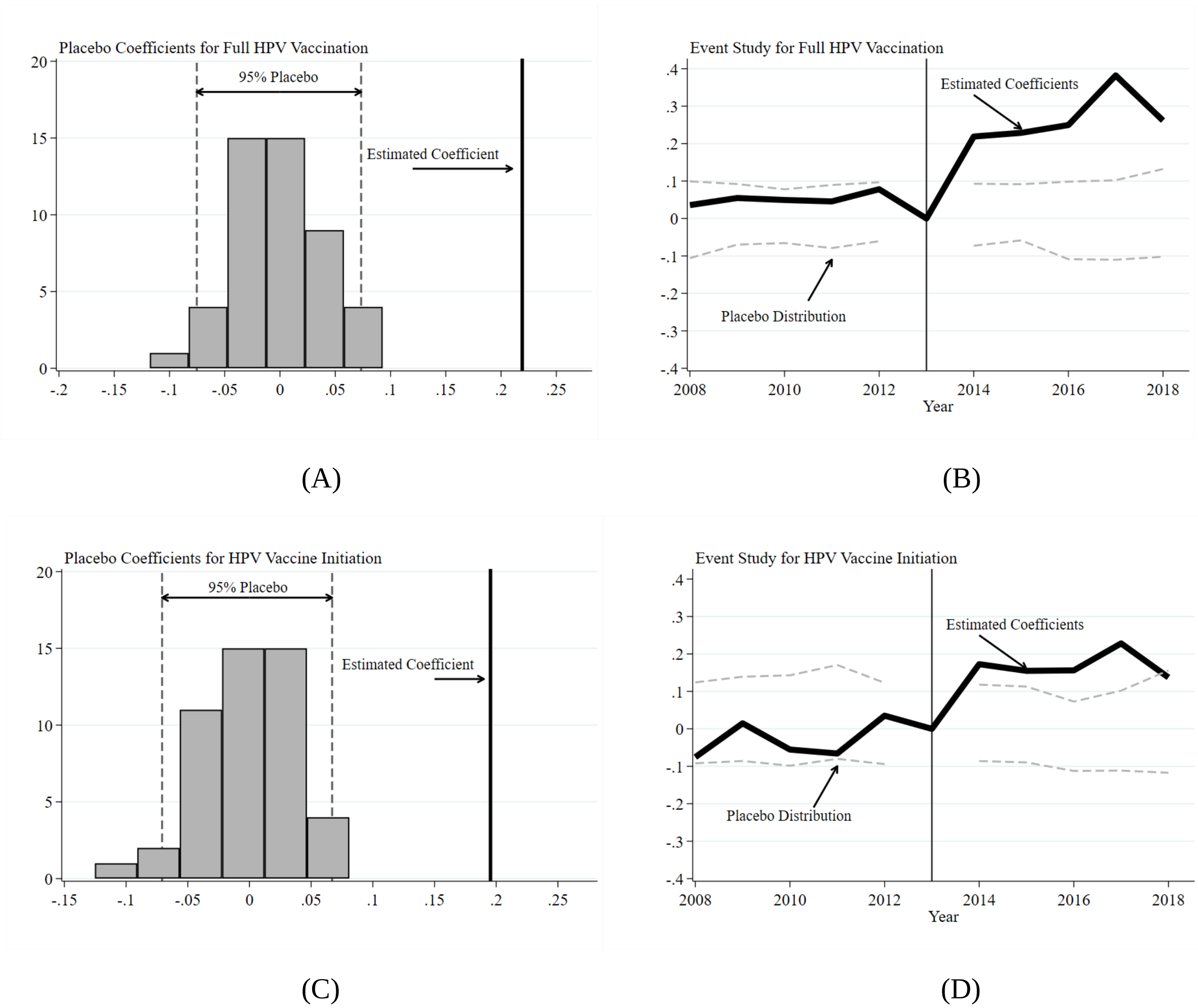
Source: National Immunization Survey—Teen 2008-2018
Note: The figure plots the share of DC teen girls receiving at least one dose of the HPV vaccine (solid black line) and the share fully vaccinated against HPV (dashed grey line). A full dose of the HPV vaccine was 3 shots between 2008 and 2016, while it was changed to only 2 shots beginning in 2017. Beginning with the 2009/2010 academic year, sixth grade girls were required to be vaccinated or submit a one-time opt-out form. Beginning in 2014, the requirement was extended to include all students 6-12th grade and those not vaccinating had to opt-out annually. The statistics were obtained by utilizing the sample weights.

Figure 2: HPV vaccination rates were trending similarly in Washington, DC and the rest of the country prior to the school vaccine requirement and diverged in the post-period



Source: National Immunization Survey—Teen 2008-2018
Note: The figure plots the share of teens fully vaccinated against HPV in Washington, DC (solid black line) and the rest of the country (dashed grey line). A full dose of the HPV vaccine was 3 shots between 2008 and 2016, while it was changed to only 2 shots beginning in 2017. The statistics were obtained by utilizing the sample weights.

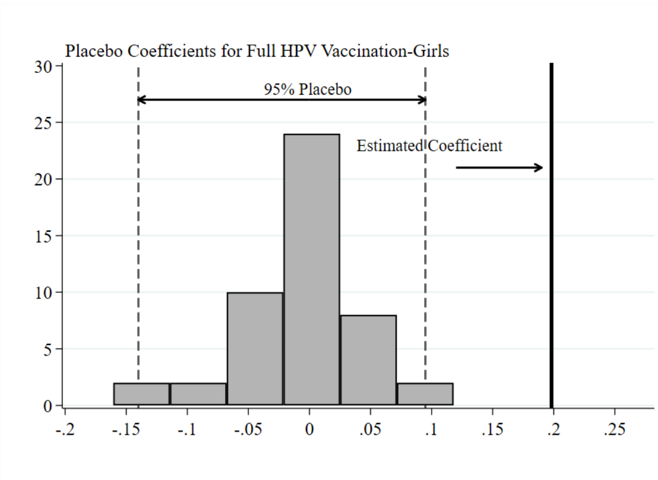
Figure 3: Washington, DC’s 2014 HPV vaccine school requirement increased HPV vaccination



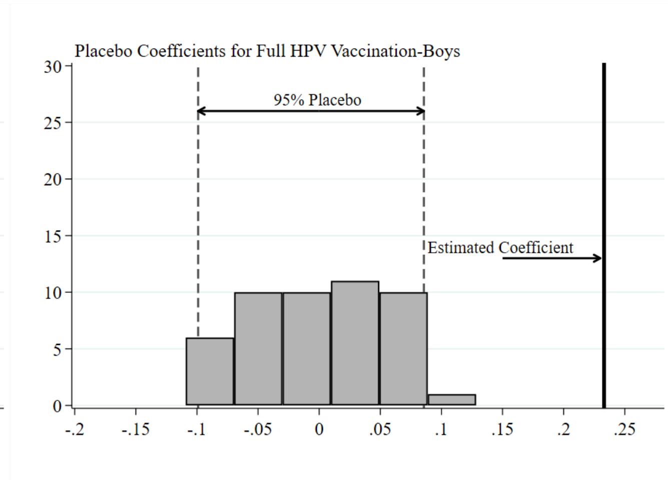
Source: National Immunization Survey—Teen 2008-2018

Note: The dependent variable in Panels (A) and (B) an indicator for having been fully vaccinated against HPV (3 doses prior to 2017 and 2 doses thereafter), while the dependent variable in Panels (C) and (D) is an indicator for having received at least 1 dose of the vaccine. In Panels (A) and (C) the independent variable of interest is an indicator for Washington, DC’s 2014 HPV vaccine school requirement. Estimates are obtained using equation (1). In Panels (B) and (D) the independent variables of interest are indicators for each year—with 2013 omitted—to capture dynamic effects. When the black line is within the placebo interval, the estimate was likely to have been obtained by chance. When the black line is outside the interval, it is unlikely that the estimate was obtained by chance. The estimates utilize the sample weights.

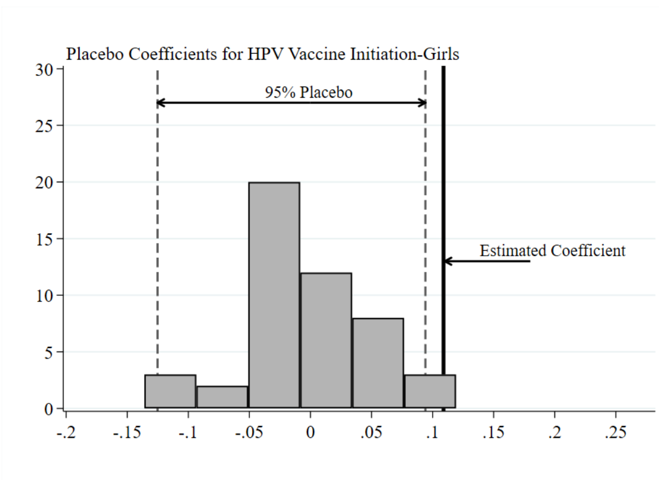
Figure 4: DC’s 2014 HPV vaccine school requirement increased vaccination for both girls and boys



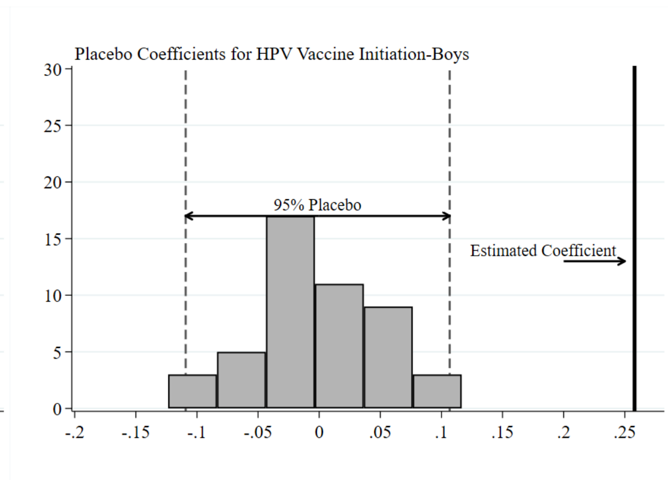
(A)



(B)



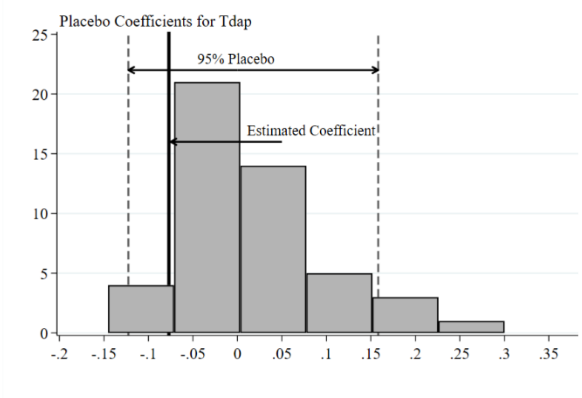
(C)



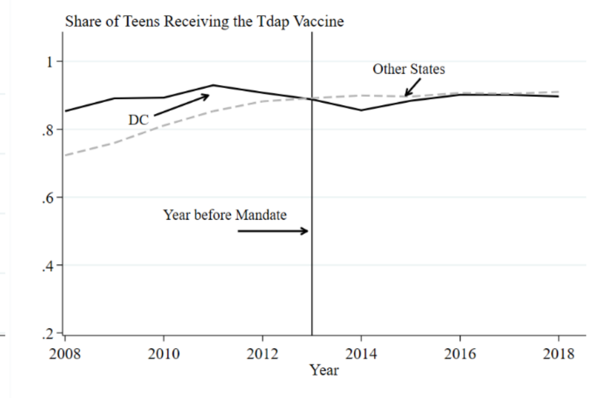
(D)

Source: National Immunization Survey—Teen 2008-2018
Note: The dependent variable in Panels (A) and (B) an indicator for having been fully vaccinated against HPV (3 doses prior to 2017 and 2 doses thereafter), while the dependent variable in Panels (C) and (D) is an indicator for having received at least 1 dose of the vaccine. The independent variable of interest is an indicator for Washington, DC’s 2014 HPV vaccine school requirement. Estimates are obtained using equation (1). Panels (A) and (C) restrict the sample to teen girls and Panels (B) and (D) restrict the sample to teen boys. When the black line is within the placebo interval, the estimate was likely to have been obtained by chance. When the black line is outside the interval, it is unlikely that the estimate was obtained by chance. The estimates utilize the sample weights.

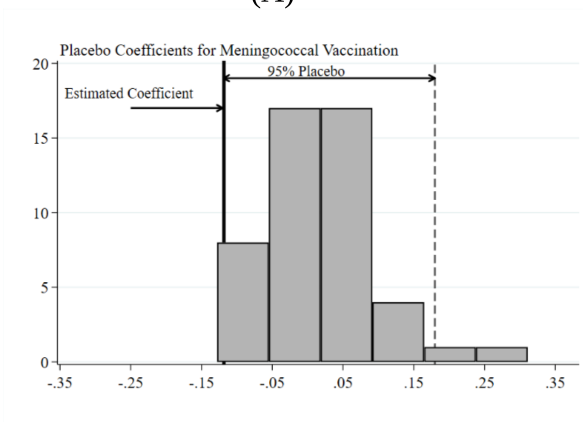
Figure 5: DC's 2014 HPV vaccine requirement was positively related to influenza vaccination



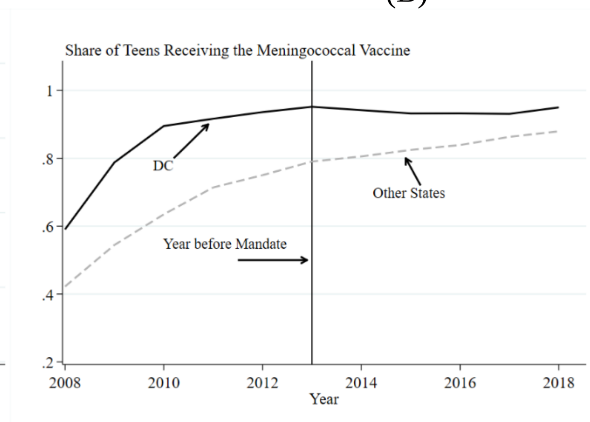
(A)



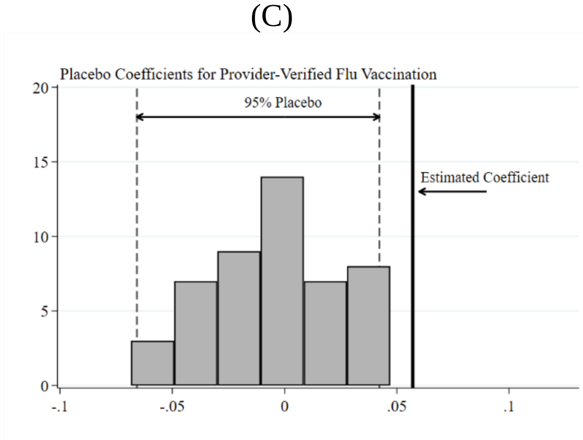
(B)



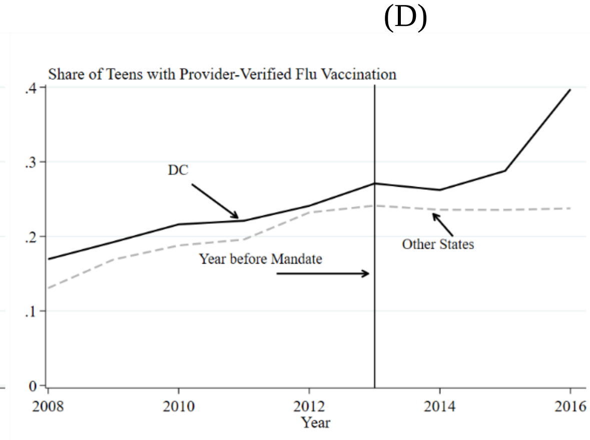
(C)



(D)



(E)

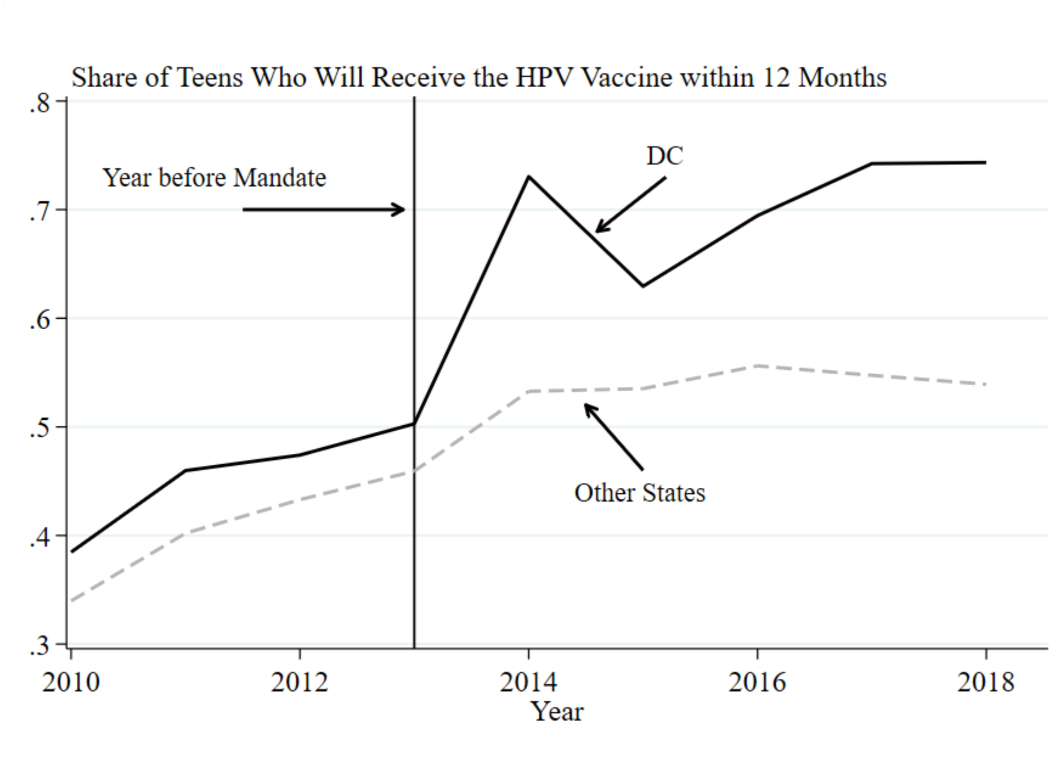


(F)

Source: National Immunization Survey—Teen 2008-2018

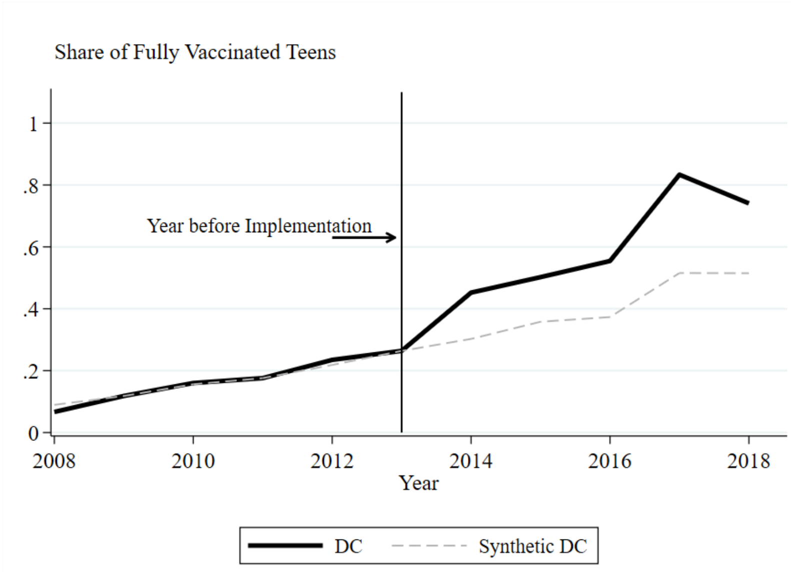
Note: Panel (A) plots the difference-in-differences estimate of how Washington, DC's 2014 HPV vaccine school requirement affected Tdap vaccination from equation (1), as well as the placebo coefficients. Panel (B) plots the shares of teens in DC and the rest of the country receiving the Tdap vaccine after they turned 10. Panel (C) plots the coefficients obtained from equation (1) for the meningococcal vaccine, while Panel (D) plots the shares of teens receiving the meningococcal vaccine. Panel (F) shows the estimate from equation (1) relating the 2014 policy to the share receiving the influenza vaccine, while Panel (E) plots the share of teens up to date on the flu vaccine. In Panels (A), (C), and (E) when the black line is within the placebo interval, the estimate was likely to have been obtained by chance. When the black line is outside the interval, it is unlikely that the estimate was obtained by chance. The estimates utilize the sample weights.

Figure 6: The share of parents reporting an intent to vaccine their teen against HPV

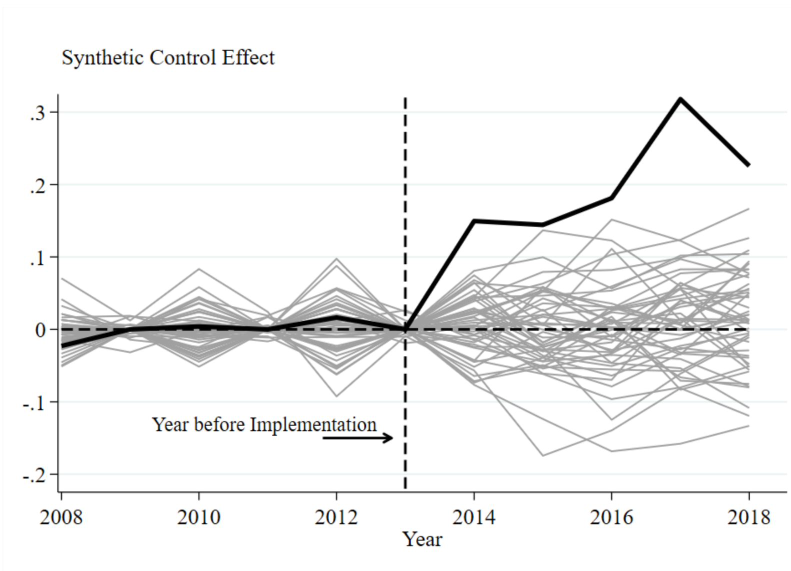


Source: National Immunization Survey—Teen 2008-2018
Note: The figure plots the share of teens whose parents report that they will receive the HPV vaccine during the subsequent 12 months after the interview date in DC (solid black line) and the rest of the country (dashed grey line). The statistics were obtained by utilizing the sample weights.

Figure 7: HPV vaccination increased more in DC than Synthetic DC



(A)



(B)

Source: National Immunization Survey—Teen 2008-2018

Note: The dependent variable is an indicator for having received the full dose of the HPV vaccine (3 shots until 2016 and only 2 shots thereafter). In Panel (A) the thicker dark line indicates the growth in HPV coverage for Washington, DC over the period, while the dashed grey line indicates the counterfactual growth for "synthetic Washington, DC" in absence of the 2014 HPV vaccine school requirement. Synthetic DC is obtained by matching on three lagged values of the dependent variable in the pre-requirement period (2009, 2011, and 2013). The states which contribute to "Synthetic Washington, DC are reported in Table A6, and the exact coefficients for the pre- and post-periods are reported in Table A7. In Panel (B) the thicker dark line is the effect, while the lighter gray lines are placebo effects obtained from repeating this process for the 50 donor states. The shares were obtained utilizing the sample weights.

Table 1: Washington, DC's HPV vaccine school requirement over time

	(1) 2006-2008	(2) 2009-2013	(3) ≥ 2014
Females			
6th Graders	No Requirement	Vaccine Required or Opt-Out	Vaccine Required or Annual Opt-Out
7th-12th Graders	No Requirement	No Requirement	Vaccine Required or Annual Opt-Out
Males			
6th Graders	No Requirement	No Requirement	Vaccine Required or Annual Opt-Out
7th-12th Graders	No Requirement	No Requirement	Vaccine Required or Annual Opt-Out

Note: Beginning with the 2009/2010 school year, sixth grade girls were required to receive the HPV vaccine or submit a one-time opt-out form. In 2014, the HPV vaccine school requirement was expanded to include teen boys and older students. Additionally, non-vaccinating students became required to opt-out annually.

Table 2: Summary statistics

	(1)	(2)	(3)	(4)	(5)	(6)
	Washington, DC			Remaining US		
	Overall	2008-2013	2014-2018	Overall	2008-2013	2014-2018
Vaccination						
Complete Vaccination	0.360	0.165	0.617	0.282	0.168	0.419
	(0.480)	(0.371)	(0.486)	(0.450)	(0.374)	(0.493)
Vaccine Initiation	0.551	0.353	0.813	0.434	0.297	0.600
	(0.497)	(0.478)	(0.390)	(0.496)	(0.457)	(0.490)
Teen Demographics						
Age 14	0.199	0.194	0.207	0.198	0.197	0.199
	(0.400)	(0.395)	(0.405)	(0.398)	(0.398)	(0.399)
Age 15	0.208	0.208	0.207	0.209	0.212	0.205
	(0.406)	(0.406)	(0.406)	(0.407)	(0.409)	(0.404)
Age 16	0.223	0.221	0.225	0.206	0.207	0.204
	(0.416)	(0.415)	(0.418)	(0.404)	(0.405)	(0.403)
Age 17	0.175	0.182	0.167	0.189	0.187	0.191
	(0.381)	(0.386)	(0.373)	(0.392)	(0.390)	(0.393)
6-8th Grade	0.245	0.243	0.249	0.272	0.273	0.272
	(0.430)	(0.429)	(0.432)	(0.445)	(0.445)	(0.445)
9-12th Grade	0.729	0.729	0.729	0.714	0.713	0.715
	(0.445)	(0.445)	(0.445)	(0.452)	(0.452)	(0.451)
HS Graduate	0.016	0.013	0.020	0.010	0.010	0.009
	(0.126)	(0.114)	(0.139)	(0.098)	(0.102)	(0.094)
White	0.157	0.146	0.170	0.560	0.578	0.537
	(0.363)	(0.353)	(0.376)	(0.496)	(0.494)	(0.499)
Black	0.696	0.726	0.656	0.140	0.142	0.136
	(0.460)	(0.446)	(0.475)	(0.347)	(0.350)	(0.343)
Hispanic	0.111	0.096	0.131	0.213	0.201	0.227
	(0.314)	(0.295)	(0.337)	(0.409)	(0.400)	(0.419)
Household Controls						
Mother ≤ 34	0.120	0.118	0.123	0.092	0.096	0.087
	(0.325)	(0.323)	(0.329)	(0.289)	(0.295)	(0.282)
Mother 35-44	0.386	0.389	0.383	0.449	0.458	0.439
	(0.487)	(0.488)	(0.486)	(0.497)	(0.498)	(0.496)
Moher < HS	0.155	0.177	0.126	0.129	0.134	0.122
	(0.362)	(0.382)	(0.332)	(0.335)	(0.341)	(0.328)
Mother HS Graduate	0.294	0.306	0.278	0.244	0.260	0.224
	(0.456)	(0.461)	(0.448)	(0.429)	(0.439)	(0.417)
Mother Some College	0.210	0.199	0.225	0.259	0.263	0.253
	(0.408)	(0.4000	(0.417)	(0.438)	(0.440)	(0.435)
Income ≤ $20K	0.283	0.310	0.247	0.186	0.187	0.184
	(0.450)	(0.463)	(0.431)	(0.389)	(0.390)	(0.388)
Income $20-30K	0.135	0.114	0.163	0.107	0.107	0.106
	(0.342)	(0.318)	(0.369)	(0.309)	(0.309)	(0.308)
Income $30-40K	0.099	0.099	0.099	0.087	0.092	0.081

	(0.299)	(0.299)	(0.298)	(0.281)	(0.288)	(0.272)
Income $40-50K	0.057	0.058	0.055	0.076	0.080	0.070
	(0.231)	(0.233)	(0.229)	(0.265)	(0.272)	(0.256)
State-Level Controls						
Tdap Requirement	1.000	1.000	1.000	0.793	0.629	0.991
	(0.000)	(0.000)	(0.000)	(0.405)	(0.483)	(0.094)
CDC Grant per Person	2.119	3.730	4.051	0.090	0.062	0.181
	(6.686)	(8.527	(8.812)	(0.403)	(0.309)	(0.599)
ACA Medicaid Expansion	0.789	0.629	1.000	0.325	0.100	0.582
	(0.408)	(0.483)	(0.000)	(0.468)	(0.301)	(0.493)
HPV Vaccine Available	0.896	0.816	1.000	0.907	0.829	1.000
	(0.306)	(0.387)	(0.000)	(0.291)	(0.376)	(0.000)
HPV Vaccine Recommended	0.803	0.654	1.000	0.814	0.661	1.000
	(0.397)	(0.476)	(0.000)	(0.389)	(0.473)	(0.000)
Consent to HPV Vaccine	1.000	1.000	1.000	0.088	0.046	0.139
	(0.000)	(0.000)	(0.000)	(0.284)	(0.210)	(0.346)
Consent to Any Procedure	0.000	0.000	0.000	0.126	0.127	0.125
	(0.000)	(0.000)	(0.000)	(0.332)	(0.333)	(0.331)
Prescriptive Authority	0.000	0.000	0.000	0.071	0.009	0.146
	(0.000)	(0.000)	(0.000)	(0.257)	(0.095)	(0.353)
General Authority	0.892	0.809	1.000	0.369	0.370	0.367
	(0.311)	(0.393)	(0.000)	(0.483)	(0.483)	(0.482)
Patient-Specific Authority	0.000	0.000	0.000	0.050	0.040	0.062
	(0.000)	(0.000)	(0.000)	(0.217)	(0.195)	(0.241)
NCI Grant	0.000	0.000	0.000	0.081	0.000	0.179
	(0.000)	(0.000)	(0.000)	(0.273)	(0.000)	(0.381)
NACCHO Grant	0.000	0.000	0.000	0.046	0.000	0.102
	(0.000)	(0.000)	(0.000)	(0.210)	(0.000)	(0.303)
Meningococcal Booster Mandate	0.000	0.000	0.000	0.066	0.002	0.143
	(0.000)	(0.000)	(0.000)	(0.248)	(0.043)	(0.350)
Meningococcal Post-Secondary Education Mandate	1.000	1.000	1.000	0.779	0.779	0.780
	(0.000)	(0.000)	(0.000)	(0.414)	(0.415)	(0.414)
Meningococcal Education Mandate	0.000	0.000	0.000	0.570	0.558	0.584
	(0.000)	(0.000)	(0.000)	(0.495)	(0.497)	(0.493)
Meningococcal Post-Secondary Mandate	0.000	0.000	0.000	0.149	0.130	0.172
	(0.000)	(0.000)	(0.000)	(0.356)	(0.337)	(0.377)
Must Cover HPV Vaccine	0.000	0.000	0.000	0.073	0.068	0.079
	(0.000)	(0.000)	(0.000)	(0.260)	(0.251)	(0.270)
Universal Purchase	0.000	0.000	0.000	0.050	0.031	0.072
	(0.000)	(0.000)	(0.000)	(0.217)	(0.172)	(0.259)
Observations	3,488	1,909	1,579	197,406	105,358	92,048

Source: National Immunization Survey-Teen 2008-2018
Note: Summary statistics utilize the sample weights.

