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Market Responses to Vaccine Recommendations

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Abstract

We provide novel evidence on how pharmaceutical companies and consumers respond to government-endorsed health recommendations. In 2014, the Advisory Committee on Immunization Practices recommended that elderly adults receive the pneumococcal vaccine Prevnar 13. Using a difference-in-differences identification strategy, we first show that the manufacturer (Pfizer) responded by increasing direct-to-consumer advertising. We then show that the recommendation increased Prevnar 13-related information-seeking behavior and pneumococcal vaccination. Overall, our analyses suggest that the recommendation directly increased Medicare Part B drug expenditures by over $14 per beneficiary and Pfizer product sales by approximately $1 billion annually, with little to no observable health benefits.

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1. Introduction

Immunization is a canonical example of a market failure, as vaccines provide social benefits that are not fully internalized by consumers. Aiming to correct this market imperfection and increase vaccination rates to socially optimal levels, the Advisory Committee on Immunization Practices (ACIP) – a group within the Centers for Disease Control and Prevention – has currently released 26 vaccine-specific recommendations. While prior work has explored how these recommendations affect vaccine take-up (Lawler 2017; Lawler 2020), little is known about how pharmaceutical firms respond to and benefit from these government-sanctioned product endorsements. Yet with the US vaccine market currently valued at nearly $30 billion and projected to grow dramatically over the next decade, these supply-side considerations can offer critical insights into how ACIP's recommendations contribute to social welfare.

This paper provides new evidence on the market-wide effects of a government recommendation for the pneumococcal vaccine targeted towards elderly adults. Pneumococcal vaccines offer protection against streptococcus pneumoniae – a bacterial infection causing over 500,000 cases of pneumonia in the United States annually (Morrill et al. 2014).[1] Pneumonia is the seventh leading cause of death in the US, and pneumonia-related hospitalizations cost an estimated $9 billion each year (Dion and Ashurst 2021). In 2011, the US Food and Drug Administration approved the pneumococcal conjugate vaccine (PCV13) – sold by Pfizer under the tradename Prevnar 13 – for adults aged 50 or older.[2] Starting August 2014, the Advisory Committee on Immunization Practices (ACIP) recommended that adults aged 65 or older routinely receive

[1] Other common causes of pneumonia in the US include influenza, respiratory syncytial virus, and SARS-CoV-2 (CDC 2020).

[2] For expositional purposes, we use the tradename Prevnar throughout the text. The recommendation specified that adults aged 65 or older should receive PCV13 without specifying a brand, though Prevnar 13 is the only available PCV13 vaccine in the US.

Prevnar.[3] While ACIP later concluded that the recommendation had 'minimal impact' on reducing pneumococcal disease and stopped recommending Prevnar 13 be routinely administered to elderly adults, we utilize the initial recommendation as a natural experiment to study how firms respond to and benefit from government product endorsements.

We first study how the ACIP's 2014 recommendation impacted product marketing using 2011-2019 data on direct-to-consumer advertising. Using a difference-in-differences identification strategy comparing changes in Prevnar 13 advertising expenditures to the associated changes for 100 comparison pharmaceuticals, we find large increases in direct-to-consumer advertising in the post-recommendation period. There is no evidence that Prevnar advertising was differentially trending during the pre-recommendation period, and a series of placebo tests indicate that the post-period increase was unlikely to have occurred by chance.

Next, we consider the effects of the recommendation on two dimensions of consumer behavior: information-seeking behavior and vaccination uptake. Using 2011-2019 Google Trends data, we show that consumers responded to the 2014 ACIP recommendation by significantly increasing their internet search intensity for the term 'Prevnar' relative to searches for comparison pharmaceuticals. To examine changes in pneumococcal vaccination among elderly adults, we use both the 2011-2019 National Health Interview Survey and 2012-2019 Medicare Part B claims public use files. Comparing vaccination changes for adults targeted by the recommendation (age 65 and older) to changes for younger adults, we find that elderly adults were 5.6-7.9 percentage points more likely to be vaccinated against pneumococcal disease in the post-recommendation period. We also document broader spillovers of the recommendation to other dimensions of health

[3] As we later discuss, there are two pneumococcal vaccines available in the United States. The first, sold by Merck under the tradename Pneumovax 23 (PPSV23), has been available and recommended for adults aged 65 or older in the United States for decades. PCV13 was recommended to be routinely administered in series with PPSV23 for adults aged 65 or older from 2014-2019.

care. After the recommendation adults aged 65 and older were significantly more likely to report having visited a health care provider in the past two weeks and having received another vaccine routinely recommended for elderly adults (herpes zoster vaccine).

Finally, we estimate the effect of ACIP's recommendation on Medicare expenditures and Prevnar 13 sales using Medicare Part B public use claims files and data collected from pharmaceutical companies' 2011-2019 annual reports and financial statements. We estimate that ACIP's Prevnar 13 recommendations directly increased Medicare Part B FFS drug spending by over $14.40 per beneficiary, or by approximately $480 million total annually. Assuming a similar increase across all Medicare beneficiaries would imply over $930 million in new Prevnar spending. We document a corresponding $1 billion annual increase in Pfizer-reported sales revenue for Prevnar 13 following ACIP's recommendation, compared to the associated changes for the comparison group pharmaceuticals. This pattern is consistent with comments made by Pfizer's then-CEO attributing increased Prevnar 13 take-up to ACIP's recommendation (Pfizer 2015). Overall, our findings highlight the value that private firms may gain from government product endorsements, even when – as ACIP concluded regarding the Prevnar 13 recommendation – the endorsement results in little to no observable public health benefit.[4]

This paper contributes to several notable bodies of literature. First, by providing the first quasi-experimental evidence on the firm marketing response to a government vaccine recommendation, we build on existing work examining the relationship between government health policies and strategic firm decisions (Finkelstein 2004; Acemoglu et al. 2006; Kyle 2007; Duggan and Scott Morton 2006; Duggan and Scott Morton 2010; Freedman et al. 2015; Lakdawalla and

[4] As we later discuss, ACIP attributed the ninefold reduction in the incidence of pneumococcal disease among elderly adults that pre-dated the 2014 recommendation to rising childhood pneumococcal vaccination rates and argued that pediatric vaccination had 'limit[ed] the utility' of the elderly Prevnar 13 recommendation (MMWR 2019).

Yin 2015; Starc, Amanda and Swanson 2021). By exploring how Pfizer's marketing changed in response to ACIP's recommendation, we add to existing work analyzing the strategic role of advertising (Kaldor 1950; Anderson and Renault 2006; Ambrus et al. 2016; Zinman and Zitzewitz 2016). These issues are especially salient in the health care sector, where recent work has shown that direct-to-consumer pharmaceutical advertising can significantly increase take-up of prescription drugs (Lakdawalla et al. 2013; Alpert et al. 2019; Sinkinson and Starc 2019; Shapiro *forthcoming*).[5] However, little is known about how pharmaceutical firms respond to positive information shocks resulting from government action (Lawler and Skira 2022).[6]

By documenting a plausibly causal positive relationship between ACIP's age-targeted recommendation and vaccine take-up, we also build on work examining the determinants of vaccination. This literature has shown that vaccine mandates for school attendance (Abrevaya and Mulligan 2011; Carpenter and Lawler 2019; Churchill 2021a) and government-endorsed vaccine recommendations (Lawler 2017; Lawler 2020) significantly increase childhood and adolescent vaccination rates. There is comparably less work on how to increase adult vaccination rates and, given differences in health care utilization and access to care for adults and children, it is unclear the extent to which findings from studies of children will apply to adults. Recent evidence suggests that promotional campaigns (Ward 2014; Bouckaert et al. 2020) and employer vaccine mandates (White 2021) are potentially effective policy levers for the adult population.[7]

[5] See https://www.gao.gov/products/gao-21-380 for a recent US Government Accountability Office report on direct-to-consumer advertising and Medicare spending on prescription drugs.

[6] Much of the work on pharmaceutical firm marketing following positive information shocks has focused on the effect of clinical trial results on physician detailing (Azoulay 2002, Ching and Ishihara 2010, Sood, et al. 2014, Shapiro 2018). Lawler and Skira (2022) examine impacts on both direct-to-consumer advertising and physician detailing in the context of a different government action (removal of a black box warning on a drug label).

[7] A closely related literature examines the effects of recommendations for other forms of preventive care on uptake, selection, and health outcomes (Stewart and Mumpower 2003; Kadiyala and Strumpf 2016; Buchmueller and Goldzahl 2017; Einav et al. 2020).

2. Clinical Evidence and Policy History

Streptococcus pneumoniae is a bacterial infection that causes over 500,000 cases of pneumonia, 40,000 cases of invasive pneumococcal disease, and 4,000 associated deaths annually in the United States (Morrill et al. 2014).[8] There are two available vaccines that reduce the likelihood of contracting pneumococcal disease, especially the most severe 'invasive' infections (CDC 2021). The pneumococcal polysaccharide vaccine (PPSV23) provides protection against 23 pneumococcal capsular types and has been available in the United States since 1983 under the tradename Pneumovax 23.[9] The Advisory Committee on Immunization Practices (ACIP) began recommending routine use of PPSV23 for adults aged 65 or older in 1989 (MMWR 1989). A new pneumococcal vaccine, Prevnar 13 (PCV13), was introduced by Pfizer in 2010 and approved by the FDA in 2011 for adults aged 50 or older.[10]

In August 2014 ACIP began recommending that Prevnar 13 be routinely administered in series with Pneumovax for adults aged 65 or older.[11] These recommendations, while publicly disseminated through CDC publications, are largely intended to provide guidance to vaccine providers (MMWR 2002). The guidelines recommended that adults aged 65 or older who had already received PPSV23 return 12 months later to receive a Prevnar dose. Meanwhile, adults who had not received any pneumococcal vaccine doses were recommended to immediately receive Prevnar and return for Pneumovax after at least a year (MMWR 2015).[12] If received on schedule, patients face no out-of-pocket costs for these vaccines. The Affordable Care Act's preventive

[8] These deaths are concentrated among the elderly. In 2019, the elderly streptococcus pneumoniae mortality rate was 3.27 per 100,000 individuals compared to 1.68 for adults aged 50-64, and 0.54 for those aged 35-49 (Active Bacterial Core Surveillance Report 2019).

[9] A version that provided protection against 14 pneumococcal capsular types, PPSV14, was first introduced under the tradename Pneumovax in 1977 (NYT 1977).

[10] Prevnar (PCV7) was introduced in 2000 exclusively for children (MMWR 2000).

[11] The recommendation was based on June 2014 results from the CAPiTA randomized placebo-controlled trial for PCV13 in elderly adults.

[12] The initial guidelines from August 2014-June 2015 recommended that unvaccinated adults receive PCV13 and then return for PPSV23 after 6-12 months (MMWR 2014).

services provision requires health insurers to cover ACIP recommended vaccines without patient cost-sharing,[13] and in December 2014 the Centers for Medicare and Medicaid Services updated their guidance to cover both pneumococcal vaccines. Medicare Part B covers the first shot at any time and a second shot if given at least one year after the first shot (Medicare 2022). Therefore, while over a longer time horizon the vaccines may be viewed as complements, the recommendation and reimbursement schedules imply that the products act as substitutes during a one-year window.

Notably, ACIP stopped recommending routine use of Prevnar 13 for elderly adults in June 2019, after concluding "that implementation of a PCV13 recommendation for all adults aged ≥65 in 2014 has had minimal impact on PCV13-type disease at the population level in this age group" (MMWR 2019).[14] Consistent with their conclusion, Figure 1 does not reveal any visual change in PCV13-type pneumococcal incidence among the elderly following the recommendation. The 2019 ACIP update further described Prevnar 13 as a safe and effective vaccine that could reduce risk for PCV13-type pneumococcal disease among adults aged 65 or older, but no longer advised that it be included as part of routine care (MMWR 2019). Table 1 summarizes these relevant policy dates.

For this article, we focus on the impacts of the initial 2014 ACIP recommendation that Prevnar 13 be routinely administered in series with Pneumovax 23 for adults aged 65 or older. Financial markets seemingly viewed this recommendation as beneficial to Pfizer; Figure 2 shows a visual increase in Pfizer's stock price following the recommendation (Panel A). This view was later shared by executives at Pfizer who expressed beliefs that ACIP's recommendation boosted sales revenue. Speaking on the Q1 2015 quarterly earnings call, then-CEO Ian C. Read alluded to ACIP's

[13] The provision requires that plans begin covering newly recommended vaccines by one year after the ACIP recommendation date (*Fed. Reg.* Vol. 80 No. 134 pg. 41318).

[14] At the time of the initial recommendation in 2014, ACIP indicated a need to 'reevaluate' the recommendation after several years because PCV13 serotypes accounted for a small proportion (10 percent) of community-acquired pneumonia cases in adults aged 65 or older (MMWR 2014). The low incidence of PCV13 serotypes among the elderly was likely due to increased PCV13 use in children, as incidence rates fell dramatically after the vaccine was approved for children in 2010 (MMWR 2019).

recommendation driving "strong uptake" of Prevnar 13 in adults aged 65 or older. On that same call Albert Bourla – then-President of Pfizer's Global Vaccines, Oncology, and Consumer Healthcare business – stated that every year 4 million adults in the US turned 65-years-old, 27 million adults had received Pneumovax, and 20 million additional adults had never received a pneumococcal vaccine(Pfizer 2015). A little over a year later, Read noted that 40 percent of these 47 million adults had been vaccinated (Pfizer 2016). At approximately $200 per shot, this amounted to $3.8 billion in sales revenue during the six quarters after ACIP's recommendation. Figure 2 descriptively shows an approximate $2 billion annual increase in Prevnar 13 sales in the first year following the recommendation (Panel B).

3. Data and Methodology

3.1 Firm Outcomes

3.1.A Advertising Behavior: Ad$pender

We explore whether Pfizer increased direct-to-consumer advertising in response to ACIP's Prevnar recommendation using Kantar Media's 2011-2019 Ad$pender database. These data contain advertising expenditure and occurrence information for over 3 million brands and 18 different media types.[15] The start of our sample period (2011) coincides with the approval of Prevnar 13 for use in adults aged 50 or older. To construct our comparison group, we sort non-Pfizer pharmaceutical products by advertising expenditure during the pre-ACIP recommendation period

[15] The full list of media types is available here: https://products.kantarmediana.com/documents/AdSpenderManual.pdf.

