INSURANCE COVERAGE, PROVIDER CONTACT, AND TAKE-UP OF THE HPV VACCINE

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ABSTRACT
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 this paper, 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 checkup, and knowledge about the HPV vaccine. Supporting this pathway, I show that Medicaid expansion states saw increased searches for "pediatrician," "Gardasil" (a trade name of the HPV vaccine), and "HPV cancer."

KEYWORDS: HPV, vaccine, Medicaid expansion
JEL CLASSIFICATION: I13, I20, I38

I. 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 United States, 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.

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2006). However, the HPV vaccine is more expensive than most other vaccines. Each injection costs around $250 (CVS 2020), and two injections are required over a 6- to 12-month period (CDC 2020).[1] 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, policy makers 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 credible 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, nonwhite 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- to 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 (1) increased take-up of public insurance by already-eligible but unenrolled teens and/or (2) 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, 40 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 checkup 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),

1 As a comparison, the seasonal flu vaccine costs $50, the meningitis vaccine costs $159, the chicken pox vaccine costs $166, and the Tdap vaccine costs $95.

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 policy makers. 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 II 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 III, I provide an overview of the NIS-Teen data and explain my difference-in-differences estimation strategy. I then show in Section IV 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 that help to explain this relationship. I conclude in Section V by discussing the policy implications of my estimates and areas for future research.

II. 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.

A. POLICY BACKGROUND AND VACCINATION RESEARCH

Gardasil was approved for females ages 9–26 in June 2006, and the Advisory Committee on Immunization Practices (ACIP) initially recommended a three-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 2009, the US Food and Drug Administration (FDA) approved the vaccine for teen boys and men (FDA 2009). In 2016, ACIP revised their guidelines to now recommend only two 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 that can be broadly categorized as those that (1) lower vaccines' costs, (2) increase knowledge about vaccines' benefits, and

(3) mandate 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 to 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 2008–12 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 because of 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 three states and the District of Columbia require students to receive the HPV vaccine for school attendance.[2] 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 the HPV vaccine school requirement in Washington, DC, increased the probability that teen boys (girls) initiated HPV vaccination by 20 (12) percentage points. While few states require 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 The states and implementation dates are Virginia (2008), Rhode Island (2015), and Hawaii (2020). Washington, DC, began requiring girls to obtain the vaccine in 2009 and boys in 2014.

B. 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 (FPL) 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 SCHIP 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 SCHIP 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 Health Insurance 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) 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.

III. Data and 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.

A. DATA

I utilize provider-verified vaccination data from the 2010–18 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.[3]

In Figure 1, I show the states that had expanded Medicaid as part of the Affordable Care Act as of 2018 (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 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 with non-expansion states over the sample period (0.51 vs. 0.45).[4] 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 with 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).

3 I analyze 2010–18 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 cell phone respondents. For 2011 they provide survey weights comparable to the 2008–10 period, though they provide only 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.

4 I present summary statistics for the remaining variables in Online Appendix Table A1. In Online Appendix Table A2, I show that the HPV vaccination summary statistics are similar when not utilizing the sample weights. I plot the unweighted statistics in Online Appendix Figure A1.