Table 3: Washington, DC's HPV vaccine school requirement increased HPV vaccine completion

	(1)	(2)	(3)	(4)	(5)
		Groups			
	Overall	Teen Boys	9-12th Graders	Non-White	Mother Lacked a BA
DC's 2014 Mandate	0.221***	0.198***	0.182***	0.180***	0.183***
Placebo 95% Lower Bound	-0.075	-0.140	-0.086	-0.083	-0.085
Placebo 95% Upper Bound	0.073	0.095	0.056	0.099	0.096
DC's 2014 Mandate x Group		0.035	0.056	0.025	0.093*
Placebo 95% Lower Bound		-0.105	-0.083	-0.114	-0.114
Placebo 95% Upper Bound		0.112	0.066	0.087	0.096
R^2	0.184	0.194	0.188	0.188	0.188
Observations	200,894	200,894	200,894	200,894	200,894

Source: National Immunization Survey—Teen 2008-2018
Note: The dependent variable is an indicator for whether the teen has received the full HPV vaccination (3 doses until 2016 and 2 doses in all subsequent years). The independent variable of interest is an indicator for Washington, DC's 2014 HPV vaccine school requirement. The regression equation also controls for the teen's sex (male, with female omitted), age (14, 15, 16, 17, with 13 omitted), grade level (6-8th grade, 9-12th grade, high school graduate, with "not enrolled" omitted), and race/ethnicity (white, black, Hispanic, with "other" omitted). The specification also controls for mother's education (less than high school, high school diploma, some college, with college degree omitted), mother's age (at most 34, 35-44, with 45+ omitted), household income (less than $20K, $20-30K, $30-40K, $40-50K, with $50K+ omitted), the presence of a school Tdap vaccination requirement, the presence of a school meningococcal vaccine requirement, and the real value of the CDC grants awarded per person for HPV vaccination during that year. Finally, it includes time-invariant state fixed effects and location-invariant year fixed effects. Column (1) considers the full sample. Column (2) interacts an indicator for being male with the treatment indicator, the full set of controls, the state fixed effects, and the year fixed effects. Column (3) repeats this process but uses an indicator for being in grades 9-12, column (4) an indicator for being non-white, and column (5) an indicator for having a non-college educated mother. To perform inference, the 95 percent intervals are obtained by estimating placebo treatments for each of the other 48 states. The estimates utilize the sample weights.
*** p < 0.01, ** p < 0.05, * p < 0.10

Table 4: DC's HPV vaccine school requirement increased HPV vaccine initiation and reduced the likelihood that teen girls initiated but did not complete vaccination

	(1)	(2)	(3)	(4)	(5)	(6)
	Vaccine Initiation		Vaccine Initiation without Completion		Complete Vaccination within 1 Year of Initiation	
	Girls	Boys	Girls	Boys	Girls	Boys
DC's 2014 Mandate	0.109***	0.258***	-0.089**	0.025	0.195***	0.030
Placebo 95% Lower Bound	-0.125	-0.109	-0.059	-0.050	-0.108	-0.142
Placebo 95% Upper Bound	0.094	0.107	0.055	0.083	0.081	0.209
DC Mean Pre-Period	0.534	0.169	0.248	0.126	0.633	0.984
R^2	0.078	0.309	0.026	0.082	0.068	0.069
Observations	96,051	104,843	96,051	104,843	32,139	19,948

Source: National Immunization Survey—Teen 2008-2018
Note: The dependent variable in columns (1) and (2) is an indicator for whether the teen has initiated HPV vaccination (at least 1 dose). The dependent variable in columns (3) and (4) is an indicator for whether the teen has initiated vaccination but was not completely vaccinated (1 or 2 doses from 2008-2016 and 1 dose from 2017-2018). The dependent variable in columns (5) and (6) is an indicator for whether the teen was fully vaccinated within 1 year of vaccine initiation, where the sample is restricted to those initiating vaccination. The odd numbered columns examine teen girls, while the even numbered columns examine teen boys. To perform inference, the 95 percent confidence intervals are obtained by estimating placebo treatments for each of the other 48 states. The estimates utilize the sample weights.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Table 5: DC's 2014 HPV vaccine school requirement led to larger increases in vaccine initiation for older teens

	(1)	(2)	(3)
	9-12th Graders	Non-White	Mother Lacked a BA
DC's 2014 Mandate	0.144***	0.172***	0.181***
Placebo 95% Lower Bound	-0.099	-0.091	-0.071
Placebo 95% Upper Bound	0.109	0.092	0.077
DC's 2014 Mandate x Group	0.073**	0.005	0.034
Placebo 95% Lower Bound	-0.084	-0.140	-0.106
Placebo 95% Upper Bound	0.072	0.128	0.078
R2	0.233	0.236	0.234
Observations	200,894	200,894	200,894

Source: National Immunization Survey—Teen 2008-2018
Note: The dependent variable is an indicator for whether the teen has received at least 1 shot of the HPV vaccine. The independent variables of interest are an indicator for Washington, DC's 2014 HPV vaccine school requirement and the interaction of that indicator with a group-specific characteristic using the triple-difference specification from equation (2). Column (1) interacts an indicator for being in grades 9-12 with the treatment indicator, the full set of controls, the state fixed effects, and the year fixed effects. Column (2) repeats this process but uses an indicator for being non-white, and column (3) an indicator for having a non-college educated mother. To perform inference, the 95 percent intervals are obtained by estimating placebo treatments for each of the other 48 states. The estimates utilize the sample weights.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Table 6: DC's HPV vaccine mandate increased physician vaccine recommendations

	(1) Likely to Vaccinate within 12 Months	(2) HPV Vaccine Recommendation	(3) Parental-Reported HPV Vaccination
DC's 2014 Mandate	0.168***	0.092**	0.147***
Placebo 95% Lower Bound	-0.075	-0.053	-0.090
Placebo 95% Upper Bound	0.087	0.059	0.058
DC Mean Pre-Period	0.445	0.500	0.446
R^2	0.074	0.198	0.158
Observations	104,765	171,596	174,278

Source: National Immunization Survey—Teen 2008-2018
Note: The dependent variable in column (1) is an indicator for whether the teen's parent reports that the teen is likely to be vaccinated within the next 12 months. The dependent variable in column (2) is an indicator for whether the teen has been recommended the HPV. In column (3), the dependent variable is an indicator for whether the teen's parent reports that s/he has been vaccinated against HPV. The sample period for column (2) is 2010-2018 because the question was not asked in prior years. The independent variable of interest is an indicator for Washington DC's 2014 HPV vaccine school mandate. To perform inference, the 95 percent confidence intervals are obtained by estimating placebo treatments for each of the other 48 states. Observations from Rhode Island and Virginia are excluded because they also implemented HPV vaccine school requirements. The estimates utilize the sample weights.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

1.8. APPENDIX A: ADDITIONAL FIGURES & TABLES

Figure A1: The information sheet and opt-out form presented to parents as part of Washington, DC's HPV vaccine school requirement

HUMAN PAPILLOMAVIRUS INFORMATION

Genital human papillomavirus (HPV) is the most common sexually transmitted virus in the United States. There are about 100 types of HPV. Most infections don't cause any symptoms and go away on their own. HPV is important mainly because it can cause cervical cancer in women and several less common types of cancer in both men and women. It can also cause genital warts and warts of the upper respiratory tract. There is no cure for HPV, but the problems it causes can be treated.

About 20 million people in the U.S. are infected, and about 6 million more get infected each year. HPV is usually spread through sexual contact. More than 50% of sexually active men and women are infected with HPV at some time in their lives. Every year in the U.S., about 12,000 women get cervical cancer and 4,000 die from it with rates of cervical cancer in DC being higher than national averages.

HPV vaccine is an inactivated vaccine (not live) which protects against four major types of HPV. These include two types that cause about 70% of cervical cancer and 2 types that cause about 90% of genital warts. HPV vaccine can prevent most genital warts and most cases of cervical cancer.

Protection is expected to be long-lasting. But vaccinated women still need cervical cancer screening because the vaccine does not protect against all HPV types that cause cervical cancer.

HPV vaccine is routinely recommended for girls and boys 11-12 years of age, but may be given as early as age 9 years. It is important for girls and boys to get HPV vaccine before their first sexual contact-because they have not been exposed to HPV. The vaccine protects against some – but not all – types of HPV. However, if female or male is already infected with a type of HPV, the vaccine will not prevent disease from that type. It is still recommended that females and males with HPV get vaccinated. In addition, the HPV vaccine can prevent vaginal and vulvar cancer in females, and genital warts and anal cancer in both males and females.

The vaccine is also recommended for females 13-26 years of age and males 13-21 years of age (or to age 26 in some cases) who did not receive it when they were younger. It may be given with any other vaccines needed.

HPV vaccine is given as a three-dose series:

- **1st Dose: Now**
- **2nd Dose: two months after Dose 1**
- **3rd Dose: six months after Dose 1**

People who have had a life-threatening allergic reaction to yeast, are pregnant, moderate to severe illness should not receive the vaccine. Side effects are mostly mild, including itching, pain, redness at the injection site and a mild to moderate fever.

(A)

Annual Opt-Out for Human Papillomavirus (HPV) Vaccine

I have received and reviewed the information provided on HPV and the benefits of the HPV vaccine in preventing cervical cancer and genital warts if it is given to preteen girls and boys. After being informed of the risk of contracting HPV and the link between HPV and cervical cancer, other cancers and genital warts, I have decided to opt-out of the HPV requirement for the above named student. I know that I may readdress this issue at any time and complete the required vaccinations.

____ _______________________

Signature of Parent/Guardian or Student if >18 years Date

____

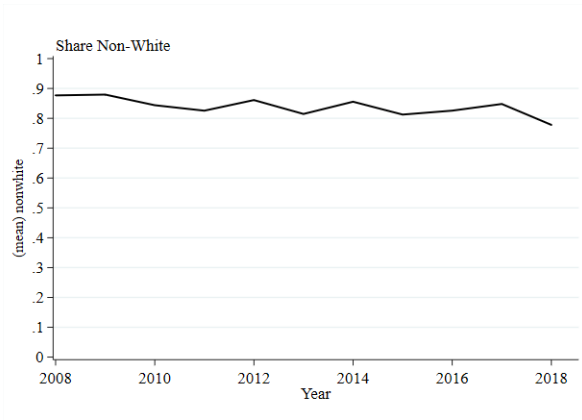
Print Name of Parent/Guardian or Student if >18 years

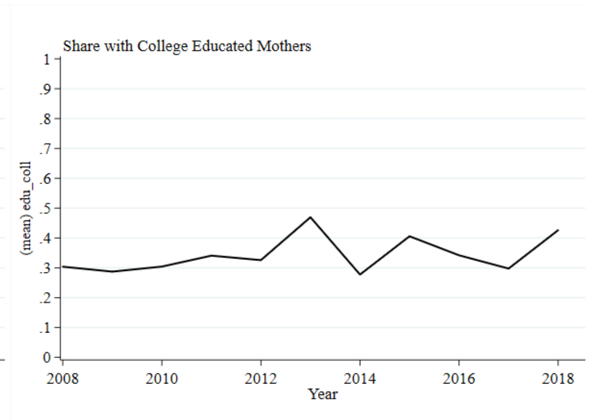
(B)

Source: DC Health (2020)

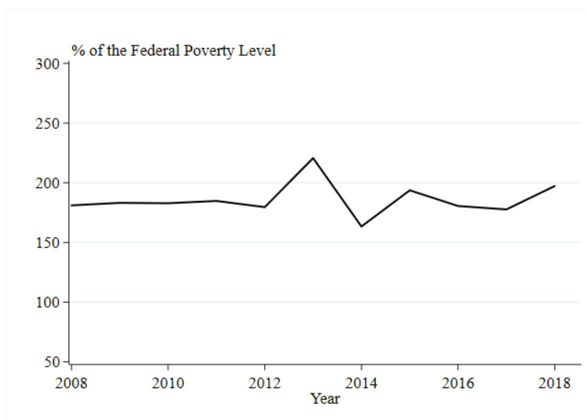
Note: Panel (A) depicts the information sheet presented to parents explaining the risks of HPV and the benefits of HPV vaccination. Panel (B) is the signature form that parents must sign each year if they opt-out of vaccinating their child.

Figure A2: Washington, DC's demographic composition changed smoothly over the 2008-2018 sample period





(A) (B)

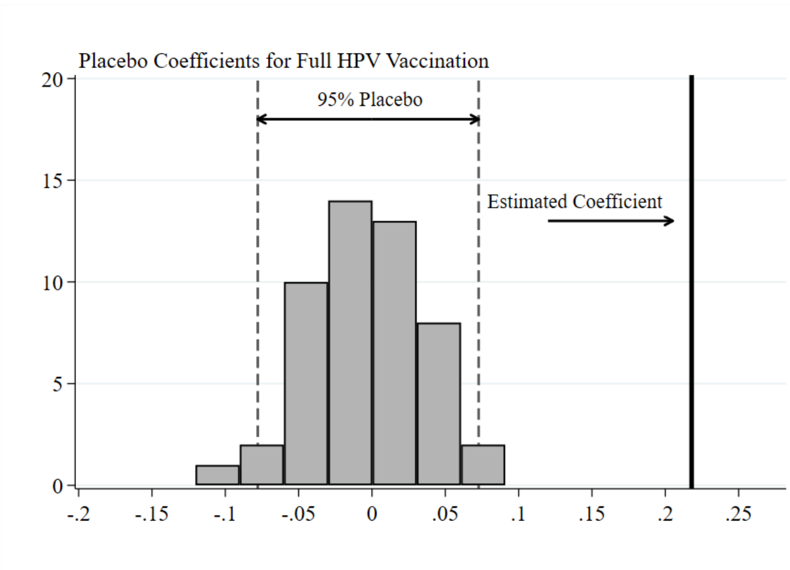


(C)

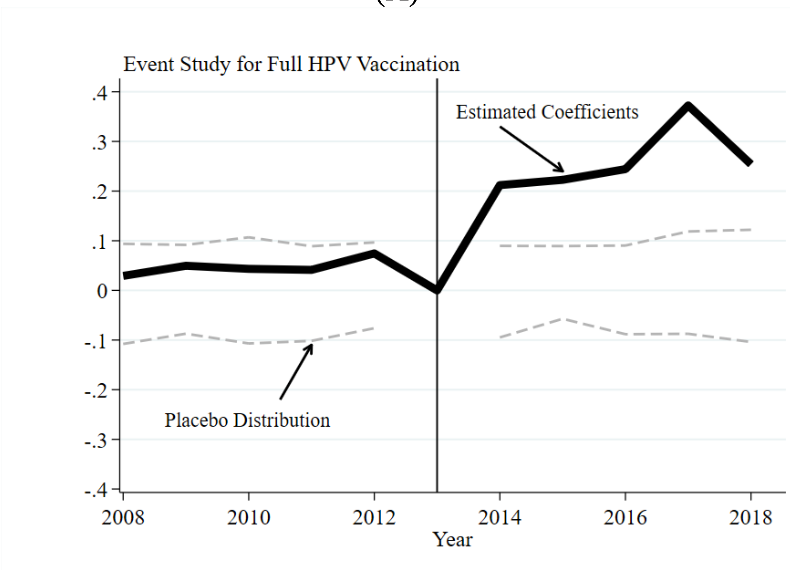
Source: National Immunization Survey—Teen 2008-2018

Note: Panel (A) plots the share of non-white teens in Washington, DC from 2008-2018. Panel (B) plots the share of teens whose mothers had college degrees. Panel (C) plots the average position relative to the federal poverty level. This variable is bottom-coded at 50 percent and top-coded at 300 percent. The shares are constructed using the sample weights.

Figure A3: The relationship between DC's HPV vaccine school requirement and HPV vaccination is robust to including observations from Virginia and Rhode Island



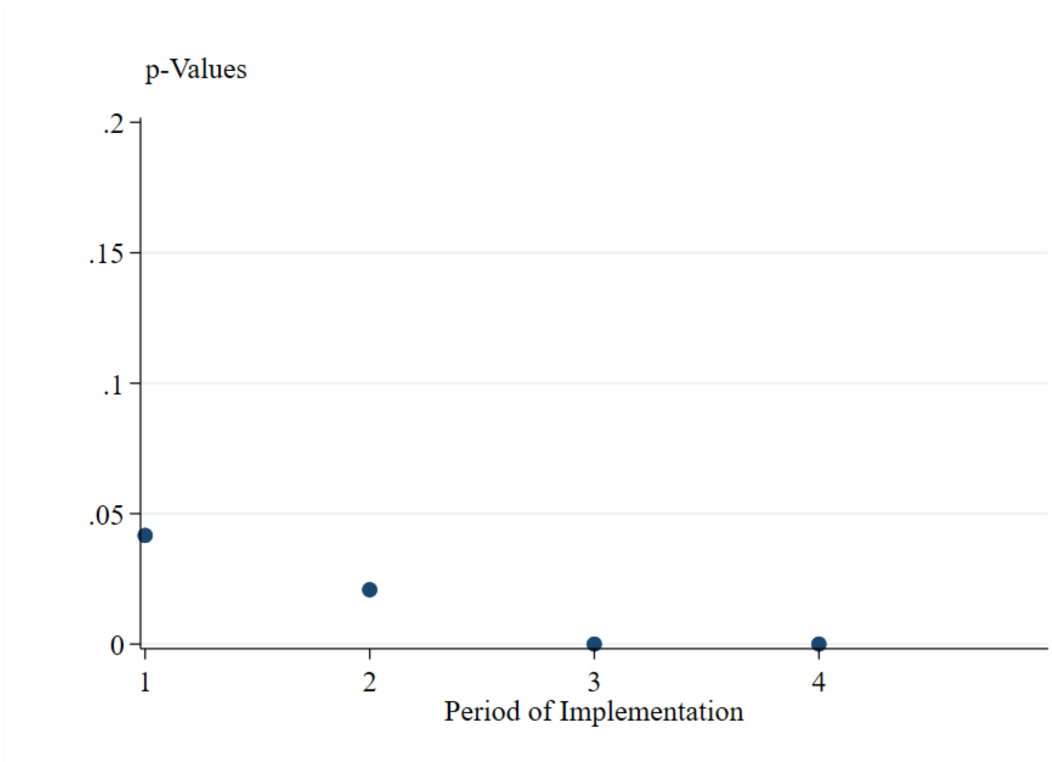
(A)



(B)

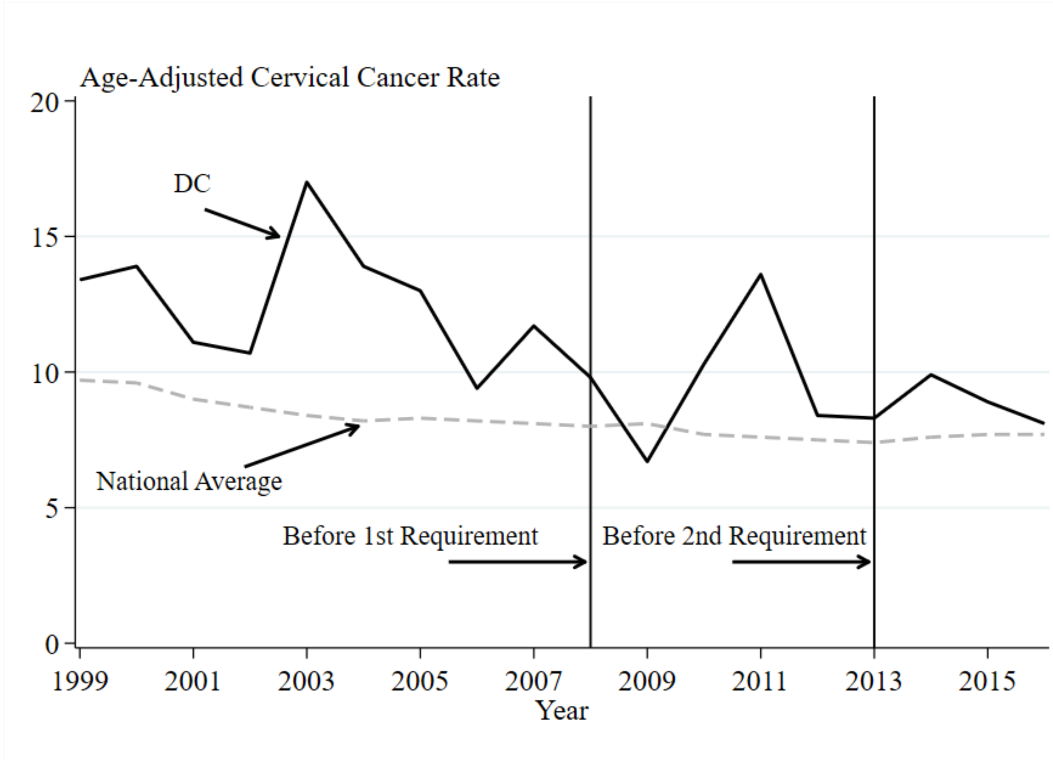
Note: The dependent is an indicator for having been fully vaccinated against HPV (3 doses prior to 2017 and 2 doses thereafter). In Panel (A) the independent variable of interest is an indicator for Washington, DC's 2014 HPV vaccine school requirement. Estimates are obtained using equation (1). In Panel (B) the independent variables of interest are indicators for each year—with 2013 omitted—to capture dynamic effects. When the black line is within the placebo interval, the estimate was likely to have been obtained by chance. When the black line is outside the interval, it is unlikely that the estimate was obtained by chance. The sample includes observations from Rhode Island and Virginia though they both had HPV vaccine school requirements. The estimates utilize the sample weights.

Figure A4: The p-values obtained from the synthetic control method



Source: National Immunization Survey—Teen 2008-2018
Note: Synthetic DC is obtained from matching on the pre-period vaccination rates in 2009, 2011, and 2013.

Figure A5: Washington, DC's cervical cancer rate over time



Source: CDC WONDER

Table A1: Additional coefficients from baseline specification

	(1) Coefficient	(2) Standard Error
DC's 2014 HPV Vaccine Requirement	0.221***	(0.012)
DC's 2009 HPV Vaccine Requirement	-0.006	(0.006)
Age 14	0.040***	(0.004)
Age 15	0.062***	(0.009)
Age 16	0.081***	(0.012)
Age 17	0.102***	(0.010)
Mother's Age ≤ 34	0.000	(0.006)
35 ≤ Mother's Age ≤ 44	-0.014***	(0.002)
Mother Less than High School	-0.002	(0.010)
Mother High School Graduate	-0.026***	(0.006)
Mother Some College	-0.031***	(0.005)
6-8th Grade	0.078***	(0.027)
9-12th Grade	0.101***	(0.026)
High School Graduate	0.100***	(0.024)
Income ≤ $20K	0.040***	(0.009)
$20K < Income ≤ $30K	0.025***	(0.007)
$30K < Income ≤ $40K	0.010	(0.007)
$40K < Income ≤ $50K	-0.007	(0.004)
White	-0.022***	(0.008)
Black	-0.010	(0.010)
Hispanic	0.031***	(0.009)
Male	-0.156***	(0.004)
Tdap Requirement	0.007	(0.006)
CDC Grant per Person	0.002	(0.003)
ACA Medicaid Expansion	0.037***	(0.010)
HPV Vaccine Recommended by ACIP	0.169***	(0.011)
HPV Vaccine Available by FDA	-0.104***	(0.007)
Consent to HPV Vaccine	0.011	(0.007)
Consent to Any Medical Procedure	0.002	(0.003)
Prescriptive Authority	0.021*	(0.011)
General Authority	-0.014*	(0.008)
Patient-Specific Authority	0.004	(0.015)
NCI Grant Receipt	-0.001	(0.008)
NACCHO Grant Receipt	-0.002	(0.010)
Meningococcal Booster Mandate	0.007	(0.010)
Meningococcal Education Post-Secondary	0.082***	(0.006)
Meningococcal Education Mandate	-0.020	(0.025)
Meningococcal Post-Secondary Mandate	-0.004	(0.019)
Insurance Explicitly Required to Cover HPV Vaccine	-0.001	(0.021)
Universal Purchase	0.026	(0.022)
R2	0.184	
Observations	200,894	

Source: National Immunization Survey—Teen 2008-2018

Note: The dependent variable is an indicator for whether the teen has received the full HPV vaccination (3 doses until 2016 and 2 doses in all subsequent years). The independent variable of interest is an indicator for Washington DC's 2014 HPV vaccine school mandate and estimated using equation (1). The table reports the coefficients from the covariates

from Table 3 column (1). Standard errors, shown in parentheses, are clustered at the state level. The estimates utilize the sample weights.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Table A2: DC's 2014 HPV vaccine school requirement increased HPV vaccination under alternative specifications

	(1) Limiting the Sample Period to 2008-2016	(2) Defining Complete Vaccination as 3 Shots	(3) Not Utilizing the Sample Weights	(4) Dropping Observations from 2013	(5) Including Only State and Year Fixed Effects
DC's 2014 Mandate	0.187***	0.223***	0.184***	0.214***	0.178***
Placebo 95% Lower Bound	-0.075	-0.077	-0.097	-0.089	-0.113
Placebo 95% Upper Bound	0.073	0.069	0.058	0.075	0.064
R2	0.150	0.139	0.191	0.193	0.116
Observations	164,720	200,894	206,808	183,938	200,894

Source: National Immunization Survey—Teen 2008-2018

Note: The dependent variable is an indicator for whether the teen has received the full HPV vaccination (3 doses until 2016 and 2 doses in all subsequent years). The independent variable of interest is an indicator for Washington DC's 2014 HPV vaccine school mandate and estimated using equation (1). Column (1) restricts the sample to the 2008-2016 period prior to the change in the definition of full HPV vaccination. Column (2) uses the full 2008-2018 period, but instead defines full vaccination as 3 shots throughout the sample period. Column (3) does not utilize the sample weights, column (4) drops observations from 2013, and column (5) only includes controls for state and year fixed effects. To perform inference, the 95 percent confidence intervals are obtained by estimating placebo treatments for each of the other 48 states. The estimates utilize the sample weights.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Table A3: The relationships between Washington, DC's 2014 HPV vaccine school requirement, vaccine initiation, and the time it took to obtain full vaccination are not sensitive to restricting the sample to the 2008-2016 period prior to the change in the number of shots for full vaccination

	(1)	(2)	(3)	(4)	(5)	(6)
	Vaccine Initiation		Vaccine Initiation without Completion		Complete Vaccination within 1 Year of Initiation	
	Girls	Boys	Girls	Boys	Girls	Boys
DC's 2014 Mandate	0.101**	0.266***	-0.076**	0.078	0.107**	-0.084
Placebo 95% Lower Bound	-0.137	-0.124	-0.070	-0.061	-0.126	-0.129
Placebo 95% Upper Bound	0.078	0.134	0.068	0.101	0.099	0.202
Dependent Mean	0.534	0.169	0.248	0.126	0.633	0.984
R^2	0.070	0.274	0.022	0.101	0.058	0.071
Observations	78,890	85,830	78,890	85,830	22,253	10,349

Source: National Immunization Survey—Teen 2008-2018
Note: The dependent variable in columns (1) and (2) is an indicator for whether the teen has initiated HPV vaccination (at least 1 dose). The dependent variable in columns (3) and (4) is an indicator for whether the teen has initiated vaccination but was not completely vaccinated (1 or 2 doses from 2008-2016 and 1 dose from 2017-2018). The dependent variable in columns (5) and (6) is an indicator for whether the teen was fully vaccinated within 1 year of vaccine initiation, where the sample is restricted to those initiating vaccination. The odd numbered columns examine teen girls, while the even numbered columns examine teen boys. To perform inference, the 95 percent confidence intervals are obtained by estimating placebo treatments for each of the other 48 states. The estimates utilize the sample weights.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Table A4: DC's HPV vaccine school requirement increased HPV vaccine initiation and reduced the likelihood that teen girls initiated but did not complete vaccination

	(1)	(2)	(3)	(4)	(5)	(6)
	Vaccine Initiation		Vaccine Initiation without Completion		Complete Vaccination within 1 Year of Initiation	
	Overall	By Sex	Overall	By Sex	Overall	By Sex
DC's 2014 Mandate	0.195***	0.109**	-0.026	-0.089**	0.165***	0.195***
Placebo 95% Lower Bound	-0.071	-0.125	-0.046	-0.059	-0.093	-0.108
Placebo 95% Upper Bound	0.067	0.094	0.051	0.055	0.073	0.081
DC's 2014 Mandate x Boy		0.149**		0.114***		-0.165*
Placebo 95% Lower Bound		-0.129		-0.071		-0.177
Placebo 95% Upper Bound		0.135		0.099		0.258
R^2	0.231	0.241	0.053	0.056	0.065	0.069
Observations	200,894	200,894	200,894	200,894	52,087	52,087

Source: National Immunization Survey—Teen 2008-2018
Note: The dependent variable in columns (1) and (2) is an indicator for whether the teen has initiated HPV vaccination (at least 1 dose). The dependent variable in columns (3) and (4) is an indicator for whether the teen has initiated vaccination but was not completely vaccinated (1 or 2 doses from 2008-2016 and 1 dose from 2017-2018). The dependent variable in columns (5) and (6) is an indicator for whether the teen was fully vaccinated within 1 year of vaccine initiation, where the sample is restricted to those initiating vaccination. The odd numbered columns use the difference-in-differences identification strategy from equation (1), while the even numbered columns use the triple-difference specification from equation (2). To perform inference, the 95 percent confidence intervals are obtained by estimating placebo treatments for each of the other 48 states. The estimates utilize the sample weights.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Table A5: Parents of teens not likely to be vaccinated over the subsequent 12 months were less likely to cite safety concerns and more likely to indicate that they believed the vaccine was not needed.

	(1)	(2)	(3)	(4)	(5)
	Reason for Not Vaccinating within 12 Months				
	Not Needed	Teen is Not Sexually Active	Safety Concerns	Lack of Knowledge	Not Recommended
DC's 2014 Mandate	0.030	0.031	-0.110***	-0.014	-0.041
Placebo 95% Lower Bound	-0.060	-0.058	-0.059	-0.055	-0.059
Placebo 95% Upper Bound	0.053	0.045	0.054	0.044	0.067
DC Mean Pre-Period	0.223	0.195	0.180	0.136	0.122
R2	0.015	0.024	0.038	0.015	0.023
Observations	53,468	53,468	53,468	53,468	53,468

Source: National Immunization Survey—Teen 2010-2018

Note: In column (1) the dependent variable is an indicator for stating that the vaccine is not needed, in column (2) it is an indicator for not vaccinating because the teen is not sexually active, in column (3) it is an indicator for opting not to vaccinate out of safety concerns, in column (4) it is an indicator for not vaccinating due to a lack of knowledge about the vaccine, and in column (5) it is an indicator for attributing the decision to a lack of recommendation for the vaccine. The sample period for is 2010-2018 and the sample is restricted to teens whose parents say they are unlikely to be vaccinated within the subsequent 12 months. The independent variable of interest is an indicator for Washington DC's 2014 HPV vaccine school mandate. To perform inference, the 95 percent confidence intervals are obtained by estimating placebo treatments for each of the each of the other 48 states. The estimates utilize the sample weights.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Table A6: The states comprising "Synthetic DC"

(1) State	(2) Percentage	(3) State	(4) Percentage
AL	0.015	MT	0.011
AK	0.012	NC	0.010
AR	0.011	ND	0.015
AZ	0.017	NE	0.013
CA	0.076	NH	0.010
CO	0.01	NJ	0.011
CT	0.009	NM	0.014
DE	0.076	NV	0.010
FL	0.014	NY	0.016
GA	0.017	OH	0.017
HI	0.007	OK	0.269
IA	0.011	OR	0.011
ID	0.016	PA	0.010
IL	0.017	SC	0.022
IN	0.012	SD	0.006
KS	0.007	TN	0.011
KY	0.011	TX	0.022
LA	0.014	UT	0.008
MA	0.007	VT	0.011
MD	0.009	WA	0.011
ME	0.033	WI	0.011
MI	0.011	WV	0.019
MN	0.011	WY	0.010
MO	0.012		
MS	0.017		

Source: National Immunization Survey-Teen 2008-2018
Note: Column (1) indicates the state and column (2) the share of the state comprising "Synthetic DC." Similarly, column (3) indicates the state and column (4) that state's share of "Synthetic DC." Synthetic DC is obtained by matching on three lagged values of the dependent variable in the pre-requirement period (2009, 2011, and 2013).

Table A7: Synthetic control estimates obtained from matching the synthetic counterfactual on DC's HPV vaccination rates in 2009, 2011, and 2013

(1) Year	(2) DC	(3) Synthetic DC	(4) (2)-(3)
2008	0.067	0.090	-0.023
2009	0.118	0.118	0.000
2010	0.160	0.156	0.004
2011	0.176	0.176	0.000
2012	0.235	0.218	0.016
2013	0.264	0.264	0.000
2014	0.452	0.303	0.150
2015	0.502	0.358	0.144
2016	0.554	0.373	0.181
2017	0.833	0.516	0.318
2018	0.741	0.515	0.226
Pre-Period RMSPE		0.729	
Post-Period Joint p-value		<0.01	

Source: National Immunization Survey-Teen 2008-2018

Note: Column (1) denotes the year. Column (2) is the HPV vaccination rate in DC during the corresponding year. Column (3) is the vaccination rate in "Synthetic DC," which is generated by matching on lagged values of the dependent variable from 2009, 2011, and 2013. Column (4) denotes the difference between columns (2) and (3) and can be interpreted as the effect of Washington, DC's HPV vaccine school requirement in the post-2014 period. I also report a metric of match quality in the pre-period, as well as the joint p-value for the post-period. Vaccination rates were constructed using the sample weights. The top three donor states are Oklahoma (27 percent), California (8 percent), and Delaware (8 percent).

Table A8: Synthetic control estimates obtained from matching the synthetic counterfactual on DC's HPV vaccination rates in 2008, 2010, and 2012

(1) Year	(2) DC	(3) Synthetic DC	(4) (2)-(3)
2008	0.067	0.067	-0.000
2009	0.118	0.139	-0.020
2010	0.160	0.160	0.000
2011	0.176	0.189	-0.013
2012	0.235	0.235	0.00
2013	0.264	0.220	0.044
2014	0.452	0.293	0.159
2015	0.502	0.337	0.165
2016	0.554	0.380	0.174
2017	0.833	0.536	0.298
2018	0.741	0.555	0.186
Pre-Period RMSPE		0.458	
Post-Period Joint p-value		0.021	

Source: National Immunization Survey-Teen 2008-2018
Note: Column (1) denotes the year. Column (2) is the HPV vaccination rate in DC during the corresponding year. Column (3) is the vaccination rate in "Synthetic DC," which is generated by matching on dependent variable in years 2008, 2010, and 2012. Column (4) denotes the difference between columns (2) and (3) and can be interpreted as the effect of Washington, DC's HPV vaccine school requirement in the post-2014 period. I also report a metric of match quality in the pre-period, as well as the joint p-value for the post-period. Vaccination rates were constructed using the sample weights. The largest donor states are Montana (36 percent), Hawaii (30 percent), and Indiana (16 percent).

Table A9: Synthetic control estimates obtained from matching the synthetic counterfactual on DC's average HPV vaccination rate from 2008-2013

(1) Year	(2) DC	(3) Synthetic DC	(4) (2)-(3)
2008	0.067	0.088	-0.021
2009	0.118	0.139	-0.021
2010	0.160	0.161	-0.000
2011	0.176	0.180	-0.004
2012	0.235	0.203	0.032
2013	0.264	0.249	0.015
2014	0.452	0.296	0.156
2015	0.502	0.352	0.151
2016	0.554	0.379	0.176
2017	0.833	0.532	0.302
2018	0.741	0.548	0.192
Pre-Period RMSPE		0.708	
Post-Period Joint p-value		0.021	

Source: National Immunization Survey-Teen 2008-2018
Note: Column (1) denotes the year. Column (2) is the HPV vaccination rate in DC during the corresponding year. Column (3) is the vaccination rate in "Synthetic DC," which is generated by matching on the average value of the dependent variable from 2008-2013. Column (4) denotes the difference between columns (2) and (3) and can be interpreted as the effect of Washington, DC's HPV vaccine school requirement in the post-2014 period. I also report a metric of match quality in the pre-period, as well as the joint p-value for the post-period. Vaccination rates were constructed using the sample weights. All donor states contribute equally.

1.9. APPENDIX B: DC GRANT EXPENDITURES

July 2013-December 2013

Preparatory work conducted to enable the budget to be loaded in the DC Financial Management System Statements of work were prepared in order to hire consultants for this project. Started preliminary work with the Registry to ensure that the reminder recall function will be functional and operational once the final documents are ready for transmission.

January 2014-June 2014

Since the hiring of contractual staff we have secured VFC providers to be a part of the HPV Pilot Program. All contracts for the for the communication campaign have been awarded. Purchase orders were issued for media purchases from Radio One Inc. CBS Outdoor Advertising Comcast Pandora Seaberry Graphic Design and Communications and Radio One. Established the reminder/recall notification system. Participated in the planning of the AAP chapter meeting on HPV Barriers and Outreach in the District of Columbia on May 16 2014. Conducted stakeholder meetings in June and scheduled some for July. Prepared stakeholder tool kits that will be distributed during the stakeholder trainings. Hosted a conference call with Mary's Center Medical Director and staff on June 13 2014 to confirm the on-site stakeholder training that will be held on July 16 2014. Other Stakeholders meetings are scheduled for July 30th and August 2014 this includes The District-wide HPV Training.

Sub-Recipient Name	Award Date	Award Number	Award Amount	Award Purpose
Seaberry	2013-09-24	H23IP000745	$42,000	Regional Advertisement Creation

July 2014-December 2014

In addition to previously met objectives, we accomplished the following within the past six months of the grant period:

1. Develop a jurisdiction-wide joint initiative with immunization stakeholders

   July

   - DOH Project Team presented our DC HPV grantee activities during the July 22 grantee presentation call.