(2011-2013).[16] Prevnar 13 was the 60th most advertised product on this updated list, and we selected the remaining top 100 products as our comparison group.[17]

Pfizer may have responded to ACIP's Prevnar 13 recommendation for adults aged 65 or older by increasing age-targeted advertising, and indeed some Prevnar 13 commercials explicitly referenced this age group.[18] Figure 3 descriptively shows a large increase in Prevnar 13-related advertising expenditures coincident with ACIP's recommendation (Panel A). To test whether this increase was unique to Prevnar 13 or part of a broader trend in pharmaceutical advertising, we estimate the following difference-in-differences model comparing changes in Prevnar 13-related advertising expenditures to the changes in expenditures for the 100 other non-Pfizer branded medications:

$$AD_{it} = \alpha + \sum_{j=-15,\, j\neq -1}^{20} \beta^{j} \cdot \mathbf{1}\{\text{Brand=Prevnar}\}_i \times \mathbf{1}\{\text{Quarter} = j\}_t + \rho_{it} + \rho^2_{it} + \theta_i + \tau_t + \varepsilon_{it} \quad (1)$$

where the dependent variable, AD, is advertising expenditure for drug brand *i* in year-month *t*. To account for the fact that advertising expenditure likely varies over the product lifecycle, we control for a quadratic in the number of months since FDA approval, ρ.[19] We include a full set of time-invariant drug-specific fixed effects, θ, and drug-invariant year-month fixed effects, τ.

[16] We exclude Pfizer's non-Prevnar pharmaceuticals, given the possibility that the firm responded to ACIP's PCV13 recommendation by shifting resources among its products. Appendix Figure 1 plots advertising expenditure (Panel A) and sales revenue (Panel B) for Pfizer's top products during the pre-recommendation period. There is no evidence that Pfizer shifted its advertising budget across products. Similarly, we drop the shingles (zoster) vaccine, as it is the only other vaccine specifically targeted towards elderly adults and so we may expect the manufacturer to strategically respond to changes in Prevnar advertising. In results available upon request, we formally explored the relationships between advertising for these products and ACIP's PCV13 recommendation; we did not detect any significant or meaningful patterns.

[17] See Appendix Table 1 for the list of products. Pneumovax 23, the other pneumococcal vaccine, is outside this range and not included as a comparison product. We also explored whether ACIP's PCV13 recommendation led to changes in Pneumovax 23 advertising, though we did not detect a significant change.

[18] For example, the Prevnar 13 'One Step' commercial stated, "What if one stalk of broccoli could protect you from cancer? What if one pushup could prevent heart disease? Wishful thinking, right? *But there is one step adults 65 or older can take to prevent another serious disease*…" (Emphasis added) See: https://www.ispot.tv/ad/nUcJ/prevnar-13-one-step.

[19] The results are unchanged if we include higher order polynomial terms or exclude the term altogether.

The independent variables of interest, β^j, measure how advertising expenditure changed *j* quarters away from ACIP's 2014 Prevnar 13 recommendation. Equation (1) allows us to test (i) whether Prevnar 13-related advertising was differentially trending before ACIP's recommendation relative to the comparison pharmaceuticals; and (ii) whether the effect of ACIP's recommendation on advertising expenditure evolved over time. Because we have one treated pharmaceutical product, we conduct inference using a variant of Fisher's (1935) permutation test whereby we estimate equation (1) an additional 100 times, iteratively assuming each of the comparison products had been recommended by ACIP in August 2014. We save the resulting placebo coefficients, $\hat{\beta}^j_{Placebo}$, and compare the event study coefficients of interest, $\hat{\beta}^j_{Prevnar}$, to the 95 percent intervals generated from these placebo estimates (Buchmueller et al. 2011; Cunningham and Shah 2018). If the Prevnar 13 coefficients are located within (outside) the interval, it indicates that the results were likely (unlikely) to have been obtained by chance.[20]

3.1.B Sales Revenue: Annual Reports and SEC Form 10-K Filings

We explore the degree to which Pfizer benefited from the government-endorsed recommendation of its product by examining changes in Prevnar 13 sales revenue. We obtained annual sales revenue data from the required financial statement (Form 10K) included in Pfizer's 2011-2019 annual reports. Figure 2 shows that, prior to ACIP's recommendation, Prevnar 13 sales remained stable at approximately $4 billion annually (Panel B). However, after ACIP recommended that adults aged 65 or older receive Prevnar 13, sales increased by over 60 percent to approximately $6 billion annually.

[20] We also explored whether the ACIP recommendation was related to physician detailing visits using the 2014-2019 CMS Open Payments Database. Appendix Figure 2 plots the descriptive trends in the share of all visits devoted to Prevnar (Panel A) and the Prevnar-related detailing dollars (Panel B). While these trends suggest an increase in detailing visits, the limited pre-period prohibits us from saying anything meaningful about the relationship.

To test whether the increased sales revenue was unique to Prevnar 13 or part of a broader trend in pharmaceutical sales, we collected product-specific sales data from annual reports and 10-K filings of other pharmaceutical firms. These reports contain information on the top-earning products each year. Because non-US sales figures may also be driven by variation in exchange rates or reporting requirements, we limit our comparison group to firms reporting annual sales in US dollars. We also require that sales information be reported in both the pre- and post-recommendation period. After starting with the 100 comparison products used to analyze advertising changes, these restrictions leave us with the 47 comparison products listed in Appendix Table 1. We empirically assess the relationship between ACIP's recommendation and sales using the difference-in-differences specification from equation (1).

3.2 Consumer Outcomes

3.2.A Information Seeking Behavior: Google Trends

We use 2011-2019 Google Trends data to test whether ACIP's Prevnar 13 recommendation affected Prevnar-related information-seeking behavior. For each month in the sample window, Google takes a random sample of all internet searches and divides the number of queries for a particular term, such as 'Prevnar,' by the total search volume. The month when this ratio is maximized is indexed to 100, and all subsequent indices are determined by dividing each month's ratio by the maximum ratio. While these data do not contain information on who is searching for the term, they have previously been used to examine changing search intensity related to vaccination (Oster 2018; Carpenter and Lawler 2019; Churchill 2021b).

Figure 3 shows how Google searches for 'Prevnar' evolved over time (Panel B). Consistent with the prior figures on advertising and firm revenue, search intensity remained relatively flat during the pre-recommendation period and increased dramatically in the months following ACIP's August 2014 Prevnar 13 recommendation. We empirically assess the relationship between ACIP's

recommendation and Prevnar 13-related information seeking behavior by comparing changes in search intensity for 'Prevnar' to the corresponding changes in search intensity for 100 other search terms using the same specification shown in equation (1). The terms in this comparison group identically match the pharmaceutical products used to analyze the Ad$pender data.

3.2.B Vaccine Take-Up: National Health Interview Surveys & Medicare Claims

To test whether ACIP's recommendation affected vaccine take-up, we use data from two complementary sources: the 2011-2019 National Health Interview Surveys (NHIS) and publicly available 2012-2019 Medicare Part B claims data. The NHIS are nationally representative cross-sectional household surveys monitoring health outcomes and behaviors of the non-institutionalized civilian US population. For our analyses, we limit our sample to adults aged 50 and older, as this is the primary adult population for which the pneumococcal vaccines are approved. Unfortunately, during our sample period, the NHIS questionnaire asked only about receipt of the pneumococcal vaccine and did not distinguish between adults receiving Prevnar 13 (newly recommended by ACIP in 2014) and Pneumovax 23 (recommended by ACIP since 1989).[21] As such, we will not measure any increases among adults who received Pneumovax before ACIP's recommendation and then returned to receive Prevnar. Instead, we will only be able to detect changes for adults who would have otherwise remained completely unvaccinated against pneumococcal disease in the absence of ACIP's recommendation.

We overcome this limitation by using publicly available summary tables of Medicare Part B claims, 2012-2019, provided at the state-year-service level. These data capture all Medicare claims and associated Medicare payments for beneficiaries with Part B Fee-For-Service (FFS)

[21] Specifically, the survey question for 2011-2018 read, "Have you EVER had a pneumonia shot? This shot is usually given only once or twice in a person's lifetime and is different from the flu shot. It is also called the pneumococcal vaccine." In 2019 the questionnaire was redesigned and began distinguishing between the two vaccines. In results available upon request, we show the robustness of our conclusions to excluding the 2019 data.

coverage – beneficiaries enrolled in Medicare Advantage plans are not included – and services are identified based on HCPCS codes.[22] Thus, we can separately identify claims for Prevnar or Pneumovax.[23] Importantly, although most drugs are covered under Medicare Part D, Medicare Part B covers the following subset of adult vaccines: the influenza vaccine, the pneumococcal vaccines, the hepatitis B vaccine (for those at high risk), and the rabies and tetanus vaccines (as needed for treatment or direct exposure).

Figure 4 demonstrates the unique change in pneumococcal vaccination occurring for adults aged 65 or older in the NHIS data (Panel A). The grey circles plot the share of each age reporting that they had received the pneumococcal vaccine before ACIP's Prevnar 13 recommendation, and the black triangles plot the share for each age in the post-recommendation period. There is no evidence that adults 50-64 years old experienced any increase in pneumococcal vaccination concurrent with ACIP's recommendation. However, there is a visually apparent increase in vaccine take-up among the recommended group in the post-recommendation period.[24]

Figure 4 also presents descriptive trends in the number of Medicare Part B FFS claims per beneficiary for each of the two pneumococcal vaccines (Panel B). These trends show that, coincident with the August 2014 ACIP recommendation that Prevnar 13 be routinely administered to adults 65 or older, there was a small increase in the number of doses of Prevnar administered in 2014 (a partially treated year), followed by a sharp and persistent increase in 2015 (the first fully

[22] In 2019, these data included claims for approximately 33.2 million beneficiaries, representing 51.5 percent of total Medicare beneficiaries (CMS 2021).
[23] The HCPCS codes used to identify the PCV13 and PPSV23 vaccines are 90670 and 90732, respectively.
[24] Appendix Table 2 provides additional descriptive statistics for the full sample and by whether the individual was older/younger than 65-years-old. Appendix Figure 3 plots the share of adults aged 65-69 (black triangles) reporting that they had received a pneumococcal vaccine during the sample period. During the years when PCV13 was approved but not yet recommended for routine use in elderly adults, nearly 50 percent of those aged 65-69 reported receiving the pneumococcal vaccine. However, after ACIP recommended adults aged 65 or older receive PCV13 in series with PPSV23, the share of 65- to 69-year-old adults reporting pneumococcal vaccination increased by approximately 10 percentage points. Meanwhile, the share of adults aged 60-64 (grey circles) reporting that they had received the pneumococcal vaccine remained largely unchanged throughout the sample period.

treated year). Moreover, these trends show that there was a slight *reduction* in the number of PPSV23 doses administered to this population in 2015 and 2016. These dynamics are consistent with the fact that the new guidelines recommended that unvaccinated adults aged 65 and older should immediately receive Prevnar and return for PPSV23 in 6-12 months.[25]

We examine whether ACIP's Prevnar 13 recommendation increased self-reported pneumococcal vaccination in the NHIS data using the following difference-in-differences identification strategy relying on within-age-group changes among those recommended to receive the vaccine (Age $\geq$ 65) relative to those for whom the vaccine was approved but not ACIP recommended (50- to 64-year-olds):

$$VACC_{iart} = \alpha + \beta \cdot \mathbf{1}\{\text{Age} \geq 65\}_{ia} \times \mathbf{1}\{\text{Recommended for Age} \geq 65\}_{t} + X_{iart}'\gamma + \theta_a + \tau_{rt} + \varepsilon_{iart} \quad (2)$$

where the dependent variable, VACC, is an indicator for whether the respondent *i* aged *a* in census region *r* reported having received the pneumococcal vaccine in year-quarter *t*. The recommendation indicator takes on the value of one starting in Q4 2014 – the first fully treated quarter – and is zero otherwise.[26]

The vector X controls for individual demographic characteristics related to vaccination, including indicators for sex (male with female omitted), race/ethnicity (white, black, Asian, Hispanic with 'other' omitted), educational attainment (less than high school, high school degree, some college with college graduate omitted), and health insurance status (insured with uninsured omitted). This last control may be particularly important given that most individuals become eligible for Medicare at age 65, and insured individuals are generally more connected to the health care system (Busch and Duchovny 2005; Simon et al. 2017). Although we are unaware of any

[25] Appendix Figure 4 shows a similar pattern for Pneumovax 23 sales using data obtained from required financial statements.
[26] The results are robust to instead defining the recommendation period as Q3 2014.

change in Medicare occurring concurrent with ACIP's Prevnar 13 recommendation, the Affordable Care Act Medicaid expansions may have increased health insurance coverage among our 50- to 64-year-old comparison group (McInerney et al. 2020; Miller et al. 2021). As the publicly available NHIS data do not include state identifiers, we are unable to control for these expansions directly – though we note that this likely makes it more difficult for us to detect a statistically significant increase in pneumococcal vaccination for adults aged 65 or older.[27]

We control for time-invariant age-specific propensities toward pneumococcal vaccination with age fixed effects, θ. We also account for secular changes in local attitudes toward vaccination, and potential seasonality in vaccine take-up, by including Census region-year-quarter fixed effects, τ. We report both heteroskedastic robust standard errors and wild bootstrapped p-values (Cameron et al. 2008; Cameron and Miller 2015) obtained from clustering standard errors at the treatment group-time level (Abadie et al. 2017).

The coefficient of interest, β, estimates the increase in pneumococcal vaccination occurring for those aged 65 or older relative to the comparison group coincident with ACIP's Prevnar 13 recommendation. Our identifying assumption is that, after accounting for the covariates and fixed effects, the treatment group's vaccination rate would have evolved similarly to the rate for the comparison group in the absence of the recommendation. While untestable, we assess the validity of this assumption with the event study specification shown in equation (3):

$$VACC_{iart} = \alpha + \sum_{j=-15,\, j\neq -1}^{20} \beta^{j} \cdot \mathbf{1}\{Age \geq 65\}_{ia} \times \mathbf{1}\{Quarter = j\}_{t} + X_{iart}'\gamma + \theta_{a} + \tau_{t} + \varepsilon_{iart} \quad (3)$$

[27] In the appendix we show that our results are robust to instead using data from the 2011-2019 Behavioral Risk Factor Surveillance System. While BRFSS data include state identifiers, allowing us to explicitly control for the ACA Medicaid expansions, they only report age in five-year groups, preventing us from granularly comparing 64- to 65-year-old adults.

where the coefficients, β^j, measure how pneumococcal vaccination differentially evolved for adults aged 65 or older compared to those 50-64 years old relative to the quarter prior to the recommendation.

