# 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 by increases in Medicaid coverage, the probability of having a recent check-up, 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:** I13; I20; I38

## 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 between 2008 and 2012 nearly 40,000 people annually were diagnosed with an HPV-related cancer (Van Dyne et al. 2018). Nearly 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 near 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 two injections are required over a 6-12 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, 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),

[1] 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.

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 expansions 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—groups that I show were more likely to be covered by Medicaid. This result is most similar to Lipton and Decker (2015) who linked the ACA's dependent coverage provision to an increase in the probability that 19-25 year old women initiated the HPV vaccine. While this is an important result, my study builds on it in several notable ways. For one, 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 receive that vaccine prior to sexual initiation (CDC 2020). As such, identifying a way to increase vaccination among teens less likely to have had sex is an important contribution.

Importantly, I provide the first evidence on the pathways through which insurance coverage may increase HPV vaccination. I show that teens in Medicaid expansion were more likely to have had a recent check-up, and that their parents report improved knowledge about the HPV vaccine. Using Google Trends data, I 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 a teen girl received the HPV vaccine, presumably by increasing contact with health care providers. Finally, Lipton and Decker (2015) did not present estimates for young males, and Carpenter and Lawler (2019) did not identify any increases in vaccination for teen boys. As such, I provide the first evidence of increased vaccine take-up for teen boys related to insurance coverage. This last point is especially critical because the incidence of male oral cancer now exceeds to incidence of cervical cancer in women (Mourad et al. 2017).

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.

In Section 2, I discuss 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. Finally, I conclude in Section 5 by discussing the policy implications of my estimates and areas for future research.

## 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.

### *2.1 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, ACIP recommended a catch-up for those who were not yet fully immunized (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 such that a full series now includes 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 vaccine 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. They 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 the Affordable Care Act's dependent coverage provision and the share of young women initiating HPV vaccination. Because the 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 the dependent coverage provision was associated with an 8 percentage point increase in vaccine initiation for 19-25-year-old women. It is worth noting that the majority of these women would already have been sexually active (Guttmacher Institute 2020), and the HPV vaccine is recommended prior to sexual initiation (CDC 2020). Lipton and Decker (2015) did not report any results for young men, though the incidence of male oral cancer now exceeds to incidence of cervical cancer in women (Mourad et al. 2017).

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.[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. 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.

### *2.2 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

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

individuals with household incomes between 100 percent 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.

Given that most low-income children were already eligible for public insurance, 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. 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, and states were mindful of these "woodwork" or "welcome mat" effects when debating Medicaid expansion (Sommers and Epstein 2011).

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.

Work on the Affordable Care Act's Medicaid expansion has pointed to more modest increases. Hudson and Moriya (2017) estimated that over 700,000 low-income children gained health insurance as a result of 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. 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.

## 3. DATA+METHODOLOGY

In this section, I provide an overview of the NIS-Teens structure, as well as provide some 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.

### *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 dates of administration.[3]

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 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). 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 compared to 23 percent in non-expansion states (Panel II columns 2 and 3). 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, while only 64 percent of teens had initiated vaccination in non-expansion states (Panel III columns 2 and 3).

[3] I analyze 2010-2018 because this is the largest window during which all individual 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 2008-2010 period, though they only provide the dual survey weights in subsequent years. Additionally, the survey underwent a redesign in 2014. For comparability purposes, I examine questions that were unchanged between surveys and I show that my results are robust to not utilizing the survey weights.