- The HPV Coordinator conducted two onsite stakeholder trainings with local providers—Mary’s Center on July 16 and Children’s National Medical Center on July 30.
- Another stakeholder training, open to various provider types throughout the District, was arranged and scheduled to be held on August 28 at Gallaudet University from 6:00–8:00 pm.
- The team developed and distributed 115 stakeholder training tool kits. Another 125 tool kits were planned for distribution at the August 28 stakeholder meeting.
- DOH Immunization staff completed and submitted the CDC PPHF Semi-Annual Recipient Reporting requirement report.

August

- DOH attorney Rudy Schreiber and CDC staff participated in the Immunization Office’s staff meeting on August 7 to discuss DC’s HPV mandate and the amendment for boys. Robin Curtis and other CDC personnel joined by phone, and this also served as our monthly reporting call.
- Submitted the CDC PPHF monthly report in August to Robin Curtis and other CDC staff.
- Through rulemaking authority, DOH attorneys submitted an emergency request to have the current DC HPV legislation amended to include boys. A period of public comments will still have to be held.
- DOH sponsored and hosted the Immunization Conference on August 25, 2014.
- The HPV Coordinator attended the 29th International Papillomavirus Conference & Clinical Workshop, August 20-25, 2014, and shared highlights at the August 28 stakeholder training.
- On August 28 from 6:30–8:30 pm, team conducted a community-wide stakeholder training held at Gallaudet University; 135 providers attended.
- DOH attorney submitted an emergency order to include a male requirement in the legislation. This was discussed at the August 7 meeting with DOH Attorney Rudy Schrieber. Next steps involve having an open forum regarding the amended legislation and receiving public comments.

September

- Participated in monthly reporting call with CDC DOH Project Team on September 4.

- HPV Coordinator has been communicating with several local providers to set up site visits for the clerks to come and assist with reminder/recall and notification letter generation and mailing.
- We received the postage for mailing the reminder/recall letters for the providers.
- We are in current discussion with the DC American Academy of Pediatricians (AAP) chapter to adapt our DOH stakeholder training curriculum for a webinar, which providers can access online via the DC AAP website. Upon completion of the training and evaluation, providers will receive continuing education units (1 credit).

October

- DOH staff and clerks participated in the October 2 monthly reporting call and the October 8 Combined 2013/14 All-Awardee PPHF HPV IZ Call.
- HPV Coordinator has spoken with Unity, Children's National Medical Center, and Mary's Center providers and is trying to schedule dates for the DOH clerks to go assist them with generating and mailing out the reminder/recall notification letters. Mark Weissman, Division Chief at Children's, will confirm their dates by Monday, November 3.
- Completed the No Cost Extension and submitted it to CDC's Robin Curtis.

November

- HPV Coordinator spoke with Unity and Children's National Medical Center. We are still trying to secure dates for the onsite trainings and reminder/recall letter generation.
- The HPV Coordinator and the DOH Clerks conducted the DOH HPV Provider training with 40 school nurses at People's Congressional Church in Northwest DC.
- On Saturday, November 22nd from 11 am until 3 pm, HPV Clerks and DOH Staff participated in the "ED Fest," a community outreach effort to promote immunizations and dental screening in DC. The event was held at the DC Stadium Armory and information was disseminated about the HPV Vaccine and other immunizations
- Making revisions to the No Cost Extension request.
- Rosie McLaren and Nancy Ejuma attended the Reverse Site Visit in Atlanta.

December

- Participated in monthly reporting call with CDC DOH Project Team on December 4.
- HPV Coordinator has been communicating with several local providers to set up site visits for the clerks to come and assist with reminder/recall and notification letter generation and mailing.
- We received the postage for mailing the reminder/recall letters for the providers.
- We are in current discussion with the DC American Academy of Pediatricians (AAP) chapter to adapt our DOH stakeholder training curriculum for a webinar, which providers can access online via the DC AAP website. Upon completion of the training and evaluation, providers will receive continuing education units (1 credit).

2. Implement comprehensive communication campaign targeted to the public

July

- Finalized all media contract awards.
- Developed HPV web page content.
- Developed communication grid showing media vendors, key HPV messages, and frequency of ad runs.
- Reviewed and solicited feedback regarding "Free HPV DC" tagline and message materials (i.e., advertisement, brochure, etc.) from CDC and DOH staff.
- Angela Simmons, DOH Events Coordinator of Community Outreach, presented the Communication Campaign during the July 22 grantee call.
- One radio ad is airing through a media buy with Radio1, one print advertisement is running through media buys with CHBS Outdoor (WMATA) and the Express Newspaper, one transit ad will be placed on WMATA Metro buses. One digital ad is being transmitted through a media buy through Pandora and one video ad is being shown on major cable networks via Comcast. One video ad will be shown in DC cinemas through a media buy with NCM.

August

- On August 7 at the Immunization Office staff meeting versions for the media ads were presented for review. DOH staff provided feedback and Robin Curtis and other CDC staff provided feedback by phone. September

- DOH is considering expanded frequency of the current media buys with remaining CDC grant funds and also some limited funds the DC AAP chapter can provide. Discussion ongoing to finalize plans for this.

October

- Advertisements ran via various media vendors.

November

- Advertisements continued running with various media vendors and are set to end in December.
- Project team members presented communication examples at the Reverse Site Visit.
- During the site visit, other program personnel commented on the tools and requested copies. These copies have been sent to these programs.
- The DC Chapter of AAP is going to use their remaining funds (approximately $2,500) to co brand and distribute printed materials (i.e., HPV poster, postcards) to providers around the city.
- Staff continued to monitor the penetration of HPV via selected media outlets.

December

- Current HPV advertisements and promotional pieces will air though December 31st.

3. Implement Immunization Information System (IIS)-based reminder/recall for adolescents who are 11–18 years old, either through a centralized approach (preferred) or by providing support to immunization providers

July

- HPV Coordinator continued to communicate with providers to assess their capacity (e.g., staff, hours of operation) for handling the anticipated increase in vaccination appointments (i.e., physician visits, walk-ins, nurse-only).

- Many providers added additional staff and have opened up additional evening and weekend appointments particularly to handle back-to-school appointments.
- The DOH Immunization Team put together a work flow process for providers to continue to educate them on how to operate the reminder/recall system and generate notification letters from the registry.
- The HPV Coordinator and clerks sent emails and made phone calls with providers (i.e., Mary's Center and Children's National Medical Center) to discuss and schedule dates when the clerks can come onsite to assist with reminder/recall and notification letter generation and mailing.

August

- Requested postage that will be used to assist providers in mailing adolescent reminder/notification letters.
- HPV Coordinator re-sent emails to invite providers to participate in the HPV Pilot Program which assists providers with reminder/recall and notification letter generation and mailing.
- HPV Coordinator contacted personnel by email and phone set up additional stakeholder trainings.
- We continue to partner with the DC AAP chapter. The director of AAP sent out email notices about the DOH stakeholder training and HPV Pilot Program opportunities.

September

- Completing a work agreement with Children's Medical Center, one of the largest providers that serves minority and underserved children in the DC area, that allows the clerks to come onsite to assist reminder/recall and notification letter generation. This is required for all non-children's employees.
- HPV Coordinator is in discussion with Unity Health Centers to schedule clerk site visit within the next week.
- In preparation for the provider site visits, all the clerks participated in Registry refresher training.

October

- Went onsite to assist with reminder/recall and notification letter generation and mailing.
- Continued following-up with schools to aid in our effort to increase rates for HPV and other ACIP vaccinations.

November

- DOH staff consistently followed up with providers to schedule onsite visits for the reminder/recall visits.
- Clerks continued to work with schools to follow up and increase HPV and other ACIP compliance rates.

December

- On December 12th DOH staff and HPV Coordinator met with the medical director, Dr. Lekeisha Terell, and other representatives from Ballou school-based health center to discuss reminder/recall and to map out logistics how DOH staff can best assist them with this effort.
- HPV Coordinator has followed up with Dr. Terrell and we are currently awaiting approval of their leadership to move forward.
- The HPV Coordinator met with health center representatives from Mary's Center on December 16 to discuss the reminder/recall notification program and support from DOH in terms of staff (DOH HPV clerks) and funds for postage to cover mailing the letters. Mary's Center is still very interested. The HPV Coordinator followed up with them and we anticipate an early January date to do onsite generation and mailing of the letters.

4. Use assessment and feedback to evaluate and improve the performance of immunization providers in administering the 3-dose HPV vaccine series consistent with current ACIP recommendations

July

- DOH General Clerks conducted follow-up calls with school administrators for charter, private, and parochial schools to request that they submit rosters for those schools with zero (0) enrollment. They also asked schools with low compliance rates to submit immunization updates. The purpose of this activity is to assist the program with establishing baseline data for HPV and other ACIP-recommended vaccines for all public, private, charter, and parochial schools.

- Confirmed with VFC Coordinator that ample vaccines are available for providers.

August

- Dr. Kirsten Feemster, MD, MPH, of the University of Pennsylvania Children's Hospital of Philadelphia made a presentation at the August 22 meeting. She gave a compelling presentation entitled "What's controversial about cancer?" to over 125 medical personnel who attended our 9th Local Immunization Conference held on Friday, August 22, 2014. She gave convincing reasons to initiate and complete the three-dose HPV vaccination series for males and females.
- Dr. Wallington dedicated an entire module at the HPV stakeholder meeting on Thursday, August 28, 2014, to improving and refining knowledge about the importance and practice of HPV reminder/recall notifications. She extended an invitation to providers to participate in our HPV Pilot Program, explaining the benefits of the program, which include postage and manpower to generate and mail the notification letters up to December of this year and the institutionalization of the reminder/recall infrastructure which is now a part of the DC Immunization Registry.

September

- Clerks are assisting with making reminder calls to day care centers to submit rosters in order to assess immunization compliance. They will be assisting with reminder calls to the schools to obtain rosters to determine immunization compliance as this will have an impact on HPV rates.

October

- DOH solicited verbal feedback from providers to determine strategies and barriers in administering the 3 dose HPV vaccine series consistent with current ACIP recommendations. November
- We initiated conversations with AAP aimed at securing a contract for specifically identified clinicians who will act as HPV vaccine ambassadors at provider events and individual practices in the upcoming year. These activities are outlined in our No Cost Extension letter.

- The Immunization Program explored ways to engage providers in a centralized reminder/recall and notification approach utilizing's Chicago approach as a benchmark.

December

- DOH Clerks, the public health advisor, the HPV Coordinator, and the VFC Coordinator met on December 8th to discuss a potential AFIX protocol utilizing the registry, CoCASA, and assistance from DOH clerk Regina Freeman. Ms. Freeman has already begun training with the VFC Coordinator on AFIX strategies. This AFIX plan will be discussed with the Immunization Manager, Nancy Ejuma, for review and approval.

5. Implement strategies targeted to immunization providers to:

July

- Disseminated Stakeholder Training Tool Kits with additional CDC HPV vaccination materials on jump drives so providers can have electronic copies of materials for themselves and to share with colleagues (ongoing activity).
- CEUs were given at each July stakeholder training and were processed.

August

- In August, the HPV Coordinator was invited by the AAP DC chapter to submit a newsletter article "Providers Are the Key: Making a Strong HPV Recommendation," and this article was published in the September edition of the newsletter. September
- DOH Immunization Office staff and clerks attended The Southeast (Ward 8) Health Expo on Saturday, September 13, 2014. The health fair served as opportunity to promote the work that Immunization Office is doing including highlighting DOH's HPV initiatives.

October

- HPV Coordinator created training modules to be used for the DC AAP's planned HPV Vaccination Webinar targeting providers.

- The DC AAP and the national AAP organization approved the contents and submitted the modules for continuing educational units.

November

- HPV Coordinator conducted DC AAP webinar on December 4th.
- 27 participants registered for the webinar.
- 1-credit CEU was given to each webinar participant.
- HPV Coordinator and clerk conducted a provider training with 40 DC Public School Nurses on November 19th. The nurses felt the training was sorely needed and helped to fill in a lot of HPV and HPV vaccine knowledge gaps.

December

- The Immunization Program wants to institutionalize provider training by creating its own recording of the provider training with the HPV Coordinator facilitating. The recorded training will be available for DOH staff and providers in the District to access the training. Nancy Ejuma will work with the HPV Coordinator to complete these recordings.

January 2015-June 2015

1. Develop a jurisdiction-wide joint initiative with immunization stakeholders

- Attended the Immunization Task Force meeting with 42 representatives from multiple organizations around Washington, DC (including public, private, non-profit and pharmaceutical companies).
- Worked with Children’s Hospital’s Mobile Clinic on a middle school initiative and will be having them add HPV to the list of vaccines they will be providing to the middle schools they are engaging.
- Dociis export fixed
- Continue our collaboration with the Health Promoters to train providers to make a strong HPV recommendation.
- We are collaborating with the Deputy Mayors of Education and Health and Human Services to identify and provide outreach to both non-compliant students and students with religious and/or HPV Exemptions.

- Plans are underway for the 10th Annual Immunization Conference. DOH is partnering again with the DC Immunization Coalition. The conference is scheduled for July 22nd at Gallaudet University.

2. Implement comprehensive communication campaign targeted to the public

- Based on the funds remaining for the no-cost extension period, we will not be participating in a large scale communication campaign. Instead, our efforts will be focused on peer to peer exchange and community meetings.
- AAP distributed CDC HPV flyers to multiple provider sites throughout the city.
- We have prepared HPV rates and vaccine dose order rates for city-wide Alliance meetings and will be discussing HPV as a primary initiative for this year throughout the various wards in the city.
- We will be participating in eight evening Ward Health Alliance meetings this year beginning with Ward 7 on April 7th. We have prepared PPT slides for the Chief Medical Officer to discuss HPV as a primary initiative for the agency.
- Providers will continue to distribute the AAP co-branded materials.

3. Implement Immunization Information System (IIS)-based reminder/recall for adolescents who are 11–18 years old, either through a centralized approach (preferred) or by providing support to immunization providers

- Public Health Analysts continued to work with schools to follow up and increase HPV and other ACIP compliance rates.
- Immunization Points of Contacts have begun to receive immunization compliance rates specific to their schools.
- Mary’s Center is still very interested in moving forward and will likely be our first site to receive centralized reminder/recall effort. We expect this effort to be closed for all sites by June of this year.

4. Use assessment and feedback to evaluate and improve the performance of immunization providers in administering the 3-dose HPV vaccine series consistent with current ACIP recommendations

- We developed a one page infographic template to make it clear to the providers what their current rates are related to HPV.

- DOH Clerks, the public health advisor, the HPV Coordinator, and the VFC Coordinator met to discuss a potential AFIX protocol utilizing the registry and CoCASA. We identified a strategy (shown in the graphic under objective 1) that we believe will work well for this project.
- Began collecting data from VTrckS, the cancer bureau and DOCIIS to begin development of all infographics. We also researched and included the CPT codes for inclusion in the packet.

5. Implement strategies targeted to immunization providers to: a) Increase knowledge regarding HPV-related diseases (including cancers), b) Increase knowledge regarding HPV vaccination safety and effectiveness, c) Improve skills needed to deliver strong, effective HPV vaccination recommendations, d) Decrease missed opportunities for timely HPV vaccination and series completion, and e) Increase administration of HPV vaccine doses consistent with current ACIP recommendations.

- HPV Coordinator trained the four (4) health promoters.
- HPV Coordinator and clerk conducted a provider training with DC Public School Nurses. The nurses felt the training was sorely needed and helped to fill in a lot of HPV and HPV vaccine knowledge gaps.
- Health Promoter meetings with community providers began to be scheduled by the CDC Public Health Advisor and the Adult Immunization Coordinator. The Adult Immunization Coordinator has stepped in to support the initiative and we re-staff the HPV clerk position. We have identified an individual to fill that role (resume attached).

July 2015-December 2015

The following activities were completed for the time period July to December 2015

- HPV Ad Campaign: Comcast advertisements were used to promote HPV vaccinations. The timing of this campaign was excellent as schools were conducting mid-year reviews to determine the status immunization rates, especially since the annual exemption requirement was expanded to include HPV vaccinations.
- Reminder/Recall: The Immunization Program with the assistance of students from McKinley High School was able to send out 20,297 reminder/recall letters, to date 204 are undeliverable. 358 do not have complete addresses so they could not be mailed. The Program made calls to all private and parochial schools to notify them know that the reminder/recall letters were forthcoming.

- HPV Peer to Peer Education: HPV Peer to Peer Education was conducted at 61 VFC Providers site by Dec 29, 2015. Five sites opted not to participate, 1 did not meet the criteria and 2 already had HPV training offered by the Cancer American Society, 1 is the Hospital for Sick Children that provides services to severely sick children.

Sub-Recipient Name	**Award Date**	**Award Number**	**Award Amount**	**Award Purpose**
Comcast Spotlight	2013-09-24	H23IP000745	$65,025	HPV Advertising Campaign
Walton & Green	2013-09-24	H23IP000745	$97,500	Education for Parents for HPV
Walton & Green	2013-09-24	H23IP000745	$97,500	Education for Parents for HPV

January 2016-June 2016

The following allocations were made with the 2016 PPHF Grant funds:

- $176,815 have been allocated to contracts
- $6,458 have been allocated to printing
- $8,200 has been allocated to office supplies
- The contract funds, printing and office supply funds are expected to be expended in the final quarter of the year (October - December 2016) in support of efforts to expand data entry into the District of Columbia Immunization Information System (DOCIIS) to schools and doctor's offices. Training manuals and supplies in support of this effort will be procured. In the District of Columbia, all immunization records are centrally entered by the Immunization Program's Data Management team. 60% of the data in DOCIIS is added through HL7 interfaces with doctor's offices while 40% is manually entered within the Department of Health. This year, the DC DOH Immunization Program will be training identified school nurses and doctor's offices to enter data into DOCIIS directly. This will ease the burden of data entry for the team and will also expand utilization of the system. The contract dollars will be used to secure human capital support for this effort.

July 2016-December 2016

These funds including funding that were allocated for the HPV grant. The Program has expended $586,171 that was allocated for the HPV grant. The Program has also expended $188,800 of the $190,473 received for the 2016 Grant.

Sub-Recipient Name	**Award Date**	**Award Number**	**Award Amount**	**Award Purpose**
Program Managers Travel to Reverse Site Visit in Atlanta	2014-11-15	H23IP000745	$1,110	Reverse Site Visit - Atlanta
Walton & Green	2014-11-15	H23IP000745	$97,500	Hire Program Coordinator for the HPV Program and Media Campaign
Gallaudet University	2014-11-15	H23IP000745	$8,280	HPV Stakeholders Training
Pandora Media Inc.	2014-11-15	H23IP000745	$10,000	Contract for Advertisement
Radio One	2014-11-15	H23IP000745	$20,000	Contract to provide Media Services for the HPV Campaign.
Post Graduate of Medicine (PIM)	2014-11-15	H23IP000745	$4,150	Processing of CEU's
Every Child By Two	2014-11-15	H23IP000745	$500	Coordinate and prepare paperwork for CEU's stakeholder and provider training
Seaberry	2014-11-15	H23IP000745	$42,000	Contract for Regional Advertisement Creation
NCM	2014-11-15	H23IP000745	$5,899	Contract for Cinema Ads
Comcast Spotlight	2014-11-15	H23IP000745	$68,324	Contract for Television ads

Sub-Recipient Name	Award Date	Award Number	Award Amount	Award Purpose
Pandora	2014-11-15	H23IP000745	$30,000	Provide Internet Radio Ad Space
CBS Outdoors	2014-11-15	H23IP000745	$12,000	Printing and Production services to support the Metro bus Ad for the Back-to-School Immunization Campaign. Period of Performance: Date of Award through September 30, 2014.
Walton and Green Consultants	2014-11-15	H23IP000745	$99,980	4 General clerks to work with the immunization campaign to facilitate reminder/recall notification using the Immunization Information System @ $24, 995 each
Dupont Computers	2014-11-15	H23IP000745	$13,400	To purchase computers for the DC Immunization Program staff
Magnificus Corporation	2014-11-15	H23IP000745	$72,684	Secure nurses to support the DC Immunization Clinic
New Beginnings LLC	2014-11-15	H23IP000745	$11,130	Contractor to support cleanup of duplicated data in the DC Immunization Registry
Motir Services, Inc.,	2014-11-15	H23IP000745	$53,280	To hire health technicians to support the VFC Program to provide quality assurance activities to ensure that providers are in compliance with the VFC Policies and practices
Midtown Personnel	2014-11-15	H23IP000745	$15,900	Hire personnel to support the Assessment Team who enter and monitor immunization data for Licensed Child Development Centers.

Sub-Recipient Name	Award Date	Award Number	Award Amount	Award Purpose
Walton & Green	2014-11-15	H23IP000745	$97,500	Hire Program Coordinator for the HPV Program and Media Campaign

January 2017-June 2017

For the budget period January through June 2017 PPHF funds supported the following personnel and activities:

Personnel –
Perinatal Hepatitis B Coordinator engages providers to report Perinatal Hepatitis B case reporting, prenatal screening for hepatitis B surface antigen (HBsAg), immunization of infants born to HBsAg-positive mothers, immunization of household/sexual contacts of HBsAg-positive pregnant women, and routine immunization of infants at birth.

45% of the Nurse Specialist/VFC Education and Compliance Specialist salary whose responsibilities are as follows: provides training for nurses and other health professionals in immunization education and vaccine administration; works directly with community organizations and social service providers in immunization awareness; systematically reviews public and private health care provider immunization programs for quality assurance; and coordinates all aspects of the Vaccine Adverse Event Reporting System (VAERS);

VPD Surveillance Investigator who enrolls the sentinel reporting sites and coordinates reporting for all sites. The Investigator contacts all late or non-reporting sentinel sites to ensure up-to-date and complete reporting, contacts providers or parents as needed to complete case reports - includes site visits in the field if required, assesses immunization status of students in second through sixth grade in sentinel schools in order to estimate vaccine efficacy.

Public Health Analyst, assigned to the VFC Program who prepares the vaccine spend plans, budgets, VFC policies, monitors vaccine uptake, oversees the administrative side of the Vaccines for Children (VFC) Program.

In addition, the PPHF funds supported contract staff who assisted with assessments for Licensed Child Development Centers, Head Start Centers and Schools and quality assurance assessments for the IIS.

Funds were also used for maintenance of machines needed to keep the Program operational, membership fees, and software and tools for the immunization Registry.

July 2017-December 2017

The Program did not issue a single contract that exceeded $25,000 during this reporting period (July 2017 – December 2017). Of the $1,355,513 PPHF funding received by the District of Columbia $956,742 of this amount was earmarked for Personnel, Fringe and Indirect Cost rate.

The remaining PPHF funds - $398,771 were allocated for non-personnel services and are listed as follows:

$372,094 was allocated for contracts and contractual support
$9,361 was allocated for travel
$5,970 was allocated for supplies
$11,346 was allocated "Other" budget line item

Approximately $160,000 of the funds currently exist in the contracts and contractual category. It has been earmarked for use in January 2018. Anticipated funding will be used to support a sub-award for the Immunization Coalition, and flu and pneumonia prevention activities for adults. The contract for the Immunization Coalition will exceed $25,000, but we do not anticipate a single source contract for the remaining funds.

CHAPTER 2

Insurance Coverage, Provider Contact, and Take-Up of the HPV Vaccine[1]

2.1. INTRODUCTION

Human papillomavirus (HPV) is the most common sexually transmitted infection in the United States (CDC 2017) and the single biggest cause of cervical cancer, as well as certain cancers of the head and throat, anus, vulva, vagina, and penis (WHO 2019). Approximately 80 percent of sexually active people are infected with HPV at some point during their lives (Cleveland Clinic 2018), and nearly 40,000 people were diagnosed annually with an HPV-related cancer between 2008 and 2012 (Van Dyne et al. 2018). Almost 300,000 women are estimated to be living with cervical cancer (National Cancer Institute 2020). Likewise, approximately 12 percent of men are thought to have oral HPV (11 million men), over 60 percent of whom have high-risk oral HPV (Deshmukh et al. 2017).

While there are limited treatment options for those already infected with HPV, a highly effective vaccine can prevent some of the most dangerous infections. Sold under the trade name Gardasil in the US, this vaccine has been shown to provide virtually total protection from several of the highest-risk strains of HPV (Villa et al. 2005; Villa et al. 2006). However, the HPV vaccine is more expensive than most other vaccines. Each injection costs around $250 (CVS 2020), and

[1] A version of this chapter is in press as "Insurance Coverage, Provider Contact, and Take-Up of the HPV Vaccine" at American Journal of Health Economics, 7(2): 222-247. It is reproduced here in accordance with the rights retained by the author.

two injections are required over a 6-12 month period (CDC 2020).[2] Accordingly, in 2018, only 68 percent of teens had received at least one dose of the vaccine.

While the health and monetary benefits of cancer prevention are likely large, policymakers remain uncertain as to the best ways to improve take-up of the HPV vaccine. As a result, state governments and public health officials have experimented with a myriad of vaccine-related policies, including improving knowledge about the HPV vaccine (Cook et al. 2018), expanding the list of people authorized to administer the vaccine (Trogdon et al. 2016), and mandating vaccination for school attendance (Thompson et al. 2018). However, none of these programs address the high up-front cost of the vaccine, and empirical evidence on their efficacy is mixed. The most consistent estimates indicate that increasing teens' contact with health care providers remains the best method for improving HPV vaccination (Moghtaderi and Adams 2016; Carpenter and Lawler 2019).

In this paper, I provide novel evidence that the Affordable Care Act Medicaid expansion increased the probability that teens received the HPV vaccine. Using the National Immunization Survey-Teen, I show that the relationship is driven by an increase in vaccination for poorer teens, non-white teens, and those whose mothers lacked college degrees. This result is most similar to Lipton and Decker (2015) who linked two ACA policies—the dependent coverage and the preventative services provisions—to an increase in the probability that 19-25 year old women initiated the HPV vaccine. However, in contrast to the reforms studied by Lipton and Decker (2015), the ACA Medicaid expansions did not affect teenagers' eligibility for public insurance. As such, the increase in HPV vaccination that I find must be attributable to either (i) increased take-

[2] As a comparison, the seasonal flu vaccine costs $50, the meningitis vaccine costs $159, the chickenpox vaccine costs $166, and the Tdap vaccine costs $95.

up of public insurance by already-eligible but unenrolled teens and/or (ii) parental insurance coverage affecting teens' health care utilization. I show evidence that Medicaid expansion increased the probability that the groups vaccinating against HPV had health insurance, though this increased coverage cannot fully explain the take-up in vaccination.

Additionally, forty percent of teens aged 15-19 report ever having penile-vaginal intercourse, and 45 percent report having had oral sex with a different-sex partner. Two-thirds of 18-year-olds report having had sex (Guttmacher Institute 2020). Because the HPV vaccine is most effective prior to exposure to HPV, it is recommended that teens get vaccinated prior to sexual initiation (CDC 2020). As such, identifying a way to increase vaccination among individuals who are less likely to have had sex is an important contribution.

Importantly, I provide the first evidence on the pathways through which increased parental eligibility for insurance may increase HPV vaccination. I show that teens in Medicaid expansion states were more likely to have had a recent check-up and that their parents reported improved knowledge about the HPV vaccine. Using Google Trends data, I also show that Medicaid expansion was associated with more frequent searches for the terms "pediatrician," "Gardasil," and "HPV Cancer." This is similar to Carpenter and Lawler (2019) who found that state Tdap school requirements increased the probability that a teen girl received the HPV vaccine, presumably by increasing contact with health care providers.

Overall, this paper suggests that Medicaid expansion induced greater provider contact for teenagers eligible to receive the HPV vaccine, and that this additional contact translated to improved vaccine take-up. Given the political difficulties in mandating the HPV vaccine for school attendance, my results suggest that programs encouraging appropriately timed contact with health care providers remain viable options for policymakers. However, it is worth noting that Gilkey et al. (2015) found that 27 percent of physicians did not strongly endorse the HPV vaccine, 26 (39) percent did not deliver timely recommendations about the vaccine to teenage girls (boys), and 32 percent said that discussing sexually transmitted infections made conversations about the vaccine uncomfortable. Together with this paper, these statistics suggest that helping physicians navigate uncomfortable topics and better communicate the benefits of the HPV vaccine may improve the national vaccination rate.

The rest of this paper proceeds as follows: Section 2 discusses the history of the HPV vaccine and the existing knowledge on vaccination policies. I then summarize the literature relating Medicaid expansion to the take-up of public insurance among previously eligible but unenrolled children. In Section 3, I provide an overview of the NIS-Teen data and explain my difference-in-differences estimation strategy. I then show in Section 4 that teens in Medicaid expansion states were 3-4 percentage points more likely to have initiated the HPV vaccine in the post-expansion period, and I explore the mechanisms which help to explain this relationship. I conclude in Section 5 by discussing the policy implications of my estimates and areas for future research.

2.2. EXISTING LITERATURE AND POLICY BACKGROUND

The social benefit of vaccination exceeds the private benefit realized by the patient, making immunization a quintessential positive externality. As a result, vaccination rates remain below socially optimal levels, and strategies for increasing vaccine take-up are of interest to economists, public health researchers, and physicians. In this section, I discuss vaccination-related research and summarize the relevant literature on Medicaid expansion.

2.2.1. Policy Background and Vaccination Research

Gardasil was approved for females ages 9-26 in June of 2006, and the Advisory Committee on Immunization Practices (ACIP) initially recommended a 3-dose vaccination series for 11- and 12-year-old girls (FDA 2006). For girls ages 13-26 who were not yet fully immunized, ACIP recommended that they receive the vaccination to catch-up (Meites, et al. 2019). Since then, eligibility for the HPV vaccine has been repeatedly expanded. In October of 2009, the FDA approved the vaccine for teen boys and men (FDA 2009). In 2016, ACIP revised their guidelines to now recommend only 2-doses of the vaccine (Meites, Kempe, and Markowitz 2016), and in 2019 the maximum recommended age was increased to 45 years old (Meites, et al. 2019).

Most research on vaccine take-up examines policies which can be broadly categorized as those: (i) lowering vaccines' costs, (ii) increasing knowledge about vaccines' benefits, and (iii) mandating vaccination. Walsh, Doherty, and O'Neill (2016) used the 1995-2014 NIS-Child to find that the Vaccines for Children Program—which provides free vaccinations to uninsured children or those who are otherwise unable to afford them—was associated with increased vaccine take-up and a reduction in racial and ethnic vaccination disparities. Relatedly, Mulligan et al. (2018) used the 1995-2014 NIS-Child to study whether universal purchase programs increased vaccination rates for children. Under these policies, states directly purchase vaccines for privately-insured children and later bill private health insurers. The authors did not find evidence that these programs led to statistically significant increases in vaccination.

Another potential way to lower costs to the patient is to increase health insurance coverage. Lipton and Decker (2015) used data from the 2008-2012 National Health Interview Survey to estimate a relationship between two Affordable Care Act components—the dependent coverage provision and the ACA preventative services provisions—and the share of young women initiating

HPV vaccination. Because the first provision targeted women ages 19-25, the authors used a difference-in-differences strategy whereby 18- and 26-year-old women served as the control group. They found that these provisions were associated with an 8 percentage point increase in vaccine initiation for 19- to 25-year-old women. It is worth noting that the majority of these women would already have been sexually active (Guttmacher Institute 2020), and that the HPV vaccine is recommended prior to sexual initiation (CDC 2020).

Existing work suggests that educating patients about the HPV vaccine is a successful strategy for increasing vaccine take-up. For instance, Gargano et al. (2013) showed that physician recommendation is the strongest predictor of HPV vaccination. Similarly, Moghtaderi and Adams (2016) found that respondents in the NIS-Teen who were more likely to encounter physicians for reasons aside from vaccination—such as for mandatory wellness checks or due to previous asthma diagnoses—were more likely to get the HPV vaccine. The ability for providers to increase vaccination may reflect a dynamic unique to the physician-patient relationship, as Trogdon et al. (2016) did not identify a significant relationship between HPV vaccination and state policies allowing pharmacists to administer the vaccine to adolescents.

Currently, only 2 states and the District of Columbia require students to receive the HPV vaccine for school attendance.[3] Thompson et al. (2018) found that Rhode Island's school HPV vaccine requirement increased the probability that a teenage boy had initiated the HPV vaccine by 11 percentage points; they did not document a change for teen girls. Likewise, Churchill (2020) found that Washington, DC's HPV vaccine school requirement increased the probability that teen boys (girls) initiated HPV vaccination by 20 (12) percentage points. While few states require

[3] These states are Virginia and Rhode Island. Hawaii will begin requiring HPV vaccination in the fall of 2020.

students to obtain the HPV vaccine, Carpenter and Lawler (2019) showed that middle school Tdap booster requirements increased HPV vaccination by 4-5 percentage points. The authors posited that by inducing appropriately aged teens to visit the doctor to obtain the booster, school Tdap requirements created additional opportunities for HPV vaccination.

2.2.2. Medicaid Expansion and "Welcome Mat" Effects

The 2010 Patient Protection and Affordable Care Act was the most significant health care reform in two generations. Among other provisions, the legislation provides premium subsidies to individuals with household incomes between 100 and 400 percent of the federal poverty level who are ineligible for public insurance, establishes health insurance exchanges, increases the age at which children can no longer remain on their parents' health insurance plans, and provides funding for states to expand Medicaid to individuals with income up to 138 percent of the federal poverty level. In *NFIB v. Sebelius*, the Supreme Court ruled that Medicaid expansion must be voluntary, creating a natural experiment through which to study the effects of gaining access to health insurance.

Most low-income minors were already eligible for public insurance. In 2013, the median income limit for health insurance coverage through a State Children's Health Insurance Program was 242 percent of the federal poverty level. Of the 38 states with separate S-CHIP eligibility limits for children, none was below 160 percent of the federal poverty level. Similarly, the median teenage eligibility limit for Medicaid was 133 percent of the federal poverty level (KFF 2020). The Vaccines for Children Program covers the cost of the HPV vaccine for teens insured through Medicaid, and S-CHIP programs are required to cover ACIP-recommended vaccines (KFF 2018). As such, the direct effect of Medicaid expansion on teen insurance coverage should be limited.

However, Medicaid expansion may have induced eligible but otherwise unenrolled teens onto public health insurance. States were mindful of these “woodwork” or “welcome mat” effects when debating Medicaid expansion (Sommers and Epstein 2011). Additionally, Guendelman et al. (2006) suggested that expanding insurance coverage to family members could improve the chances that children have regular interactions with the health care system.

Early evidence suggested that these welcome mat effects could be large. For instance, Dubay and Kenney (2003) found that the 1997 Massachusetts’ Medicaid expansion resulted in a 15 percentage point increase in the number of children covered by public insurance. However, Sacarny, Baicker, and Finkelstein (2020) provided evidence that welcome mat effects may only shift the timing of enrollment, as opposed to whether the child ever receives public insurance. Analyzing the Oregon Medicaid Experiment, the authors showed that winning the insurance lottery increased the number of previously eligible children enrolled in public insurance. However, this effect faded over time as children in the control group eventually also enrolled in public insurance.