For analyses using the publicly available Medicare Part B summary files we implement a slightly different identification strategy than for the NHIS, as the Medicare Part B data do not include information about patient age at the time of vaccination. Specifically, we identify the impact of the ACIP recommendation on pneumococcal vaccination by comparing uptake of a given pneumococcal vaccine to uptake of other adult vaccines that are similarly covered by Medicare Part B, but which plausibly should not be impacted by the recommendation change. Specifically, we define our set of control vaccines to be hepatitis B, tetanus, and rabies, as these are only recommended to be administered as treatment or in cases of direct exposure (tetanus and rabies) or to specific high-risk populations (hepatitis B).[28] For these analyses we estimate the following modified version of equation (1):

$$VACC_{it} = \alpha + \beta \cdot \mathbf{1}\{\text{Brand=Prevnar 13}\}_i \times \mathbf{1}\{\text{Recommended for Age} \geq 65\}_t + \theta_i + \tau_t + \varepsilon_{it} \qquad (4)$$

where the dependent variable, VACC, is an annual measure of the number of Medicare Part B FFS claims per beneficiary for vaccine brand *i* in year *t*. Since these data are at the annual level, the indicator variable $\mathbf{1}\{\text{Recommended for Age} \geq 65\}$ takes on a value of one starting in the first full year following the recommendation change (2015) and is equal to zero otherwise. We include a full set of time-invariant drug-specific fixed effects, θ, and drug-invariant time fixed effects, τ. Regressions are weighted by the number of Medicare Part B Fee-For-Service beneficiaries in a given state-year.

[28] We plot the descriptive trends for these variables in Appendix Figure 5.

The Medicare Part B claims data also allows us to examine the impact of the recommendation on Medicare Part B expenditure for pneumococcal vaccination, as it includes measures of average Medicare payments for each service. For these analyses we estimate equation (4) described above, where the dependent variable is an annual measure of the total Medicare Part B FFS payments per beneficiary for vaccine brand *i* in year *t*.

4. Results

4.1 Effects on Advertising and Awareness

We begin by testing whether Pfizer responded to ACIP's 2014 Prevnar 13 recommendation by increasing Prevnar 13-related advertising. On one hand, we might expect Pfizer to have reduced advertising for Prevnar 13 knowing that physicians were now more likely to recommend the vaccine. Yet Figure 5 suggests that Pfizer viewed ACIP's recommendation as complementary to their advertising (Panel A). The dependent variable is Prevnar 13 direct-to-consumer advertising dollars. The solid black line plots the event study coefficients obtained from equation (1), and the dashed grey lines are the corresponding 95 percent placebo intervals. Prior to the recommendation, the coefficients are small in magnitude and within the range one would expect to obtain by chance. However, after ACIP began recommending that elderly adults routinely receive Prevnar 13, monthly Prevnar direct-to-consumer advertising initially increased by approximately $10 million, and the coefficients are larger than their corresponding placebo intervals. In Appendix Table 3, we further examine how the changes in advertising varied across media types (television, print, internet, and radio) and for national versus local-level ads. These results suggest the observed increase in overall advertising expenditure was primarily driven by increases in television and print ads at the national level.

We next test whether ACIP's recommendation generated additional interest in Prevnar 13 using the 2011-2019 Google Trends data. Figure 5 shows that search intensity for 'Prevnar' was evolving similarly to that of other pharmaceuticals during the pre-recommendation period (Panel B). After ACIP began recommending that elderly adults routinely receive Prevnar 13, search intensity increased by more than would be expected from chance. Collectively, Figure 5 provides compelling evidence that ACIP's recommendation led to large increases in advertising and awareness about pneumococcal vaccination.[29]

4.2 Effects on Vaccination

We now use NHIS data to test whether the increased pneumococcal vaccine awareness documented in Section 4.1 translated into greater vaccine take-up. The dependent variable in Table 2 is an indicator for reporting pneumococcal vaccination and the columns present the coefficient of interest from the difference-in-differences specification given in equation (2). As previously noted, in the NHIS data we cannot identify Prevnar take-up among individuals who had already received Pneumovax because the survey question does not distinguish between the vaccines. Therefore, the estimates are identified off increased take-up among individuals who would have otherwise remained completely unvaccinated, and we interpret them as lower bounds for increased Prevnar 13 take-up. Heteroskedastic robust standard errors are shown in parentheses, and we report wild bootstrapped p-values from clustering standard errors at the treatment group-time level in brackets.

The results in Table 2 show that ACIP's Prevnar 13 recommendation significantly increased pneumococcal vaccination among the elderly by 5.6-7.0 percentage points.[30] In 2013, there were

[29] Appendix Figure 6 shows that the advertising (Panel A) and Google Trends (Panel B) results are robust to instead using a weighted average of the comparison group to construct a 'Synthetic Prevnar' Index that best approximates true Prevnar advertising and search behavior during the pre-period and comparing the post-period search intensity to this counterfactual. Appendix Table 4 shows suggestive evidence that ACIP's 2014 PCV13 recommendation increased search intensity for the terms 'pneumovax' and 'pneumonia,' though the estimates are statistically insignificant.

[30] Appendix Figure 8 shows that our results persist when we limit the sample to include only adults with health insurance coverage. In Appendix Table 5 we do not detect any meaningful difference in vaccine take-up by sex, race/ethnicity,

approximately 44.6 million elderly adults in the US (SEER 2022), so our estimates imply that ACIP's recommendation resulted in approximately 2.5 million more adults receiving the pneumococcal vaccine. Event study coefficients obtained by estimating equation (3) are presented in Figure 6. There is no evidence that pneumococcal vaccination was differentially trending for the treated and comparison groups during the pre-period; the point estimates are all small in magnitude and statistically insignificant. However, after ACIP began recommending that adults aged 65 or older receive Prevnar 13, the likelihood that elderly adults reported pneumococcal vaccination increased by an average of 6.1 percentage points. In Appendix Table 7 we perform a similar analysis on data from the 2011-2019 Behavioral Risk Factor Surveillance System. Unlike in the NHIS data where we know exact age, the BRFSS data report age in 5-year groups (50-54, 55-59, 60-64, etc.), yet these data allow us to control for state-level time-varying policies (e.g., the Affordable Care Act Medicaid Expansion). Even after controlling for ACA Medicaid Expansion-by-age group, we continue to find increased pneumococcal vaccine take-up.

Prior work has found that policies meant to increase take-up of particular adolescent vaccines can increase contact with health care providers and lead to increased childhood vaccination against other diseases (Carpenter and Lawler 2019). To examine this possibility in our context we revisit the NHIS data and estimate the difference-in-differences model specified in equation (2). The results from these analyses are reported in Table 3. Each column reports the coefficient of interest from a separate regression, and all columns use the full set of controls. The results in columns 1 and 2 show that the ACIP recommendation did not significantly affect the likelihood that elderly adults reported visiting any health care provider during the prior 12 months, but it did increase the probability of visiting a health care provider during the prior 2 weeks by 1.6

or educational attainment using the difference-in-differences model. Nor do we detect any significant differences across groups when we interact the righthand side variables with demographic group-specific indicators in Appendix Table 6.

percentage points. This pattern of results suggests that the recommendation is inducing additional doctors visits among the subset of elderly individuals who are *already* in regular contact with their health care provider. Column 3 shows a positive but not statistically significant increase in the likelihood elderly adults reported receiving the flu vaccine, while column 4 offers strong evidence that elderly adults were more likely to report receiving the herpes zoster vaccine. [31] Notably, this latter vaccine was recommended for adults 60 or older during our sample period but had relatively low take-up in the pre-period (25.2 percent).[32]

We next examine the impact of the ACIP recommendation on vaccination uptake using publicly available Medicare Part B claims data, 2012-2019. The results in Table 4 show that the recommendation significantly increased the number of annual Medicare Part B FFS claims for Prevnar 13 by 0.079 claims per beneficiary (column 1). This magnitude is similar to, though slightly larger than, the effect on pneumococcal vaccine take-up estimated using the NHIS, consistent with our inability to detect changes for those who had previously received Pneumovax 23 in the NHIS data. In 2013 there were 38.3 million FFS beneficiaries, implying approximately 3 million more adults receiving Prevnar per year (Murphy-Barron et al. 2020). Meanwhile, our estimate in column 2 suggests that the ACIP recommendation had a small negative effect on the number of claims per beneficiary for Pneumovax, although the significance is not robust to the wild bootstrap procedure.

[31] Appendix Figure 9 plots the trends for these outcomes.

[32] We also explored whether ACIP's recommendation resulted in changes in pneumococcal-related disease incidence. Appendix Table 8 analyzes changes in the incidence of invasive pneumococcal disease using 1998-2019 Active Bacterial Core Surveillance data collected by the CDC. Column 1 compares changes in pneumococcal disease among eight age groups, column 2 compares changes in pneumococcal disease for adults aged 65 or older to changes in three other diseases for which similar surveillance data are collected (Group A Streptococcus, Group B Streptococcus, and Haemophilus Influenzae), and column 3 uses a triple-difference specification with age group-by-disease, year-by-disease, and age group-by-year fixed effects. Similarly, Appendix Figure 10 shows no evidence of a clear change in the crude death rate for pneumonia among adults aged 65 or older using the 2011-2019 CDC WONDER database, and the difference-in-differences estimate presented in Appendix Table 8 is not statistically different from zero (column 4). Consistent with ACIP's later assessment, these exhibits offer little consistent evidence that the 2014 PCV13 recommendation reduced the incidence of pneumococcal disease among elderly adults.

Consistent with the NHIS result, column 3 shows no evidence that the increased take-up of the pneumococcal vaccine had positive spillovers onto take-up of the influenza vaccine.[33]

4.3 Effects on Medicare Expenditure and Sales Revenue

Thus far, we have shown that: (i) Pfizer increased Prevnar-related advertising in response to ACIP's Prevnar 13 recommendation, (ii) Prevnar-related information-seeking behavior increased after ACIP's recommendation, and (iii) elderly adults were more likely to report pneumococcal vaccination in the post-recommendation period. We now explore how ACIP's Prevnar 13 recommendation affected Medicare expenditure for the pneumococcal vaccine. Appendix Figure 11 shows similar levels of spending per beneficiary for Prevnar 13 and other non-routinely recommended vaccines in the pre-recommendation period and a notable increase for Prevnar 13 in the post-period. The corresponding difference-in-differences estimate reported in Table 4 column 4 indicates that the 2014 recommendation resulted in a statistically significant $14.41 increase in Medicare Part B FFS spending per beneficiary for the Prevnar 13 vaccine, or $478 million annually ($14.41 × 33.2 million Part B FFS beneficiaries).[34,35] The Medicare Part B FFS beneficiaries included in our analysis comprise 51.5 percent of all Medicare beneficiaries (CMS 2021). If we

[33] We are unable to examine uptake of the zoster vaccine using these data, as it is not covered by Medicare Part B.

[34] In the Appendix we explore how the recommendation affected Prevnar 13's price. Appendix Figure 12 presents suggestive evidence of an increase in Prevnar 13's price following the ACIP recommendation relative to the change experienced by Pneumovax 23. Indeed, Appendix Table 9 – which compares changes in prices of Prevnar to the associated changes in the prices of other plausibly unaffected vaccines covered by Medicare Part B – suggests that Pfizer raised the average price of Prevnar by approximately $38 following ACIP's recommendation (column 1). Yet we interpret these results cautiously given the pre-recommendation trends in prices of the comparison pharmaceuticals shown in Appendix Figure 13.

[35] We also conducted supplemental analyses using the Medicare Geographic Variation Public Use Files, 2011-2019, which contain information on total Part B drug expenditure per beneficiary, separately for enrollees younger than 65 and those aged 65 or older. Descriptive trends are presented in Appendix Figure 14. Results from estimating a version of equation (2), which compares outcomes for individuals below age 65 to outcomes for those aged 65 or older, before and after the recommendation change, indicate that the recommendation significantly increased Medicare Part B drug spending per beneficiary by $44.63 (robust SE=15.59, wild bootstrapped p-value=0.001). While larger in magnitude than our Prevnar 13-specific result in Table 4, we note that this estimate captures any potential spillover effects, and the confidence interval is large.

assume a similar increase in Prevnar 13 spending for those enrolled in Medicare Advantage plans, our estimate implies over $930 million in additional annual spending on Prevnar 13.

To complement this analysis, Figure 7 compares changes in Prevnar 13 sales revenue to the associated changes in the 47 comparison products (Panel A). There is no evidence that Prevnar 13 sales revenue was differentially trending relative to sales revenue from the comparison products during the pre-recommendation period; the point estimates are negative, smaller in magnitude, and within the placebo interval. However, in line with the implied increase in Medicare expenditure from Table 4, the average of the post-period event study coefficients indicates a statistically significant $1.03 billion annual increase in Prevnar 13 sales revenue.[36] Notably, these patterns are consistent with Pfizer's own interpretation of the sales data. Speaking to investors on the Q1 2015 earnings call, Pfizer's then-CEO Ian C. Read stated that Prevnar 13's revenue growth was "primarily due to strong uptake amongst adults 65 years of age and older, following the positive recommendation from the US Centers for Disease Control and Prevention's Advisory Committee on Immunization Practice."

Finally, we explore the degree to which these estimated effects were due to ACIP's 2014 recommendation or the results from the clinical trial that informed ACIP's decision. We leverage the fact that while ACIP's recommendation was unique to the US, these clinical data were known and discussed in other countries. This setup allows us to net out the effect of the clinical trial by comparing changes in US sales to the associated changes in international sales. While country-specific pharmaceutical sales data is not readily available for all products in the comparison group, Pfizer's annual reports do distinguish between US and international Prevnar 13 sales. Figure 7 plots these descriptive statistics and shows that US Prevnar 13 annual sales (black triangles) increased

[36] Appendix Figure 15 instead uses a data-driven approach to construct a 'synthetic' Prevnar that best mirrored Prevnar's true sales revenue in the pre-recommendation period. The conclusion remains unchanged.

by $2 billion the year following ACIP's Prevnar 13 recommendation and remained elevated in the subsequent years (Panel B). In contrast, there was no visible change in international Prevnar 13 sales (grey circles) occurring in tandem with ACIP's recommendation. Appendix Figure 16 shows that the statistically significant increase in Prevnar 13 sales revenue was unique to US sales, suggesting that the effect was driven by ACIP's recommendation and not the clinical trial performance. Overall, the evidence indicates that ACIP's Prevnar 13 recommendation increased Pfizer's sales of Prevnar 13 by approximately $2 billion annually.