*3.2 Methodology*

Using the NIS-Teen data, I exploit geographic and temporal variation in the Affordable Care Act's Medicaid expansions 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.[4] The $\eta_{Pre}$ and $\eta_{Post}$ indicator variables capture observations occurring more than 4 years prior to Medicaid expansion and more than 2 years post-expansion. I also include time-invariant state fixed effects, $\theta_s$, location-invariant year fixed effects, $\tau_t$, 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:

$$VACC_{ist} = \alpha + \sum_{j=-6,\, j\neq -1}^{2} \beta_j I_{st}^{j} + \eta_{Pre} + \eta_{Post} + \mathbf{D'}_{ist}\boldsymbol{\delta} + \mathbf{X'}_{st}\boldsymbol{\gamma} + \theta_s + \tau_t + \theta_s * TREND + \varepsilon_{ist} \quad (2)$$

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

[4] 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.

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 (6-8$^{th}$, 9-12$^{th}$, and high school graduate, with "not enrolled" omitted), and race/ethnicity (white, black, 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 and 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). 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.

## 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.

*4.1 HPV Vaccination*

While the descriptive statistics indicate that teenage girls 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 A2 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.[5]

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).[6]

[5] In Table A2, 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.

[6] I show in Table A3 that the estimates are robust to using probit or logistic regression (columns 1 and 2). Because the NIS-Teen began sampling individuals via both landline and cellphone in 2011. In addition, the survey underwent a redesign in 2014. Accordingly, I show that the relationship is robust to excluding the sample weights (column 3). Finally, I find a 3 percentage point increase in HPV vaccination when I restrict the sample to only states which ever expanded Medicaid (column 4).

In Table 3, I show that the Medicaid expansion-HPV vaccination relationship was driven by teens 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).

Next, I 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). Finally, I find that that the point estimate is larger for teen boys (column 7) compared to teen girls (column 8). In 2013, 35 percent of teen boys had received the HPV vaccine compared to 58 percent of teen girls. As such, these last two estimates may be due to the fact that teen boys had more room to improve vaccine coverage.

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 ACA's dependent coverage provision increased the probability that women ages 18-25 had health insurance by 7.4 percentage points and had initiated the HPV vaccine by 7.7 percentage points (Page 761, Exhibit 3). Their increase can be viewed as the direct effect of a provision intended to increase coverage for that group. In contrast, the 3-4 percentage point increase that I find is an indirect effect that comes from teens gaining health insurance after their parents become eligible for Medicaid. This estimate is closer in size to Carpenter and Lawler (2019) who

found that middle school Tdap vaccination requirements increased HPV initiation by 4-5 percentage points (Page 114, Table 3). Critically, neither Lipton and Decker (2015) nor Carpenter and Lawler (2019) identified increases in HPV coverage for teen boys, while I find a 4 percentage point increase in HPV vaccine initiation for this group.

Thus far, I have restricted my attention to provider-verified immunization data. However, the NIS-Teen also asks parents about the child's vaccination history. Reassuringly, I show in Table 4 that parents were almost 2 percentage points more likely to report that their child had received the HPV vaccine after Medicaid expansion (column 1). 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). Given that I documented a 3 percentage point increase in vaccine initiation, this estimate suggests that most children went on to receive a full dose of the vaccine.

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). 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), the ACA 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 the ACA Medicaid expansion was associated with an increase in meningococcal vaccination (column 6). Consistent with the estimates for Tdap vaccination, the relationship is driven by a 1.8 percentage point increase in vaccination for teens residing in states that do not require students to obtain the meningococcal vaccine (column 8). It is also worth noting that during this period the HPV vaccine required three shots costing around $250 each. Meanwhile, the Tdap vaccine required one $95 shot, and the meningococcal vaccine required two shots costing $159 each (CVS 2020). Accordingly, the robustness of the relationship between Medicaid expansion and immunization appears to be stronger for more expensive vaccinations.