Other studies, though, have pointed to more modest effects. Using data from the Survey of Income and Program Participation, Hamersma, Kim, and Timpe (2019) also found a 2-5 percentage point increase in the probability that a child was covered by public insurance following Medicaid expansion. Similarly, Hudson and Moriya (2017) estimated that over 700,000 low-income children gained health insurance as a result of the ACA Medicaid expansion, translating to a 3-5 percentage point increase in public insurance coverage. Similarly, Sommers et al. (2016) exploited county-level variation in California’s early expansion effort and found that already-eligible children were approximately 3 percentage points more likely to take up public health insurance.

2.3. DATA+METHODOLOGY

In this section, I provide an overview of the NIS-Teen data structure and provide basic descriptive statistics about HPV vaccination. I show that teens in states that eventually expanded Medicaid as part of the Affordable Care Act had comparable HPV vaccination rates to teens in non-expansion states in 2010. By 2018, teens in Medicaid expansion states were nearly 7 percentage points more likely to have initiated the HPV vaccine.

2.3.1. Data

I utilize provider-verified vaccination data from the 2010-2018 National Immunization Survey-Teen. The NIS-Teen is administered by the Centers for Disease Control and Prevention (CDC) and contains individual-level state-representative data on teenagers ages 13-17. These data are collected in two parts. First, the CDC uses phone surveys to collect demographic information on eligible teens from their parents and guardians. The interviewer asks the parent for information on, and permission to contact, the teen's vaccination provider(s). Next, a questionnaire is mailed to each provider to obtain information on the types of vaccinations, number of doses, and age at administration.[4]

In Figure 1, I show the states which have expanded Medicaid (Panel A) and the state-level teenage HPV vaccination rate as of 2018 (Panel B). State HPV vaccination rates varied considerably. While the median rate was nearly 70 percent, coverage ranged from Mississippi's 52 percent to Rhode Island's near universal coverage of 90 percent. Moreover, these differences

[4] I analyze 2010-2018 because this is the largest window during which all individuals in the sample were eligible to receive the HPV vaccine. Unfortunately, the NIS-Teen underwent two changes during my period of interest. Beginning in 2011, the NIS-Teen moved from being a landline-only survey to including cellphone respondents. For 2011 they provide survey weights comparable to the 2008-2010 period, though they only provide the dual survey weights in subsequent years. Additionally, the survey underwent a redesign in 2014. I show that my results are robust to accounting for these changes.

appear correlated with Medicaid expansion. Of the 26 states and DC with the highest vaccination rates, 21 had expanded Medicaid. Meanwhile, the same is true for only 11 of the bottom 25 states.

Similarly, I show in Table 1 that Medicaid expansion states had a higher HPV vaccine initiation rate compared to non-expansion states over the sample period (0.51 vs. 0.45).[5] This difference was not present prior to Medicaid expansion. In 2010, 25 percent of teens in expansion states had received at least one dose of the HPV vaccine (column 3) compared to 23 percent in non-expansion states (column 6). By 2018, this 2 percentage point difference had tripled. Nearly 71 percent of teens in Medicaid expansion states had initiated the HPV vaccine in 2018 (column 4), while only 64 percent of teens had initiated vaccination in non-expansion states (column 7).

2.3.2. Methodology

Using the NIS-Teen data, I exploit geographic and temporal variation in the Affordable Care Act's Medicaid expansion to estimate the following sparse event study specification:

$$VACC_{ist} = \alpha + \sum_{j=-4,\, j\neq-1}^{2} \beta_j I_{st}^{j} + \eta_{Pre} + \eta_{Post} + \theta_s + \tau_t + \varepsilon_{ist} \quad (1)$$

where the dependent variable, VACC, is an indicator for whether the teen had initiated HPV vaccination (Doses ≥ 1). My independent variables of interest, I^j, are indicators for being *j* periods away from Medicaid expansion.[6] The η_{Pre} and η_{Post} indicator variables capture observations occurring more than 4 years prior to Medicaid expansion and more than 2 years post-expansion, so as to ensure that the coefficient is due to the policy and not changes in the sample of states being analyzed at each period. I also include time-invariant state fixed effects, θ_s, location-invariant year

[5] I present summary statistics for the remaining variables in Table A1. In Table A2, I show that the HPV vaccination summary statistics are similar when not utilizing the sample weights. I plot the unweighted statistics in Figure A1.
[6] In order to have direct comparability to my two-way fixed effects specification, I analyze observations from every state. However, I show in Table A1 that my results are robust to dropping states which expanded Medicaid prior to 2014 and analyzing a balanced panel of states. Because my data begins in 2010, I can have at most 4 pre-periods in a balanced panel. Similarly, the final observed policy change in the data occurs in 2016, so I can have at most 2 post-periods.

fixed effects, τ_t, and I cluster standard errors at the state level (Bertrand, Duflo, and Mullainathan 2004).

I use an event study framework to examine whether pre-Medicaid expansion trends in HPV vaccination may bias my estimates in the post-expansion periods. This specification also allows me to test whether the relationship between Medicaid expansion and HPV vaccine initiation varied over time. Informed by my results from equation (1), I also estimate the following two-way fixed effects specification:

$$VACC_{ist} = \alpha + \beta \text{ACA Expansion} + \mathbf{D'}_{ist}\boldsymbol{\delta} + \mathbf{X'}_{st}\boldsymbol{\gamma} + \theta_s + \tau_t + \theta_s * TREND + \varepsilon_{ist} \quad (2)$$

The vector **D'** includes individual-level demographic controls about the teen and the teen's mother which may be correlated with both Medicaid expansion and the decision to initiate HPV vaccination. In particular, I include indicators for the teen's sex (male, with female omitted), age (14, 15, 16, and 17, with 13 omitted), grade level (6-8th, 9-12th, and high school graduate, with "not enrolled" omitted), and race/ethnicity (white, black, and Hispanic, with "other" omitted). I also include indicators for mother's age ($\leq$ 34, and 35-44, with 45+ omitted), mother's education (< high school, high school graduate, and some college, with college+ omitted), and household income (< \$20K, \$20-30K, \$30-40K, and \$40-50K, with \$50K+ omitted).

I control for state-level time-varying characteristics in the vector **X'**, including the state unemployment rate. I also control for whether the state requires middle school students to obtain the Tdap or meningococcal vaccines, policies which have been shown to increase HPV vaccination (Carpenter and Lawler 2019). Additionally, I control for whether the state requires teens to receive the HPV vaccine for school attendance (Thompson et al. 2018; Churchill 2020). In 2013 and 2014, the CDC entered into cooperative agreements with 20 states seeking to improve HPV vaccination using Prevention and Public Health Funding. To account for these policies, I include an indicator for when these awards were active using detailed information on when the funds were awarded and spent obtained from the Department of Health and Human Services. Finally, I augment the model with state-specific linear time trends by interacting each state fixed effect with a variable, TREND, taking on the value of 1 in 2010, 2 in 2011, up through 9 in 2018.

2.4. RESULTS

I first show that the positive relationship between Medicaid expansion and teen HPV vaccination is only present in the post-expansion period. I then show that this relationship is robust to the inclusion of a variety of individual and state-level controls, as well as state-specific linear time trends. In examining heterogeneity, I find that the relationship is driven by poorer teens, those whose mothers lacked college degrees, and non-white teens. Data on provider visits and Google search results suggest that Medicaid expansion improved HPV vaccine coverage by increasing contact with health care providers.

2.4.1. HPV Vaccination

While the descriptive statistics indicate that teenagers in Medicaid expansion states were more likely to have initiated HPV vaccination, I formally test whether this was the case using the sparse event study specification from equation (1). In Figure 2, I show that the probability that a teen had initiated the HPV vaccine was statistically unrelated to Medicaid expansion in the pre-period. Indeed, I show in Table A3 that the pre-expansion coefficients are uniformly negative and not significantly different from zero. In the post-expansion period, I find that Medicaid expansion was positively related to HPV vaccination, and I can reject the null hypothesis that the post-expansion coefficients are jointly equal to zero. Moreover, I can reject the hypothesis that the pre- and post-period coefficients are equal to each other.[7]

I next analyze the relationship using the traditional two-way fixed effects specification from equation (2). After controlling for only state and year fixed effects, I find that Medicaid expansion was associated with a 4 percentage point increase in the probability that a teen had received at least one dose of the HPV vaccine (column 1). The estimate is essentially unchanged after controlling for demographic characteristics (column 2) and state-level covariates (column 3). In the preferred specification including state-specific linear time trends, I continue to find that teenagers in Medicaid expansion states were 3 percentage points more likely to have initiated the HPV vaccine (column 4).

The NIS-Teen underwent a revision in 2014 whereby the survey was shortened to improve response rates. In making these changes, the criteria used to determine if a respondent had "adequate provider data" was modified (NCIRD, NCHS, and NORC 2015). Importantly, this change should not have affected expansion and non-expansion states differently. However, the majority of the ACA Medicaid expansions occurred in 2014. As such, I perform a series of robustness tests in Table 3 to alleviate concerns that the survey change is behind the estimated relationship.

First, I perform the analysis on all respondents with provider-verified information on HPV vaccination, regardless of whether that teen was classified as having adequate provider data. I continue to find a 3 percentage point increase in HPV vaccine take-up (column 1).[8] Next, I modify

[7] In Table A3, I estimate the event study analogue to Table 2 to show that estimates are robust to controlling for demographic characteristics, state-level covariates, and state-specific linear time trends.
[8] In Table A4, I show that Medicaid expansion was unrelated to whether a teen was classified as having adequate provider data.

the sample period to the directly-comparable years 2008-2013 and leverage variation generated from states opting to implement the ACA Medicaid expansion prior to 2014. I find a 5 percentage point increase in HPV vaccine initiation (column 2) demonstrating that the ACA Medicaid expansion-HPV vaccination relationship is not due to the survey modification. In order to account for possible differences between expansion and non-expansion states which may be correlated with HPV vaccination, I next limit my sample to states which ever expanded Medicaid as part of the ACA. Again, I find a 3 percentage point increase in vaccine take-up (column 3).

In 2011, the NIS-Teen moved from being a landline-only survey to including cellphone respondents. This switch led to a change in the survey weights. While the move to including cellphone respondents should not have affected expansion and non-expansion states differently, I repeat the analysis without employing the survey weights. I find a 2 percentage point increase in HPV vaccine take-up (column 4) indicating that the relationship was not attributable to this change. In the final two columns, I explore the robustness of the estimate to other policy changes associated with HPV vaccination. Regardless of whether I exclude states requiring students to receive the HPV vaccine for school attendance (column 5) or states receiving CDC funding for HPV vaccination (column 6), I continue to find a 3 percentage point increase in HPV vaccination.

Given recent developments regarding the mechanics of difference-in-differences estimation when there is variation in treatment timing (Goodman-Bacon 2018), I also explore the extent to which the estimated relationship is due to comparing treated states to untreated states, as opposed to comparing early-treatment states to later-treatment states. First, I show in Table A5 that the difference-in-differences point estimate is largely due to comparing treated states to states which never expanded Medicaid as part of the ACA, comparable to difference-in-differences when there is not variation in treatment timing. In Table A6, I then restrict my sample to observations from states which either expanded Medicaid in 2014 as part of the ACA or did not expand Medicaid between 2010 and 2018 (columns 1 and 2). Alternatively, I use the full sample but define a state as treated only if it expanded Medicaid in 2014 (columns 3 and 4). In both cases, I continue to find that Medicaid expansion was associated with a 3 percentage point increase in vaccine take-up.

In Table 4, I show that the Medicaid expansion-HPV vaccination relationship was driven by teens whose parents were more likely to have been affected by Medicaid expansion. I first show that the relationship is driven by teens from poorer households. While teens living within 200 percent of the federal poverty level were almost 5 percentage points more likely to initiate HPV vaccination after Medicaid expansion (column 1), the estimate is less than half the size and statistically insignificant for those above 200 percent of the federal poverty level (column 2). Similarly, teens whose mothers lacked college degrees were nearly 5 percentage points more likely to have received the HPV vaccine (column 3), while the point estimate for those with college educated mothers is small and statistically insignificant (column 4).[9]

I also show that while non-white teens were 6 percentage points more likely to have initiated the HPV vaccine (column 5), there was no detectable increase for white teens (column 6). There are a number of explanations for this result. For one, the incidence of HPV-related cancers is higher in non-white adults. While the incidence of cervical cancer is 9.5 and 9.7 per 100,000 for black and Hispanic women, the incidence is 7.0 per 100,000 for white women (Spencer, Calo, and Brewer 2017). If they are aware of this disparity, the parents of non-white teens may be more

[9] In Table A7, I show the estimates stratified by sex. While the point estimate is larger for teen boys than teen girls (column 1 vs. column 2), the estimates are not statistically different from each other when using a triple-difference specification whereby I interact the male indicator with all of the covariates (column 3). Given the lack of evidence on ways to improve boys' take-up of the HPV vaccine, the similarity of the estimates is perhaps itself surprising and important.

inclined to vaccinate when presented with the opportunity. Additionally, prior work has found that a strong physician recommendation is the strongest predictor of HPV vaccination (Moghtaderi and Adams 2016), and there is evidence that physicians are more dominant and direct with non-white patients (Cooper and Roter 2003; Johnson et al. 2004). Accordingly, in a review of the HPV vaccine literature, Spencer, Calo, and Brewer (2017) found that non-white patients were *more* likely to be vaccinated in provider-verified data but *less* likely to self-report vaccination. The authors posited that a lack of informed discussion between non-white patients and their vaccine providers may be behind this discrepancy. This pattern is consistent with Carpenter and Lawler (2019) who found that school Tdap mandates were associated with larger increases in HPV vaccine take-up for non-white teens (Table 4 column 3 rows 4-7).

At this point, it is useful to compare these estimates to the broader literature on HPV vaccination. Perhaps most comparable to this study, Lipton and Decker (2015) found that the combined effect of the ACA's dependent coverage provision and the preventative care provisions was an increased probability that women ages 18-25 had initiated the HPV vaccine by 7.7 percentage points (Page 761, Exhibit 3). Their back-of-the-envelope calculations suggested that 0.9-2.7 percentage points of this increase were due to changes in insurance coverage, while the rest was due to improvements in coverage generosity. Similarly, Carpenter and Lawler (2019) found that middle school Tdap vaccination requirements increased HPV vaccine initiation by 4-5 percentage points (Page 114, Table 3). At the same time, other authors have found 10-20 percentage point increases for HPV vaccine school requirements (Thompson et al. 2018; Churchill 2020).

In addition to the provider-verified immunization data, the NIS-Teen also contains parental-reported information regarding the child's vaccination history. Thus far, I have restricted my attention to the provider-verified data because it is likely to be more accurate than the parental-reported information. Indeed, over the full sample period only 42 percent of parents reported that their child has been vaccinated, while the provider-verified data indicates 46 percent of teens were vaccinated. In 2018, 64 percent of parents reported HPV vaccination compared to 69 percent of vaccine providers. Nevertheless, I show in Table 5 that Medicaid expansion was associated with a 2 percentage point increase in HPV vaccination (column 1). In Table A8, I show that the increase was concentrated among poorer teens, teens whose mothers lacked college degrees, and non-white teens.[10]

Turning again to the provider-verified immunization data, I find that Medicaid expansion was associated with a 2 percentage point increase in the probability that a teen had received all three shots of the HPV vaccine (column 2). Because I documented a 3 percentage point increase in vaccine initiation, this estimate suggests that most teens went on to receive the full vaccine series.

I next test whether Medicaid expansion was associated with changes in two other vaccines administered around the same age as the HPV vaccine. I do not find evidence of a statistically significant relationship between Medicaid expansion and the probability that a teen received the Tdap vaccine (column 3).[11] However, this relationship may vary if students are required to obtain

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[10] For the 2010-2013 data, the interviewer first asked the parent if they had a shotcard for the teen available. If one was available, the parent-reported HPV vaccination information was based off of that card. If they did not have a shotcard available, the HPV vaccine question was based entirely on recall. In 2014, the NIS-Teen only began asking parents to recall if the teen had been vaccinated against HPV. In Table A8, I drop observations drawn from shotcards during the 2010-2013 period. I continue to find an approximately 2 percentage point increase in HPV vaccine take-up, though the estimate is less precise.

[11] It is worth pointing out that this small and statistically insignificant point estimate provides further evidence that the estimated relationship between Medicaid expansion and HPV vaccination is not attributable to the 2014 survey redesign. If the survey change altered the responses in such a way to systematically increase provider-verified reporting of vaccination only in Medicaid expansion states, the coefficients relating the ACA Medicaid expansions to the Tdap and meningococcal vaccines would be similar to coefficients in Table 2. While Table 3 provides evidence

a Tdap booster for school attendance, because states with these policies have higher vaccination rates (Carpenter and Lawler 2019) and, consequently, smaller margins for adjustment. I show that while the point estimate for teens residing in states with Tdap school requirements is negative and statistically insignificant (column 4), Medicaid expansion was associated with a 3.3 percentage point increase in Tdap vaccination for teens in states without Tdap school requirements (column 5). Similarly, I find suggestive evidence that Medicaid expansion was associated with an increase in meningococcal vaccination (column 6). Consistent with the estimates for the Tdap booster, the relationship is driven by a 1.7 percentage point increase in vaccination for teens residing in states that did not require students to obtain the meningococcal vaccine (column 8).

2.4.2. Potential Mechanisms: Health Insurance Coverage

I next explore how Medicaid expansion may have affected HPV vaccine take-up. In Table 6, I show that teens were approximately 1 percentage point more likely to have health insurance in the post-expansion period (column 1). As with the HPV vaccination estimates, the increase is larger for poorer children. I find that teens living below 200 percent of the federal poverty level were approximately 2 percentage points more likely to have health insurance (column 2) after Medicaid expansion, while the point estimate is half the size for teens in higher-income households (column 3). Again, mirroring the HPV vaccination estimates, I find that the increase in insurance coverage was driven entirely by teens whose mothers lacked college degrees (column 4 vs. column 5). The point estimates indicate a 2 percentage point increase in insurance coverage for non-white teens (column 6) and a 1 percentage point increase for white teens (column 7).

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that the relationship is not due to the redesign, Table 5 indicates that the redesign would have had to differentially affect provider-verified vaccine information in Medicaid expansion states only for HPV vaccination.

In Table A9, I show that the increases in health insurance coverage were entirely attributable to changes in the probability that teens had public health insurance (Panel I). I do not find any evidence that Medicaid expansion significantly crowded out other forms of health insurance (Panel II). Beginning in 2016, health insurance information is only available for teens with adequate provider data, while in prior years it is available for all teens.[12] In order to leverage as large of a sample as possible, I use all observations with data on health insurance coverage. However, I show in Table A10 that the estimated increase in insurance coverage is actually larger if I restrict my sample to the 2010-2015 period prior to the change in availability.

The estimated relationship between the ACA Medicaid expansion and HPV vaccination is larger than the relationship between expansion and health insurance coverage (3 percentage points vs. 1-2 percentage points). There are several possibilities to explain this pattern. One explanation is simply that the relationship between Medicaid expansion and insurance coverage is more tightly estimated. For health insurance coverage, the 95 percent confidence interval indicates that Medicaid expansion was associated with a 0.3-2.3 percentage point increase in the probability that a teen had health insurance and a 0.3-6.3 percentage point increase in the probability of HPV vaccine initiation. As such, there is considerable overlap in the estimates.

I also estimate smaller increases in insurance coverage than other papers examining "welcome mat" effects. Studying expansions in parental Medicaid eligibility between 1996 and 2007, Hamersma, Kim, and Timpe (2018) found a 3 (5) percentage point increase in the probability

[12] Prior to 2016, the NIS-Teen provided a series of variables regarding the teen's health insurance coverage. Specifically, it asked whether the teen was covered by (i) employer-sponsored insurance, (i) Medicaid, (iii) S-CHIP, (iv) Medicaid or S-CHIP, (v) Indian Health Service, military health care, Tricare, CHAMPUS, or CHAMP-VA, or (vi) any other health insurance. All of these variables are indicators, and the public insurance questions varied by the teen's state of residence. Since 2016, the NIS-Teen has constructed a single insurance status variable taking on values 1-4 which harmonizes the underlying data. I define a teen as on public health insurance of s/he is covered by Medicaid or S-CHIP from 2010-2015 and if s/he is covered by Medicaid from 2016-2018. I show in Table A10 that my estimates are robust to only using the 2010-2015 period.

that a child had any (public) health insurance (Tables 3 columns 1 and 2). Similarly, Aizer and Grogger (2003) found that expanded parental eligibility for Medicaid increased the probability that children had health insurance by 4 percentage points. Leveraging variation from the fact that some California counties opted to expand Medicaid in 2011 under the ACA, Sommers et al. (2016) found that children residing in these counties were 3.2 percentage points more likely to have public health insurance.

Yet even a 3-5 percentage point increase in insurance coverage would likely be too small to completely explain the increased vaccine take-up. An alternative explanation is that Medicaid expansion made parents more likely to interact with the health care system, which gave them more chances to learn about the HPV vaccine. When examining state Medicaid eligibility changes from 1996-2002, Busch and Duchovny (2005) found that increased eligibility resulted in approximately 30 percent of women being screened for breast cancer and cervical cancer that otherwise would not have been screened. Similarly, Simon, Soni, and Cawley (2017) found evidence that the ACA Medicaid expansion increased the probability that some women received cervical cancer screenings. By increasing the probability that women received cervical cancer screenings, the Medicaid expansion may have provided mothers with a new opportunity to learn about HPV vaccination.

In order to gauge the plausibility of these spillovers, it is important to consider how the ACA Medicaid expansion affected the insurance coverage of these teens' parents. Frean, Gruber, and Sommers (2017) found that new Medicaid eligibility reduced the likelihood that an adult was uninsured by 8.9-13.7 percentage points with larger effects (10.7-19.7 percentage points) for those who gained coverage through the early ACA expansions. The authors also found a 2.6-4.6 percentage point increase in the probability that already-eligible adults became insured. The authors found no evidence of crowd-out. These large coverage gains suggest a sizable increase in the probability that these teens' parents interacted with the health care system.

Another possibility is that Medicaid expansion affected teens' utilization of health care services. There are a number of papers documenting a positive association between parents' health care utilization and children's use of services (Hanson 1998; Goedken, Urmie, and Polgreen 2014), as well as a positive association between parents' insurance status and children's health care utilization (Davidoff et al. 2003; Dubay and Kenney 2003; Gifford, Weech-Maldonado, and Short 2005). However, I am unaware of any published paper employing a research design intended to uncover a plausibly-causal relationship. As such, a further contribution of my current study is to provide evidence that Medicaid expansion was associated with changes in children's health behaviors which cannot be fully explained by increased insurance coverage.

2.4.3. Potential Mechanisms: Provider Contact

In the prior tables, I have shown that Medicaid expansion was positively associated with the probability that a teen had health insurance, as well as the probability that a teen had received the HPV vaccine. In Table 7, I explore the ways in which Medicaid coverage may have increased vaccination. First, I find that Medicaid expansion was associated with a 2 percentage point increase in the probability that a teen had a check-up within the last year (column 1). By increasing teens' interactions with health care providers, Medicaid expansion may have created more opportunities for vaccination. In support of this possibility, I find that parents were 1.6 percentage points more likely to report that their teen had been recommended the HPV vaccine by a health care provider (column 2), though the estimate is outside of conventional levels of statistical significance (p=0.14).

The NIS-Teen also asks parents if their child will receive the HPV vaccine within the next 12 months, as well as their specific reasons for not vaccinating.[13] I find that parents were 1.8 percentage points less likely to give "lack of knowledge" as the reason for not vaccinating their child (column 5). Coupled with the prior estimates on having a recent check-up and receiving an HPV vaccine recommendation, this estimate suggests that Medicaid expansion induced contact with health care providers. This contact in turn led to improved knowledge about the HPV vaccine and, consequently, an increase in vaccination. This is consistent with prior work showing that physician recommendation is one of the strongest predictors of HPV vaccination (Gargano et al. 2013; Moghtaderi and Adams 2016; Carpenter and Lawler 2019). Using the event study specification from equation (1), I show in Figure 3 that the probability that parents listed a "lack of knowledge" as a reason for not vaccinating was not statistically different from zero in the pre-expansion period. After Medicaid expansion was implemented, the probability fell.

Perhaps surprisingly, I find that parents were more likely to list the cost of the vaccine as a reason for not vaccinating their child (column 7). It should be noted, though, that by increasing the share of teens vaccinated for HPV, Medicaid expansion would change the composition of those who opt not to vaccinate. This estimate suggests that after Medicaid expansion, those opting not to vaccinate are those for whom price remains a barrier. Additionally, respondents may be unaware whether the vaccine is covered by the teen's health insurance. However, using the event study specification, I show in Table A11 that I cannot reject the null hypothesis that the pre-expansion coefficients were different from zero, while the post-expansion coefficients are not statistically

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[13] The NIS-Teen lists over 30 reasons for not vaccinating, including the child already being up to date on the vaccine, the child being fearful of the vaccine, and religious objections. In order to minimize testing, I focus on the top four given reasons (Not Needed, No Recommendation, Lack of Knowledge, and Safety Concerns), which are the only answers with averages over 10 percent. I also examine Cost as a reason for not vaccinating—though it is the 7th most frequently stated reason—given that Medicaid expansion may have reduced the cost of the vaccine through increased health insurance coverage.

different from zero. Given how infrequently people listed cost as the reason for not vaccinating—as well as the event study estimates—it is important to use caution in interpreting the point estimate.

In Table 8, I examine the relationship between Medicaid expansion and Google searches for various terms using Google Trends data. For every month during the sample period, Google takes a random sample of all searches performed within each state. Google then constructs an index by dividing the number of searches for a specific term—such as "Medicaid"—by the total number of searches. For every state, the month when the relative search rate is maximized is assigned 100. The index for the rest of the period is determined by taking the ratio of the relative search rate to the maximum relative rate.

Google Trends data have been used in economics to explore topics including racism (Stephens-Davidowitz 2013), teen fertility (Kearney and Levine 2015), and vaccination decisions (Oster 2018; Carpenter and Lawler 2019). While the data cannot say anything about the number of people searching for a particular term, it does provide insight into the relative intensity of search behaviors. As expected, I find an increase in searches for the term "Medicaid" after Medicaid expansion (column 1). I also document an increase in searches for the term "pediatrician" (column 2). Together with the estimated increase in the probability of having a recent check-up in Table 6, this estimate supports the notion that children were more engaged with the health care system after Medicaid expansion.

While not statistically significant, the point estimate suggests that Medicaid expansion states experienced an increase in Google searches for "HPV" in the post-expansion period (column 3). Similarly, I detect statistically significant increases in searches for the phrases "HPV Cancer" (column 4) and "Gardasil" (column 5).[14] Overall, Table 8 suggests that individuals in Medicaid expansion states were more likely to seek out information about both pediatricians and the HPV vaccine in the post-expansion period.

2.5. DISCUSSION

Almost 40,000 people annually are diagnosed with an HPV-related cancer (Van Dyne et al. 2018). As such, public health officials are interested in reducing the number of future infections, and one straightforward strategy is to increase take-up of the HPV vaccine. Though there have been meaningful coverage gains over the last decade, only 70 percent of teens had initiated vaccination as of 2018. While two states and the District of Columbia mandate HPV vaccination for entry into middle school, and several other states are debating similar legislation, these requirements have been met by fierce opposition.

In this paper, I use the National Immunization Survey-Teen to show that Medicaid expansion was associated with a 3 percentage point increase in the probability that a teenager initiated HPV vaccination. The increase was driven by those whose parents were most likely to have gained Medicaid—poorer teenagers, teenagers whose mothers lacked a college degree, and non-white teenagers. In this way, this paper draws on and contributes to the "welcome mat" literature examining how eligible but unenrolled children are more likely to gain public insurance after their parents become eligible (Dubay and Kenney 2003; Sommers et al. 2016; Hudson and Moriya 2017; Hamersma, Kim, and Timpe 2019; Sacarny, Baicker, and Finkelstein 2020).

A 3 percentage point increase in HPV vaccination estimate is large, especially given that these teens were not directly affected by the ACA Medicaid expansion. Instead, I posit that the

[14] A second trade name of the HPV vaccine, "Cervarix," was available from 2009-2016. However, it did not receive sufficient search traffic to be detectable in Google Trends data.

change is due to increased take-up of public insurance among already-eligible teens and that parental-coverage gains improved teens' connectedness with the health care system. In support of the first possibility, I find that Medicaid expansion was associated with a 1-2 percentage point increase in the probability that teens had health insurance. However, this cannot fully explain the change in vaccination, suggesting a positive relationship between parental insurance and teens' health care utilization. Supporting this possibility, I find evidence that Medicaid expansion increased the probability that a teenager had a recent check-up. This provider-contact pathway is supported by Google Trends data showing that people in expansion states were more likely to search for the terms "pediatrician," "Gardasil," and "HPV Cancer" after Medicaid expansion. These results add to existing evidence that contact with health care providers remains an effective method for improving HPV vaccination (Gilkey et al. 2016; Moghtaderi and Adams 2016; Carpenter and Lawler 2019).

Of course, this study has several limitations. For one, my sample covers a period of expansive growth in HPV vaccination. As such, the physician-vaccination relationship may be less salient now that a larger share of teens has initiated the vaccine. Additionally, the NIS-Teen underwent a survey redesign during my sample period. While I undertake a number of robustness checks to assuage concerns that this change drives my results—such as showing that the relationship is robust to not utilizing the sample weights—it is still possible that my estimates are picking up a survey change which was correlated with both teenagers' HPV vaccination rates and Medicaid expansion. Finally, I am unable to identify with certainty the pathway through which Medicaid expansion is related to greater initiation of the HPV vaccine. In particular, I am unable to directly link parental insurance coverage with changes in utilization of services. With a number of states exploring policies directly intended to increase vaccine take-up, analyzing the efficacy of these policies will be an important area for future research.

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Table 1: Teenagers in Medicaid expansion states were more likely to have received at least one dose of the HPV vaccine

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Full	Expansion States			Non-Expansion States		
	Sample	All Years	2010	2018	All Years	2010	2018
Mean	0.487	0.508	0.253	0.706	0.452	0.227	0.638
Standard Deviation	(0.500)	(0.500)	(0.435)	(0.456)	(0.498)	(0.416)	(0.481)
Observations	172,891	104,254	10,859	10,375	68,637	7,100	7,331

Source: National Immunization Survey—Teen 2010-2018
Note: HPV initiation is an indicator for whether provider-verified immunization records indicate that the child had received at least one dose of the HPV vaccine. All summary statistics utilize the sample weights.

Table 2: Medicaid expansion was associated with an increase in HPV vaccination

	(1)	(2)	(3)	(4)
Medicaid Expansion	0.041***	0.039***	0.035***	0.033**
	(0.013)	(0.013)	(0.011)	(0.015)
State and Year FE?	Y	Y	Y	Y
Demographic Controls?	N	Y	Y	Y
State-Level Covariates?	N	N	Y	Y
State-Specific LTT?	N	N	N	Y
Mean	0.487	0.487	0.487	0.487
Observations	172,891	172,891	172,891	172,891

Note: The dependent variable is an indicator for whether the child's immunization provider reports that the child had received at least one dose of the HPV vaccine. The independent variable of interest is an indicator for whether the state expanded Medicaid as part of the Affordable Care Act. Column (1) includes time-invariant state fixed effects and location-invariant year fixed effects. Column (2) controls for demographic characteristics, including indicators for the child's sex (male with female omitted), age (14, 15, 16, 17, with 13 omitted), the child's race/ethnicity (white, black, Hispanic, with "other" omitted), mother's age (less than 34, 35-44, with 45+ omitted), mother's education level (less than high school, high school graduate, some college, with college+ omitted), and household income (less than $20K, $20-30K, $30-40K, $40-50K, with $50K+ omitted). Column (3) adds state-level covariates, including the unemployment rate, an indicator for the presence of a Tdap booster requirement, an indicator for the presence of a meningococcal vaccination requirement, whether the state had received funding from the CDC to promote HPV vaccination, and whether the state required students to receive the HPV vaccine for school attendance. Finally, column (4) augments the model with state-specific linear time trends. The estimates utilize the sample weights. Robust standard errors, shown in parentheses, are clustered at the state level.

*** p<0.01, ** p<0.05, * p<0.10

Table 3: The relationship between Medicaid expansion and HPV vaccination is robust to alternative sample restrictions

	(1) Including Providers with Inadequate Data	(2) Sample Years 2008-2013	(3) Only Expansion States	(4) Excluding Sample Weights	(5) Excluding States Ever Enacting HPV Vaccine School Requirements	(6) Excluding States Receiving CDC Funding for HPV Vaccination
Medicaid Expansion	0.030**	0.051***	0.030*	0.018**	0.034**	0.029**
	(0.014)	(0.016)	(0.017)	(0.007)	(0.015)	(0.014)
Mean	0.470	0.297	0.508	0.484	0.486	0.487
Observations	176,536	111,154	104,254	172,891	163,896	172,891

Source: National Immunization Survey 2008-2018

Note: The dependent variable is an indicator for whether the child's immunization provider reports that the child had received at least one dose of the HPV vaccine. The independent variable of interest is an indicator for whether the state expanded Medicaid as part of the Affordable Care Act. All columns include the full set of controls from Table 2 column (4). Column (1) includes all observations with HPV vaccine information, regardless of whether the teen is marked as having inadequate provider data. Column (2) restricts attention to the 2008-2013 period, prior to the survey redesign. Column (3) only examines states which ever expanded Medicaid as part of the Affordable Care Act. Column (4) performs the analysis without sample weights. Column (5) excludes states which ever implemented an HPV vaccine school requirement. Column (6) excludes states which received Prevention and Public Health Funds for HPV vaccination. Except for column (4), the estimates utilize the sample weights. Robust standard errors, shown in parentheses, are clustered at the state level.