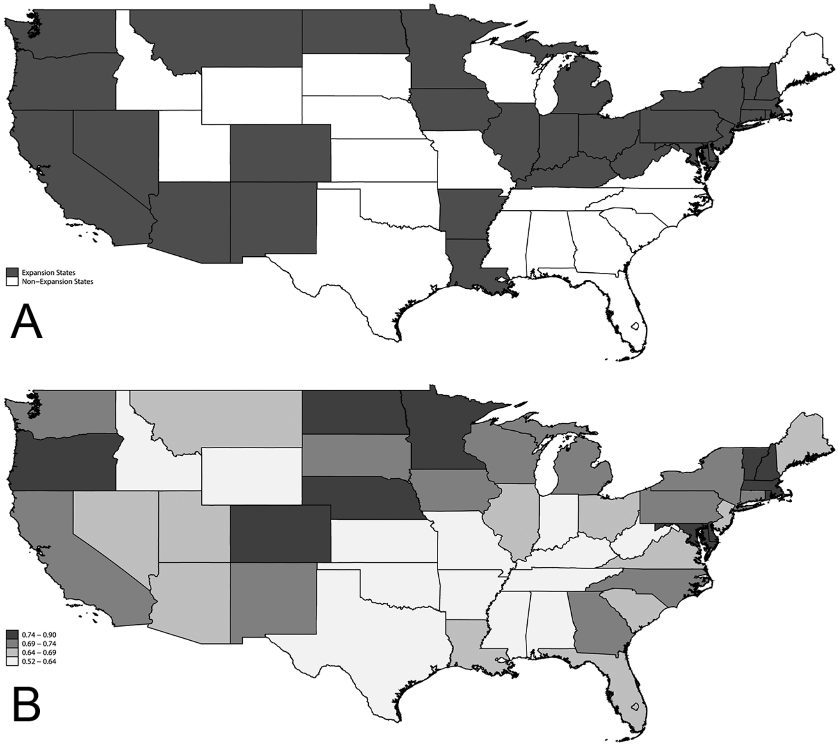

FIGURE 1. Medicaid expansion and teen HPV vaccination rates as of 2018. A: States (shaded darker) that had expanded Medicaid as of 2018. B: State HPV vaccination rates for teens in 2018. Sources: National Immunization Survey–Teen, 2018 (CDC 2018); Kaiser Family Foundation (2020).

B. 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:

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

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.[5] The η_{Pre} and η_{Post} indicator variables

5 In order to have direct comparability to my two-way fixed-effects specification, I analyze observations from every state. However, I show in Online Appendix Table A1 that my results are robust to dropping states that expanded Medicaid prior to 2014 and analyzing a balanced panel of states. Because my data begin in 2010, I can have at most four pre-periods in a balanced panel. Similarly, the final observed policy change in the data occurs in 2016, so I can have at most three post-periods.

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

		Expansion states			Non-expansion states		
	Full sample (1)	All years (2)	2010 (3)	2018 (4)	All years (5)	2010 (6)	2018 (7)
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 (CDC 2010–18).
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. The first row displays the average vaccination rate. The second row reports the standard deviation in brackets, and the third row reports the number of observations. All summary statistics utilize the sample weights.

capture observations occurring more than four years prior to Medicaid expansion and more than two years post-expansion, so as to ensure that the coefficient is due to the policy and not to changes in the sample of states being analyzed at each period. I also include time-invariant state fixed effects, θ_s, and location-invariant year 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:

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

The vector $\mathbf{D}'$ includes individual-level demographic controls about the teen and the teen's mother that 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 (6th–8th, 9th–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 (≤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, \$20K–30K, \$30K–40K, and \$40K–50K, with \$50K+ omitted).

I control for state-level time-varying characteristics in the vector $\mathbf{X}'$, including the state unemployment rate. I also control for whether the state requires middle school students to obtain the Tdap or meningococcal vaccines, policies that 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 awarded 22 states with money 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.

IV. 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 nonwhite teens. Data on provider visits and Google search results suggest that Medicaid expansion improved HPV vaccine coverage by increasing contact with health-care providers.

A. 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 Online Appendix 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

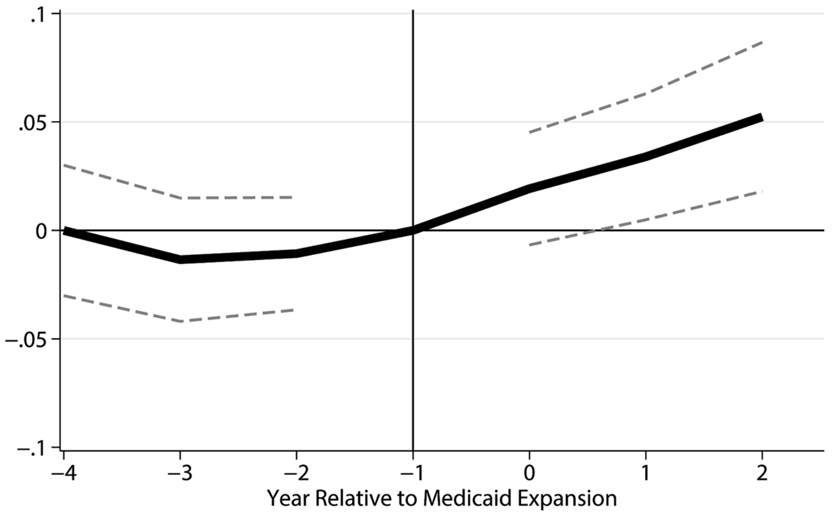

FIGURE 2. HPV vaccination

TABLE 2. Medicaid expansion was associated with an increase in HPV vaccination

	(1)	(2)	(3)	(4)
Medicaid expansion	0.041[a] (0.013)	0.039[a] (0.013)	0.035[a] (0.011)	0.033[b] (0.015)
State and year fixed effects?	Y	Y	Y	Y
Demographic controls?	N	Y	Y	Y
State-level covariates?	N	N	Y	Y
State-specific linear time trends?	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, $20K–30K, $30K–40K, $40K–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.
$^{a}p < 0.01$, $^{b}p < 0.05$, $^{c}p < 0.10$.