*4.2 Mechanisms: Medicaid Coverage*

In Table 5, I show that teens were nearly 3 percentage points more likely to be covered by Medicaid in the post-expansion period (column 1). As with the HPV vaccination estimates, the increase is concentrated among poorer children. I find that teens living below 200 percent of the federal poverty level were over 6 percentage points more likely to have Medicaid coverage (column 2) after Medicaid expansion. Meanwhile, I do not uncover a statistically significant change for teens from more affluent households (column 3). Again, mirroring the HPV vaccination estimates, I find that the increase in Medicaid coverage was driven entirely by teens whose mothers lacked college degrees (column 4 vs. column 5).[7]

[7] Beginning in 2016, health insurance questions were only available for teens with adequate provider data. In order to leverage as large of a sample as possible, I use the full sample of teens with insurance data available each year. However, I show in Table A4 that my results are robust to limiting the sample to the period prior to the change (2010-2015).

The point estimates indicate a 3 percentage point increase in Medicaid coverage for non-white teens (column 6) and a 2 percentage point increase for white teens (column 7), though only the latter is statistically significant. In the final two columns, I stratify the sample by sex. I find that teen boys were 3 percentage points more likely to be covered by Medicaid after Medicaid expansion (column 8). While I find a similar increase for teen girls, the estimate is statistically insignificant (column 9). This pattern illuminates why I documented a smaller increase in HPV vaccination for girls relative to teen boys in Table 3. If the relationship between Medicaid expansion and HPV vaccination is driven by increased Medicaid coverage, it is not surprising that I find greater vaccination increases for boys given the weaker first order relationship for girls.

*4.3 Mechanisms: Provider Contact*

In the prior tables, I have shown that Medicaid expansion was positively associated with the probability that a teen was covered by Medicaid, as well as the probability that a teen had received the HPV vaccine. In Table 6, I explore ways in which Medicaid coverage may have increased vaccination. First, I find that Medicaid expansion was associated with a 3 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 teens were 1.6 percentage points more likely to have been recommended the HPV vaccine by a health care provider (column 2), though the estimate is outside of conventional statistical significance levels ($p=0.13$).

The NIS-Teen asks parents if their child will receive the HPV vaccine within the next 12 months, as well as their specific reasons for not vaccinating.[8] 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).

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.[9] Moreover, the share of parents attributing the decision not to vaccinate to cost shrank considerably over the sample period. In 2010, 8.6 percent of respondents said their child would not receive the HPV vaccine

[8] 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 7$^{th}$ most frequently stated reason—given that Medicaid expansion may have reduced the cost of the vaccine through increased health insurance coverage.

[9] In Table A5, I show the results when I restrict attention to teens living below 200 percent of the federal poverty level (Panel I) and those whose mothers lacked college degrees (Panel II). While less precisely estimated, the pattern of results remains the same. Teens more likely to qualify for Medicaid were more likely to have had a recent check-up (Panels I and II column 1). Poorer and less educated parents were less likely to attribute the decision not to vaccinate to a lack of knowledge about the HPV vaccine (Panel I column 5), and the parents of teens whose mothers lacked college degrees were more likely to report that the teen had been recommended the vaccine (Panel II column 2).

due to cost. By 2013 this number had fallen to 2.1 percent, and in 2018 only 0.4 percent of parents said that their child would not receive the HPV vaccine due to cost.

In Table 7, 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 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 to be 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). [10] Overall, Table 7 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.

## 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 who were most likely to have gained Medicaid—poorer teenagers, teenagers whose mothers lacked a college degree, and non-white teenagers. In this way, my paper draws on and contributes to the "welcome mat" literature examining how eligible but unrolled 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).

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

A 3 percentage point increase in HPV vaccination estimate is large, especially given that it is due to an indirect increase in teen insurance coverage attributable to expanded parental eligibility for Medicaid. Moreover, it indicates that teen HPV vaccination is highly responsive to insurance status, given that I documented a 3 percentage point increase in Medicaid coverage. It should be noted, though, that this pattern is in line with Lipton and Decker (2015) who found that the ACA's dependent coverage provision increased both insurance coverage and HPV vaccine initiation by approximately 7 percentage points.