5. Conclusion

In this paper, we comprehensively study a policy intended to promote adult vaccination take-up to measure the important role of supply-side responses of public health recommendations. Using the 2011-2019 Ad$pender data on direct-to-consumer advertising, we show that Pfizer significantly increased Prevnar marketing following ACIP's recommendation that adults 65 or older receive Prevnar 13. We then document increased online search intensity for the phrase 'Prevnar' using 2011-2019 Google Trends data, as well as increased pneumococcal vaccination among in the 2011-2019 NHIS data and the 2012-2019 Medicare Part B Summary Files. In doing so, we provide the first quasi-experimental evidence of the impact of adult vaccine recommendations on firm marketing decisions and consumer vaccination and information-seeking behavior. Together with existing literature showing that direct-to-consumer advertising increases pharmaceutical take-up (Shapiro 2018, 2020; Alpert et al. 2018), these results are consistent with the idea that private firm responses can serve as an important pathway through which government interventions increase vaccination rates to socially desirable levels.

While our results show that the ACIP recommendation led to increased vaccination rates among the elderly, ACIP concluded in 2019 that their 2014 recommendation for routine vaccination

of the elderly had done little to reduce PCV13-type disease at the population level for this age group. ACIP acknowledged historically low incidence of PCV13-type disease among the elderly, instead attributing these declines to pediatric take-up of Prevnar. Yet we identify at least one major beneficiary of the recommendation – Pfizer. We estimate that ACIP's Prevnar 13 recommendation increased annual Medicare Part B Fee-For-Service spending on Prevnar 13 by $14.41 per beneficiary, or $478 million per year. Given that the Medicare Part B FFS population we study represented approximately 51.5 percent of the total Medicare population in 2019 (CMS 2021), this estimate extrapolates to a total increase in Medicare expenditure for the pneumococcal vaccine of $930 million per year. Similarly, we also find that the recommendation increased annual Prevnar 13 sales by approximately $1.03 billion compared to the associated changes experienced by comparison pharmaceuticals. Overall, these estimates highlight the value pharmaceutical firms gain from government recommendations.

This paper is subject to some limitations. For one, our NHIS measure of vaccine take-up is limited to self-reported information in the NHIS data. While it is likely that ACIP's recommendation increased awareness about vaccination among the targeted age group, it is not apparent that this would induce individuals to misreport their own status. Importantly, we identify similar patterns using the Medicare Part B Summary Files, and our findings are also consistent with Pfizer's own data on pneumococcal vaccination. An additional limitation is our inability to disentangle the importance of an ACIP recommendation from Pfizer's subsequent advertising campaign. Working to separate these pathways remains an important area for future research. Despite these limitations, this paper offers the most comprehensive understanding to date of the market-wide effects of government vaccination policies.

6. References

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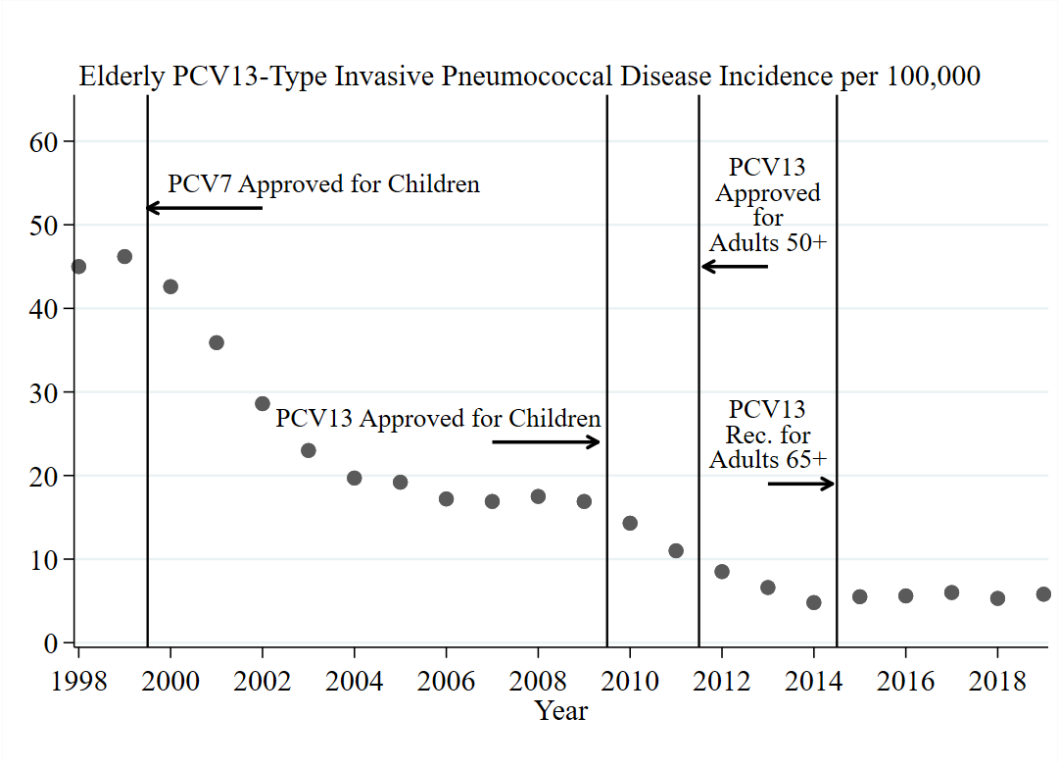
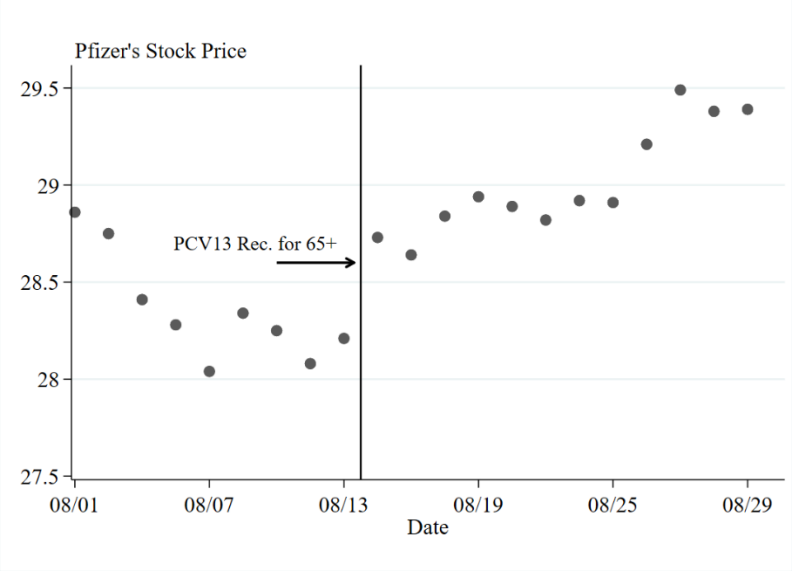
Figure 1: Invasive Pneumococcal Disease Incidence Over Time

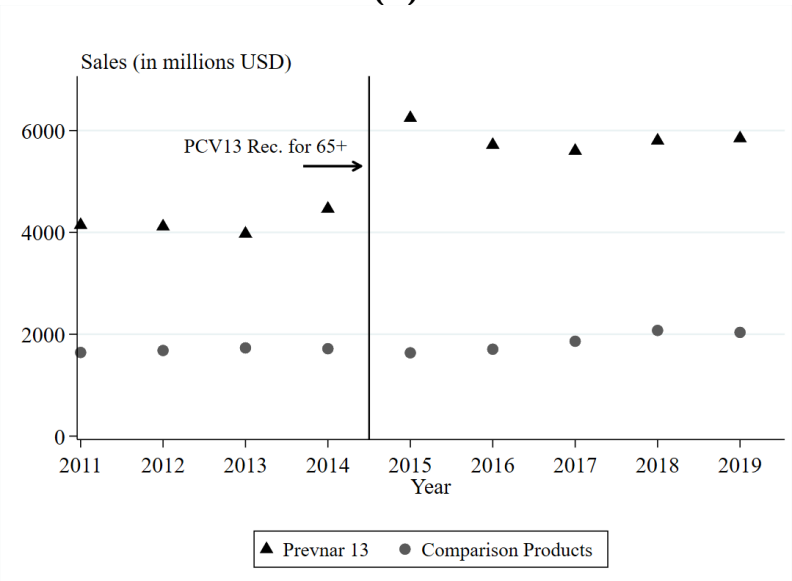


Source: Active Bacterial Core Surveillance Trends by Serotype Group, 1998-2019
Note: The grey dots plot the incidence of PCV13-type invasive pneumococcal disease (i.e. serotypes of pneumococcal disease that Prevnar 13 (PCV13) provides protection against) among adults aged 65 or older from 1998 through 2019 in the United States.

Figure 2: Trends in Pfizer's Stock Price and Prevnar 13 Sales



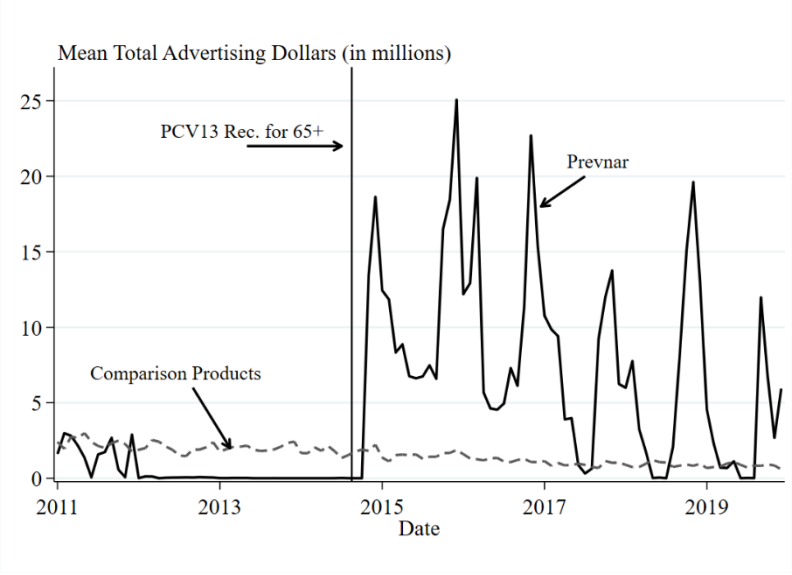
(A)



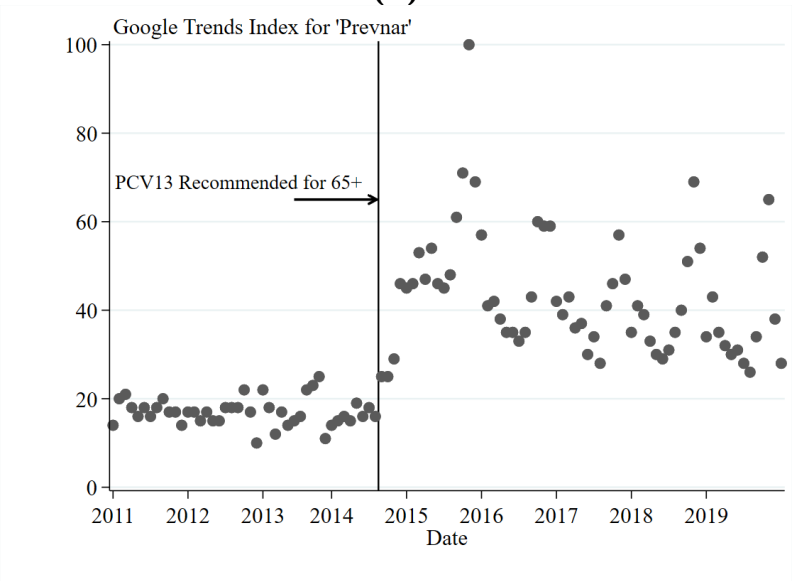
(B)

Source: CRSP, 2014; Annual Reports, 2011-2019
Note: Panel A shows how Pfizer's stock price evolved during the month of ACIP's recommendation that adults aged 65 or older receive PCV13 (August 2014). Panel B plots annual sales for Prevnar (black triangles) and the average of 47 non-Pfizer pharmaceutical products (grey circles). The comparison products are described in section 3.1.A.

Figure 3: Trends in Prevnar Advertising and Google Searches



(A)

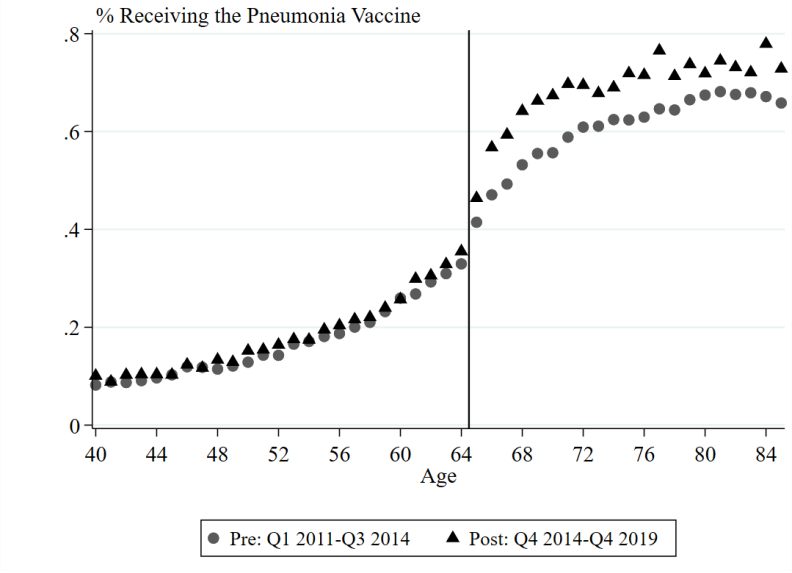


(B)

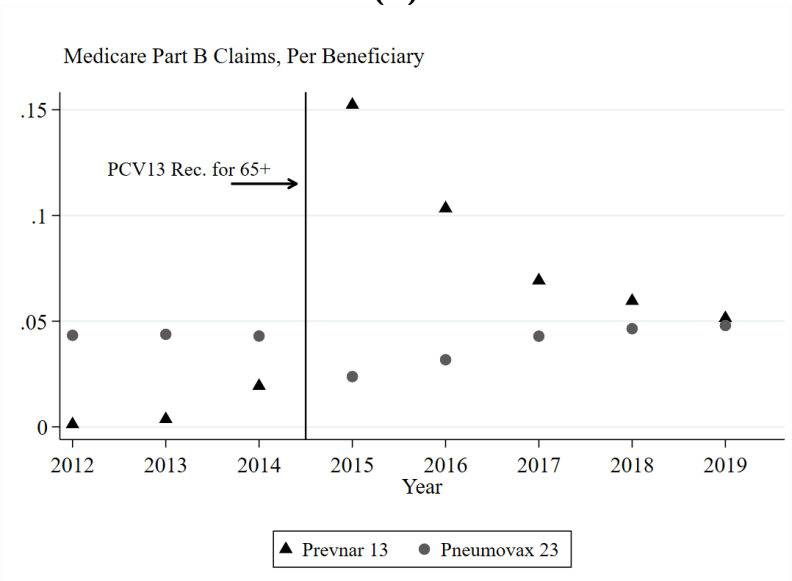
Source: Ad$pender, 2011-2019; Google Trends Index, 2011-2019

Note: Panel A examines changes in monthly Prevnar-related advertising and the advertising of 100 non-Pfizer comparison pharmaceuticals. The solid black line plots the total amount of money spent on advertising for Prevnar across all mediums over the sample period. The dashed grey line plots the average amount of money spent on advertising for the comparison products. Panel B examines information-seeking behavior using Google Trends data. The circles denote the relative search intensity for the term 'Prevnar' – the tradename of Pfizer's PCV13 pneumococcal vaccine – over time.