*** p<0.01, ** p<0.05, * p<0.10

Table 4: The increase in HPV vaccination was larger for poorer teens, those whose mothers lacked college degrees, and non-white teens

	(1) ≤ 200% FPL	(2) > 200% FPL	(3) Mother lacked BA	(4) Mother had BA	(5) Non- White	(6) White
Medicaid Expansion	0.047***	0.020	0.047**	0.009	0.057**	0.005
	(0.017)	(0.016)	(0.018)	(0.018)	(0.023)	(0.011)
Mean	0.527	0.455	0.492	0.478	0.547	0.437
Observations	60,252	112,639	94,546	78,345	61,310	111,581

Source: National Immunization Survey—Teen 2010-2018
Note: The dependent variable is an indicator for whether the child's immunization provider reports that the child had received at least one dose of the HPV vaccine. The independent variable of interest is an indicator for whether the state expanded Medicaid as part of the Affordable Care Act. Columns (1) and (2) stratify the sample by poverty status. Similarly, columns (3) and (4) stratify the sample by mother's education, and columns (5) and (6) by race/ethnicity. Each column includes the full set of controls from Table 2 column (4), and the estimates utilize the sample weights. Robust standard errors, shown in parentheses, are clustered at the state level.
*** p<0.01, ** p<0.05, * p<0.10

Table 5: Medicaid expansion was associated with increased HPV vaccine completion

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Parental Reported HPV Vaccine Initiation	Provider Verified						
		Complete HPV Vaccination	Tdap Vaccine			Meningococcal Vaccine		
			Overall	School Requirement	No School Requirement	Overall	School Requirement	No School Requirement
Medicaid Expansion	0.023***	0.021**	0.008	-0.008	0.033*	0.013*	-0.016	0.017**
	(0.008)	(0.009)	(0.011)	(0.012)	(0.017)	(0.008)	(0.015)	(0.008)
Mean	0.425	0.284	0.893	0.903	0.803	0.788	0.874	0.723
Observations	286,759	172,891	172,891	149,189	23,702	172,891	79,036	93,855

Source: National Immunization Survey—Teen 2010-2018

Note: The dependent variable in column (1) is an indicator for whether the parent reports that the child had received at least one dose of the HPV vaccine obtained either from recall or a shotcard. The dependent variable in column (2) is an indicator for whether the provider-verified immunization records indicate that the child has received 3 doses of the HPV vaccine. The dependent variable in columns (3)-(5) is an indicator for whether the child received the Tdap booster. Column (3) considers the full sample, column (4) restricts attention to teens residing in states with Tdap booster requirements, and column (5) considers teens residing in states without Tdap booster requirements. The dependent variable in columns (6)-(8) is an indicator for the meningococcal vaccine. Column (6) considers the full sample, column (6) restricts attention to teens in states with meningococcal vaccine school requirements, and column (8) considers teens in states without the requirement. Each column includes the full set of controls from Table 2 column (4), and the estimates utilize the sample weights. Robust standard errors, shown in parentheses, are clustered at the state level.

*** p<0.01, ** p<0.05, * p<0.10

Table 6: Medicaid expansion was associated with greater health insurance coverage for poorer individuals and teens whose mothers lacked college degrees

	(1) Full Sample	(2) ≤ 200% FPL	(3) > 200% FPL	(4) Mother lacked BA	(5) Mother had BA	(6) Non-White	(7) White
Medicaid Expansion	0.013**	0.018**	0.009**	0.016**	0.007	0.019**	0.008**
	(0.005)	(0.008)	(0.004)	(0.006)	(0.005)	(0.008)	(0.004)
Mean	0.937	0.896	0.970	0.914	0.976	0.907	0.961
Observations	198,169	70,006	128,163	110,044	88,125	71,808	126,361

Source: National Immunization Survey—Teen 2010-2018
Note: The dependent variable is an indicator for whether the child was covered by health insurance. The independent variable of interest is an indicator for whether the state expanded Medicaid as part of the Affordable Care Act. Column (1) examines the full sample, while columns (2) and (3) stratify the sample by poverty status. Similarly, columns (4) and (5) stratify the sample by mother's education, and columns (6) and (7) by race/ethnicity. Each column includes the full set of controls from Table 2 column (4), and the estimates utilize the sample weights. Robust standard errors, shown in parentheses, are clustered at the state level.
*** p<0.01, ** p<0.05, * p<0.10

Table 7: Medicaid expansion was associated with an increase in provider contact and improved knowledge about the HPV vaccine

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
			Reason for Not Vaccinating				
	Had a Recent Check-Up	Has Been Recommended the HPV Vaccine	Not Needed	No Recommendation	Lack Knowledge	Safety Concerns	Cost
Medicaid Expansion	0.022**	0.016	-0.009	0.009	-0.018***	0.001	0.013***
	(0.010)	(0.010)	(0.016)	(0.009)	(0.007)	(0.007)	(0.005)
Mean	0.462	0.565	0.206	0.179	0.136	0.118	0.031
Observations	304,235	285,628	126,395	126,395	126,395	126,395	126,395

Source: National Immunization Survey—Teen 2010-2018
Note: The dependent variable in column (1) is an indicator for whether the parent reports that the child had a check-up within the last year and in column (2) an indicator that the child had been recommended the HPV vaccine. In columns (3)-(7) the dependent variable is the reason given for not vaccinating the child, including that the vaccine is not needed; the child has not been recommended the vaccine; a lack of knowledge; safety concerns; and the cost of the vaccine. The independent variable of interest is an indicator for whether the state expanded Medicaid as part of the Affordable Care Act. Each column includes the full set of controls from Table 2 column (4), and the estimates utilize the sample weights. Robust standard errors, shown in parentheses, are clustered at the state level.
*** p<0.01, ** p<0.05, * p<0.10

Table 8: Medicaid expansion was associated with greater Google searches of terms related to obtaining the HPV vaccine

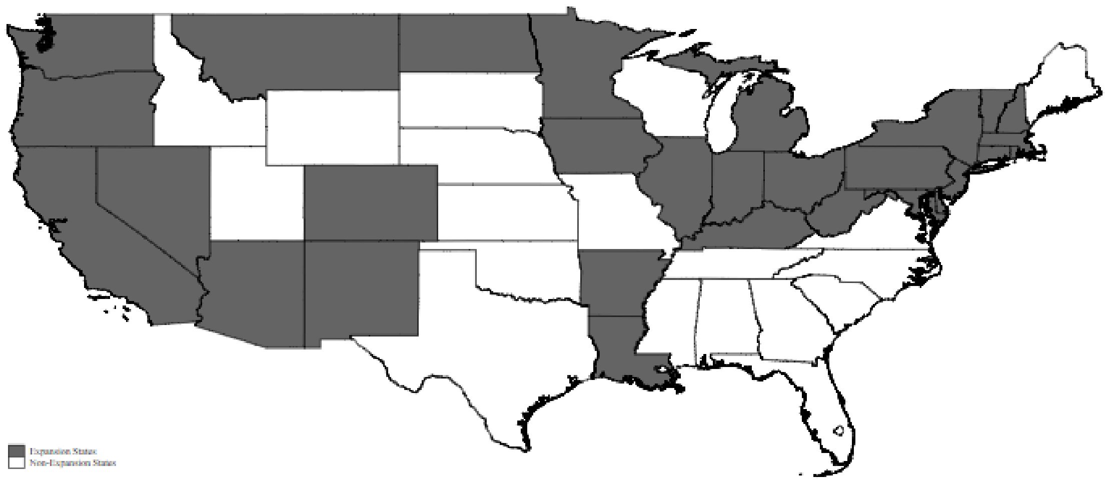
	(1) Medicaid	(2) Pediatrician	(3) HPV	(4) HPV Cancer	(5) Gardasil
Medicaid Expansion	8.206***	3.251**	1.890	2.506*	2.540*
	(2.025)	(1.569)	(1.278)	(1.382)	(1.356)
Mean	66.327	52.655	48.000	28.685	33.688
Observations	5,508	5,508	5,508	5,508	5,508

Source: Google Trends Data, 2010-2018

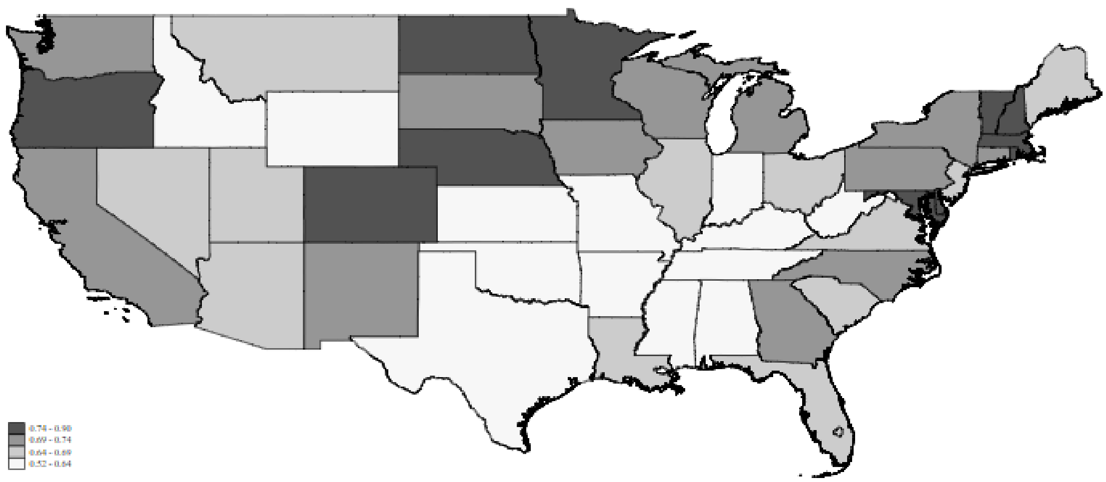
Notes: The dependent variable is a measure of the popularity of a given search term. For every state, the month of peak search volume is normalized to 100. The independent variable of interest is an indicator for the month the state expanded Medicaid as part of the Affordable Care Act. Each column also controls for time-invariant state fixed effects, location-invariant month-year fixed effects, and state-specific linear time trends. Column (1) examines searches for “Medicaid,” column (2) “Pediatrician,” column (3) “HPV,” column (4) “HPV Cancer,” and column (5) “Gardasil.” Robust standard errors, shown in parentheses, are clustered at the state level.

*** p<0.01, ** p<0.05, * p<0.10

Figure 1: Medicaid expansion and teen HPV vaccination rates as of 2018



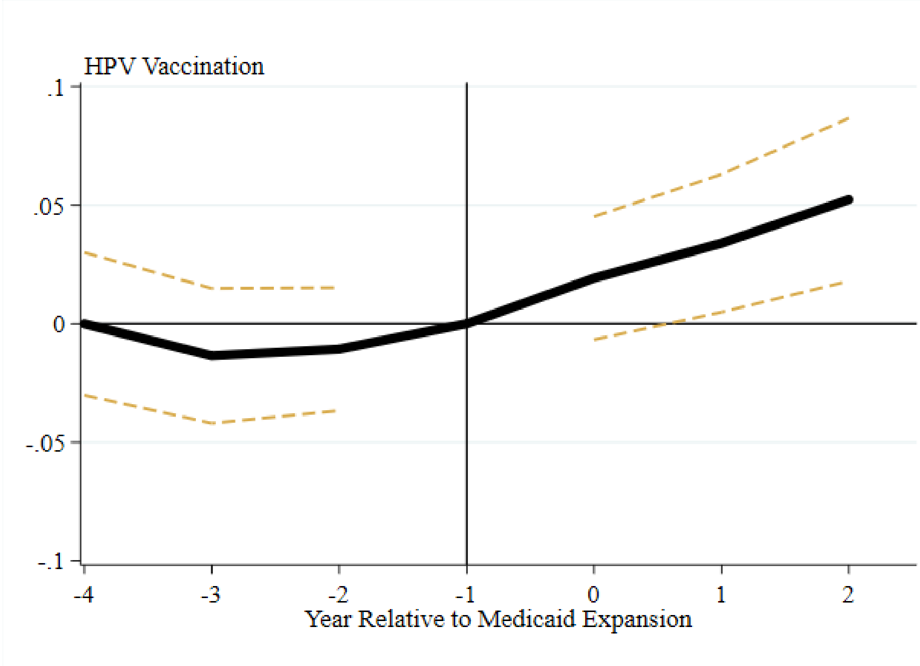
(A)



(B)

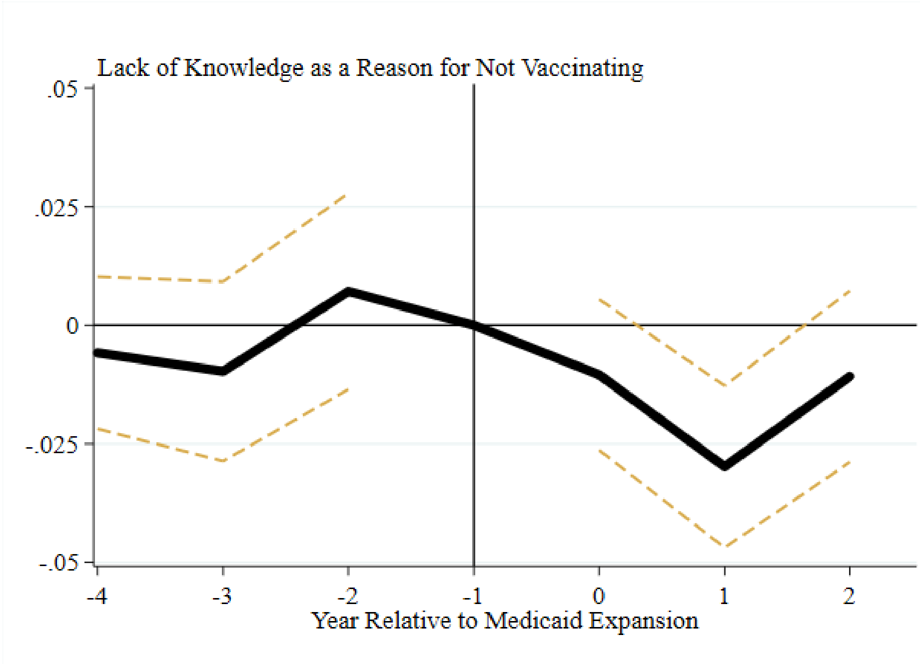
Source: National Immunization Survey 2018; Kaiser Family Foundation 2020.
Note: Panel (A) depicts the states (shaded darker) which expanded Medicaid as of 2018. Panel (B) depicts state HPV vaccination rates for teens in 2018.

Figure 2: Medicaid expansion was unrelated to HPV vaccination in the pre-period and positively related in the post-expansion period



Source: National Immunization Survey- Teen 2008-2018
Note: The dependent variable is an indicator for having received at least one dose of the HPV vaccine. The independent variables are indicator variables for being *j* periods away from Medicaid expansion. The regression controls for time-invariant state fixed effects and location-invariant year fixed effects. The estimation utilizes the survey weights, and standard errors are clustered at the state level. Exact coefficients and tests of joint significance—as well as alternative specifications with additional controls—are reported in Table A3. The pre-expansion coefficients are not jointly different from zero (p=0.665), while the post-expansion coefficients are statistically different from zero (p=0.016).

Figure 3: Medicaid expansion was unrelated to whether parents listed "lack of knowledge" as the primary reason for not vaccinating the teen against HPV in the pre-period and negatively related in the post-expansion period



Source: National Immunization Survey- Teen 2008-2018
Note: The dependent variable is an indicator for listing a lack of knowledge as the primary reason for not vaccinating the teen against HPV during the subsequent 12 months. The independent variables are indicator variables for being *j* periods away from Medicaid expansion. The regression controls for time-invariant state fixed effects and location-invariant year fixed effects. The estimation utilizes the survey weights, and standard errors are clustered at the state level. Exact coefficients and tests of joint significance—as well as alternative specifications with additional controls—are reported in Table A9. The pre-expansion coefficients are not jointly different from zero (p=0.514), while the post-expansion coefficients are statistically different from zero (p=0.006).

2.7. APPENDIX

Table A1: Summary statistics of additional variables

	(1) Overall	(2) Expansion States	(3) Non-Expansion States
Male	0.511	0.510	0.512
	(0.500)	(0.500)	(0.500)
Age Indicators			
14	0.198	0198	0.199
	(0.399)	(0.698)	(0.399)
15	0.207	0.207	0.208
	(0.406)	(0.405)	(0.406)
16	0.206	0.204	0.207
	(0.404)	(0.403)	(0.405)
17	0.188	0.192	0.186
	(0.391)	(0.394)	(0.389)
Grade-Level Indicators			
6-8th	0.274	0.259	0.283
	(0.446)	(0.438)	(0.451)
9-12th	0.713	0.728	0.703
	(0.452)	(0.445)	(0.457)
High School Graduate	0.009	0.009	0.009
	(0.096)	(0.096)	(0.097)
Race/Ethnicity Indicators			
White	0.551	0.524	0.568
	(0.497)	(0.499)	(0.495)
Black	0.141	0.105	0.163
	(0.348)	(0.307)	(0.370)
Hispanic	0.216	0.259	0.189
	(0.411)	(0.438)	(0.391)
Mother's Age Indicators			
≤ 34	0.093	0.079	0.102
	(0.291)	(0.269)	(0.303)
35-44	0.444	0.415	0.462
	(0.497)	(0.493)	(0.499)
Mother's Education Indicators			
< High School	0.127	0.137	0.121
	(0.333)	(0.343)	(0.326)
High School Graduate	0.235	0.220	0.245
	(0.424)	(0.414)	(0.430)

Some College	0.258	0.242	0.268
	(0.486)	(0.428)	(0.443)
Household Income Indicators			
< $20K	0.190	0.181	0.196
	(0.392)	(0.385)	(0.397)
$20-30K	0.107	0.102	0.111
	(0.310)	(0.303)	(0.314)
$30-40K	0.085	0.080	0.088
	(0.279)	(0.272)	(0.283)
$40-50K	0.074	0.067	0.078
	(0.261)	(0.250)	(0.269)
Time-Varying State Controls			
Unemployment Rate	6.839	6.171	7.264
	(2.363)	(2.185)	(2.373)
Tdap Mandate	0.899	0.970	0.854
	(0.301)	(0.172)	(0.353)
Meningococcal Mandate	0.427	0.511	0.374
	(0.495)	(0.500)	(0.484)

Source: National Immunization Survey—Teen 2010-2018

Table A2: Summary statistics for HPV vaccine initiation that do not utilize the sample weights

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Full	Expansion States			Non-Expansion States		
	Sample	All Years	2010	2018	All Years	2010	2018
Mean	0.484	0.506	0.248	0.713	0.451	0.237	0.636
Standard Deviation	(0.500)	(0.500)	(0.432)	(0.453)	(0.498)	(0.425)	(0.481)
Observations	172,891	104,254	10,859	10,375	68,637	7,100	7,331

Source: National Immunization Survey—Teen 2010-2018

Note: HPV initiation is an indicator for whether provider-verified immunization records indicate that the child had received at least one dose of the HPV vaccine.

Table A3: Across specifications, the event study specification does not find any relationship between Medicaid expansion and HPV vaccination in the pre-period and a positive relationship in the post-period

		(1)	(2)	(3)	(4)	(5)
Pre-Expansion						
	-4	-0.000	-0.018	0.002	0.003	-0.050
		(0.015)	(0.014)	(0.017)	(0.014)	(0.032)
	-3	-0.014	-0.025*	-0.010	-0.007	-0.041*
		(0.015)	(0.013)	(0.015)	(0.014)	(0.024)
	-2	-0.011	-0.023*	-0.009	-0.010	-0.029*
		(0.013)	(0.012)	(0.014)	(0.012)	(0.015)
Pre=0?						
	F-Stat	0.530	1.670	0.460	0.390	1.290
	Prob>F	0.665	0.187	0.711	0.758	0.288
Post-Expansion						
	0	0.019	0.005	0.020	0.016	0.028*
		(0.013)	(0.015)	(0.014)	(0.012)	(0.015)
	1	0.034**	0.025*	0.034**	0.030**	0.054**
		(0.015)	(0.014)	(0.016)	(0.013)	(0.022)
	2	0.052***	0.042**	0.051***	0.047***	0.083**
		(0.018)	(0.021)	(0.018)	(0.015)	(0.032)
Post=0?						
	F-Stat	3.800	2.690	3.560	3.910	2.350
	Prob>F	0.016	0.057	0.021	0.014	0.084
Pre=Post?						
	F-Stat	2.290	2.250	2.870	3.050	1.930
	Prob>F	0.022	0.065	0.023	0.018	0.106
State and Year FE?		Y	Y	Y	Y	Y
Demographic Controls?		N	N	Y	Y	Y
State-Level Covariates?		N	N	N	Y	Y
State-Specific LTT?		N	N	N	N	Y
Including Early Expanders?		Y	N	Y	Y	Y
Observations		172,891	157,987	172,891	172,891	172,891

Source: National Immunization Survey 2010-2018
Note: The dependent variable is an indicator for receiving at least one dose of the HPV vaccine. The independent variables are indicator variables for being *j* periods away from Medicaid expansion. Column (1) includes controls for time-invariant state fixed effects and location-invariant year fixed effects. Column (2) uses this same specification but excludes states which expanded Medicaid prior to 2014 as part of the ACA. Column (3) includes demographic controls, column (4) state-level policies, and column (5) state-specific linear time trends. The exact controls are detailed in Table 2.
*** p<0.01, ** p<0.05, * p<0.10

Table A4: Medicaid expansion was unrelated to whether an observation had adequate provider information

	(1) Observations with HPV Vaccine Information	(2) All Observations
Medicaid Expansion	-0.006	-0.002
	(0.006)	(0.007)
Mean	0.979	0.497
Observations	176,536	309,830

Note: The dependent variable is an indicator for whether the teen has adequate provider-verified vaccination data. The independent variable of interest is an indicator for whether the state expanded Medicaid as part of the Affordable Care Act. All columns include the full set of controls from Table 2 column (4). Columns (1) examines only observations with data on HPV vaccination, while column (2) analyzes all observation. Robust standard errors, shown in parentheses, are clustered at the state level.
*** p<0.01, ** p<0.05, * p<0.10

Table A5: Most of the difference-in-differences estimate is identified from comparing treated states to never treated states

	(1) Weight	(2) Avg DD Estimate
Earlier Treated vs. Later Control	0.067	0.032
Later Treated vs. Earlier Control	0.101	0.021
Treated vs. Never Treated	0.718	0.043
Treated vs. Already Treated	0.113	-0.038

Source: National Immunization Survey 2010-2018
Note: The dependent variable is the share of teens vaccinated against HPV, while the independent variable of interest is an indicator for whether the state had expanded Medicaid as part of the ACA. The regression includes state and year fixed effects. The weight assigned to each comparison group and the average difference-in-differences coefficient is obtained from first collapsing the data to the state-year level and then using the bacondecomp command with ddetail.

Table A6: The relationship between Medicaid expansion and HPV vaccination is driven by comparing changes in expansion states to changes in non-expansion states, as opposed to comparing changes in early- and late-expanders

	(1) Excluding States which Expanded but not in 2014	(2) Excluding States which Expanded but not in 2014	(3) Only Leveraging the 2014 ACA Expansions	(4) Only Leveraging the 2014 ACA Expansions
Medicaid Expansion	0.038***	0.030	0.030***	0.031*
	(0.013)	(0.019)	(0.011)	(0.016)
State & Year FE?	Y	Y	Y	Y
Full Set of Covariates?	N	Y	N	Y
Mean	0.474	0.474	0.487	0.487
Observations	136,532	136,532	172,891	172,891

Source: National Immunization Survey 2010-2018

Note: The dependent variable is an indicator for whether the child's immunization provider reports that the child had received at least one dose of the HPV vaccine. The independent variable of interest is an indicator for whether the state expanded Medicaid as part of the Affordable Care Act. Odd numbered columns includes only time-invariant state fixed effects and location-invariant year fixed effects. Even numbered columns include the full set of controls from Table 2 column (4). Columns (1) and (2) exclude states which expanded Medicaid as part of the ACA in any year except 2014. Columns (3) and (4) uses all observations but redefines treatment as an indicator which takes on the value of 1 if the state expanded Medicaid in 2014 and 0 otherwise. Robust standard errors, shown in parentheses, are clustered at the state level.

*** $p<0.01$, ** $p<0.05$, * $p<0.10$

Table A7: The relationship between Medicaid expansion and HPV vaccine initiation was not statistically different for teen boys and teen girls

	(1) Boys	(2) Girls	(3) Full Sample	(4) Full Sample 2012-2018
Medicaid Expansion	0.040*	0.026	0.027	0.003
	(0.022)	(0.018)	(0.017)	(0.020)
Medicaid Expansion * Boy			0.012	0.024
			(0.026)	(0.029)
Mean	0.599	0.379	0.487	0.547
Observations	90,431	82,460	172,891	132,893

Source: National Immunization Survey—Teen 2010-2018

Note: The dependent variable is an indicator for whether the child's immunization provider reports that the child had received at least one dose of the HPV vaccine. The independent variable of interest is an indicator for whether the state expanded Medicaid as part of the Affordable Care Act. Column (1) restricts the sample to teen boys and column (2) restricts the sample to teen girls. Columns (3) and (4) use a triple-difference specification whereby every covariate is interacted with an indicator for being male. Column (4) further restricts the sample to the years 2012-2018 after ACIP recommended the HPV vaccine for teen boys. Each column includes the full set of controls from Table 2 column (4), and the estimates utilize the sample weights. Robust standard errors, shown in parentheses, are clustered at the state level.

*** p<0.01, ** p<0.05, * p<0.10

Table A8: Medicaid expansion was associated with an increase in the probability of parent-reported HPV vaccine take-up for poorer teens, teens whose mothers lacked college degrees, and non-white teens

	(1) Excluding Responses from Shotcard	(2) ≤ 200% FPL	(3) > 200% FPL	(4) Mother lacked BA	(5) Mother had BA	(6) Non-White	(7) White
Medicaid Expansion	0.017*	0.029**	0.015	0.028***	0.011	0.032**	0.006
	(0.010)	(0.012)	(0.013)	(0.009)	(0.015)	(0.013)	(0.011)
Mean	0.420	0.444	0.413	0.417	0.438	0.459	0.400
Observations	282,379	92,567	194,102	154,164	132,595	102,014	184,745

Source: National Immunization Survey—Teen 2010-2018

Note: The dependent variable is an indicator for whether the child's parent reports that the teen had received at least one dose of the HPV vaccine. The independent variable of interest is an indicator for whether the state expanded Medicaid as part of the Affordable Care Act. Column (1) does not include observations from parents who used a shotcard to answer the question in years 2010-2013. Instead, it exclusively uses recall responses. Columns (2)-(7) utilize the full sample of parent-reported vaccination. Columns (2) and (3) stratify the sample by poverty status. Similarly, columns (4) and (5) stratify the sample by mother's education, and columns (6) and (7) by race/ethnicity. Each column includes the full set of controls from Table 2 column (4), and the estimates utilize the sample weights. Robust standard errors, shown in parentheses, are clustered at the state level.

*** p<0.01, ** p<0.05, * p<0.10

Table A9: Medicaid expansion was associated with greater public health insurance coverage for poorer individuals and teens whose mothers lacked college degrees

	(1) Full Sample	(2) ≤ 200% FPL	(3) > 200% FPL	(4) Mother lacked BA	(5) Mother had BA	(6) Non-White	(7) White
	Panel II: Public Health Insurance						
Medicaid Expansion	0.014*	0.026*	0.005	0.017	0.007	0.018	0.006
	(0.008)	(0.013)	(0.006)	(0.011)	(0.005)	(0.013)	(0.006)
Mean	0.374	0.696	0.110	0.513	0.134	0.531	0.246
	Panel II: Non-Public Health Insurance						
Medicaid Expansion	-0.001	-0.008	0.004	-0.001	0.000	0.002	0.001
	(0.006)	(0.012)	(0.006)	(0.008)	(0.006)	(0.011)	(0.006)
Mean	0.563	0.200	0.860	0.402	0.842	0.377	0.715
Observations	198,169	70,006	128,163	110,044	88,125	71,808	126,361

Source: National Immunization Survey—Teen 2010-2018
Note: The dependent variable in Panel I is an indicator for whether the child was covered by public health insurance. The dependent variable in Panel II is an indicator for whether the child was covered by any health insurance that was not public insurance. The independent variable of interest is an indicator for whether the state expanded Medicaid as part of the Affordable Care Act. Column (1) examines the full sample, while columns (2) and (3) stratify the sample by poverty status. Similarly, columns (4) and (5) stratify the sample by mother's education, and columns (6) and (7) by race/ethnicity. Each column includes the full set of controls from Table 2 column (4), and the estimates utilize the sample weights. Robust standard errors, shown in parentheses, are clustered at the state level.
*** p<0.01, ** p<0.05, * p<0.10

Table A10: The relationship between Medicaid expansion and health insurance coverage is robust to only examining the 2010-2015 period prior to a survey modification limiting which observations include information about health insurance coverage

	(1) Full Sample	(2) ≤ 200% FPL	(3) > 200% FPL	(4) Mother lacked BA	(5) Mother had BA	(6) Non-White	(7) White
Medicaid Expansion	0.018***	0.026**	0.011***	0.021***	0.010*	0.022**	0.012**
	(0.006)	(0.010)	(0.004)	(0.007)	(0.005)	(0.009)	(0.005)
Mean	0.929	0.883	0.967	0.905	0.973	0.894	0.957
Observations	141,258	50,192	91,066	80,524	60,734	50,355	90,903

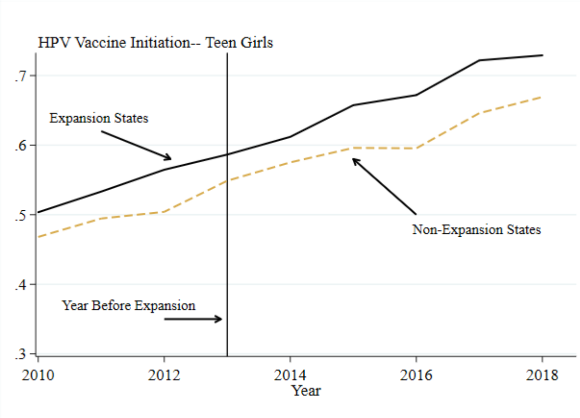
Source: National Immunization Survey—Teen 2010-2015
Note: The dependent variable is an indicator for whether the child was covered by any health insurance. The independent variable of interest is an indicator for whether the state expanded Medicaid as part of the Affordable Care Act. Column (1) examines the full sample, while columns (2) and (3) stratify the sample by poverty status. Similarly, columns (4) and (5) stratify the sample by mother's education, and columns (6) and (7) by race/ethnicity. Each column includes the full set of controls from Table 2 column (4), and the estimates utilize the sample weights. Robust standard errors, shown in parentheses, are clustered at the state level.
*** p<0.01, ** p<0.05, * p<0.10

Table A11: Medicaid expansion was associated with a reduction in the probability that a parent gives "lack of knowledge" as a reason for the child not receiving the HPV vaccine within the subsequent 12 months

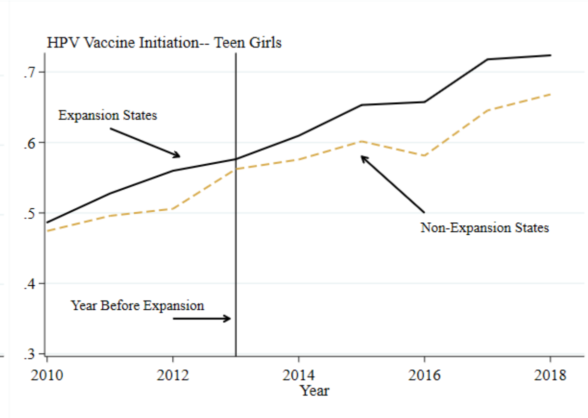
		(1) Not Needed	(2) No Rec.	(3) Lack Knowledge	(4) Safety Concerns	(5) Cost	(6) Not Needed	(7) No Rec.	(8) Lack Knowledge	(9) Safety Concerns	(10) Cost
Pre-Expansion											
	-4	-0.010	0.011	-0.006	-0.015	0.017*	0.000	0.083**	0.018	-0.027	0.009
		(0.008)	(0.014)	(0.008)	(0.009)	(0.009)	(0.031)	(0.039)	(0.026)	(0.024)	(0.012)
	-3	-0.018*	0.015	-0.010	-0.002	0.006	-0.012	0.066**	0.006	-0.012	-0.001
		(0.009)	(0.014)	(0.010)	(0.012)	(0.008)	(0.021)	(0.032)	(0.016)	(0.022)	(0.007)
	-2	-0.014*	-0.011	0.007	0.004	0.012*	-0.016	0.023	0.016	0.002	0.005
		(0.007)	(0.014)	(0.011)	(0.010)	(0.007)	(0.013)	(0.016)	(0.015)	(0.015)	(0.004)
Pre=0?											
	F-Stat	2.010	2.130	0.770	1.860	3.250	2.080	1.650	0.560	2.780	2.550
	Prob>F	0.124	0.108	0.514	0.148	0.029	0.114	0.190	0.643	0.051	0.066
Post-Expansion											
	0	0.011	-0.002	-0.010	-0.008	0.009**	-0.003	-0.009	-0.013	-0.001	0.007
		(0.010)	(0.009)	(0.008)	(0.007)	(0.004)	(0.015)	(0.011)	(0.011)	(0.007)	(0.006)
	1	-0.013	-0.001	-0.030***	0.011*	0.014**	-0.031	-0.023	-0.039***	0.024**	0.012
		(0.014)	(0.009)	(0.009)	(0.006)	(0.007)	(0.031)	(0.014)	(0.014)	(0.009)	(0.009)
	2	-0.013	-0.006	-0.011	0.009	0.012*	-0.036	-0.038*	-0.024	0.020	0.012
		(0.013)	(0.010)	(0.009)	(0.010)	(0.006)	(0.034)	(0.022)	(0.017)	(0.013)	(0.012)
Post=0?											
	F-Stat	0.980	0.180	4.650	3.560	2.000	0.770	1.400	4.440	4.890	0.710
	Prob>F	0.410	0.907	0.006	0.021	0.125	0.519	0.253	0.008	0.005	0.550
Pre=Post?											
	F-Stat	2.280	1.800	8.400	2.950	1.170	0.940	1.090	3.830	4.390	1.340
	Prob>F	0.060	0.130	0.000	0.021	0.338	0.463	0.380	0.005	0.002	0.263
Observations		126,395	126,395	126,395	126,395	126,395	126,395	126,395	126,395	126,395	126,395

Source: National Immunization Survey 2010-2018
Note: The dependent variable is an indicator for the reason given for not vaccinating the child, including that the vaccine is not needed; the child has not been recommended the vaccine; a lack of knowledge; safety concerns; and the cost of the vaccine. The independent variables are indicator variables for being *j* periods away from Medicaid expansion. Columns (1)-(5) include controls for time-invariant state fixed effects and location-invariant year fixed effects. Columns (6)-(1) use the full set of controls from Table 2 column (4). The estimates utilize the sample weights. Standard errors, shown in parentheses, are clustered at the state level.
*** p<0.01, ** p<0.05, * p<0.10

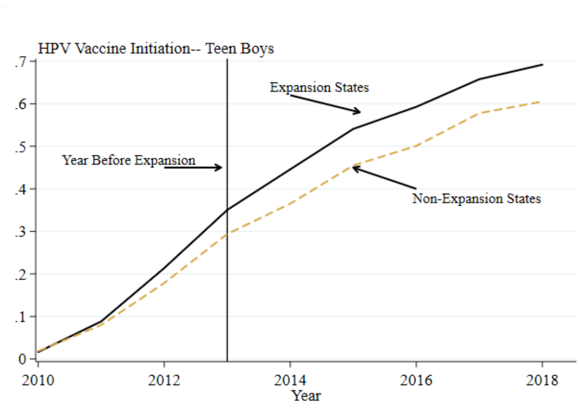
Figure A1: After accounting for CDC funds to promote HPV vaccination, HPV vaccination rates were trending similarly in states which did and did not expand Medicaid as part of the ACA



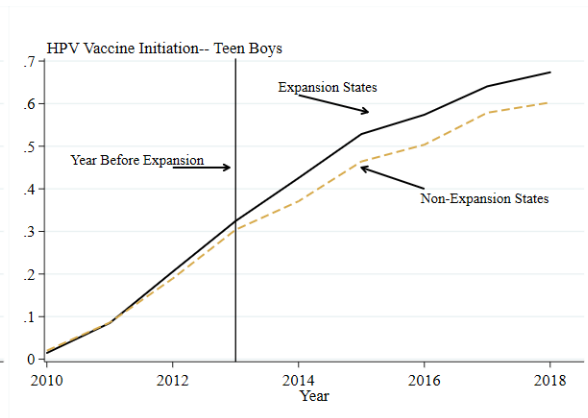
(A)



(B)



(C)



(D)

Source: National Immunization Survey- Teen 2010-2018
Note: The figures plot the unweighted share of teen girls and teen boys who had initiated the HPV vaccine by whether the teens resided in states which expanded Medicaid as part of the ACA. Panels (A) and (C) presents the estimates for boys and girls, respectively. Panels (B) and (D) present these same shares but exclude states which received CDC funding to improve HPV vaccination.