While gaining health insurance reduced the cost of the HPV vaccine, I also find evidence that Medicaid expansion increased the probability that a teenager had a recent check-up and had been recommended the HPV vaccine. This provider-contact pathway is supported by Google Trends data showing that people in expansion states were more likely to search 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. 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) Full Sample | (2) Expansion States | (3) Non-Expansion States |
|---|---|---|---|
| | | Panel I: Overall | |
| Mean | 0.487 | 0.508 | 0.452 |
| Standard Deviation | (0.500) | (0.500) | (0.498) |
| Observations | 172,891 | 104,254 | 68,637 |
| | | Panel II: 2010 | |
| Mean | 0.243 | 0.253 | 0.227 |
| Standard Deviation | (0.429) | (0.435) | (0.419) |
| Observations | 17,959 | 10,859 | 7,100 |
| | | Panel III: 2018 | |
| Mean | 0.679 | 0.706 | 0.638 |
| Standard Deviation | (0.467) | (0.456) | (0.481) |
| Observations | 17,706 | 10,375 | 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*** | 0.037*** | 0.033** |
| | (0.013) | (0.013) | (0.012) | (0.014) |
| 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, and an indicator for the presence of a meningococcal vaccination requirement. 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 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 | (7) Boys | (8) Girls |
|---|---|---|---|---|---|---|---|---|
| Medicaid Expansion | 0.048*** | 0.020 | 0.047*** | 0.008 | 0.058** | 0.004 | 0.041* | 0.025 |
| | (0.017) | (0.015) | (0.018) | (0.017) | (0.023) | (0.011) | (0.021) | (0.018) |
| Mean | 0.527 | 0.455 | 0.492 | 0.478 | 0.547 | 0.437 | 0.379 | 0.599 |
| Observations | 60,252 | 112,639 | 94,546 | 78,345 | 61,310 | 111,581 | 90,431 | 82,460 |

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. Finally, columns (7) and (8) stratify the sample by sex. 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 4: Medicaid expansion was associated with increased HPV vaccine completion

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | Parental | Provider Verified | | | | | | |
| | Reported HPV Vaccine Initiation | Complete HPV Vaccination | Tdap Vaccine | | | Meningococcal Vaccine | | |
| | | | Overall | School Requirement | No School Requirement | Overall | School Requirement | No School Requirement |
| Medicaid Expansion | 0.017* | 0.021** | 0.007 | -0.008 | 0.033* | 0.013 | -0.017 | 0.018** |
| | (0.010) | (0.008) | (0.012) | (0.012) | (0.017) | (0.008) | (0.014) | (0.008) |
| Mean | 0.420 | 0.284 | 0.893 | 0.903 | 0.803 | 0.788 | 0.874 | 0.723 |
| Observations | 282,379 | 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. 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 5: Medicaid expansion was associated with greater Medicaid 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 | (8) Boys | (9) Girls |
|---|---|---|---|---|---|---|---|---|---|
| Medicaid Expansion | 0.027** | 0.063*** | -0.002 | 0.036** | 0.008 | 0.031 | 0.019*** | 0.029** | 0.025 |
| | (0.012) | (0.020) | (0.007) | (0.013) | (0.012) | (0.022) | (0.007) | (0.012) | (0.017) |
| Mean | 0.328 | 0.625 | 0.083 | 0.459 | 0.103 | 0.463 | 0.209 | 0.331 | 0.324 |
| Observations | 140,947 | 50,314 | 90,633 | 78,325 | 62,622 | 51,266 | 89,681 | 73,914 | 67,033 |

Source: National Immunization Survey—Teen 2010-2018

Note: The dependent variable is an indicator for whether the child was covered by Medicaid. 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. Finally, columns (8) and (9) stratify the sample by sex. 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 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 | -0.007 | 0.009 | -0.018*** | 0.001 | 0.012** |
| | (0.009) | (0.011) | (0.017) | (0.010) | (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 7: Medicaid expansion was associated with greater Google searches of terms related to obtaining the HPV vaccine