Figure 4: Trends in Pneumococcal Vaccine Uptake and Claims



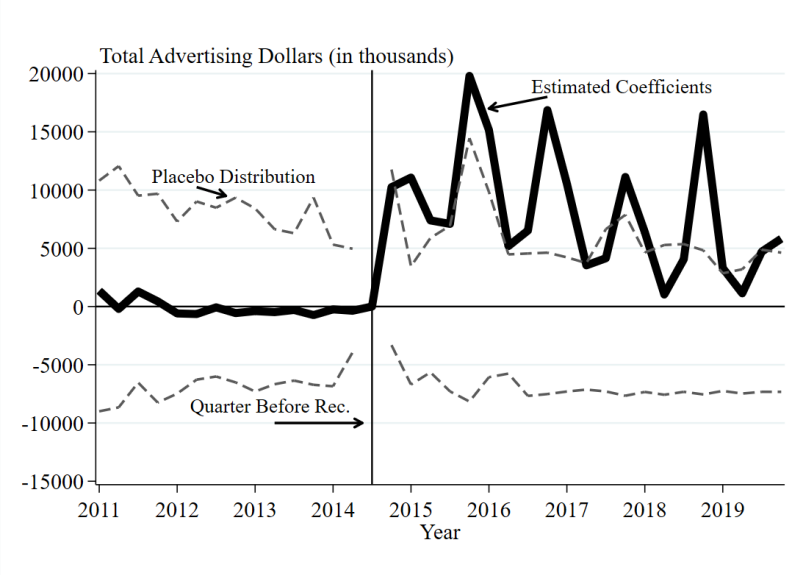
(A)



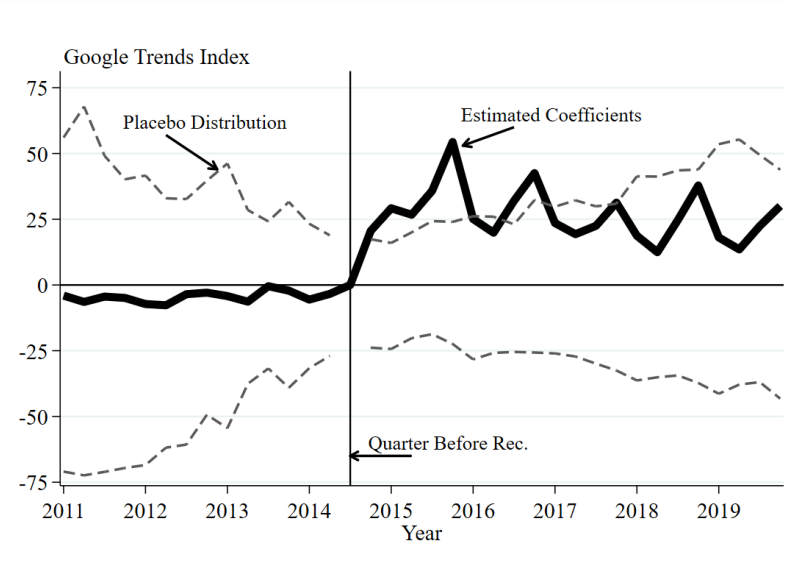
(B)

Source: National Health Interview Survey, 2011-2019; Medicare Part B Summary Files, 2012-2019
Note: The grey circles in Panel A denote the share of each age reporting that they had received the pneumonia vaccine prior to when PCV13 (Prevnar 13) was recommended for those 65+. The black triangles in Panel A indicate the share of each age reporting that they had received the pneumonia vaccine after PCV13 was recommended for those 65+. Panel B examines the annual number of claims per beneficiary for pneumococcal vaccination among Medicare Part B Fee-For-Service beneficiaries. The grey circles denote the annual number of claims per beneficiary for Pneumovax 23 and the black triangles indicate the annual number of claims per beneficiary for Prevnar 13.

Figure 5: Dynamic Effects of ACIP's Prevnar 13 Recommendation on Prevnar-Related Advertising and Information-Seeking Behavior



(A)

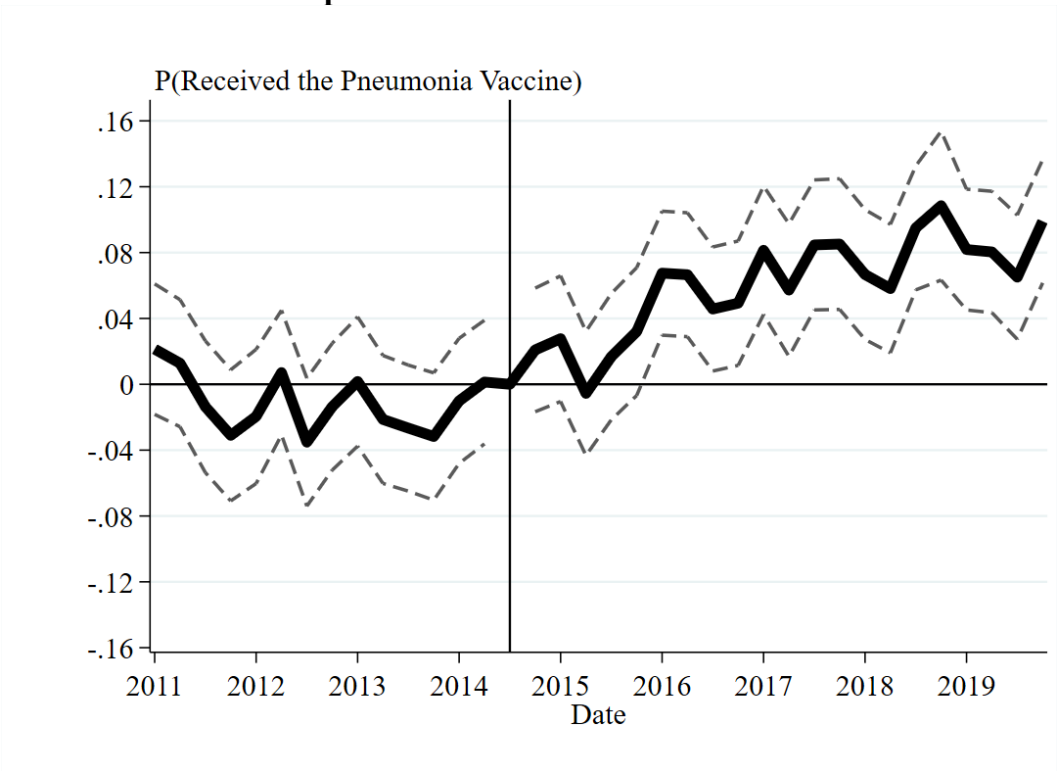


(B)

Source: Ad$pender, 2011-2019; Google Trends, 2011-2019

Note: The dependent variable in Panel A is the total monthly advertising dollars spent on a product, while the dependent variable in Panel B is the Google Trends Index for the term 'Prevnar.' The solid black line plots the event study coefficients obtained from estimating equation (1) via ordinary least squares. The dashed grey lines plot the 95 percent placebo intervals obtained from iteratively assuming that each comparison product was treated, estimating equation (1), and saving the placebo coefficients. When the solid black estimates obtained from the true treatment data are located within the placebo intervals, it indicates that the relationship was likely to have been obtained by chance. When the estimates are outside of the placebo interval, it indicates that the relationship was unlikely to have been obtained by chance.

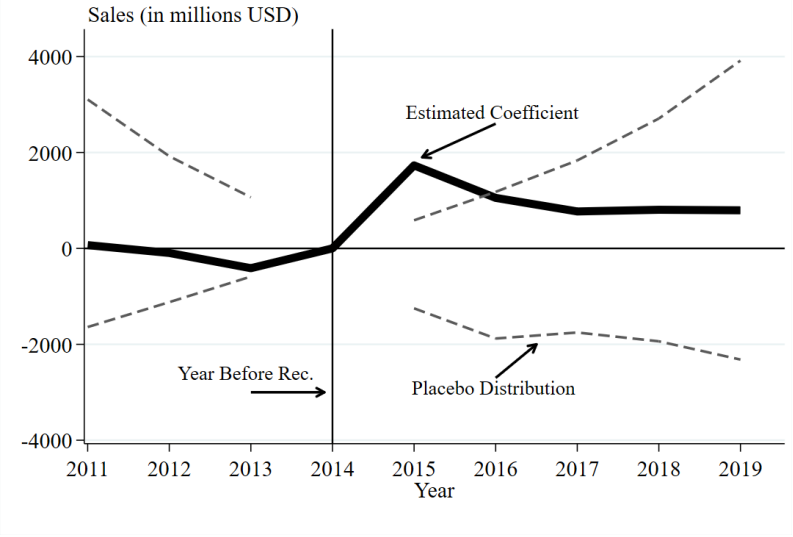
Figure 6: Dynamic Effects of ACIP's Prevnar 13 Recommendation on Uptake of the Pneumonia Vaccine



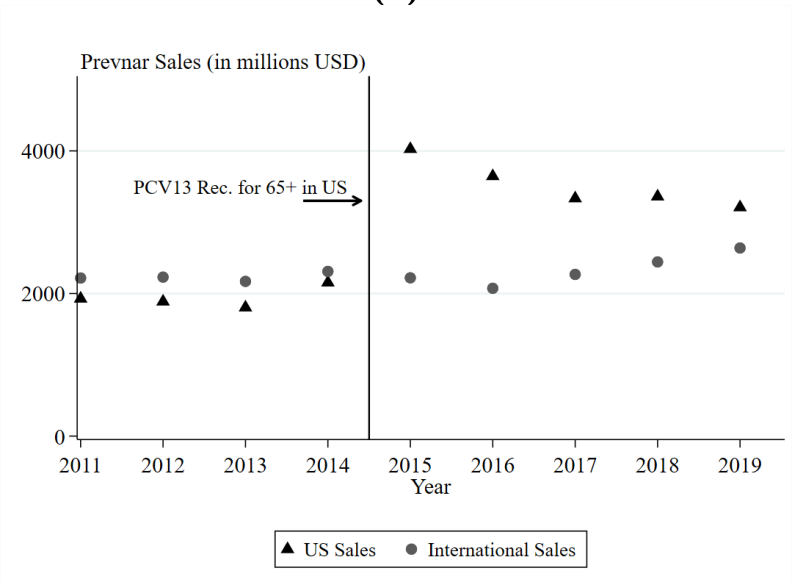
Source: National Health Interview Survey, 2011-2019

Note: The solid dark line indicates the coefficients obtained from estimating equation (3). The lighter dashed lines plot the 95 percent confidence intervals. The dependent variable is an indicator for whether the respondent reported receiving the pneumonia vaccine. The sample includes individuals 50-85 years old.

Figure 7: Effects of ACIP's Prevnar 13 Recommendation on Prevnar Sales



(A)



(B)

Source: Annual Reports 2011-2019

Note: Panel A plots the event study estimates from equation (1). The dependent variable is annual pharmaceutical sales (in millions USD). The independent variables are indicators for being *j* years away from ACIP recommending PCV13 (Prevnar 13) for adults 65 or older. The solid black line plots the point estimates, and the dashed gray lines plot the 95 percent placebo intervals generated from iteratively assuming each of the 46 comparison pharmaceuticals received ACIP's recommendation in August of 2014, estimating equation (1), and saving the placebo coefficients. The regression includes time-invariant fixed effects for each product, as well as product-invariant year fixed effects. The figure in Panel B plots the annual US sales (black triangles) and the international sales (grey circles) of Prevnar 13.

Table 1: Relevant Policy Dates for Adult Vaccination

Vaccine Type	Trade Name	FDA Approval		ACIP Routine Recommendation	
		Year	Age	Year	Age
PPSV23	Pneumovax 23	1989	50+	1989	65+
PCV13	Prevnar 13	2011	50+	2014-2019	65+

Note: Adults receiving PCV13 were still recommended to receive PPSV23. ACIP stopped recommending routine use of PCV 13 for those aged 65 or older in 2019.

Table 2: Effect of ACIP's Age-Targeted Prevnar 13 Recommendation on Pneumococcal Vaccination

	(1)	(2)	(3)
1{Age ≥ 65}×	0.060***	0.070***	0.056***
1{Rec. for Age ≥ 65}	(0.005)	(0.005)	(0.006)
	[0.000]	[0.000]	[0.001]
R^2	0.183	0.216	0.227
Mean for Age ≥ 65 in 2013	0.593	0.593	0.593
Observations	139,742	139,742	139,742
Covariates?		Y	Y
Survey Weights?			Y

Source: National Health Interview Survey, 2011-2019

Note: The dependent variable is an indicator for whether the respondent reported receiving the pneumococcal vaccine. The estimates are obtained using the difference-in-differences specification shown in equation (2). Column 1 utilizes a sparse framework including only indicators for being over the recommended age, being in the post-recommendation period, and the interaction of these terms. Column 2 includes indicators for each age (50-85 with 85+ omitted), race/ethnicity (white, black, Hispanic, Asian with 'other' omitted), educational attainment (less than high school, high school degree, some college with college degree omitted), and health insurance coverage (insured with uninsured omitted). Column 2 also includes Census region-by-year and year-quarter fixed effects. Column 3 utilizes the survey weights. Robust standard errors are shown in parentheses, and wild bootstrapped p-values obtained after clustering standard errors at the group-year level are reported in brackets.

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

Table 3: Effect of ACIP's Age-Targeted Prevnar 13 Recommendation on Receipt of Other Health Care

	(1)	(2)	(3)	(4)
Outcome →	Visited Any Health Care Provider during Prior 12 Months	Visited Any Health Care Provider during Prior 2 Weeks	Influenza Vaccination	Herpes Zoster Vaccination for Shingles Prevention
1{Age ≥ 65}×	0.005	0.016**	0.010	0.058***
1{Rec. for Age ≥ 65}	(0.004)	(0.005)	(0.005)	(0.007)
	[0.190]	[0.017]	[0.159]	[0.005]
R^2	0.069	0.019	0.096	0.092
Mean for Age ≥ 65 in 2013	0.850	0.297	0.669	0.252
Observations	125,768	127,188	142,402	69,325

Source: National Health Interview Survey, 2011-2018

Note: The dependent variable in column 1 is an indicator for whether the respondent reported having a health care visit during the prior 12 months, in column 2 an indicator for whether the respondent reported having a health care visit during the prior 2 weeks, in column 3 an indicator for whether the respondent reported receiving the influenza vaccine, and in column 4 an indicator for whether the respondent reported receiving the herpes zoster vaccine for shingles prevention. The estimates are obtained using the difference-in-differences specification shown in equation (2). Robust standard errors are shown in parentheses, and wild bootstrapped p-values obtained after clustering standard errors at the group-year level are reported in brackets.