CHAPTER 3

E-Verify Mandates and Unauthorized Immigrants' Health Insurance Coverage

3.1. INTRODUCTION

Immigrants disproportionately rely on the labor market for health insurance due to restrictions on public insurance for new authorized arrivals and unauthorized immigrants (Borjas 2003). Nearly a quarter of lawful permanent residents and over 40 percent of unauthorized immigrants lack health insurance (KFF 2017), and over the last two decades state and local governments have experimented with policies intended to disrupt unauthorized immigrants' access to the formal labor market. One such policy is the requirement that at least some employers electronically verify (E-Verify) that their new hires are eligible to work in the United States.

E-Verify mandates previously enjoyed bipartisan support (Politico 2013), and several high-profile GOP leaders have expressed optimism about achieving a comprehensive immigration reform package with the Biden administration (The Hill 2020). Because E-Verify mandates remain popular throughout the Republican party (White House 2017; White House 2018; Romney 2019) a nationwide mandate is almost certain to be a part of these discussions. Indeed, a nationwide E-Verify mandate was included in proposed legislation from Senators Mitt Romney (R-UT) and Tom Cotton (R-AR) to increase the federal minimum wage to $10 an hour (Vox 2021). Yet President Biden has simultaneously called for expanding unauthorized immigrants' access to health insurance, going so far as to propose allowing unauthorized immigrants to enroll in public health insurance plans (Washington Post 2019). In absence of such a proposal, barring unauthorized immigrants from the formal labor market through a nationwide E-Verify mandate could eliminate their only option for health insurance coverage.

In this paper, I show that state-level E-Verify mandates reduced the probability that likely unauthorized immigrants had health insurance coverage, a relationship driven by reductions in the likelihood of having employer-sponsored insurance. Event study estimates demonstrate the reduction only occurred after the mandate was implemented, and in a series of falsification tests I show that that naturalized citizens, Hispanic natives, and white non-Hispanic natives did not experience a similar change. Interestingly, the effect for likely unauthorized immigrants was limited to the period immediately after implementation. In all subsequent periods, the relationship between E-Verify mandates and health insurance coverage was near zero. I show that this pattern can be explained by selective outmigration of otherwise unemployed and subsequently uninsured likely unauthorized immigrants.

This paper contributes to the literature on immigrants' access to insurance by demonstrating a plausibly causal link between E-Verify mandates and health insurance coverage (Borjas 2003; Buchmueller et al. 2008; Bronchetti 2014; Dillender 2017). Additionally, it adds to a growing body of work on the effect of E-Verify mandates on likely unauthorized immigrants which has thus far focused primarily on employment outcomes and migration decisions (Amuedo-Dorantes and Bansak 2014; Bohn et al. 2014; Orrenius and Zavodny 2015; Orrenius and Zavodny 2016). It also contributes to a broader literature on the spillover effects of immigration enforcement (Bitler and Hoynes 2011; Watson 2014; Amuedo-Dorantes, Arenas-Arroyo, and Sevilla 2018; East 2019; Churchill, Amuedo-Dorantes, and Song 2020) by showing suggestive evidence that children with likely unauthorized parents and native adults in mixed-status households lose access to health insurance.

The rest of this paper proceeds as follows: Section 2 discusses existing work on E-Verify, as well as the literature on immigrants and health insurance, discussing how unauthorized immigrants can obtain insurance coverage. The data, methods, and summary statistics are discussed in Section 3. Section 4 starts by showing that E-Verify mandates reduce likely unauthorized immigrants' employment prospects, an effect which is driven by reduction in wage-employment and employment at larger firms. I then show that this effect is limited to one period post-implementation, after which point unauthorized immigrants opt to leave the state. I then present the main insurance results. Finally, Section 5 discusses broad conclusions and opportunities for future work.

3.2. EXISTING LITERATURE

Since 2007, nine states have implemented laws requiring all employers to utilize E-Verify, and an additional fourteen states require public employees or contractors to be screened through E-Verify. Proponents argue that these mandates can reduce the flow of unauthorized immigrants (or induce return migration), while also benefitting citizen workers. For instance, Congressman Lamar Smith (R-Texas) stated, "E-Verify is the most effective deterrent to illegal immigration because it shuts off the jobs magnet and saves jobs for hardworking Americans" (CNN 2018).

3.2.1. E-Verify and Employment

The Immigration Reform and Control Act of 1986 barred firms from knowingly hiring or employing unauthorized immigrants. However, uneven enforcement (Reyes et al. 2002) did little to stem the flow of unauthorized labor into the United States (Amuedo-Dorantes and Bansak 2014). A decade later, the Illegal Immigration Reform and Immigrant Responsibility Act of 1996 established the Basic Pilot program. Now known as E-Verify, this program compares information from a new hire's Form I-9 against databases maintained by the Social Security Administration and Department of Homeland Security, helping employers assure they hire authorized workers (Stumpf 2012). E-Verify was made available to select states beginning in 1997, with all states having access by 2003 (Orrenius and Zavodny 2015).

There is mixed evidence on the relationship between E-Verify mandates and unauthorized immigrants' labor market outcomes. Focusing on Arizona's E-Verify mandate, Bohn and Lofstrom (2012) found reductions in wage-and-salary employment for non-citizen Hispanics. Examining a broader set of universal and public E-Verify mandates with the 2004-2011 Current Population Survey (CPS) data, Amuedo-Dorantes and Bansak (2014) also found employment reductions for likely unauthorized immigrants and improved job prospects for those competing with unauthorized labor. However, when using the 2002-2012 CPS data, Orrenius and Zavodny (2015) failed to detect a negative employment effect; indeed, their point estimate was positive and statistically insignificant.

E-Verify mandates may also affect state composition by (i) inducing unauthorized immigrants to leave the state and/or (ii) discouraging future unauthorized immigrants from settling. Bohn, Lofstrom, and Raphael (2014) found Arizona's E-Verify mandate reduced the fraction of the state's population comprised of Hispanic non-citizens. Looking at a broader group of states, Orrenius and Zavodny (2016) found that universal E-Verify mandates reduced the number of likely unauthorized immigrants in a state. While they found evidence that unauthorized immigrants settled in other states in response to E-Verify laws, they also posited that some unauthorized individuals may have opted to return to their native countries. On the other hand, using administrative data from the Department of Homeland Security on the usage of E-Verify systems, Ayromloo, Feigenberg, and Lubotsky (2020) did not find evidence that these mandates induced work-ineligible individuals to relocate.

3.2.2. Immigrants and Health Insurance

The 1996 Personal Responsibility and Work Opportunity Reconciliation Act (PRWORA) barred lawful permanent residents (LPRs) from most means-tested programs during their first five years in the US. Borjas (2003) found that the PRWORA eligibility changes did reduce Medicaid participation, though affected immigrants compensated by increasing their labor supply to gain employer-sponsored insurance, which indicates the existence of crowd-out. However, several papers suggest that there is less crowd-out for immigrant children (Currie 2000; Kaushal and Kaestner 2005, 2007; Lurie 2008).

Under PRWORA, states had the option to offer LPRs public insurance, though they were barred from using federal money for this purpose until 2002. After this point, limited funds were available for prenatal care through the SCHIP "unborn child" option, and these funds were expanded in 2009 through the SCHIP reauthorization bill (Bitler and Hoynes 2011). Bronchetti (2014) examined these state actions to restore access to public health insurance and found that expanded eligibility increased take-up of public insurance among immigrant children.

In addition to reductions expected mechanically from changes in eligibility, there is a growing awareness that hostile policy environments may exacerbate reductions in program take-up (Fix and Passel 1999; Borjas 2001; Kandula et al. 2004). For example, the PRWORA-induced reductions in Medicaid participation could not be entirely explained by eligibility changes, leading Borjas (2003) to attribute the disproportionate response to chilling effects. Sommers (2010) found that the Deficit Reduction Act (DRA) of 2005, which imposed citizenship documentation requirements on Medicaid applicants, reduced the share of adult immigrants enrolled in Medicaid, though the overall adult insurance rate was not affected.

There is also evidence that some unauthorized immigrants forgo health care visits due to fears of interacting with law enforcement officers (Núñez and Heyman 2007; Heyman et al. 2009). Watson (2014) found that increased federal immigration enforcement lowered Medicaid participation among children with immigrant mothers while also decreasing (increasing) the probability that these children were reported to be in *Very Good Health* (*Poor Health*). Similarly, Alsan and Yang (2018) found that county participation in the Secure Communities program reduced the probability that a Hispanic citizen utilized means-tested benefit programs, such as SNAP and SSI.

Given these restrictions on public insurance, immigrants must largely rely on private health insurance. However, immigrants are less likely to have private insurance relative to their native counterparts, in part because they are less likely to be employed by firms offering health insurance coverage. Indeed, Buchmueller et al. (2007) found that the citizen/noncitizen coverage gap could largely be explained by noncitizens working at firms which did not offer employer-sponsored health insurance. Among those working at firms offering health insurance, noncitizens were only slightly less likely to be eligible for coverage and, among that group, only slightly less likely to take up coverage. Building off this finding, Dillender (2017) showed that immigrants possessing stronger English ability were more likely to have employer-sponsored health insurance. These barriers are especially acute for unauthorized immigrants. Unauthorized immigrants are barred from receiving the Affordable Care Act's private insurance subsidies. While it is possible to obtain coverage outside the Marketplace or through an employer without providing a Social Security Number, the cost is often prohibitive (KFF 2019).

3.3. DATA, MEASURES, AND METHODS

I first obtained preliminary information on state E-Verify mandates from the National Council of

State Legislatures (2015) and Urban Institute (2017). I then determined specific implementation dates by examining each piece of legislation. Table 1 lists these bills and dates, while Figure 1 shows the 9 states which had implemented a universal E-Verify mandate (darker color) and the 14 states which had implemented at most a public mandate (lighter color) by 2016.[1] Two indicator variables, UNIVERSAL_{st} and PUBLIC_{st}, were constructed from these dates. When a state with a public E-Verify mandate later implemented a universal E-Verify mandate, the public indicator is set equal to 0.

3.3.1. Data and Measures

I obtained information on health insurance coverage from the 2000-2016 Current Population Survey's Annual Social and Economic Supplement (ASEC), extracted from the IPUMS-CPS database (Flood et al. 2018). In Table 2, I present summary statistics for E-Verify coverage and the main dependent variables.[2] Because the ASEC does not contain information on authorization status, I identify likely unauthorized immigrants using the residual imputation strategy described by Borjas (2017). I start with a sample of all 18- to 64-year-old foreign-born individuals, and then I consider each respondent a legal immigrant if s/he (i) arrived before 1980, (ii) reports being a citizen, (iii) receives Social Security benefits, (iv) is a veteran or currently in the Armed Forces, (v) works in the government sector, (vi) resides in public housing or receives rental subsidies, or is the spouse of a person who resides in public housing or receives rental subsidies, (vii) was born in Cuba, (viii) works in an occupation requiring licensing, or (ix) is the spouse of a legal immigrant

[1] It is worth noting that Louisiana and Tennessee both originally had exceptions to E-Verify, whereby employers could instead just retain work authorization documentation. Because these states required a form of employment-verification, I classify them as universal mandate states throughout the analysis. However, the results are robust to (i) classifying them as untreated, (ii) classifying them as a new category called PARTIAL for partially treated states, and (iii) excluding them from the analysis entirely. Minnesota dropped E-Verify in April of 2008, though it was reinstated legislatively in July of that year. Rhode Island abandoned its E-Verify requirement in January 2011.

[2] Summary statistics for the additional covariates are reported in Table A1.

or citizen. The remaining foreign-born individuals are classified as likely unauthorized.[3]

I make one notable adjustment to Borjas's (2017) procedure. While the author considers anyone receiving Medicaid, Medicare, or Military Insurance as being likely authorized, I drop this restriction to avoid selecting treatment status (authorization) using a variant of the dependent variable (health insurance). However, I show in my analysis that my results are robust to including this restriction, as well as to using other commonly accepted definitions of likely unauthorized. Using Borjas's (2017) procedure, I estimate approximately 12 million unauthorized immigrants were in the United States in 2016.

Over the full sample period, nearly 5 percent of likely unauthorized immigrants resided in a state with a universal E-Verify mandate compared to 10 percent who resided in a state with a public E-Verify mandate. Likely unauthorized immigrants were less likely than naturalized immigrants (0.33 vs 0.62), Hispanic natives (0.33 vs 0.53), and white non-Hispanic natives (0.33 vs 0.69) to be covered by employer-sponsored insurance.

3.3.2. Potential Channels

E-Verify mandates may directly reduce the probability that an unauthorized immigrant has health insurance through the *employment channel*. If E-Verify mandates reduce unauthorized immigrants' labor market prospects—and these individuals would have otherwise obtained employer-sponsored insurance—overall coverage will fall. When a low-income US citizen loses her job, she does not necessarily lose health insurance coverage. Though she may lose her employer-sponsored health insurance, she will qualify for a special enrollment period allowing her to directly purchase health insurance through the Marketplace with potential ACA subsidies. Additionally, the most economically disadvantaged citizens qualify for public health insurance. In

[3] The code for this procedure is graciously provided on Borjas's website: https://scholar.harvard.edu/files/gborjas/files/le2020archive.zip

contrast, unauthorized immigrants are ineligible for the ACA health insurance subsidies and are generally ineligible for public health insurance. For these individuals, losing a job is tantamount to losing insurance coverage.

In addition to affecting *whether* an unauthorized immigrant is employed, state E-Verify mandates may affect unauthorized immigrants' health insurance coverage by altering the *types* of jobs available to these individuals. In 2008—the year of the first universal E-Verify mandate—87 percent of employees were offered employer-sponsored health insurance (Vistnes et al. 2012). Yet this statistic masks substantial variation by firm size. While over 95 percent of employees at large firms were offered health insurance, the share among smaller firms varied between 44 (<10 employees) and 84 percent (25-99 employees). Only 25 percent of unauthorized immigrants were employed by large firms throughout my sample period, compared to 21 percent employed at firms with fewer than 10 employees. Because Ayromloo et al. (2020) found that larger firms were more likely to comply with E-Verify mandates, E-Verify mandates may induce unauthorized immigrants to work for smaller firms which are less likely to offer employer-sponsored health insurance. Moreover, E-Verify mandates may shift unauthorized immigrants from full-time to part-time jobs, and part-time workers are less likely to qualify for employer-sponsored health insurance (Farber and Levy 2000).

E-Verify mandates may also affect the *composition* of a state. Faced with diminished labor market outcomes and a hostile policy environment, unauthorized immigrants may simply choose to leave a state (Bohn et al. 2014; Orrenius and Zavodny 2016). If these individuals would otherwise have lost insurance due to the implementation of a mandate, any estimated reductions in the probability of having insurance will be attenuated.

3.3.3. Empirical Strategy

I begin by employing an event study specification on the sample of likely unauthorized immigrants to examine whether the probability that likely unauthorized immigrants were insured was differentially trending in states which eventually implemented E-Verify mandates. Though less efficient than the traditional difference-in-differences estimator, it imposes no assumptions about how the treatment effect varies over time (Goodman-Bacon 2019).[4] This specification is shown in equation (1):

$$Y_{isrt} = \alpha + \sum_{j=-8, j\neq -1}^{3} \beta_j D_{st}^{j} + \mu PUBLIC_{srt} + \eta_{Pre} + \eta_{Post} + \mathbf{H'_{srt}}\boldsymbol{\phi} + \mathbf{E'_{srt}}\boldsymbol{\rho} + \mathbf{B'_{srt}}\boldsymbol{\pi} + \mathbf{X'_{isrt}}\boldsymbol{\gamma} + \theta_s + \tau_{rt} + \varepsilon_{ist} \quad (1)$$

where Y_{ist} is an indicator for whether person, *i*, in state, *s*, and census region, *r*, was employed or had insurance in year, *t*. D_{st}^{j} is an indicator for whether state, *s*, had adopted a universal E-Verify mandate *j* periods from year *t*. Similarly, η_{Pre} and η_{Post} are indicators for observations occurring outside the balanced sample window, and I control for whether the state had implemented a public E-Verify mandate.

In 2016, 18 states allowed unauthorized pregnant women access to Medicaid, while 32 states extended these benefits to newly arrived pregnant lawful permanent residents who would otherwise have been ineligible. Because states may have been concurrently expanding immigrant access to public health insurance while others adopted E-Verify mandates, **H** includes several immigrant-related health policy controls. These include indicators for whether the state offered Medicaid to lawful permanent resident children during the five-year ban, public health insurance for all lawful permanent residents during the five-year ban, or public health insurance to

[4] The ASEC is collected in March but the health insurance questions refer to insurance coverage during the prior year. Therefore, when examining health insurance outcomes, I match observations to treatment status in March of the prior year.

unauthorized immigrant children. The vector also includes indicators for whether a state offered food assistance for lawful permanent resident children during the five-year ban, as well for whether a state expanded Medicaid as part of the Affordable Care Act (Urban Institute 2017).

The vector **E** includes controls for local-level police-based enforcement measures implemented over the same period. For example, under the 287(g) program, local law enforcement officers are deputized and charged with arresting and detaining those suspected of immigration violations (Capps et al. 2011). Additionally, under the county-level Secure Communities program, biometric information of arrestees is checked against a DHS database of legal immigrants (Miles and Cox 2014). I obtain both measures from the Urban Institute's Immigration Policy Resource (2017). Because the 287(g) program and Secure Communities programs were implemented at the local level, I utilize the Urban Institute's coding which considers a state treated if some or all of the counties with the highest immigrant population had adopted the relevant measure.

The vector **B** controls for state-level business cycle characteristics, including the natural log of real value of residential building permits in the state and the state unemployment rate. Equation (1) also controls for individual level demographic characteristics, **X**, including whether an individual is of Hispanic origin, white, black, male, proficient in English, or married, as well as indicator variables for each age between 18 and 64 (Dillender 2017).[5]

Equation (1) includes a full set of time-invariant state fixed effects, θ_s. As shown in Figure 1, the states implementing universal E-Verify mandates from 2000-2016 were largely concentrated in the southeast. Notably, these states were also less likely to expand Medicaid as part of the Affordable Care Act and may have been differentially affected by the Great Recession. To account for these possibilities, I also include a full set of census region-by-year fixed effects, τ_{rt}. Robust

[5] When estimating the relationship between E-Verify mandates and the likelihood of having health insurance, I do not control for whether the individual was employed to avoid conditioning on an endogenous variable.

standard errors are clustered at the state level (Bertrand et al. 2004). However, given the small number of states implementing E-Verify mandates, I conduct inference using a wild cluster bootstrap technique (Cameron et al. 2008; 2012).

Following the event study results, I next utilize a standard two-way fixed effects framework, shown in equation (2), where UNIVERSAL indicates whether the state had implemented a universal E-Verify mandate and PUBLIC indicates whether a state had implemented a public mandate.

$$Y_{isrt} = \alpha + \beta_1 UNIVERSAL_{srt} + \beta_2 PUBLIC_{srt} + \mathbf{H'_{srt}\phi} + \mathbf{E'_{srt}\rho} \tag{2}$$

$$+ \mathbf{B'_{srt}\pi} + \mathbf{X'_{isrt}}\gamma + \theta_s + \tau_{rt} + \varepsilon_{ist}$$

The sample is restricted to likely unauthorized immigrants, so that β_1 identifies the relationship between insurance and the implementation of a universal mandate and β_2 does the same for the implementation of a public mandate.

3.4. RESULTS

I begin by examining the relationship between E-Verify mandates and likely unauthorized immigrants' employment prospects. After demonstrating that E-Verify mandates reduce the likelihood that these individuals are employed, especially at larger firms, I show that likely unauthorized individuals may engage in compensatory behavior by leaving the state. As a result, the employment effects are largely limited to one period post-implementation. Next, I document a similar pattern with regards to health insurance coverage, and I show that this result is robust to several robustness exercises. Interestingly, I show that E-Verify mandates may also harm US citizens, including native-born children with likely unauthorized parents and native adults residing in mixed-status households.

3.4.1. E-Verify Mandates, Employment, and Migration

Using the event study specification from equation (1), I show in Figure 2 that likely unauthorized immigrants were 7.5 percentage points less likely to be employed following the implementation of a universal E-Verify mandate. However, this reduction is short-lived. Within three years of implementation, E-Verify mandates no longer appear to have affected likely unauthorized immigrants' employment prospects. Indeed, the last point estimate is small (-0.01) and statistically indistinguishable from zero.

In Table 3, I use the two-way fixed effects specification from equation (2) to measure the average post-period change in labor market outcomes.[6] First, I find that universal E-Verify mandates reduced likely unauthorized immigrants' employment by 4.7 percentage points (column 1 row 1). Interestingly, I also find that likely unauthorized immigrants were 1.6 percentage points less likely to be employed after the implementation of a public E-Verify mandate (column 1 row 2).

These estimates are consistent with Amuedo-Dorantes and Bansak (2014), who found that universal (public) E-Verify mandates reduced likely unauthorized immigrants' probability of being employed by 4.6 (2.0) percentage points. Yet they stand in contrast to Orrenius and Zavodny (2015), who did not detect statistically significant reductions in employment using a near identical dataset and identification strategy but longer time window than Amuedo-Dorantes and Bansak (2014). From the event study in Figure 2, one possible explanation is that the difference-in-differences estimates over a longer time horizon may be attenuated because the treatment effect appears short-lived.[7]

[6] I report the control variables' coefficients for the primary specifications in Table A3.
[7] In a later analysis using an instrumental variables identification strategy, Orrenius and Zavodny (2020) found that universal E-Verify mandates led to a 3-percentage point reduction in the probability that likely unauthorized men were employed. They did not detect a statistically significant change in employment for likely unauthorized women.

Next, I show that likely unauthorized immigrants were 6 percentage points less likely to be employed for wages after the implementation of a universal E-Verify mandate (column 2 row 1) and 1.5 percentage points less likely to be employed for wages after the implementation of a public E-Verify mandate (column 2 row 2). I also find suggestive evidence that universal E-Verify mandates increased the probability that likely unauthorized immigrants were classified as self-employed (column 3 row 1), consistent with a compensatory response to reduced access to formal employment.[8] Next, I show that E-Verify mandates appear to have reduced the probability that likely unauthorized immigrants were full-time employees (column 4), while the point estimates for part-time status are smaller and statistically insignificant (column 5).

In the final two columns, I show that universal E-Verify mandates were most effective at curbing unauthorized immigrants' employment at larger firms (column 6 row 1); the point estimate for smaller firms is almost 90 percent smaller in absolute magnitude, opposite signed, and statistically insignificant (column 7 row 1). This pattern is consistent with statutory language requiring larger firms to be the earliest adopters of the E-Verify system.[9] Additionally, in a working paper, Ayromloo et al. (2020) showed that larger firms were more likely to comply with E-Verify mandates. Perhaps surprisingly, I also find evidence that public E-Verify mandates reduced the probability that likely unauthorized immigrants were employed by larger firms (column 6 row 2). One possible explanation is that these firms were more likely to be awarded government contracts. Alternatively, it may be that larger firms preemptively began using E-Verify in anticipation that a public sector mandate would later be expanded to all firms.

[8] It is worth noting that worker class is defined even for individuals who are unemployed at the time of the survey. Therefore, the indicator variable takes on the value of one if a person reports being a wage/salary employee, even if the individual is not presently employed. The estimates are robust in both size and statistical significance to recoding unemployed individuals as zero.

[9] For example, Georgia's universal mandate took effect on January 1, 2012 for firms with at least 500 employees. Firms with 100-499 employees were required to being using E-Verify on July 1, 2012, and firms with 10-100 employees were required to use E-Verify starting July 1, 2013.

The event study estimates from Figure 2 indicate that E-Verify's relationship with employment was largely limited to the year following implementation. One explanation is that likely unauthorized immigrants who would have otherwise been unemployed because of the mandate opted to leave the state. To test this possibility, I examine the relationship between E-Verify mandates and the share of the foreign-born population comprised of likely unauthorized immigrants.[10] First, I show in Figure 3 that there was no statistical relationship between this share and the eventual implementation of a universal mandate; the pre-implementation coefficients are not jointly different from zero (p=0.585). However, this share fell by approximately 9 percentage points two years after the implementation of a universal E-Verify mandate—the exact period in which E-Verify ceased to affect likely unauthorized immigrants' employment prospects. This post-period reduction was statistically different from zero (p=0.015).[11]

Outmigration in response to E-Verify mandates is consistent with Bohn et al. (2014), who found that Arizona's universal E-Verify mandate led to meaningful reduction in the share of population comprised of prim-age non-citizen Hispanics with at most a high school degree. Similarly, Orrenius and Zavodny (2016) found that universal E-Verify mandates led to a reduction in the number of new and recent likely unauthorized immigrants residing in a state. They estimate that some individuals moved to other states, while others left the country entirely. However, this finding contrasts Ayromloo et al. (2020), who found no evidence that work-ineligible individuals relocated in response to E-Verify mandates.

[10] In Figure A1, I replicate this analysis replacing the dependent variable with the natural log of the number of likely unauthorized immigrants. Though less precisely estimated, Figure A1 is consistent with a net reduction in likely unauthorized immigrants occurring two periods after the implementation of a universal E-Verify mandate.

[11] Using the two-way fixed effects specification from equation (2), I estimated a statistically insignificant 2.9 percentage point reduction in the share of foreign-born individuals comprised of likely unauthorized immigrants (p=0.20). It is worth noting that it takes years for this migration to occur. Moreover, Goodman-Bacon (2018) showed that when the treatment effect increases over time, as is the case in Figure 3, difference-in-differences estimates will be biased toward zero.

3.4.2. E-Verify Mandates and Health Insurance

In the prior section, I showed that E-Verify mandates reduced likely unauthorized immigrants' employment prospects, especially at larger firms. I now explore how these mandates may have affected likely unauthorized immigrants' access to health insurance. In Table 4, I show that universal E-Verify mandates were associated with a 4.4 percentage point reduction in the probability that likely unauthorized immigrants had health insurance (column 1 row 1), while public mandates were associated with a 3.7 percentage point reduction (column 1 row 2).[12] To test the generalizability of these estimates, I follow the literature and show in Figure 4 that the estimate is robust to iteratively excluding each state which ever adopted an E-Verify mandate (Orrenius and Zavodny 2016; Amuedo-Dorantes et al. 2020). This is especially important because Orrenius and Zavodny (2015) argued that while Arizona's E-Verify mandate was particularly detrimental to likely unauthorized immigrants, other states' mandates were less salient.[13]

Consistent with E-Verify mandates harming the labor market prospects of likely

[12] In Table A4, I show that the estimates are robust to using a probit estimation framework (column 1), including an indicator for place of birth (column 2), and limiting the sample only to states which ever implemented an E-Verify mandate (column 3). I also show that my results are robust to excluding the census region-by-year fixed effects (column 4), as well as to following Dube (2019) and replacing them with state-by-Great Recession year fixed effects. I continue to find a 4-5-percentage point reduction in the probability that likely unauthorized immigrants had health insurance (column 5). I also show that the results are robust to excluding observations from states which had expanded Medicaid as part of the Affordable Care Act (column 6). I show that the effect sizes are unchanged if I restrict the sample to the years prior to when the ACA employer-mandate was supposed to be implemented (column 7). Finally, in Table A4 I instead perform the analysis at the household level. I find that universal E-Verify mandates reduced the likelihood that at least one person in a household possessing unauthorized immigrants had any health insurance by 6 percent relative to the sample mean (column 8).

[13] The event study coefficients in Figure 3 indicate that likely unauthorized immigrants opted to leave a state in response to universal E-Verify mandates. If these individuals moved to neighboring states, the control states would be indirectly treated. However, Orrenius and Zavodny (2016) showed that most individuals moving in response to E-Verify mandates appear to have left the country altogether. In Table A5, I explore whether neighboring state E-Verify mandates affect the probability that unauthorized immigrants have health insurance. I define a "neighbor" as the states sharing a border. For example, California is bordered by Arizona, Nevada, and Oregon, while Nevada is bordered by Arizona, California, Idaho, Oregon, and Utah. I do not detect any statistically significant effects.

unauthorized immigrants, I show in Table 4 that E-Verify's relationship with health insurance coverage is driven by a reduction in the probability of having private insurance (column 2). In contrast, the point estimate for public insurance is one-third the size and statistically insignificant (column 6).[14] This change is driven by a nearly 3 percentage point reduction in the probability that a likely unauthorized immigrant was the policyholder for an employer-sponsored health insurance plan following the implementation of a universal E-Verify mandate (column 3 row 1).[15] I also document a 2.2 percentage point reduction in the probability of being the policyholder after the implementation of a public E-Verify mandate (column 3 row 2).[16]

Using the event study specification from equation (1), I show in Figure 5 that the probability that a likely unauthorized immigrant had private health insurance was unrelated to whether a state eventually implemented a universal E-Verify mandate (p=0.216). However, one period after implementation this probability fell by over 7 percentage points. Though the effect decreased in absolute magnitude after another year, I can reject the null hypothesis that the post-implementation coefficients are jointly equal to zero (p=0.002). Consistent with the employment

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[14] It is worth noting that while the relationship between E-Verify and private insurance coverage is perhaps more obvious, E-Verify mandates *could* reduce take-up of public health insurance by discouraging participation in public programs (Watson 2014). While generally ineligible for public insurance, some states have expanded public insurance coverage for select unauthorized immigrants (Bronchetti 2014).

[15] When studying the mechanics of difference-in-differences, Goodman-Bacon (2018) showed that covariates can contribute to identification when there is variation in treatment timing. In Table A6, I use the order-invariant decomposition proposed by Gelbach (2016) to test the sensitivity of these results to the various covariates relative to a sparse baseline model containing only state and year fixed effects. My results are not being driven by the control variables.

[16] Amuedo-Dorantes and Bansak (2014) found statistically significant employment reductions for both sexes, but the point estimates were larger for likely unauthorized men. In contrast, Orrenius and Zavodny (2015) did not uncover any negative employment effects for men or women. More recently, Orrenius and Zavodny (2020) found negative employment effects for men and positive employment effects for women. In Table A7, I test whether the employment and insurance effects vary by sex. I find that universal mandates are associated with a 4.5 percentage point reduction in the probability of employment for likely unauthorized men (column 1 row 1) and a 4-percentage point reduction for likely unauthorized women (column 2 row 1). However, the triple-difference specification does not indicate that these values are statistically different from each other (column 3). Similarly, I find that universal mandates were associated with a 3.1 percentage point reduction in the probability of being the policyholder for employer-sponsored health insurance for likely unauthorized men (column 4 row 1) and a 2.6 percentage point reduction for likely unauthorized women (column 5 row 1). Again, the triple-difference specification does not indicate that these values are statistically different from each other.

event study, the effect is near zero three periods post-implementation.

3.4.3. Falsification Tests and Sensitivity to Likely Unauthorized Definition

In Table 5, I conduct falsification tests on groups less likely to have been affected by E-Verify mandates, including naturalized citizens (column 2), native-born Hispanics (column 3), and white non-Hispanic natives (column 4).[17] However, it is worth noting that E-Verify mandates could conceivably affect these groups' insurance coverage. For example, it is possible that E-Verify mandates *improve* the labor market prospects of those competing against unauthorized immigrants (Orrenius and Zaovdny 2015; Churchill et al. 2019), thereby increasing their access to health insurance. Moreover, naturalized citizens and natives in mixed-status households may receive health insurance through an unauthorized family member. However, I find no evidence that E-Verify mandates affected these groups' access to employer-sponsored health insurance.[18]

Next, I test the sensitivity of my estimates to how I assign likely authorization status. As mentioned previously, the ASEC does not contain information on legal status, and I instead classify an individual as likely unauthorized using a modified version of the residual imputation scheme proposed by Borjas (2017). Alternatively, authors have classified individuals as likely unauthorized based on a combination of citizenship, education, and ethnicity. For example, Amuedo-Dorantes and Bansak (2014) consider a person likely unauthorized if s/he is a non-citizen

[17] In Table A8, I employ a triple-difference specification by pooling the sample of likely unauthorized immigrants with each respective falsification group. I then repeat the analysis but fully interact the likely unauthorized indicator with the all the covariates (the independent variables of interest, demographic characteristics, business cycle controls, enforcement measures, health policy controls, state fixed effects, and census region-by-year fixed effects). I continue to find an approximate 2-3 percentage point reduction in the likelihood of being the policyholder for employer-sponsored health insurance.

[18] I present the event study coefficients for each of these four groups in Figure A2. For likely unauthorized immigrants, I document a large reduction in the probability of being the policyholder for employer-sponsored health insurance one period after the implementation of a universal E-Verify mandate (Panel A). There is no systematic relationship for naturalized citizens (Panel B), native Hispanics (Panel C), or white non-Hispanic natives (Panel D).