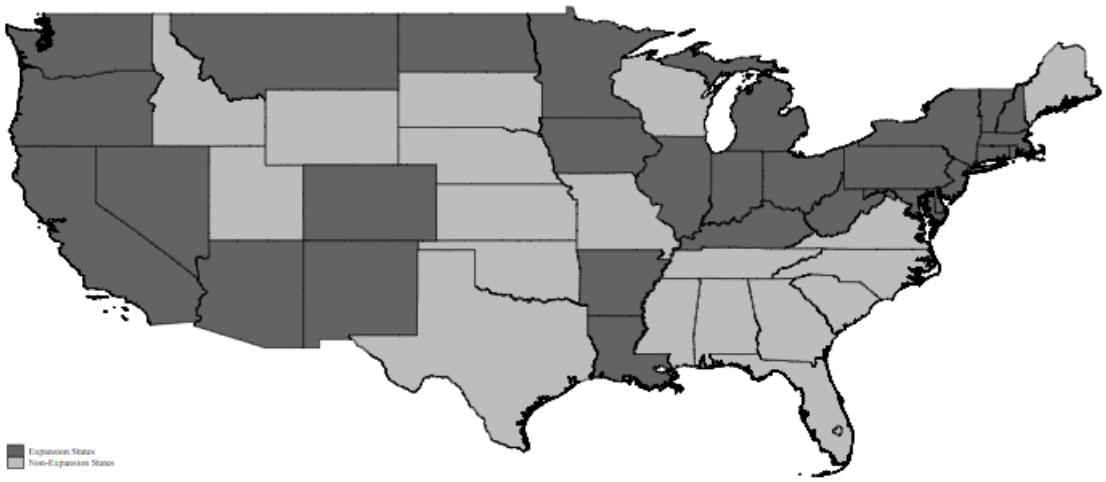
| | (1) Medicaid | (2) Pediatrician | (3) HPV | (4) HPV Cancer | (5) Gardasil |
|---|---|---|---|---|---|
| Medicaid Expansion | 8.206*** | 3.251** | 1.890 | 2.506* | 2.540* |
| | (2.025) | (1.569) | (1.278) | (1.382) | (1.356) |
| Mean | 66.327 | 52.655 | 48.000 | 28.685 | 33.688 |
| Observations |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

Source: Google Trends Data, 2010-2018

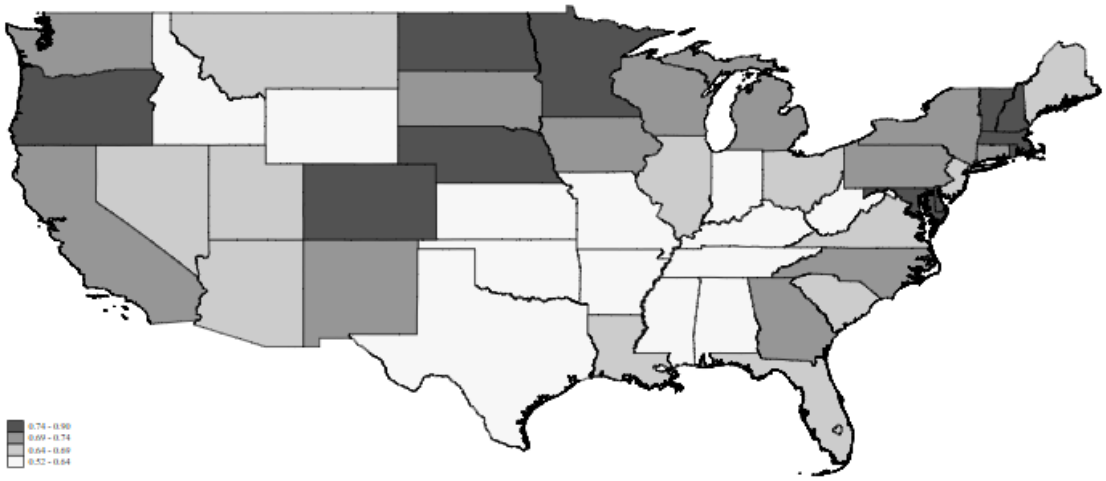
Notes: The dependent variable is a measure of the popularity of a given search term. For every state, the month of peak search volume is normalized to 100. The independent variable of interest is an indicator for the month the state expanded Medicaid as part of the Affordable Care Act. Each column also 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