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.[6]

In Table 2, 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 whether a

6 In Online Appendix 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.

TABLE 3. The relationship between Medicaid expansion and HPV vaccination is robust to alternative sample restrictions

	Including providers with inadequate data (1)	Sample years (2008–13) (2)	Only expansion states (3)	Excluding sample weights (4)	Excluding states ever enacting HPV vaccine school requirements (5)	Excluding states receiving CDC funding for HPV vaccination (6)
Medicaid expansion	0.030[b]	0.051[a]	0.030[c]	0.018[b]	0.034[b]	0.039[b]
	(0.014)	(0.016)	(0.017)	(0.007)	(0.015)	(0.014)
Mean	0.470	0.297	0.508	0.484	0.486	0.482
Observations	176,536	111,154	104,254	172,891	163,896	105,048

Source: National Immunization Survey–Teen (CDC 2010–18).
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 2008–13 period, prior to the survey redesign. Column 3 examines only states that ever expanded Medicaid as part of the Affordable Care Act. Column 4 performs the analysis without sample weights. Column 5 excludes states that ever implemented an HPV vaccine school requirement. Column 6 excludes states that 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. [a]$p < 0.01$, [b]$p < 0.05$, [c]$p < 0.10$.

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).[7] Next, I modify the sample period to the directly comparable years 2008–13 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

7 In Online Appendix Table A4, I show that Medicaid expansion was unrelated to whether a teen was classified as having adequate provider data.

is not due to the survey modification. In order to account for possible differences between expansion and non-expansion states that may be correlated with HPV vaccination, I next limit my sample to states that 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 cell phone respondents. This switch led to a change in the survey weights. While the move to including cell phone 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 with untreated states, as opposed to comparing early treatment states to later treatment states. First, I show in Online Appendix Table A5 that the difference-in-differences point estimate is largely due to comparing treated states with states that never expanded Medicaid as part of the ACA, comparable to difference-in-differences when there is not variation in treatment timing. In Online Appendix Table A6, I then restrict my sample to observations from states that 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).[8]

8 In Online Appendix Table A7, I show the estimates stratified by sex. While the point estimate is larger for teen boys than for 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.

TABLE 4. The increase in HPV vaccination was larger for poorer teens, those whose mothers lacked college degrees, and nonwhite teens

	≤200% FPL (1)	>200% FPL (2)	Mother lacked BA (3)	Mother had BA (4)	Nonwhite (5)	White (6)
Medicaid expansion	0.047[a]	0.020	0.047[b]	0.009	0.057[b]	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 (CDC 2010–18).
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. [a]$p < 0.01$, [b]$p < 0.05$, [c]$p < 0.10$.

I also show that while nonwhite 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 nonwhite 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 2019). If they are aware of this disparity, the parents of nonwhite teens may be more 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 nonwhite patients (Cooper and Roter 2003; Johnson et al. 2004). Accordingly, in a review of the HPV vaccine literature, Spencer, Calo, and Brewer (2019) found that nonwhite 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 nonwhite 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 nonwhite teens (Table 4, column 3, rows 4–6).

At this point, it is useful to compare these estimates with the broader literature on HPV vaccination. Perhaps most comparable to this study, Lipton and Decker (2015, 761, Exhibit 3) 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. 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, 114, Table 3) found that middle school Tdap vaccination requirements increased HPV vaccine initiation by 4–5 percentage points. 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 these data are 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 had been vaccinated, while the provider-verified data indicates that 46 percent of teens were vaccinated. In 2018, 64 percent of parents reported HPV vaccination, compared with 69 percent of vaccine providers. Nevertheless, I show in Table 5 that Medicaid expansion was associated with a 2 percentage point increase in parental-reported HPV vaccination (column 1). In Online Appendix Table A8, I show that the increase was concentrated among poorer teens, teens whose mothers lacked college degrees, and nonwhite teens.[9]

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).[10] However, this relationship may vary if students are required to obtain 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

9 For the 2010–13 data, the interviewer first asked the parent whether they had a shot card 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 shot card available, the HPV vaccine question was based entirely on recall. In 2014, the NIS-Teen began only asking parents to recall whether the teen had been vaccinated against HPV. In Online Appendix Table A8, I drop observations drawn from shot cards during the 2010–13 period. I continue to find an approximately 2 percentage point increase in HPV vaccine take-up, though the estimate is less precise.

10 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 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.

TABLE 5. Medicaid expansion was associated with increased HPV vaccine completion

		Provider verified						
			Tdap vaccine			Meningococcal vaccine		
	Parental-reported HPV vaccine initiation (1)	Complete HPV vaccination (2)	Overall (3)	School requirement (4)	No school requirement (5)	Overall (6)	School requirement (7)	No school requirement (8)
Medicaid expansion	0.023[a]	0.021[b]	0.008	−0.008	0.033[c]	0.013[c]	−0.016	0.017[b]
	(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 (CDC 2010–18).