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

Table 4: Effect of ACIP's Prevnar 13 Recommendation On Vaccination Claims and Spending in Medicare Part B

	(1)	(2)	(3)	(4)
Outcome →	Prevnar 13 Claims Per Beneficiary	Pneumovax 23 Claims Per Beneficiary	Influenza Vaccination Claims Per Beneficiary	Prevnar 13 Spending Per Beneficiary
1{Treated Group}×	0.0788***	-0.00528	0.00381	14.41***
1{PCV13 Rec.}	(0.003)	(0.001)	(0.00932)	(0.369)
	[0.002]	[0.273]	[0.751]	[0.002]
R^2	0.811	0.884	0.888	0.847
Mean for Treated group in 2013	0.00329	0.0391	0.399	0.454
Observations	1,224	1,224	1,224	1,224

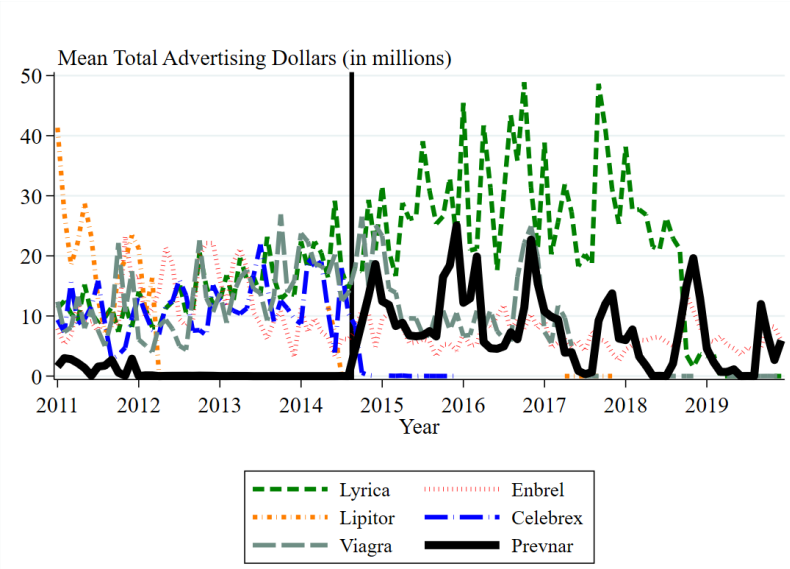
Source: Medicare Part B Claims Public Use Summary Files, 2012-2019

Note: The dependent variable in column 1 is the number of Prevnar 13 (PCV13) claims per beneficiary, in column 2 the number of Pneumovax 23 (PPSV23) claims per beneficiary, in column 3 the number of influenza vaccine administration claims per beneficiary, and in column 4 the amount of Medicare Part B spending on Prevnar 13 per beneficiary. The specifications in columns 1-4 compare changes in outcomes to the concurrent changes in outcomes of other non-routinely recommended vaccines covered by Medicare Part B (hepatitis B, rabies, and tetanus). All columns include year fixed effects and product fixed effects. Robust standard errors are shown in parentheses and wild bootstrapped p-values obtained after clustering standard errors at the group-year level are reported in brackets. Columns 1-4 are weighted by the total number of Medicare Part B Fee-For-Service beneficiaries in a given state-year.

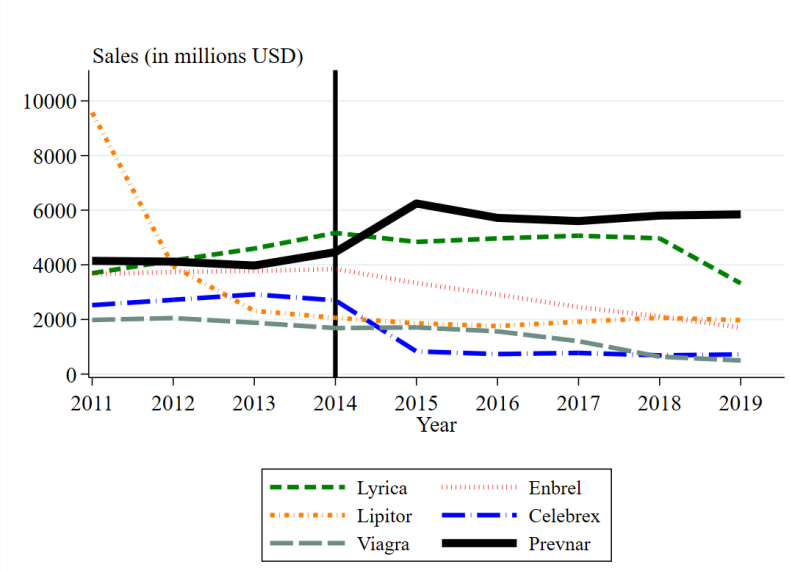
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

7. Appendix

Appendix Figure 1: Advertising Trends of Other Pfizer Products



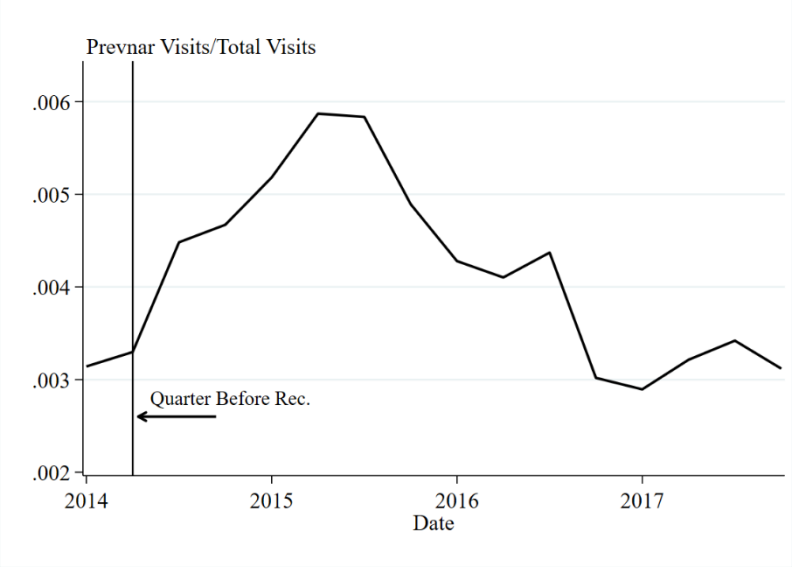
(A)



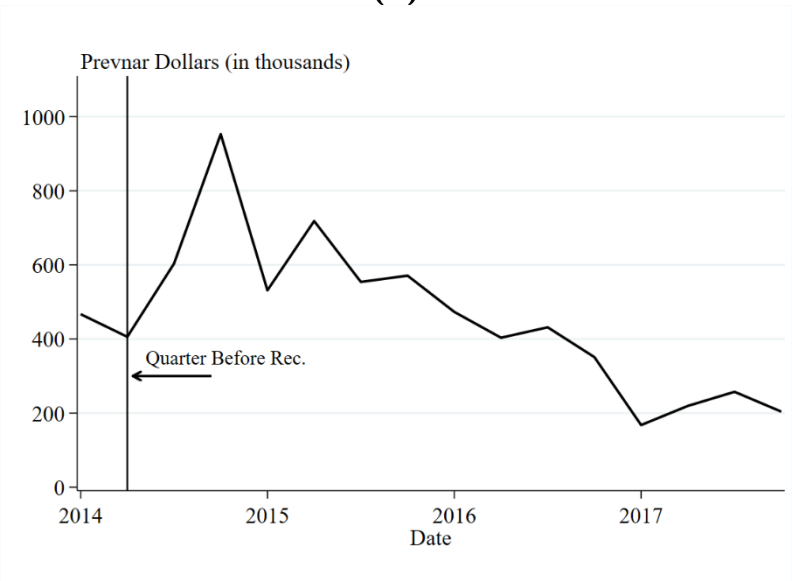
(B)

Source: Ad$pender, 2011-2019; Annual Reports, 2011-2019
Note: Panel A plots total advertising dollars for 5 other Pfizer products. Panel B plots the corresponding annual sales revenue for these products.

Appendix Figure 2: Trends in Prevnar-Related Physician Detailing



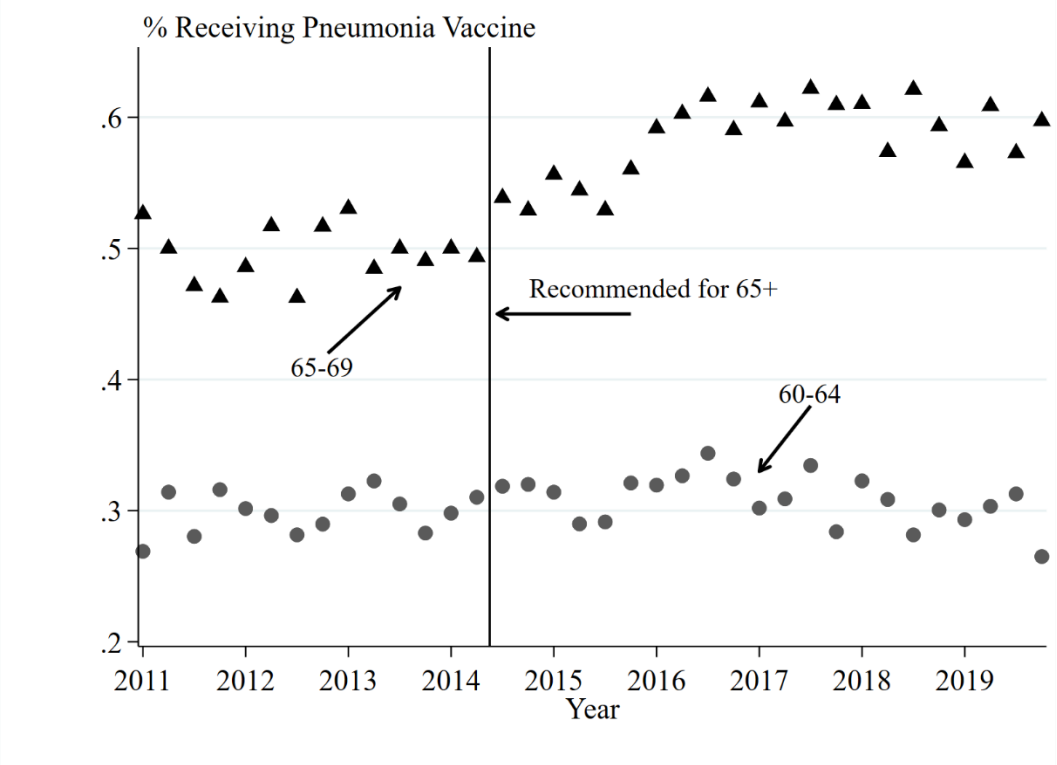
(A)



(B)

Source: CMS Open Payments, 2014-2017
Note: Panel A plots the fraction of all visits in the Open Payments database where physicians received 'food and beverage' related to Prevnar. Panel B plots the total dollars (in thousands) spent on Prevnar detailing in the form of 'food and beverage.'

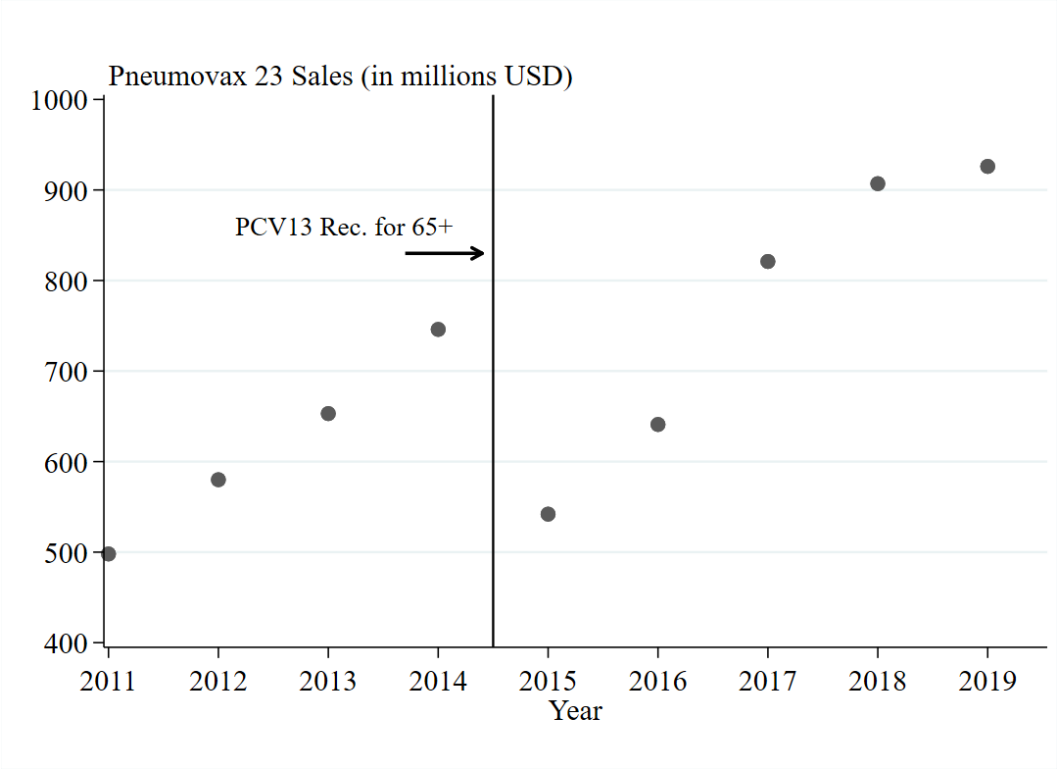
Appendix Figure 3: Share of Adults Receiving the Pneumonia Vaccine Over Time



Source: National Health Interview Survey, 2011-2019

Note: The grey circles denote the share of 60- to 64-year-old individuals reporting that they had received the pneumonia vaccine. The black triangles indicate the share of 65- to -69-year-old individuals reporting that they had received the pneumonia vaccine. PCV13 was recommended for people over 65 in August 2014.