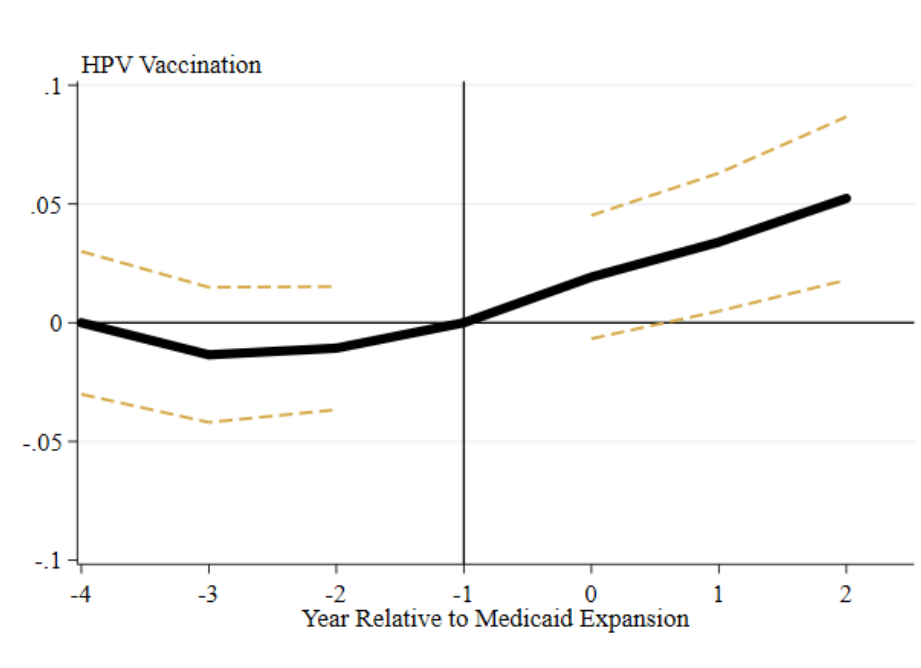

(A)




(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 A2. 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).

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 | | | |
| 6-8$^{th}$ | 0.274 | 0.259 | 0.283 |
| | (0.446) | (0.438) | (0.451) |
| 9-12$^{th}$ | 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: 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 | 0.000 | -0.052 |
| | | (0.015) | (0.014) | (0.017) | (0.015) | (0.033) |
| | -3 | -0.014 | -0.025* | -0.010 | -0.009 | -0.045* |
| | | (0.015) | (0.013) | (0.015) | (0.015) | (0.024) |
| | -2 | -0.011 | -0.023* | -0.009 | -0.012 | -0.030* |
| | | (0.013) | (0.012) | (0.014) | (0.013) | (0.015) |
| Pre=0? | | | | | | |
| | F-Stat | 0.530 | 1.670 | 0.460 | 0.420 | 1.340 |
| | Prob>F | 0.665 | 0.187 | 0.711 | 0.737 | 0.272 |
| Post-Expansion | | | | | | |
| | 0 | 0.019 | 0.005 | 0.020 | 0.016 | 0.029* |
| | | (0.013) | (0.015) | (0.014) | (0.011) | (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*** | 0.046*** | 0.083** |
| | | (0.018) | (0.021) | (0.018) | (0.015) | (0.031) |
| Post=0? | | | | | | |
| | F-Stat | 3.800 | 2.690 | 3.560 | 3.730 | 2.370 |
| | Prob>F | 0.016 | 0.057 | 0.021 | 0.017 | 0.082 |
| Pre=Post? | | | | | | |
| | F-Stat | 2.290 | 2.250 | 2.870 | 3.070 | 1.900 |
| | Prob>F | 0.022 | 0.065 | 0.023 | 0.017 | 0.111 |
| 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. 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 A3: The relationship between Medicaid expansion and HPV vaccination is robust to alternative estimation strategies and sample restrictions