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 from either recall or a shot card. The dependent variable in column 2 is an indicator for whether the provider-verified immunization records indicate that the child has received three 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 7 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. [a]$p < 0.01$, [b]$p < 0.05$, [c]$p < 0.10$.

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).

B. 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 nonwhite teens (column 6) and a 1 percentage point increase for white teens (column 7).

In Online Appendix 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

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

	Full sample (1)	≤200% FPL (2)	>200% FPL (3)	Mother lacked BA (4)	Mother had BA (5)	Nonwhite (6)	White (7)
Medicaid expansion	0.013[b]	0.018[b]	0.009[b]	0.016[b]	0.007	0.019[b]	0.008[b]
	(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 (CDC 2010–18).

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. [a]$p < 0.01$, [b]$p < 0.05$, [c]$p < 0.10$.

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.[11] 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 Online Appendix Table A10 that the estimated increase in insurance coverage is actually larger if I restrict my sample to the 2010–15 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 (2019) found a 3 (5) percentage point increase in the probability that a child had any (public) health insurance (Table 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 to 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

11 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 (1) employer-sponsored insurance, (2) Medicaid, (3) SCHIP, (4) Medicaid or SCHIP, (5) Indian Health Service, military health care, Tricare, CHAMPUS, or CHAMP-VA, or (6) 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 that harmonizes the underlying data. I define a teen as on public health insurance of s/he is covered by Medicaid or SCHIP from 2010 to 2015 and if s/he is covered by Medicaid from 2016 to 2018. I show in Online Appendix Table A10 that my estimates are robust to using only the 2010–15 period.

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 that cannot be fully explained by increased insurance coverage.

C. 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 checkup 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 whether their child will receive the HPV vaccine within the next 12 months, as well as their specific reasons for not vaccinating.[12] I find that parents

12 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 seventh most frequently stated reason—given that Medicaid expansion may have reduced the cost of the vaccine through increased health insurance coverage.

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

			Reason for not vaccinating				
	Had a recent checkup (1)	Has been recommended the HPV vaccine (2)	Not needed (3)	No recommendation (4)	Lack of knowledge (5)	Safety concerns (6)	Cost (7)
Medicaid expansion	0.022[b]	0.016	−0.009	0.009	−0.018[a]	0.001	0.013[a]
	(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 (CDC 2010–18).

Note: The dependent variable in column 1 is an indicator for whether the parent reports that the child had a checkup 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. [a]$p < 0.01$, [b]$p < 0.05$, [c]$p < 0.10$.

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 checkup 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 Online Appendix 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 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,

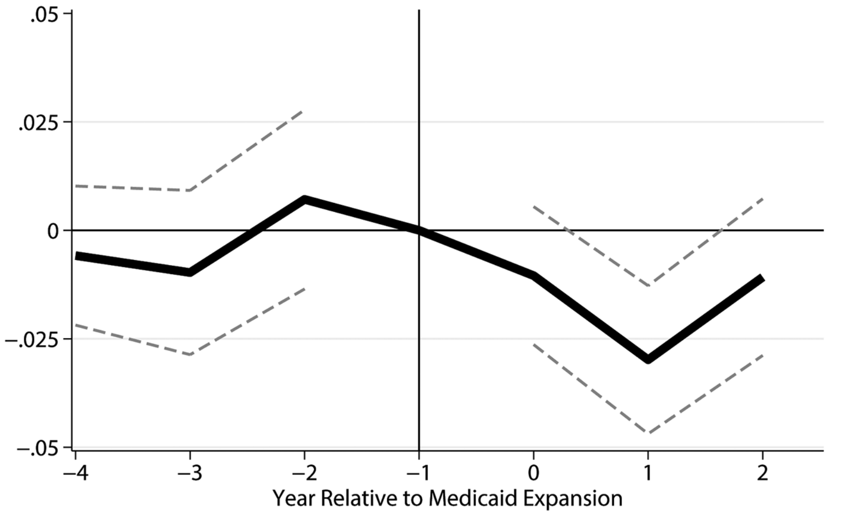

FIGURE 3. Lack of knowledge as a reason for not vaccinating

TABLE 8. Medicaid expansion was associated with increased Google searches of terms related to obtaining the HPV vaccine

	Medicaid (1)	Pediatrician (2)	HPV (3)	HPV cancer (4)	Gardasil (5)
Medicaid expansion	8.206[a]	3.251[b]	1.890	2.506[c]	2.540[c]
	(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, 2010–18.

Note: 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. [a]$p < 0.01$, [b]$p < 0.05$, [c]$p < 0.10$.

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, they do 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 checkup 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).[13] 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.

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

V. 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 nonwhite 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 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 checkup. 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 that 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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