Hispanic between the ages of 18 and 45 with at most a high school degree. Similarly, Orrenius and Zavodny (2015) classify people as likely unauthorized if they are non-citizen immigrants with at most a high school degree who were born in Mexico.

While most people in Amuedo-Dorantes and Bansak (2014) and Orrenius and Zavodny's (2015) samples are probably unauthorized, these authors likely misclassify some unauthorized immigrants as authorized. In contrast, Borjas's (2017) specification scheme probably captures most of the unauthorized population, while also misclassifying some authorized immigrants as likely unauthorized. Indeed, I show in Table 6 that the correlation between these schemes is surprisingly small.

Fortunately, I show in Table 7 that each definition produces a qualitatively similar conclusion. Regardless of whether I include the public health insurance restriction from Borjas's (2017) residual imputation method, I estimate that universal E-Verify mandates reduced the probability that likely unauthorized immigrants were policyholders of employer-sponsored insurance by 3-percentage points (columns 1 and 2 row 1). This amounts to a 12-13 percent reduction relative to the sample mean. When using the classification employed by Amuedo-Dorantes and Bansak (2014), I estimate a near 13 percent reduction relative to the sample mean (column 3 row 1). Finally, when using Orrenius and Zavodny's (2015) classification, I estimate that an 18 percent relative to the sample mean (column 4 row 1).

In contrast to the universal E-Verify mandate estimates, the relationship between public E-Verify mandates and access to health insurance is sensitive to how I assign likely authorization status. Using both Borjas's (2017) and Amuedo-Dorantes and Bansak's (2014) methods, I estimate that public E-Verify mandates result in an 8-10 percent reduction in the probability that likely unauthorized immigrants were policyholders of employer-sponsored health insurance relative to the sample mean (columns 1-3 row 2). Meanwhile, the estimate using Orrenius and Zavodny's (2015) definition implies a statistically insignificant 1.2 percent reduction. In Table A9, I show that public mandates yield negative employment effects using both Borjas's (2017) and Amuedo-Dorantes and Bansak's (2014) methods, while the point estimate from Orrenius and Zavodny's (2015) method is small and positive. One interpretation of these patterns is Orrenius and Zavodny's (2015) definition better captures the unauthorized population, though another possibility is that the smaller sample size (75,510 vs. 129,211) leaves me underpowered to detect an effect. Indeed, the standard error using the Orrenius and Zavodny (2015) definition is two times larger than using the Borjas (2017) definition (0.012 vs. 0.006).

3.4.4. Spillovers onto US Citizens

There is growing evidence that interior immigration enforcement measures can harm US citizens, including children with unauthorized parents and spouses with unauthorized partners (Watson 2014; Novak et al. 2017; Amuedo-Dorantes et al. 2018; Torche and Sirois 2019; Churchill et al. 2020; East 2020; Vu 2020). In Table 8, I present suggestive evidence that E-Verify mandates reduced the probability that children with at least one likely unauthorized parent had health insurance coverage.[19]

First, I show in Table 8 that universal E-Verify mandates reduced the probability that citizen children with at least one likely unauthorized parent had health insurance coverage by almost 3 percentage points, though the estimate is not statistically significant after adjusting for the small number of treated clusters (column 1). Next, I show large and statistically significant

[19] The demographic controls include indicators for the child's age, citizenship status, and race/ethnicity, as well as indicators for mother's education, father's education, whether the mother was not present, and whether the father was not present. The results are robust to excluding the demographic controls, only focusing on children with likely unauthorized mothers, or only focusing on children with likely unauthorized fathers.

reductions in the probability that children were covered by private health insurance (column 2) without corresponding statistically significant increases in public insurance coverage (column 4). Together, these results suggest an overall reduction in insurance coverage for children with likely unauthorized parents. As a falsification test, I show that E-Verify mandates were unrelated to insurance coverage for children with native-born white non-Hispanic parents (columns 4-6).

In Table 9, I examine how E-Verify mandates affected the likelihood that adult native-born citizens in mixed-status households (i.e., residing with a likely unauthorized individual) had health insurance. First, I show that both universal and public E-Verify mandates reduced the likelihood that natives in mixed-status households had any form of health insurance (column 1). Next, I find that universal E-Verify mandates were associated with a nearly 5 percentage point reduction in the likelihood of private insurance coverage, though the estimate is statistically insignificant (column 2 row 1). I also find that both private and public E-Verify mandates were associated with a nearly 4 percentage point reduction in the probability that native-born citizens in mixed-status households had public insurance, and I do not document any meaningful relationship among white non-Hispanic adult citizens without immigrants in the household (columns 4-6).

Table 9 suggests that E-Verify mandates reduced the likelihood that native-born adult citizens in mixed-status households were enrolled in public health insurance. This pattern is consistent with prior work finding that intensified immigration enforcement affects native safety net participation. For example, Watson (2014) found that intensified immigration enforcement reduced the likelihood that children of noncitizen immigrants were enrolled in Medicaid, and Alsan and Yang (2019) found that police-based immigration enforcement reduced the probability that Hispanic citizens in mixed-status households participated in SNAP and SSI.

3.5. DISCUSSION

The United States is currently debating the future of immigration policy. Despite receiving significant attention from policymakers and the popular press, the full implications of many proposed policies remain under-studied. In this paper, I first show that E-Verify mandates reduced the probability that likely unauthorized immigrants were employed by 2-5 percentage points. This change is driven by a reduction in the likelihood of being employed for wages as opposed to being self-employed, working full-time as opposed to part-time, and working for large firms as opposed to smaller firms. However, I show that these changes were limited to one period after implementation of a universal E-Verify mandate. After that point, the estimated effect is smaller and statistically insignificant. I then show that these dynamics can be explained by likely unauthorized immigrants having exited the state.

Next, I show that E-Verify mandates reduced the probability that likely unauthorized immigrants had health insurance by 2-4 percentage points, a reduction attributable to reduced access to employer-sponsored health insurance. Consistent with the employment and migration patterns, I show that this change was limited to one period after implementation. Additionally, I find suggestive evidence that E-Verify mandates reduced health insurance coverage among children with likely unauthorized parents and native adults living in mixed-status households. For this latter group, I uncover evidence that E-Verify mandates reduced the probability that they enrolled in public health insurance. This finding adds to prior work showing that immigration enforcement affects native-born citizens' engagement with the US social safety net (Watson 2014; Alsan and Yang 2019).

Though President Trump made immigration reform a central issue of his presidential campaign, his administration failed in delivering a comprehensive immigration reform plan.

However, both Senators Cornyn (R-TX) and Graham (R-SC) have expressed optimism about working with the Biden administration on such a bill (The Hill, 2020), and E-Verify mandates will likely be a part of this conversation. For one, Senator Romney (R-UT) has called for instituting a nationwide E-Verify mandate (Romney 2019). Moreover, Senators Romney and Cotton (R-AR) recently introduced legislation instituting a nationwide E-Verify mandate as part of a proposal to raise the federal minimum wage to $10 an hour (Vox 2021). Yet President Biden has also called for expanding unauthorized immigrants' access to health insurance, including allowing them to receive public insurance (Washington Post 2019). In this paper, I show that immigration and health policy are not two distinct issues and attempts to address one will invariably have spillovers onto the other.

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Table 1: States implementing E-Verify mandates

State	Bill	Type	Passage Date	Implementation Date
Alabama	HB 56	Universal	06/09/2011	04/01/2012
Arizona	HB 2779	Universal	07/02/2007	12/31/2007
Colorado	HB 1343	Public	06/09/2006	08/07/2006
Florida	EO 11-02	Public	01/04/2011	01/04/2011
Georgia	SB 529	Public	04/17/2006	07/01/2007
Georgia	HB 87	Universal	05/13/2011	01/01/2012
Idaho	EO 09-10	Public	05/29/2009	07/01/2009
Indiana	SB 590	Public	05/10/2011	07/01/2011
Louisiana	HB 646	Universal	07/01/2011	08/18/2011
Michigan	HB 5365	Public	06/26/2012	03/01/2013
Minnesota	EO 08-01	Public	01/01/2008	01/01/2008
Mississippi	SB 2988	Universal	03/17/2008	07/01/2008
Missouri	HB 1549	Public	07/07/2008	01/01/2009
Nebraska	L 403	Public	04/08/2009	10/01/2009
North Carolina	SB 1523	Public	08/23/2006	01/01/2007
North Carolina	HB 36	Universal	06/23/2011	10/01/2012
Oklahoma	HB 1804	Public	05/08/2007	02/02/2010
Pennsylvania	SB 637	Public	07/05/2012	01/01/2013
Rhode Island	EO 08/01	Public	03/27/2008	10/17/2008
South Carolina	HB 4400	Public	06/04/2008	01/01/2009
South Carolina	SB 20	Universal	06/27/2011	01/01/2012
Tennessee	HB 1378	Universal	06/07/2011	10/01/2011
Texas	SB 372	Public	06/10/2015	09/01/2015
Utah	SB 81	Public	03/13/2008	07/01/2009
Utah	SB 251	Universal	03/31/2010	07/01/2010
Virginia	HB 737	Public	04/11/2010	12/01/2012
West Virginia	SB 659	Public	03/16/2012	06/24/2012

Source: National Conference of State Legislatures (2015); Urban Institute (2017).
Note: Louisiana and Tennessee originally had exceptions to E-Verify, whereby employers could instead just retain work authorization documentation. The results are not sensitive to excluding these states from those imposing universal mandates. Minnesota dropped E-Verify in April of 2008, though it was reinstated legislatively in July of that year. Rhode Island abandoned its E-Verify requirement in January 2011.

Table 2: Summary statistics of primary variables

	Likely Unauthorized Immigrants	Naturalized Immigrants	Hispanic Natives	White Non-Hispanic Natives
Universal Mandate	0.048	0.036	0.050	0.059
	(0.214)	(0.187)	(0.218)	(0.236)
Public Mandate	0.102	0.115	0.109	0.141
	(0.302)	(0.319)	(0.312)	(0.348)
Employed	0.668	0.722	0.653	0.714
	(0.471)	(0.478)	(0.476)	(0.452)
Employer-Sponsored Insurance				
Any	0.327	0.618	0.528	0.692
	(0.469)	(0.486)	(0.479)	(0.462)
Policyholder	0.231	0.432	0.356	0.470
	(0.422)	(0.495)	0.479	(0.499)
Dependent	0.110	0.224	0.199	0.260
	(0.303)	(0.417)	(0.399)	(0.439)
Observations	131,978	134,410	151,679	1,273,252

Sources: Current Population Survey Annual Social and Economic Supplement (ASEC) 2000-2016, National Council of State Legislatures (2015); Urban Institute (2017).

Note: Authorization status is assigned using the residual imputation method proposed by Borjas (2017). Specifically, a foreign-born person is considered to be authorized if s/he (a) arrived before 1980, (b) is a citizen, (c) receives Social Security benefits or SSI, (d) is a veteran or is currently in the Armed Forces, (e) works in the government sector, (f) resides in public housing or receives rental subsidies, or is the spouse of someone who resides in public housing or receives rental subsidies, (g) was born in Cuba, (h) works in an occupation requiring some form of licensing, (i) is the spouse of a legal immigrant or citizen. All remaining foreign-born persons are classified as likely unauthorized. The sample is restricted to individuals between the ages of 18 and 64 and summary statistics utilize the sample weights. The employment observations include 129,211 likely unauthorized immigrants, 129,948 naturalized citizens, 146,679 Hispanic natives, and 1,264,158 white non-Hispanic natives. Additional summary statistics are reported in Table A1.

Table 3: E-Verify Mandates and Unauthorized Immigrants' Employment Prospects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Employed	Works for Wages	Self-Employed	Full-time Status	Part-time Status	Employed at a Larger Firm	Employed at a Smaller Firm
Universal Mandate	-0.047**	-0.060**	0.009	-0.031	-0.013	-0.055***	0.007
	(0.010)	(0.013)	(0.005)	(0.013)	(0.008)	(0.008)	(0.010)
	[0.019]	[0.014]	[0.169]	[0.145]	[0.204]	[0.001]	[0.584]
Public Mandate	-0.016*	-0.015**	0.003	-0.018**	0.005	-0.023**	0.015
	(0.006)	(0.006)	(0.005)	(0.006)	(0.006)	(0.007)	(0.011)
	[0.055]	[0.035]	[0.518]	[0.038]	[0.548]	[0.024]	[0.227]
Dependent Variable Mean	0.668	0.680	0.058	0.567	0.116	0.252	0.439
Observations	129,211	129,211	129,211	129,211	129,211	131,978	131,978

Source: Current Population Survey Annual Social and Economic Supplement (ASEC) 2000-2016
Note: The dependent variable in column (1) is an indicator for whether the person was employed. The dependent variable in column (2) is an indicator for whether the individual typically works for wages, while the dependent variable in column (3) is an indicator for whether the individual is self-employed. The dependent variable in column (4) is an indicator for whether the individual is a full-time worker, while the dependent variable in column (5) is an indicator for whether the individual is a part-time worker. The dependent variable in column (6) is an indicator for whether the individual was employed at a firm with at least 100 employees, while the dependent variable in column (7) is an indicator for whether the individual was employed at a firm with between 1 and 99 employees. The dependent variables in columns (1)-(5) are measured contemporaneously, while the dependent variables in columns (6) and (7) refer to employment during the prior year. Accordingly, observations in columns (6) and (7) are matched to covariates during the prior year. he independent variables of interest are state-level indicators for having implemented a universal E-Verify mandate or a public E-Verify mandate. Each estimate includes the full set of controls from equation (2). Standard errors, shown in parentheses, are clustered at the state level. Wild bootstrap p-values are reported in brackets. Estimates utilize the sample weights.
*** p<0.01, ** p<0.05, * p<0.10

Table 4: E-Verify Mandates and Unauthorized Immigrants' Health Insurance Coverage

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		Private Health Insurance				Public Health Insurance		
	Any Health Insurance	Any Private Insurance	Employer-Sponsored Insurance Policyholder	Employer-Sponsored Insurance Dependent	Non-Employer Sponsored Private Insurance	Any Public Insurance	Medicaid	Medicare
Universal Mandate	-0.044**	-0.035*	-0.028**	0.002	-0.006	-0.010	-0.010	-0.001
	(0.017)	(0.012)	(0.008)	(0.008)	(0.007)	(0.011)	(0.012)	(0.002)
	[0.021]	[0.055]	[0.029]	[0.797]	[0.421]	[0.476]	[0.493]	[0.788]
Public Mandate	-0.037**	-0.027	-0.022**	-0.000	-0.005	-0.011	-0.012	0.000
	(0.012)	(0.013)	(0.007)	(0.005)	(0.008)	(0.006)	(0.006)	(0.001)
	[0.035]	[0.130]	[0.015]	[0.985]	[0.627]	[0.138]	[0.104]	[0.900]
Dependent Mean	0.480	0389	0.231	0.110	0.063	0.1088	0.104	0.004
Observations	131,978	131,978	131,978	131,978	131,978	131,978	131,978	131,978

Source: Current Population Survey Annual Social and Economic Supplement (ASEC) 2000-2016
Note: The dependent variable in column (1) is an indicator for whether the individual had any health insurance coverage (private insurance, Medicaid, or Medicare). The dependent variables in columns (2)-(5) refer to private insurance. The dependent variable in column (2) is an indicator for any private insurance coverage, in column (3) an indicator for being the policyholder for employer-sponsored health insurance, in column (4) an indicator for being a dependent on an employer-sponsored health insurance plan, and in column (5) an indicator for having non-employer-sponsored private insurance. The dependent variables in columns (6)-(8) reference public insurance. The dependent variable in column (6) is an indicator for having any public health insurance, in column (7) an indicator for Medicaid coverage, and in column (8) an indicator for Medicare coverage. The independent variables of interest are state-level indicators for having implemented a universal E-Verify mandate or a public E-Verify mandate. Each estimate includes the full set of controls from equation (2). Standard errors, shown in parentheses, are clustered at the state level. Wild bootstrap p-values are reported in brackets. Estimates utilize the sample weights.
*** p<0.01, ** p<0.05, * p<0.10

Table 5: E-Verify Mandates and the Likelihood of being the Policyholder for Employer-Sponsored Health Insurance

	(1)	(2)	(3)	(4)
	Likely-Unauthorized Immigrants	Naturalized Citizens	Hispanic Natives	White Non-Hispanic Natives
Universal Mandate	-0.028**	0.006	-0.003	0.001
	(0.008)	(0.008)	(0.011)	(0.008)
	[0.029]	[0.531]	[0.826]	[0.902]
Public Mandate	-0.022**	-0.006	-0.004	0.005
	(0.007)	(0.006)	(0.008)	(0.004)
	[0.015]	[0.354]	[0.718]	[0.698]
Dependent Variable Mean	0.231	0.432	0.356	0.471
Observations	131,978	134,410	151,679	1,273,252

Source: Current Population Survey Annual Social and Economic Supplement (ASEC) 2000-2016
Note: The dependent variable is an indicator for being the policyholder for employer-sponsored health insurance. The independent variables of interest are state-level indicators for having implemented a universal E-Verify mandate or a public E-Verify mandate. Each estimate includes the full set of controls from equation (2). The sample in column (1) includes likely unauthorized immigrants, the sample in column (2) naturalized citizens, the sample in column (3) Hispanic natives, and the sample in column (4) white non-Hispanic natives. Standard errors, shown in parentheses, are clustered at the state level. Wild bootstrap p-values are reported in brackets. Estimates utilize the sample weights.
*** p<0.01, ** p<0.05, * p<0.10

Table 6: Correlation in Alternative Criteria for Likely Unauthorized Classification

	(1)	(2)	(3)	(4)
	Borjas (2017) w/o Public Health Insurance Restriction	Borjas (2017) w/ Public Health Insurance Restriction	Amuedo-Dorantes and Bansak (2014)	Orrenius and Zavodny (2015)
Borjas (2017) w/o Public Health Ins. Restriction	1.000			
Borjas (2017) w/ Public Health Ins. Restriction	0.912	1.000		
Amuedo-Dorantes and Bansak (2014)	0.433	0.394	1.000	
Orrenius and Zavodny (2015)	0.372	0.335	0.682	1.000

Source: Current Population Survey Annual Social and Economic Supplement (ASEC) 2000-2016
Note: The table shows the correlation in foreign-born individuals classified as likely unauthorized using various strategies from the literature. The strategy used in this paper mimics Borjas (2017) but excludes the restriction on public health insurance. Specifically, a foreign-born person is considered to be authorized if s/he (a) arrived before 1980, (b) is a citizen, (c) receives Social Security benefits or SSI, (d) is a veteran or is currently in the Armed Forces, (e) works in the government sector, (f) resides in public housing or receives rental subsidies, or is the spouse of someone who resides in public housing or receives rental subsidies, (g) was born in Cuba, (h) works in an occupation requiring some form of licensing, (i) is the spouse of a legal immigrant or citizen. All remaining foreign-born persons are classified as likely unauthorized. Borjas (2017)—shown in column (2)—classifies an immigrant who receives public health insurance as being authorized. Amuedo-Dorantes and Bansak (2014) classify non-citizen Hispanic immigrants between 18 and 45 with at most a high school degree as being likely unauthorized. Orrenius and Zavodny (2015) consider an immigrant likely unauthorized if s/he is a non-citizen with at most a high school degree who was born in Mexico. The correlations utilize the sample weights.

Table 7: Robustness to Alternative Criteria for Likely Unauthorized Classification

	(1)	(2)	(3)	(4)
	Borjas (2017) w/o Public Health Insurance Restriction	Borjas (2017) w/ Public Health Insurance Restriction	Amuedo-Dorantes and Bansak (2014)	Orrenius and Zavodny (2015)
	Panel A: Employed			
Universal Mandate	-0.047**	-0.047***	-0.053**	-0.041**
	(0.010)	(0.010)	(0.012)	(0.010)
	[0.019]	[0.009]	[0.030]	[0.017]
Public Mandate	-0.016*	-0.016*	-0.012	0.000
	(0.006)	(0.007)	(0.008)	(0.012)
	[0.055]	[0.078]	[0.236]	[0.976]
Dependent Mean	0.668	0.689	0.673	0.645
Observations	129,211	115,936	81,384	74,510
	Panel B: Employer-Sponsored Health Insurance Policyholder			
Universal Mandate	-0.028**	-0.033**	-0.020	-0.030**
	(0.008)	(0.007)	(0.009)	(0.009)
	[0.029]	[0.012]	[0.124]	[0.032]
Public Mandate	-0.022**	-0.026***	-0.013	-0.002
	(0.007)	(0.007)	(0.007)	(0.009)
	[0.015]	[0.009]	[0.135]	[0.807]
Dependent Mean	0.231	0.249	0.156	0.166
Observations	131,978	117,514	81,388	75,404

Source: Current Population Survey Annual Social and Economic Supplement (ASEC) 2000-2016
Note: The dependent variable in Panel (A) is an indicator for whether the individual was employed, while the dependent variable in Panel (B) is an indicator for being the policyholder for employer-sponsored health insurance. Each column employs a different set of criteria for being classified as a likely unauthorized immigrant, with the specific restrictions being detailed in Table 6. The independent variables of interest are state-level indicators for having implemented a universal E-Verify mandate or a public E-Verify mandate. Each estimate includes the full set of controls from equation (2). Standard errors, shown in parentheses, are clustered at the state level. Wild bootstrap p-values are reported in brackets. Estimates utilize the sample weights.
*** p<0.01, ** p<0.05, * p<0.10

Table 8: E-Verify Mandates and Child Health Insurance Coverage

	(1)	(2)	(3)	(4)	(5)	(6)
	Children with Likely-Unauthorized Parents			Children with White Non-Hispanic Parents		
	Any Insurance	Private Insurance	Public Insurance	Any Insurance	Private Insurance	Public Insurance
Universal Mandate	-0.027	-0.045*	0.006	-0.005	-0.009	-0.006
	(0.016)	(0.015)	(0.015)	(0.005)	(0.011)	(0.012)
	[0.329]	[0.069]	[0.674]	[0.400]	[0.482]	[0.688]
Public Mandate	-0.020	-0.051*	0.038	-0.003	0.005	-0.011
	(0.018)	(0.019)	(0.024)	(0.004)	(0.006)	(0.007)
	[0.410]	[0.074]	[0.203]	[0.522]	[0.474]	[0.216]
Dependent Mean	0.785	0.300	0.533	0.932	0.817	0.168
Observations	65,487	65,487	65,487	364,783	364,783	364,783

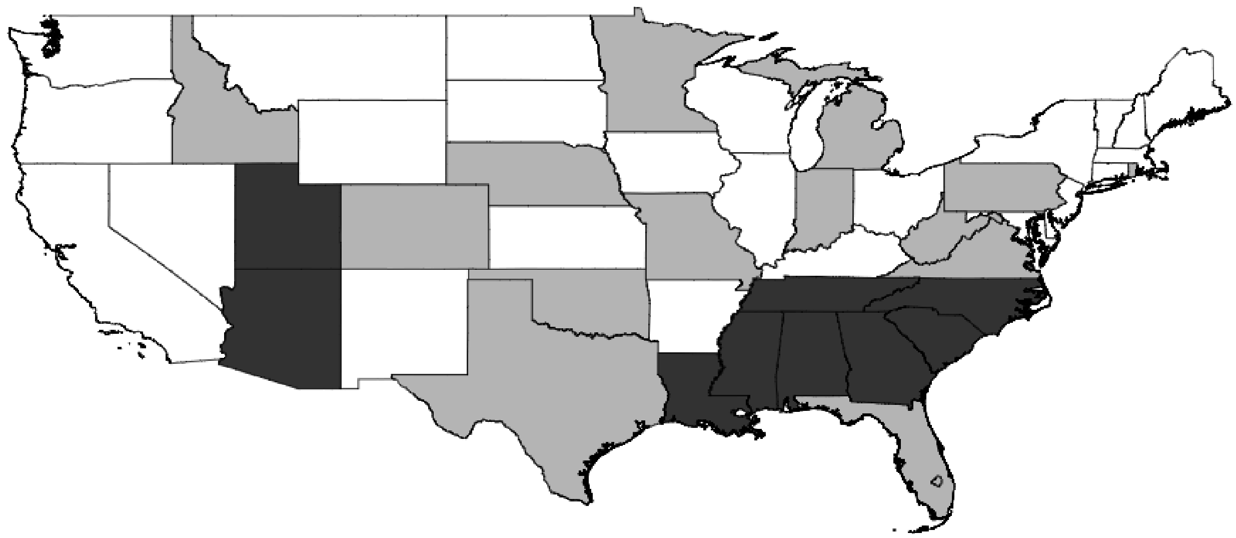
Source: Current Population Survey Annual Social and Economic Supplement (ASEC) 2000-2016
Note: The dependent variable in columns (1) and (4) is an indicator for whether the child has any (private or public) health insurance coverage. The dependent variable in columns (2) and (5) is an indicator for whether the child has private health insurance, while the dependent variable in columns (3) and (6) is an indicator for whether the child has public (Medicaid or SCHIP) coverage. The sample is limited to children 14 years of age or younger. The independent variables of interest are state-level indicators for having implemented a universal E-Verify mandate or a public E-Verify mandate. Each estimate controls for time-invariant state fixed effects, state-invariant year fixed effects, business cycle characteristics, immigration enforcement policies, health care policies, and demographics. The demographic controls include indicators for the child's age, the child's race/ethnicity (white, black, Hispanic, with other omitted), the child's citizenship (US citizen and naturalized citizen with non-citizen omitted), and indicators for parental education (less than high school, high school, some college, or college graduate, beyond college omitted, with missing information omitted). Columns (1)-(3) examine children that have either a likely unauthorized mother or a likely unauthorized father. Columns (4)-(6) examine children with white non-Hispanic citizen parents. Standard errors, shown in parentheses, are clustered at the state level. Wild bootstrap p-values are reported in brackets. Estimates utilize the sample weights.
*** p<0.01, ** p<0.05, * p<0.10

Table 9: E-Verify Mandates and Health Insurance Coverage of US Adult Citizens

	(1)	(2)	(3)	(4)	(5)	(6)
	Adult Citizens with a Likely Unauthorized Immigrant in the Household			White Non-Hispanic Adult Citizens without an Immigrant in the Household		
	Any Insurance	Private Insurance	Public Insurance	Any Insurance	Private Insurance	Public Insurance
Universal Mandate	-0.077	-0.046	-0.037	-0.009	-0.006	-0.004
	(0.040)	(0.045)	(0.025)	(0.006)	(0.006)	(0.005)
	[0.257]	[0.619]	[0.225]	[0.181]	[0.371]	[0.419]
Public Mandate	-0.034**	0.005	-0.036***	-0.003	-0.003	-0.001
	(0.015)	(0.019)	(0.010)	(0.003)	(0.003)	(0.003)
	[0.042]	[0.825]	[0.004]	[0.414]	[0.469]	[0.660]
Dependent Mean	0.785	0.300	0.533	0.932	0.817	0.168
Observations	20,753	20,753	20,753	1,229,901	1,229,901	1,229,901

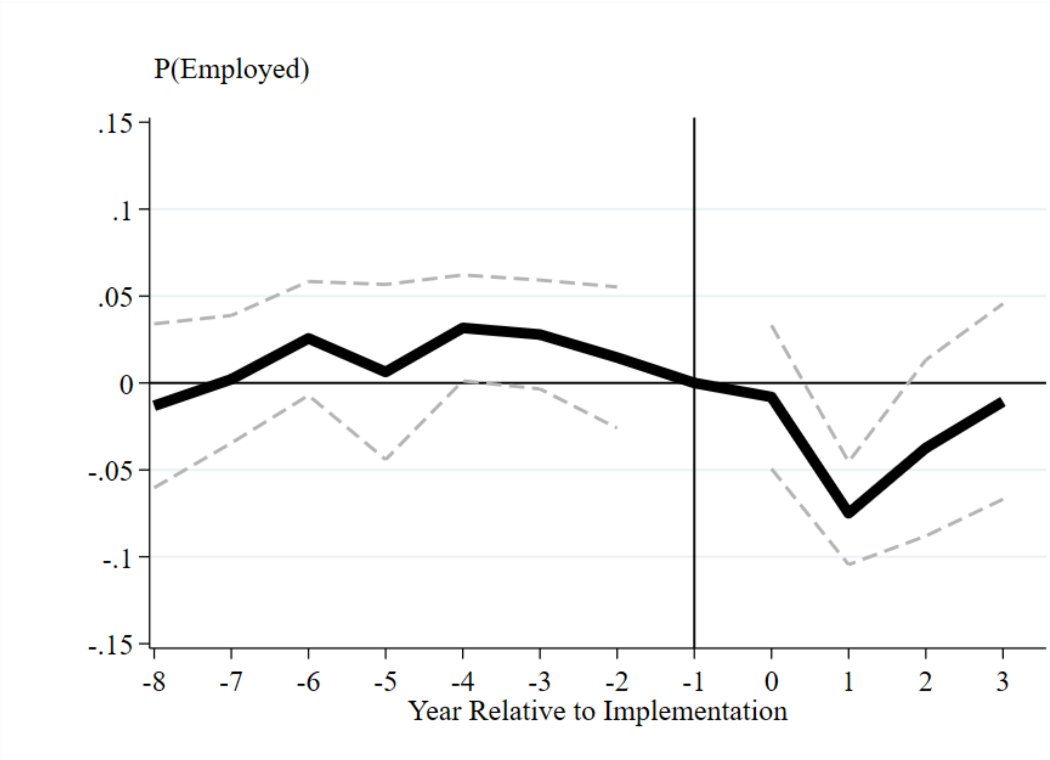
Source: Current Population Survey Annual Social and Economic Supplement (ASEC) 2000-2016
Note: The dependent variable in columns (1) and (4) is an indicator for whether the child has any (private or public) health insurance coverage. The dependent variable in columns (2) and (5) is an indicator for whether the child has private health insurance, while the dependent variable in columns (3) and (6) is an indicator for whether the child has public (Medicaid or SCHIP) coverage. The sample is limited to children 14 years of age or younger. The independent variables of interest are state-level indicators for having implemented a universal E-Verify mandate or a public E-Verify mandate. Each estimate controls for time-invariant state fixed effects, state-invariant year fixed effects, business cycle characteristics, immigration enforcement policies, health care policies, and demographics. The demographic controls include indicators for the child's age, the child's race/ethnicity (white, black, Hispanic, with other omitted), the child's citizenship (US citizen and naturalized citizen with non-citizen omitted), and indicators for parental education (less than high school, high school, some college, or college graduate, beyond college omitted, with missing information omitted). Columns (1)-(3) examine children that have either a likely unauthorized mother or a likely unauthorized father. Columns (4)-(6) examine children with white non-Hispanic citizen parents. Standard errors, shown in parentheses, are clustered at the state level. Wild bootstrap p-values are reported in brackets. Estimates utilize the sample weights.
*** p<0.01, ** p<0.05, * p<0.10

Figure 1: State E-Verify Mandates



Source: National Conference of State Legislatures (2015); Urban Institute (2017)
Note: Non-shaded states did not adopt an E-Verify mandate between 2000 and 2016. he lighter color indicates states which implemented at most a public E-Verify mandate, while the darker color indicates states which implemented a universal E-Verify mandate.

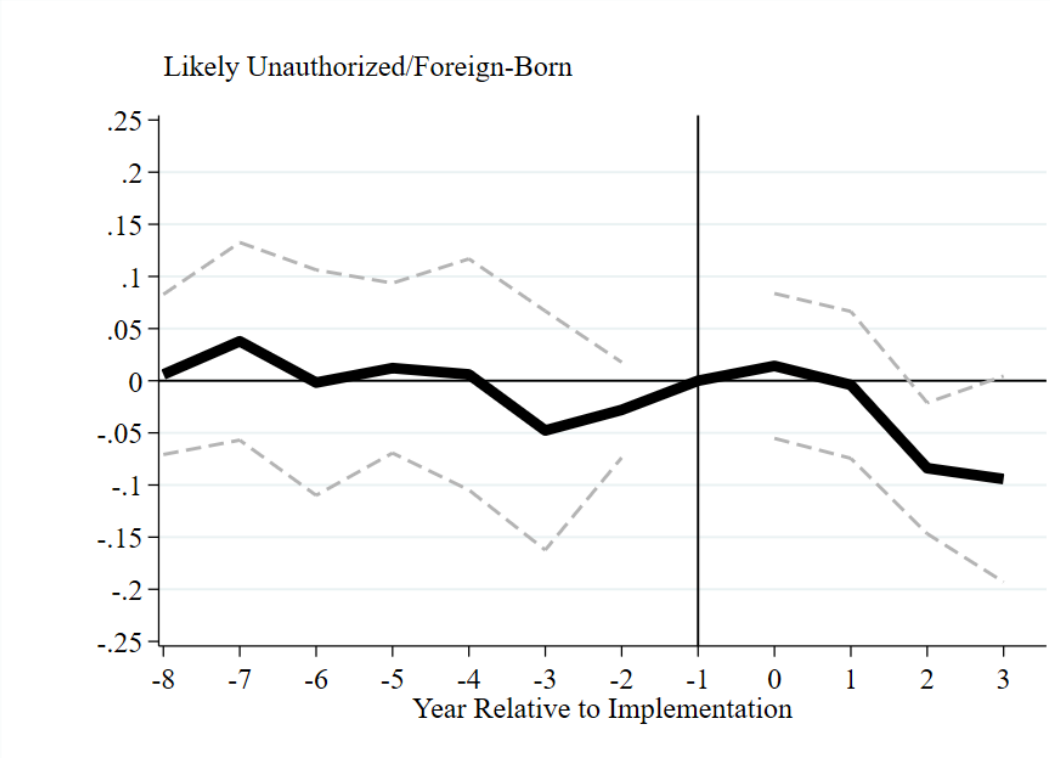
Figure 2: Event Study Estimates on State E-Verify Mandates and
Likely Unauthorized Immigrants' Employment



Source: Current Population Survey Annual Social and Economic Supplement (ASEC) 2000-2016

Note: The dependent variable is an indicator for whether the individual was employed. The figure plots the coefficients obtained from estimating equation (1) which captures how the relationship between universal E-Verify mandates and the dependent variables evolved over time. Exact coefficients and tests of joint significance are shown in Table A2. The estimates utilize the sample weights.