| | (1) Probit Regression | (2) Logistic Regression | (3) Excluding Sample Weights | (4) Only Expansion States |
|---|---|---|---|---|
| Medicaid Expansion | 0.029** | 0.028** | 0.019** | 0.030* |
| | (0.013) | (0.013) | (0.007) | (0.017) |
| Mean | 0.487 | 0.487 | 0.484 | 0.508 |
| Observations | 172,891 | 172,891 | 172,891 | 104,254 |

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) uses a probit regression framework, while column (2) uses a logistic regression framework. For convenience, marginal effects are reported. Column (3) uses the linear probability framework but does not utilize the sample weights. Column (4) restricts the sample to states which ever expanded Medicaid as part of the Affordable Care Act. Robust standard errors, shown in parentheses, are clustered at the state level.
*** p<0.01, ** p<0.05, * p<0.10

Table A4: The relationship between Medicaid expansion and Medicaid coverage is robust to only examining the 2010-2015 period prior to a survey modification limiting which respondents were asked the question

| | (1) Full Sample | (2) ≤ 200% FPL | (3) > 200% FPL | (4) Mother lacked BA | (5) Mother had BA | (6) Non-White | (7) White | (8) Boys | (9) Girls |
|---|---|---|---|---|---|---|---|---|---|
| Medicaid Expansion | 0.028* | 0.069*** | -0.006 | 0.038** | 0.002 | 0.028 | 0.021*** | 0.030* | 0.025 |
| | (0.016) | (0.024) | (0.011) | (0.018) | (0.015) | (0.030) | (0.008) | (0.017) | (0.020) |
| Observations | 84,036 | 30,500 | 53,536 | 48,805 | 35,231 | 54,223 | 29,813 | 43,963 | 40,073 |

Source: National Immunization Survey—Teen 2010-2015

Note: The dependent variable is an indicator for whether the child was covered by Medicaid. 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. Finally, columns (8) and (9) stratify the sample by sex. 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 A5: 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 |
| | Panel I: ≤ 200% Federal Poverty Level | | | | | | |
| Medicaid Expansion | 0.024 | 0.002 | -0.003 | 0.024 | -0.050*** | 0.019 | 0.016*** |
| | (0.016) | (0.011) | (0.020) | (0.018) | (0.012) | (0.016) | (0.004) |
| Mean | 0.448 | 0.515 | 0.193 | 0.190 | 0.158 | 0.104 | 0.025 |
| Observations | 101,325 | 93,355 | 37,888 | 37,888 | 37,888 | 37,888 | 37,888 |
| | Panel II: Mother Lacked a BA | | | | | | |
| Medicaid Expansion | 0.031* | 0.018 | -0.008 | -0.000 | -0.013* | 0.008 | 0.017*** |
| | (0.018) | (0.011) | (0.015) | (0.011) | (0.008) | (0.011) | (0.004) |
| Mean | 0.444 | 0.520 | 0.203 | 0.184 | 0.150 | 0.113 | 0.028 |
| Observations | 165,914 | 154,401 | 68,831 | 68,831 | 68,831 | 68,831 | 68,831 |

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 has 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. Panel I restricts attention to teens living below 200 percent of the federal poverty level, while Panel II restricts attention to teens whose mothers lacked a college degree. Robust standard errors, shown in parentheses, are clustered at the state level.

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