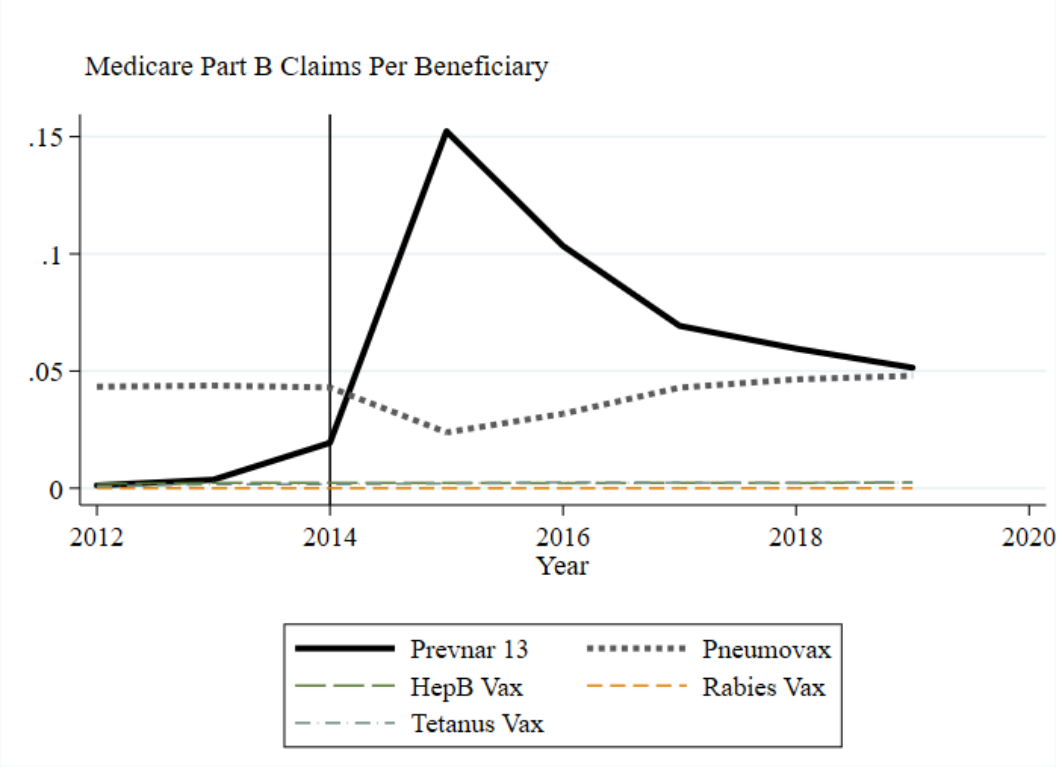
Appendix Figure 4: Pneumovax 23 Sales Trends



Source: Annual Reports, 2011-2019

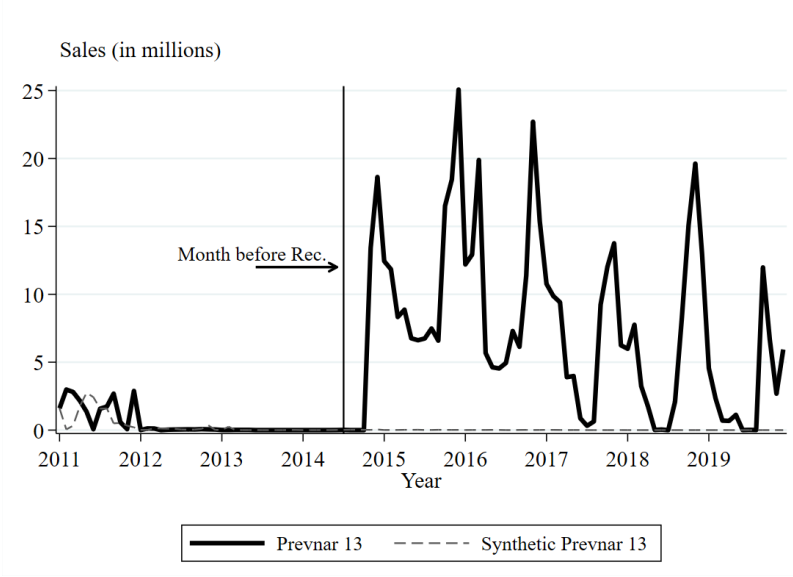
Note: The grey circles plot the annual sales (in millions USD) of Pneumovax 23 in the years surrounding the 2014 ACIP recommendation that adults aged 65 or older receive PCV13.

Appendix Figure 5: Trends in Medicare Part B Claims

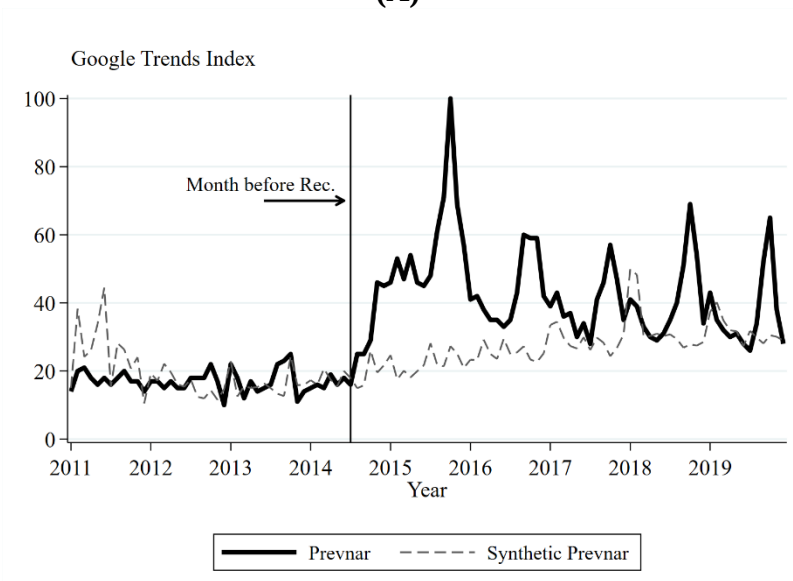


Source: Part B Summary Files, 2012-2019
Note: The figure examines the annual number of claims per beneficiary for covered vaccines among Medicare Part B Fee-For-Service beneficiaries.

Appendix Figure 6: Dynamic Effects on Advertising and Google Searches, Synthetic Control Approach



(A)

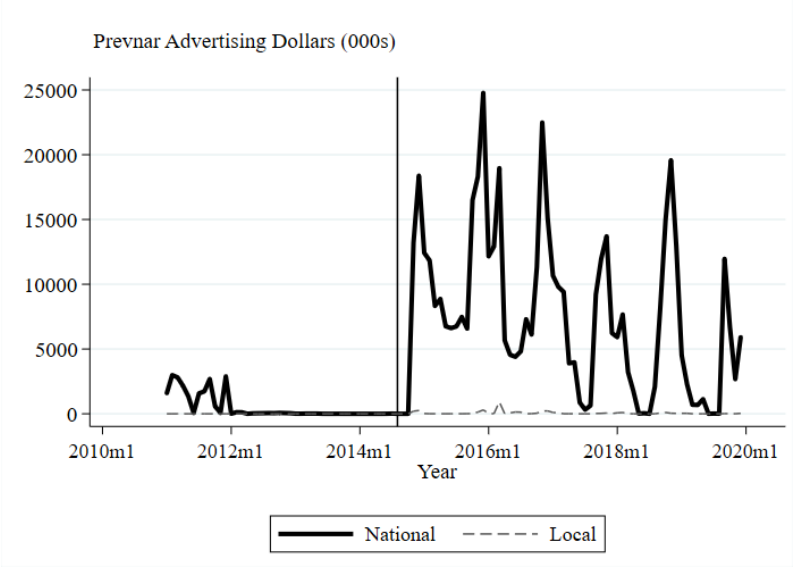


(B)

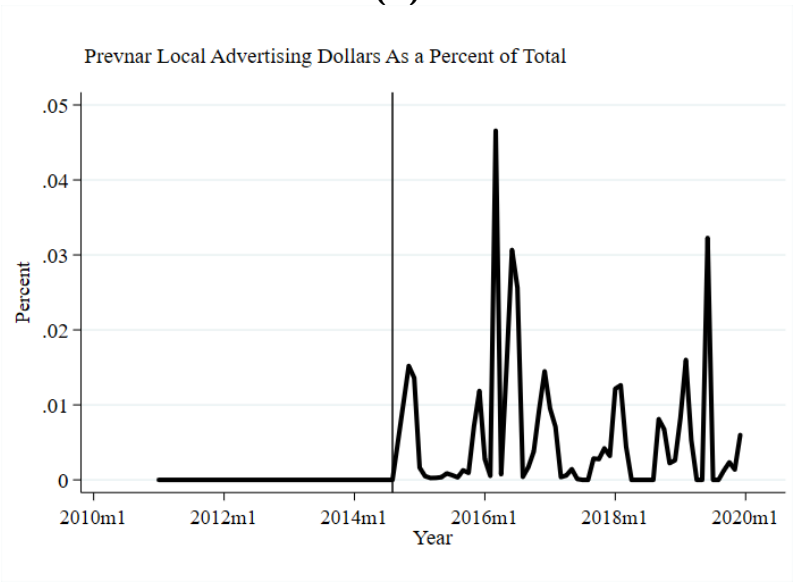
Source: Ad$pender 2011-2019; Google Trends 2011-2019

Note: In Panel A the solid black line plots monthly direct-to-consumer advertising expenditure by Pfizer on Prevnar 13. The grey dashed line plots the advertising expenditures for a 'Synthetic Prevnar' which is constructed by determining the weighted average of placebo pharmaceuticals which best approximates advertising expenditures on Prevnar 13 during the pre-period. Synthetic Prevnar is determined by matching on advertising expenditures in January and July of each year prior to ACIP's recommendation. Similarly, in Panel B the solid black line plots the Google Trends Index for the search term 'Prevnar.' The grey dashed line plots the Google Trends Index for a 'Synthetic Prevnar' which is constructed by determining the weighted average of placebo terms which best approximates searches for 'Prevnar' during the pre-period. Synthetic Prevnar is determined by matching on Google searches in January and July of each year prior to ACIP's recommendation.

Appendix Figure 7: National and Local Trends in Prevnar Advertising Expenditures



(A)

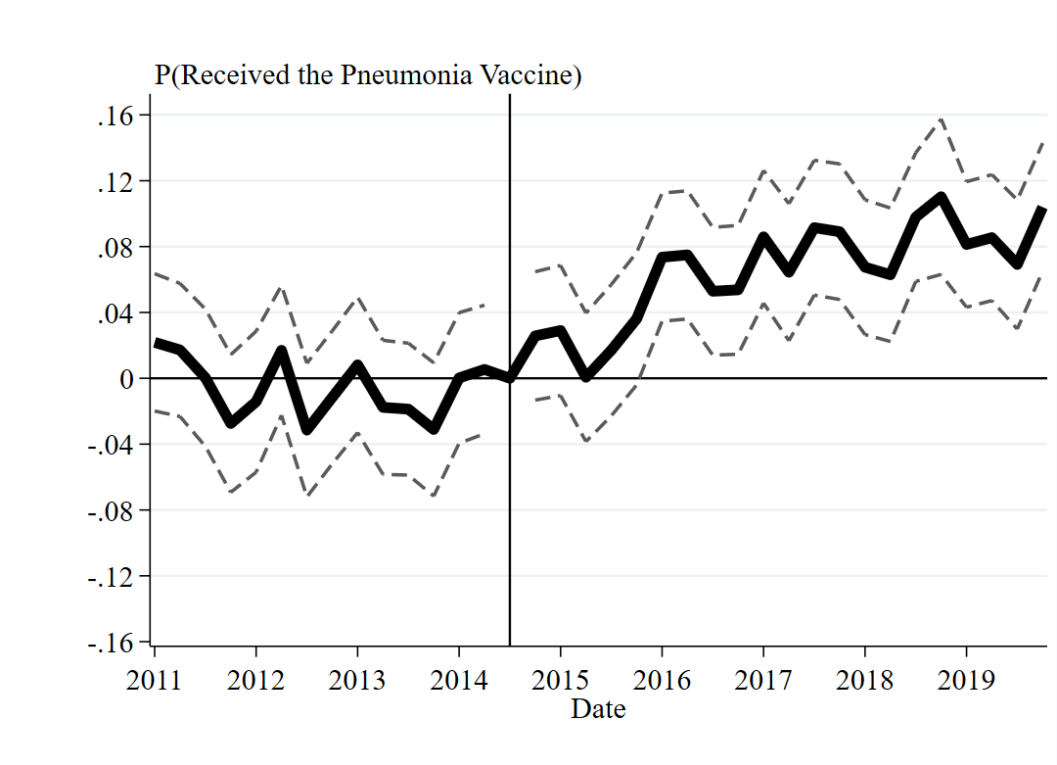


(B)

Source: Ad$pender, 2011-2019

Note: The solid black line in Panel A plots national advertising dollars for Prevnar 13 over time. The dashed grey line plots advertising dollars spent in local media markets. The solid black line in Panel B plots the share of total Prevnar 13 advertising dollars that were spent at the local level.