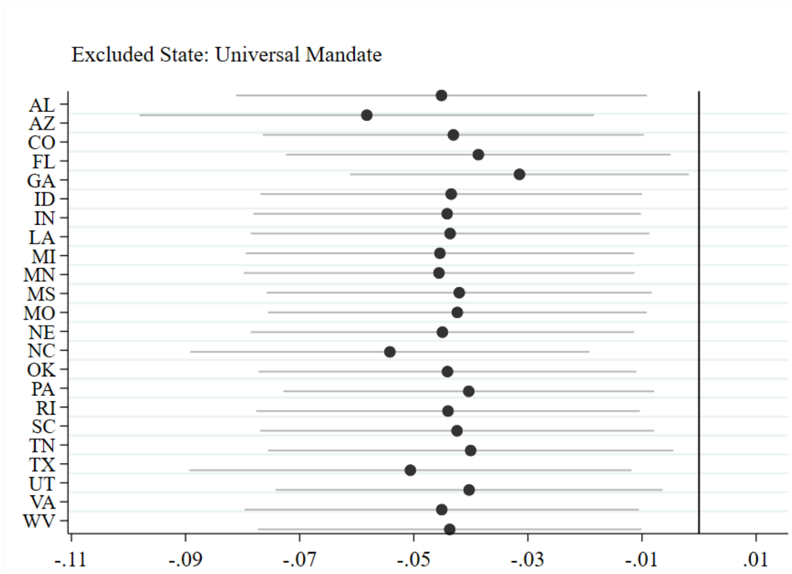
Figure 3: Event Study Estimates on State E-Verify Mandates and Foreign-Born Composition



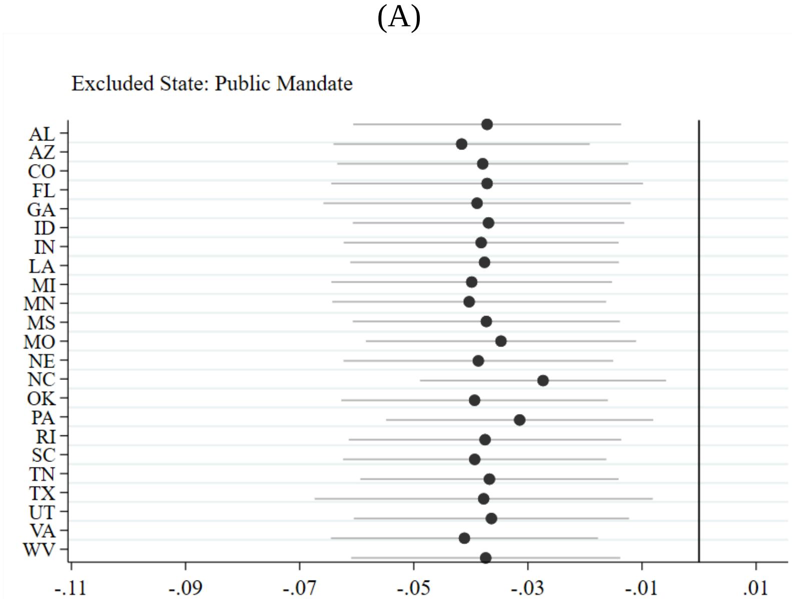
Source: Current Population Survey Annual Social and Economic Supplement (ASEC) 2000-2016

Note: The dependent variable is the share of the foreign-born population comprised of likely unauthorized immigrants. The figure plots the coefficients obtained from estimating equation (1) capturing how the relationship between universal E-Verify mandates and the dependent variable evolved over time. Exact coefficients and tests of joint significance are shown in Table A2. The estimates utilize the sample weights.

Figure 4: Robustness of the E-Verify/Health Insurance Relationship to Iteratively Excluding Each Treated State



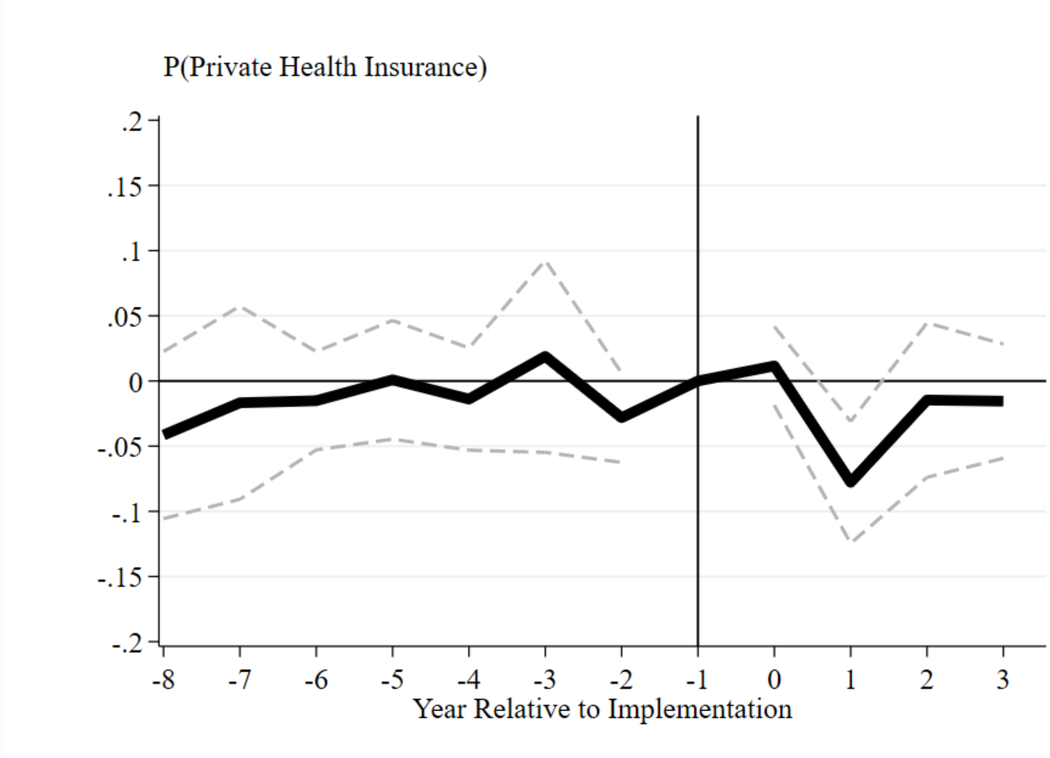
(A)



(B)

Source: Current Population Survey Annual Social and Economic Supplement (ASEC) 2000-2016
Note: The dependent variable is an indicator for whether the individual had health insurance. Both figures plot the estimated coefficients for the universal and public E-Verify mandate indicators from equation (2) after iteratively excluding each of the treated states. Panel (A) plots the universal mandate coefficient, while Panel (B) plots the public mandate coefficient. The dark circles indicate each point estimate, and the lighter lines denote 95 percent confidence intervals. The estimates utilize the sample weights.

Figure 5: Event Study Estimates on State E-Verify Mandates and Likely Unauthorized Immigrants' Access to Private Health Insurance



Source: Current Population Survey Annual Social and Economic Supplement (ASEC) 2000-2016
Note: The dependent variable is an indicator for whether the individual is covered by private health insurance. The figure plots the coefficients obtained from estimating equation (1) capturing how the relationship between universal E-Verify mandates and the dependent variable evolved over time. Exact coefficients and tests of joint significance are shown in Table A2. The estimates utilize the sample weights.

3.7. APPENDIX

Table A1: Additional summary statistics

	Likely-Unauthorized Immigrants	Naturalized Citizens	Hispanic Natives	White Non-Hispanic Natives
Education				
< High School	0.424	0.155	0.179	0.073
	(0.494)	(0.362)	(0.383)	(0.260)
High School Diploma	0.256	0.247	0.333	0.295
	(0.436)	(0.431)	(0.471)	(0.456)
Some College	0.130	0.233	0.340	0.313
	(0.336)	(0.423)	(0.474)	(0.464)
College Diploma	0.118	0.232	0.108	0.215
	(0.322)	(0.4220	(0.311)	(0.411)
Advanced Degree	0.072	0.133	0.039	0.105
	(0.259)	(0.339)	(0.195)	(0.307)
Demographics				
Age	35.508	44.252	34.173	41.525
	(10.828)	(11.680)	(12.570)	(13.301)
Hispanic	0.640	0.342	1.000	-
	(0.480)	(0.475)		
White	0.114	0.229	-	1.000
	(0.318)	(0.420)		
Black	0.058	0.099	-	-
	(0.233)	(0.299)		
Male	0.558	0.475	0.493	0.497
	(0.497)	(0.499)	(0.500)	(0.500)
Married	0.534	0.687	0.393	0.578
	(0.497)	(0.464)	(0.488)	(0.494)
Business Cycle Controls				
ln(Real Value of Residential	16.013	15.962	16.178	15.442
Building Permits)	(1.040)	(1.030)	(1.039)	(1.034)
State Unemployment Rate	6.524	6.727	6.713	6.227
	(2.167)	(2.228)	(2.158)	(2.053)
% Covered by Enforcement Policies				
287(g)	0.446	0.446	0.531	0.270
	(0.497)	(0.497)	(0.499)	(0.444)
Secure Communities	0.379	0.410	0.450	0.353
	(0.485)	(0.492)	(0.498)	(0.478)
% Covered by Health Policies				
Medicaid for Unauthorized	0.617	0.649	0.629	0.411
Pregnant Women	(0.486)	(0.477)	(0.483)	(0.492)
Public Insurance for LPR w/ in	0.425	0.484	0.387	0.249
5-year ban	(0.494)	(0.500)	(0.487)	(0.433)
Medicaid for LPR	0.710	0.743	0.715	0.557
Pregnant Women	(0.454)	(0.437)	(0.452)	(0.497)
Medicaid for LPR Kids	0.740	0.758	0.764	0.526
	(0.438)	(0.428)	(0.424)	(0.499)

Public Insurance for Unauthorized Kids	0.180	0.226	0.130	0.140
	(0.384)	(0.418)	(0.336)	(0.347)
Food Assistance for LPR Adults w/ in 5-year ban	0.306	0.325	0.320	0.168
	(0.461)	(0.468)	(0.466)	(0.374)
ACA Medicaid Expansion	0.190	0.234	0.233	0.134
	(0.392)	(0.423)	(0.423)	(0.340)
Observations	131,978	134,410	151,679	1,273,252

Sources: Current Population Survey Annual Social and Economic Supplement (ASEC) 2000-2016, National Council of State Legislatures (2015); Urban Institute (2017).
Note: The sample is restricted to individuals between the ages of 18 and 64 and summary statistics utilize the sample weights.

Table A2: Event-Study Coefficients

	(1)	(2)	(3)	(4)	(5)
		Employer-Sponsored Health Insurance			Likely Unauthorized/ Foreign-Born Population
	Employed	Any	Policyholder	Dependent	
Pre-Implementation					
-8	-0.005	-0.019	-0.037	0.010	-0.032
	(0.029)	(0.030)	(0.025)	(0.018)	(0.058)
-7	0.001	-0.013	-0.022	0.008	0.012
	(0.017)	(0.042)	(0.036)	(0.017)	(0.073)
-6	0.047**	0.017	0.025	-0.006	0.017
	(0.020)	(0.022)	(0.025)	(0.014)	(0.069)
-5	0.030	0.020	0.016	0.001	0.008
	(0.031)	(0.034)	(0.032)	(0.017)	(0.057)
-4	0.038*	-0.004	-0.006	-0.006	0.009
	(0.023)	(0.016)	(0.012)	(0.015)	(0.038)
-3	0.019	0.024	0.003	0.018	-0.008
	(0.015)	(0.034)	(0.028)	(0.017)	(0.035)
-2	0.025	-0.022*	-0.027**	-0.004	0.002
	(0.020)	(0.013)	(0.013)	(0.015)	(0.018)
Jointly Equal Zero?					
F-Stat	2.01	0.780	15.420	2.860	1.400
Prob>F	0.072	0.605	0.000	0.014	0.227
Post-Implementation					
0	0.000	-0.022	-0.024	0.001	-0.011
	(0.026)	(0.021)	(0.018)	(0.018)	(0.044)
1	-0.083***	-0.078	-0.052	-0.025	0.023
	(0.011)	(0.051)	(0.032)	(0.028)	(0.058)
2	-0.024	0.056	0.018	0.052*	-0.039
	(0.027)	(0.037)	(0.021)	(0.030)	(0.036)
3	-0.018	0.037	0.002	0.034**	-0.041
	(0.024)	(0.036)	(0.032)	(0.015)	(0.053)
Jointly Equal Zero?					

F-Stat	22.120	15.810	5.510	16.220	5.250
Prob>F	0.000	0.000	0.000	0.000	0.001
Pre=Post?					
F-Stat	16.820	32.990	32.990	49.350	11.350
Prob>F	0.000	0.000	0.000	0.000	0.000
Observations	129,211	131,978	131,978	131,978	867

Source: Current Population Survey Annual Social and Economic Supplement (ASEC) 2000-2016
Note: The dependent variable in column (1) is an indicator for being employed, while the dependent variable in column (2) is an indicator for being the policyholder of employer-sponsored health insurance. The dependent variable in column (3) is the share of the foreign-born population comprised of likely unauthorized immigrants. This share is calculated from the ASEC microdata using the sample weights, and the regression is weighted by the sum of these weights, while columns (1) and (2) retain the microdata structure and utilize the sample weights. The independent variables are indicators for being *j* periods away from the implementation of a universal E-Verify mandate. Each estimate controls for time-invariant state fixed effects, state-invariant year fixed effects, business cycle characteristics, immigration enforcement policies, and health care policies. Columns (1) and (2) also control for demographic characteristics. Column (3) does not include these controls because they are selected on the dependent variable. *** p<0.01, ** p<0.05, * p<0.10

Table A3: E-Verify Mandates and
Unauthorized Immigrants' Employment and Health Insurance Coverage

	(1)	(2)	(3)	(4)
		Health Insurance		
	Employed	Any	Private	Public
Universal Mandate	-0.050***	-0.050*	-0.032**	-0.021
	(0.009)	(0.025)	(0.016)	(0.018)
Public Mandate	-0.017***	-0.051***	-0.027*	-0.027***
	(0.006)	(0.014)	(0.014)	(0.009)
Unemployment Rate	-0.006*	-0.011**	-0.005	-0.010**
	(0.003)	(0.004)	(0.004)	(0.004)
ln(Building Permit Value)	0.014	0.009	0.012	-0.009
	(0.010)	(0.016)	(0.015)	(0.012)
287(g)	-0.003	-0.012	-0.013**	0.000
	(0.005)	(0.011)	(0.005)	(0.009)
Secure Communities	-0.004	0.016	0.013	0.005
	(0.008)	(0.011)	(0.011)	(0.006)
Medicaid for Unauthorized	0.002	-0.058***	-0.040**	-0.022
Pregnant Women	(0.018)	(0.021)	(0.016)	(0.014)
Public Insurance for LPR	0.018*	0.048***	0.018*	0.039***
Adults	(0.009)	(0.010)	(0.009)	(0.011)
Medicaid for LPR	-0.001	0.004	0.019	-0.019**
Pregnant Women	(0.014)	(0.017)	(0.016)	(0.009)
Medicaid for LPR	-0.004	0.008	0.018	-0.012
Children	(0.015)	(0.024)	(0.023)	(0.010)
Public Insurance for	0.005	0.024	-0.010	0.043*
Unauthorized Children	(0.007)	(0.020)	(0.011)	(0.025)
Food Assistance for LPR	0.042	-0.016	0.021	-0.043
Adults	(0.029)	(0.025)	(0.024)	(0.031)
ACA Medicaid Expansion	-0.004	0.043***	0.010	0.045***
	(0.008)	(0.011)	(0.010)	(0.011)
Male	0.321***	-0.035***	0.014**	-0.049***
	(0.017)	(0.008)	(0.005)	(0.008)
Hispanic	0.072***	-0.185***	-0.190***	0.003
	(0.008)	(0.017)	(0.016)	(0.011)
White	0.033***	-0.005	-0.020	0.012
	(0.009)	(0.017)	(0.015)	(0.014)
Black	0.034***	-0.043**	-0.070***	0.032*
	(0.007)	(0.017)	(0.017)	(0.016)
Less than High School	-0.081***	-0.318***	-0.408***	0.099***
	(0.017)	(0.013)	(0.014)	(0.020)
High School Diploma	-0.026*	-0.265***	-0.335***	0.082***

	(0.013)	(0.012)	(0.012)	(0.015)
Some College	-0.068***	-0.176***	-0.231***	0.066***
	(0.010)	(0.016)	(0.017)	(0.013)
College Degree	-0.045***	-0.113***	-0.136***	0.029***
	(0.007)	(0.013)	(0.014)	(0.005)
Married	-0.075***	0.072***	0.050***	0.030***
	(0.005)	(0.011)	(0.006)	(0.008)
Dependent Mean	0.668	0.480	0.389	0.107
Observations	129,211	131,978	131,978	131,978

Source: Current Population Survey Annual Social and Economic Supplement (ASEC) 2000-2016
Note: The dependent variable in column (1) is an indicator for being employed. The dependent variables in columns (2)-(4) relate to health insurance coverage. The dependent variable in column (2) is an indicator for having any health insurance coverage (private insurance, Medicaid, or Medicare). The dependent variable in column (3) is an indicator for private insurance coverage, while the dependent variable in column (4) is an indicator for public insurance (Medicaid or Medicare). The independent variables of interest are state-level indicators for having implemented a universal E-Verify mandate or a public E-Verify mandate. Each estimate controls for time-invariant state fixed effects, state-invariant year fixed effects, business cycle characteristics, immigration enforcement policies, health care policies, and demographics. Though not reported, the regressions also include indicators for each age, each state, and each year. Standard errors, shown in parentheses, are clustered at the state level. Each estimate utilizes the sample weights.
*** $p<0.01$, ** $p<0.05$, * $p<0.10$

Table A4: Robustness Tests

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Probit Estimation	Birthplace Control	Ever Treated	Excluding Census Region-by-Year FE	State-by-Great Recession Fixed Effects	Excluding States which had Expanded Medicaid via ACA	Years before the ACA Employer-Mandate was Supposed to be Implemented	Household Level Analysis
Universal Mandate	-0.046***	-0.047	-0.050**	-0.050*	-0.041	-0.049***	-0.046*	-0.041**
	(0.016)	(0.024)	(0.014)	(0.025)	(0.029)	(0.015)	(0.019)	(0.019)
	[0.007]	[0.112]	[0.015]	[0.079]	[0.303]	[0.009]	[0.085]	[0.043]
Public Mandate	-0.038**	-0.049***	-0.042**	-0.051***	-0.047**	-0.042**	-0.044*	-0.019
	(0.012)	(0.014)	(0.010)	(0.025)	(0.015)	(0.012)	(0.016)	(0.012)
	[0.016]	[0.007]	[0.030]	[0.005]	[0.012]	[0.020]	[0.057]	[0.189]
Mean	0.480	0.480	0.418	0.480	0.480	0.444	0.446	0.651
Observations	131,978	131,978	50,378	131,978	131,978	109,695	109,280	79,180

Source: Current Population Survey Annual Social and Economic Supplement (ASEC) 2000-2016.
Note: Each column indicates a separate regression. The dependent variable is an indicator for having health insurance. The independent variables of interest are indicators for whether the state had implemented a universal or public E-Verify mandate. Each estimate controls for time-invariant state fixed effects, state-invariant year fixed effects, business cycle characteristics, immigration enforcement policies, health care policies, and demographics. Column (1) utilizes a probit estimation framework and reports the marginal effects. Column (2) includes indicators for birthplace. Column (3) restricts the sample to states which ever enacted an E-Verify mandate. Column (4) excludes the census region-by-year fixed effects. Column (5) replaces the census region-by-year fixed effects with state-by-Great Recession years fixed effects, while column (6) excludes all state-years where the state had expanded Medicaid as part of the Affordable Care Act. Column (7) restricts the sample to 2000-2013 prior to when the ACA employer-mandate was supposed to be implemented. Column (8) analyzes households of individuals ages 18-64 possessing at least one likely unauthorized immigrant. The dependent variable is an indicator for whether at least one person in the household had health insurance. Standard errors, shown in parentheses, are clustered at the state level. Wild bootstrap p-values are reported in brackets, except for column (1) the p-values are obtained using a score bootstrap. Estimates utilize the sample weights.
*** p<0.01, ** p<0.05, * p<0.10

Table A5: Cross-State Spillovers

	(1)	(2)
Neighbor Universal Mandate	0.004	0.001
	(0.018)	(0.018)
	[0.865]	[0.970]
Neighbor Public Mandate	0.016	0.012
	(0.011)	(0.012)
	[0.239]	[0.393]
Universal Mandate		-0.041**
		(0.016)
		[0.031]
Public Mandate		-0.037**
		(0.012)
		[0.024]
Mean	0.480	0.480
Observations	131,978	131,978

Source: Current Population Survey Annual Social and Economic Supplement (ASEC) 2000-2016.
Note: Each column indicates a separate regression. The dependent variable is an indicator for having health insurance. The independent variables of interest are indicators for whether the neighboring state had implemented a universal or public E-Verify mandate, as well as indicators for whether the individual's state had implemented a universal or public E-Verify mandate. Each estimate controls for time-invariant state fixed effects, state-invariant year fixed effects, business cycle characteristics, immigration enforcement policies, health care policies, and demographics. Standard errors, shown in parentheses, are clustered at the state level. Wild bootstrap p-values are reported in brackets. Estimates utilize the sample weights.
*** p<0.01, ** p<0.05, * p<0.10

Table A6: Sensitivity of the Estimates to the Covariates

	(1)	(2)	(3)	(4)	(5)	(6)
	Employed			Policyholder for Employer-Sponsored Insurance		
	Specification			Specification		
	Base	Full	Explained	Base	Full	Explained
Universal Mandate	-0.055***	-0.047**	-0.020	-0.026	-0.028**	0.002
	(0.009)	(0.010)	(0.008)	(0.014)	(0.008)	(0.012)
	[0.004]	[0.019]		[0.135]	[0.029]	
Health Policies	N	Y	0.001	N	Y	0.001
Immigration Enforcement	N	Y	0.001	N	Y	-0.001
Business Cycle Controls	N	Y	-0.008	N	Y	-0.010
Demographic Characteristics	N	Y	-0.003	N	Y	0.006
Region-by-Year Fixed Effects	N	Y	-0.012	N	Y	0.006
Public Mandate	-0.012*	-0.016*	-0.004	-0.026**	-0.022**	-0.004
	(0.007)	(0.006)	(0.007)	(0.009)	(0.007)	(0.011)
	[0.099]	[0.055]		[0.019]	[0.015]	
Health Policies	N	Y	0.001	N	Y	-0.000
Immigration Enforcement	N	Y	0.000	N	Y	-0.000
Business Cycle Controls	N	Y	-0.004	N	Y	-0.005
Demographic Characteristics	N	Y	0.006	N	Y	0.004
Region-by-Year Fixed Effects	N	Y	-0.008	N	Y	-0.004

Source: Current Population Survey Annual Social and Economic Supplement (ASEC) 2000-2016
Note: The dependent variable in columns (1) and (2) is an indicator for being employed, while the dependent variable in columns (4) and (5) is an indicator for having being the policyholder for employer-sponsored health insurance. The independent variables are state-level indicators for having implemented a universal E-Verify mandate for at least half the year or a public E-Verify mandate for at least half the year. The coefficients in columns (1) and (4) are from a regression which includes state and year fixed effects, while those in columns (2) and (5) are from a regression including controls for health policies, immigration enforcement, business cycle characteristics, demographic controls, and census-region by year fixed effects. Standard errors, shown in parentheses, are clustered at the state level. Each estimate utilizes the sample weights. Columns (3) and (6) are from an order invariant conditional decomposition proposed by Gelbach (2016) to analyze how the covariates affect the estimates of interest. The sum of these numbers then explains the difference in the coefficients between columns (1) and (2) with any differences attributed to rounding error. The sample in columns (1) and (2) is 129,211 likely unauthorized immigrants, while the sample size in columns (4) and (5) is 131.978 likely unauthorized immigrants.
*** p<0.01, ** p<0.05, * p<0.10

Table A7: Estimates Stratified by Sex

	(1) Male Employment	(2) Female Employment	(3) Full Sample Employment	(4) Male Employer-Sponsored Insurance Coverage	(5) Female Employer-Sponsored Insurance Coverage	(6) Full Sample Employer-Sponsored Insurance Coverage
Universal Mandate	-0.045**	-0.040**	-0.040**	-0.031**	-0.026	-0.026
	(0.013)	(0.012)	(0.012)	(0.011)	(0.011)	(0.011)
	[0.045]	[0.031]	[0.030]	[0.042]	[0.132]	[0.114]
Public Mandate	-0.016	-0.012	-0.012	-0.021	-0.024*	-0.024*
	(0.011)	(0.013)	(0.013)	(0.010)	(0.010)	(0.010)
	[0.304]	[0.369]	[0.394]	[0.112]	[0.076]	[0.077]
Universal Mandate x Male			-0.005			-0.005
			(0.015)			(0.016)
			[0.718]			[0.755]
Public Mandate x Male			-0.003			0.003
			(0.020)			(0.015)
			[0.892]			[0.858]
Mean				0.453	0.513	0.480
Observations	69,151	60,060	129,211	70,412	61,566	131,978

Source: Current Population Survey Annual Social and Economic Supplement (ASEC) 2000-2016.

Note: Each column indicates a separate regression. The dependent variable in columns (1)-(3) is an indicator for being employed. The dependent variable in columns (4)-(6) is an indicator for being the policyholder for employer-sponsored health insurance. The independent variables are indicators for whether a state implemented a universal E-Verify mandate or a public mandate for at least half the year. Each estimate controls for time-invariant state fixed effects, state-invariant year fixed effects, business cycle characteristics, immigration enforcement policies, health care policies, and demographics. Columns (1) and (4) examine only men, columns (2) and (5) only women, and columns (3) and (6) employ a triple-difference specification whereby the full sample is analyzed, and the male indicator is interacted with all the covariates. Standard errors, shown in parentheses, are clustered at the state level. Wild bootstrap p-values are reported in brackets, except for column (1) the p-values are obtained using a score bootstrap. The estimates utilize the sample weights.

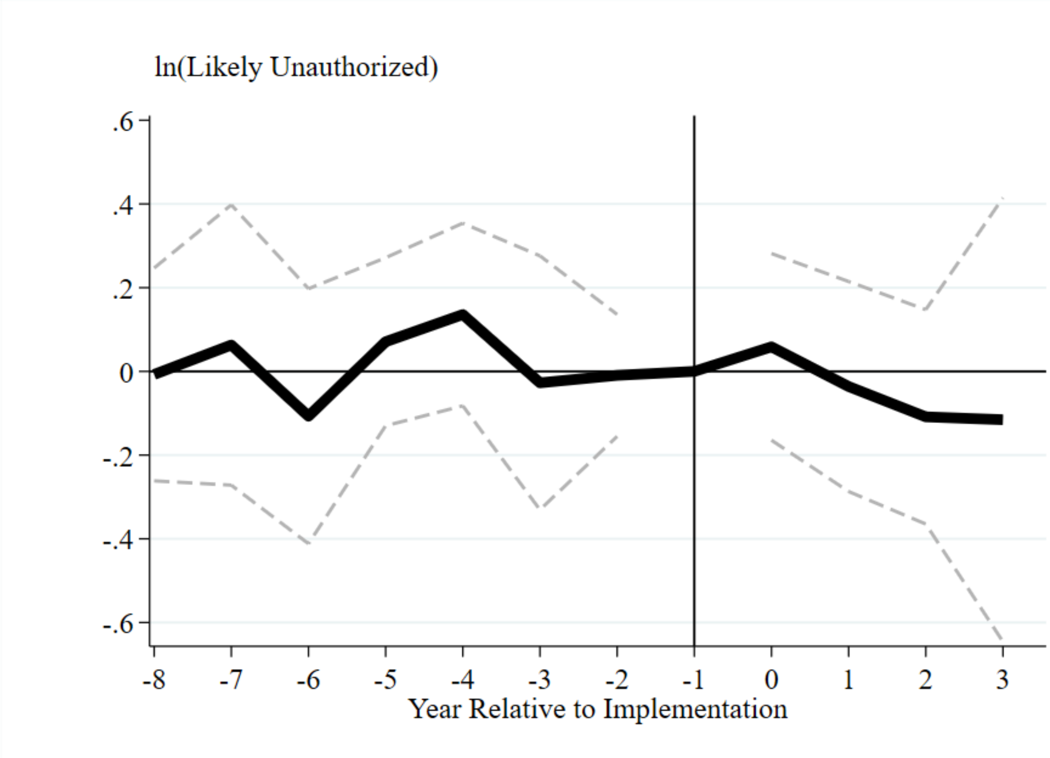
*** p<0.01, ** p<0.05, * p<0.10

Table A8: Triple-Difference Specification Relating E-Verify Mandates to Likely Unauthorized Immigrants Health Insurance Coverage

	(1)	(2)	(3)
Comparison Group →	Naturalized Citizens	Hispanic Natives	White Non-Hispanic Natives
Universal Mandate	0.006	-0.003	0.001
	(0.008)	(0.011)	(0.006)
	[0.532]	[0.832]	[0.893]
Public Mandate	-0.006	-0.004	0.002
	(0.006)	(0.008)	(0.004)
	[0.329]	[0.729]	[0.752]
Universal Mandate x Comparison Group	-0.034**	-0.025	-0.029**
	(0.008)	(0.010)	(0.009)
	[0.011]	[0.182]	[0.047]
Public Mandate x Comparison Group	-0.016*	-0.018	-0.024**
	(0.008)	(0.011)	(0.009)
	[0.091]	[0.141]	[0.024]
Dependent Variable Mean	0.333	0.296	0.448
Observations	266,388	283,657	1,405,230

Source: Current Population Survey Annual Social and Economic Supplement (ASEC) 2000-2016
Note: The dependent variable is an indicator for being the policyholder for employer-sponsored health insurance. The independent variables of interest are state-level indicators for having implemented a universal E-Verify mandate or a public E-Verify mandate, as well as the interaction of these indicators with an indicator for being likely unauthorized. Each estimate includes the full set of controls from equation (2) and all of these covariates (including the state, year, and region-by-year fixed effects) are interacted with an indicator for being likely unauthorized. The sample in column (1) includes likely unauthorized immigrants and naturalized citizens. The sample in column (2) includes likely unauthorized immigrants and Hispanic natives. The sample in column (3) includes likely unauthorized immigrants and white non-Hispanic natives. Standard errors, shown in parentheses, are clustered at the state level. Wild bootstrap p-values are reported in brackets. Estimates utilize the sample weights.
*** p<0.01, ** p<0.05, * p<0.10

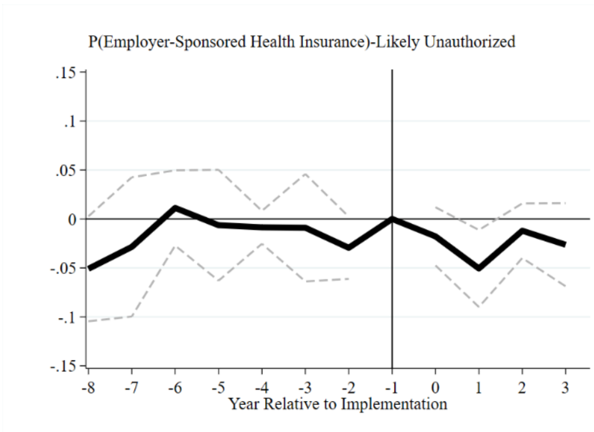
Figure A1: Event Study Estimates on State E-Verify Mandates and Likely Unauthorized Immigrant Mobility



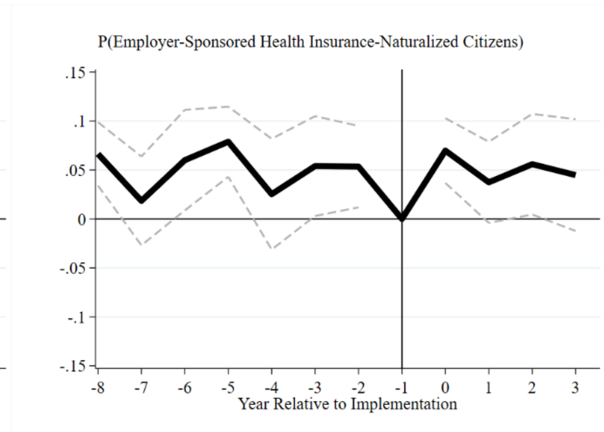
Source: Current Population Survey Annual Social and Economic Supplement (ASEC) 2000-2016

Note: The dependent variable is the natural log of the number of likely unauthorized immigrants in the state. The figure plots the coefficients obtained from estimating equation (1) which captures how the relationship between universal E-Verify mandates and the dependent variables evolved over time. The estimates utilize the sample weights.

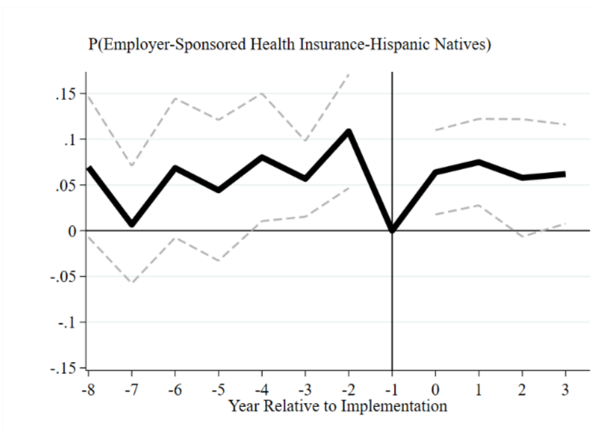
Figure A2: Event Study Estimates for
Employer-Sponsored Health Insurance and Placebo Groups



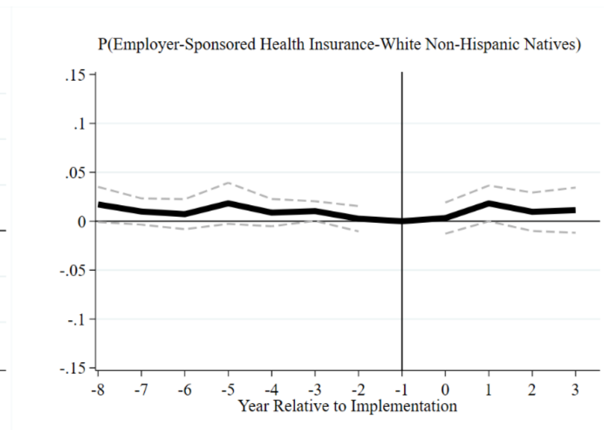
(A)



(B)



(C)



(D)

Source: Current Population Survey Annual Social and Economic Supplement (ASEC) 2000-2016
Note: The dependent variable is an indicator for being the policyholder for employer-sponsored health insurance. Panel (A) restricts the sample to likely unauthorized immigrants, Panel (B) naturalized citizens, Panel (C) Hispanic natives, and Panel (D) white non-Hispanic natives The figure plots the coefficients obtained from estimating equation (1) which captures how the relationship between universal E-Verify mandates and the dependent variables evolved over time. The estimates utilize the sample weights.