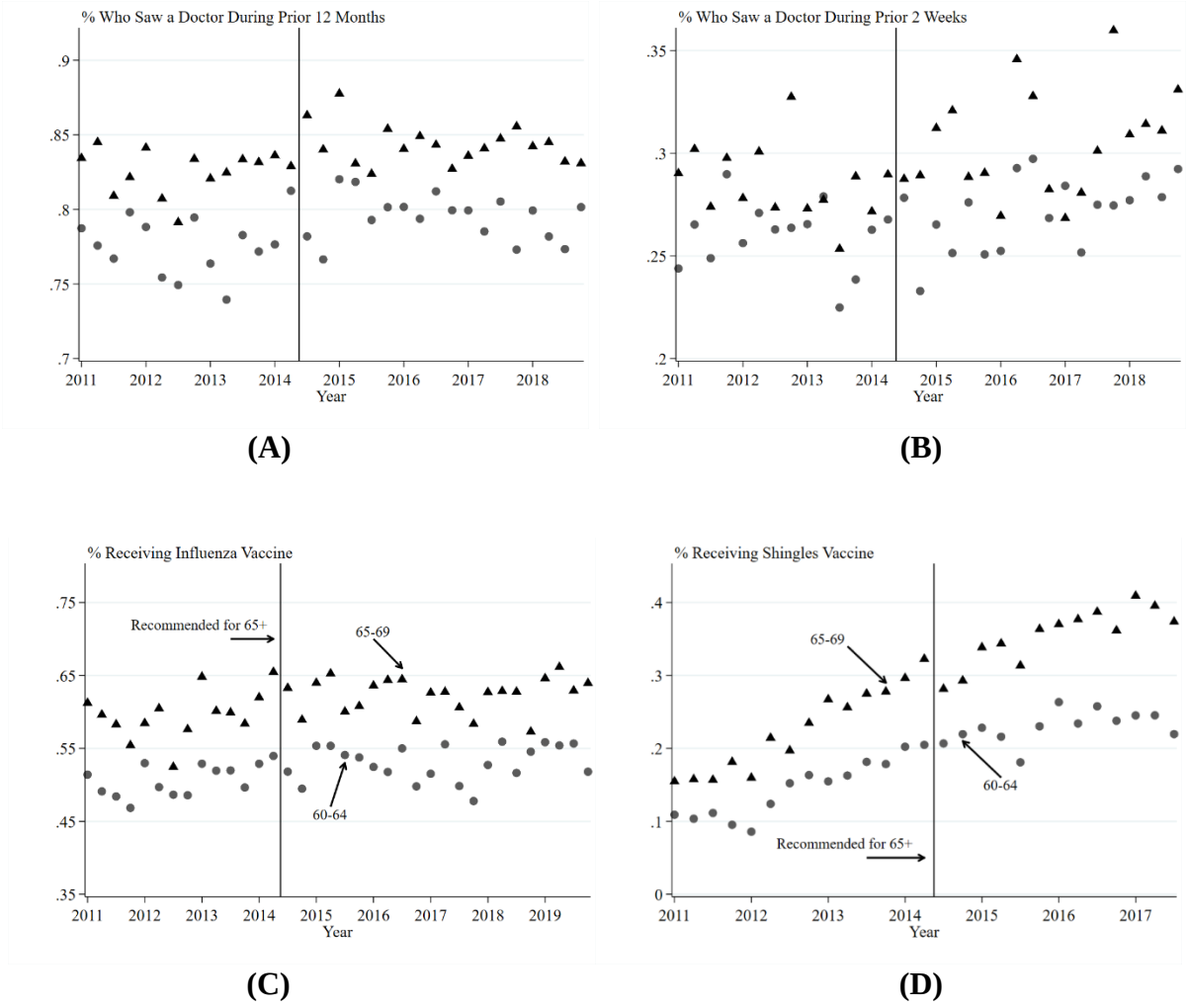
Appendix Figure 8: Dynamic Effects of ACIP's Recommendation on Vaccination for the Sample of Adults with Health Insurance



Source: National Health Interview Survey, 2011-2019

Note: The solid black line indicates the coefficients obtained from estimating equation (3). The grey dashed lines plot the 95 percent confidence intervals. The dependent variable is an indicator for whether the respondent reported receiving the pneumonia vaccine. The sample includes individuals 50-85 years old with health insurance.

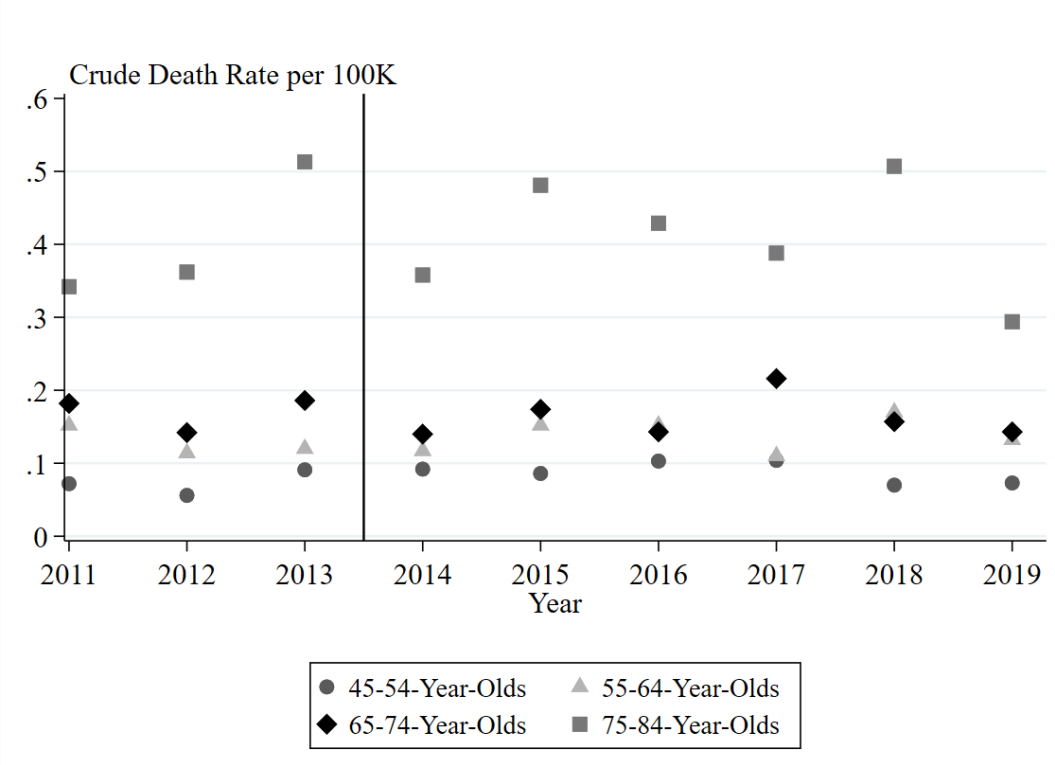
Appendix Figure 9: Trends in Additional NHIS Outcomes Over Time



Source: National Health Interview Survey, 2011-2019

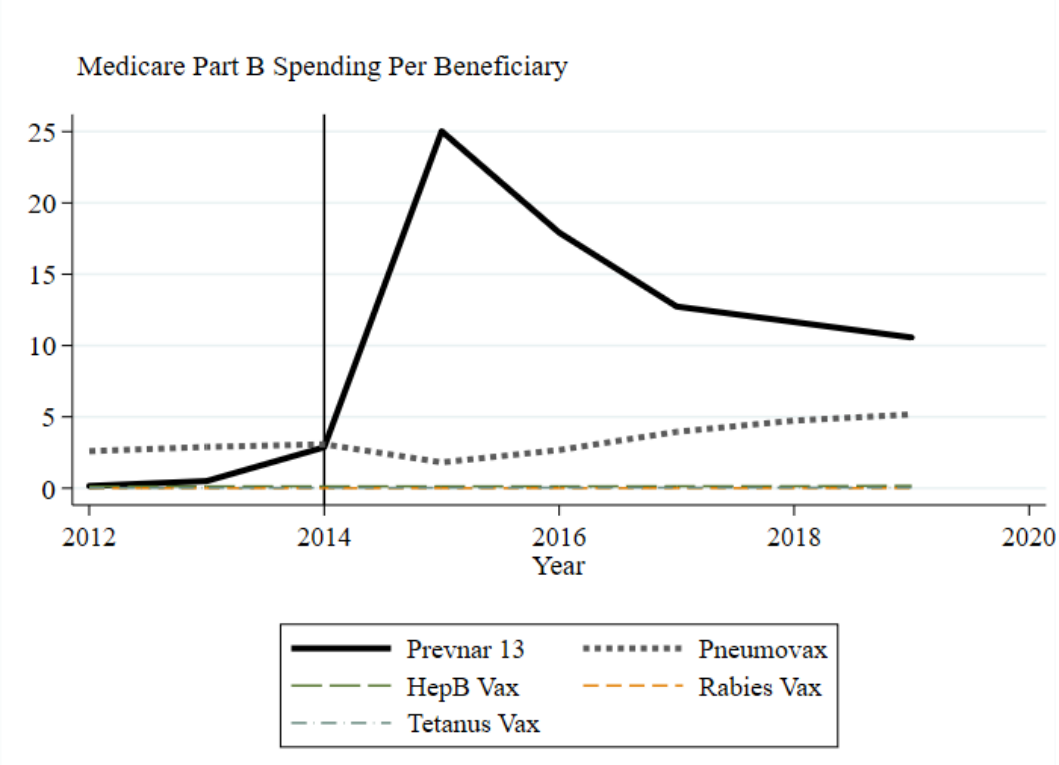
Note: In each panel, the grey circles denote the share of 60- to 64-year-old individuals and the black triangles indicate the share of 65- to 69-year-old individuals. Panel A measures the share reporting they saw a doctor during the prior 12 months, Panel B measures the share reporting they saw a doctor during the prior two weeks, Panel C measures the share reporting they received the influenza vaccine, and Panel D measures the share reporting they received the shingles vaccine. The sample in Panel D is limited to the period prior to the introduction of a new, more effective shingles vaccine that was recommended for adults aged 50 or older. In August 2014, PCV13 was recommended for people over 65.

Appendix Figure 10: Trends in Pneumonia-Related Mortality



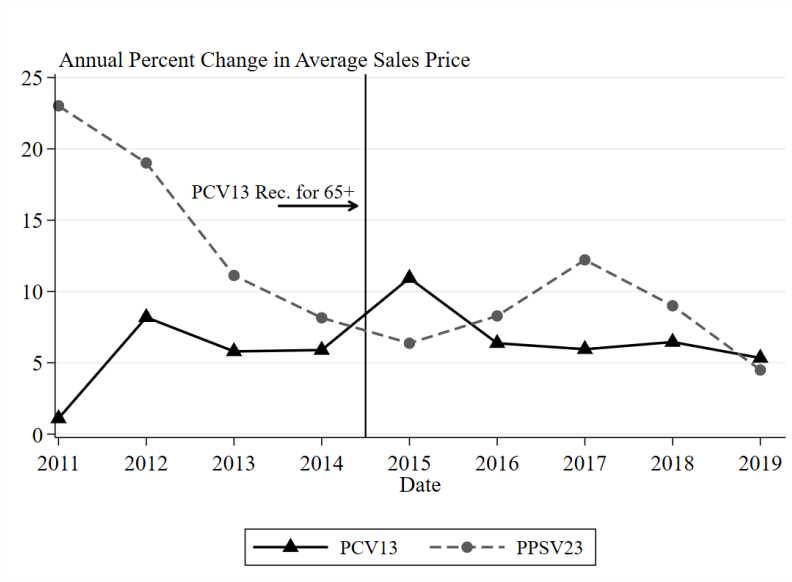
Source: CDC Wonder, 2011-2019
Notes: The figure plots the pneumonia-related crude death rate per 100,000 by age group.

Appendix Figure 11: Trends in Medicare Part B Payments

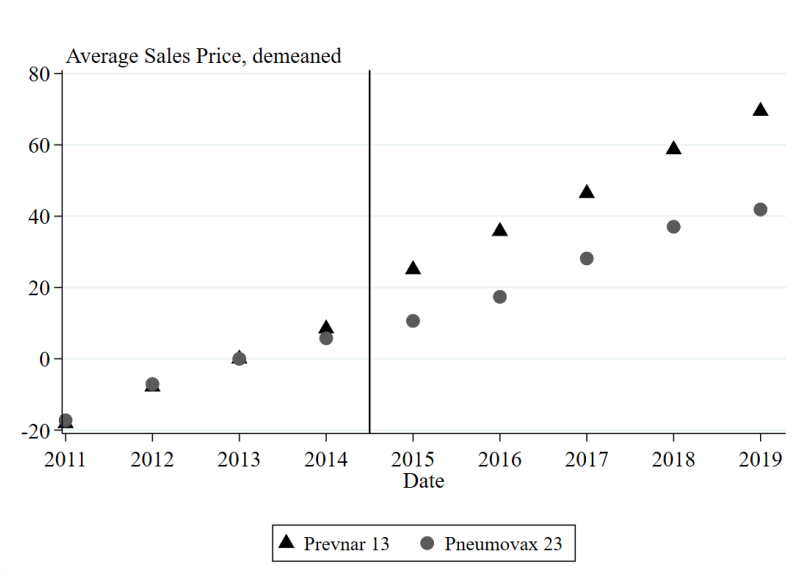


Source: Part B Summary Files, 2012-2019
Note: The figure examines the annual spending per beneficiary for covered vaccines among Medicare Part B Fee-For-Service beneficiaries.

Appendix Figure 12: Trends in Medicare Part B Pneumococcal Vaccine Claims and Average Sale Price



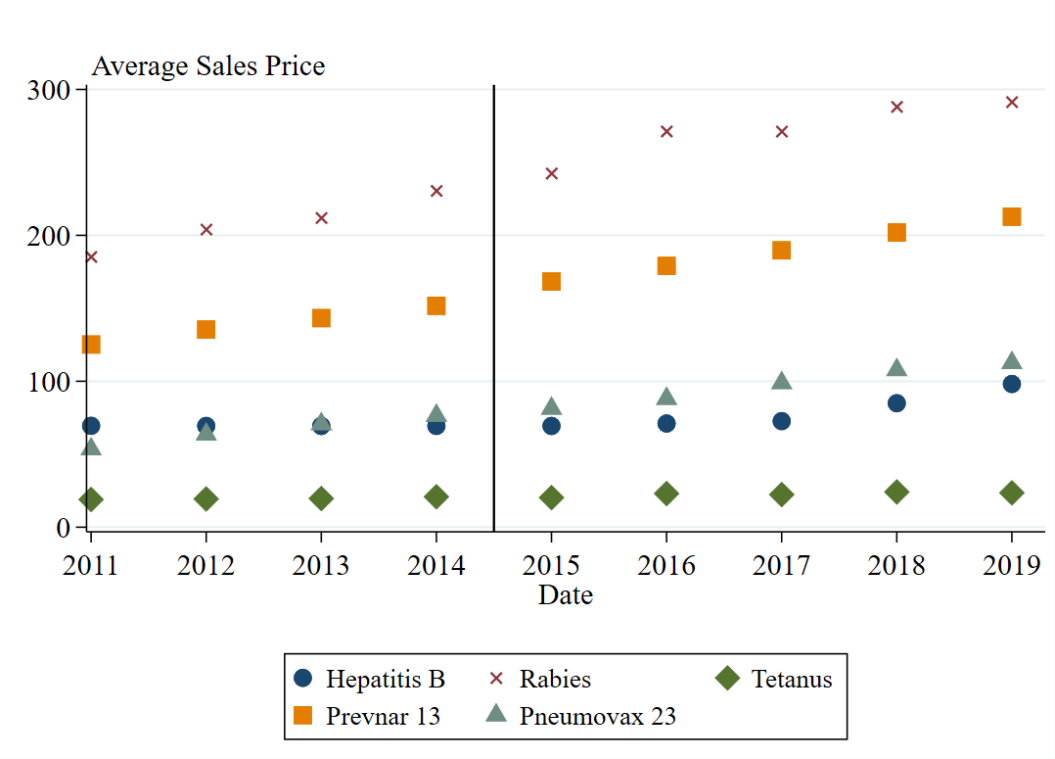
(A)



(B)

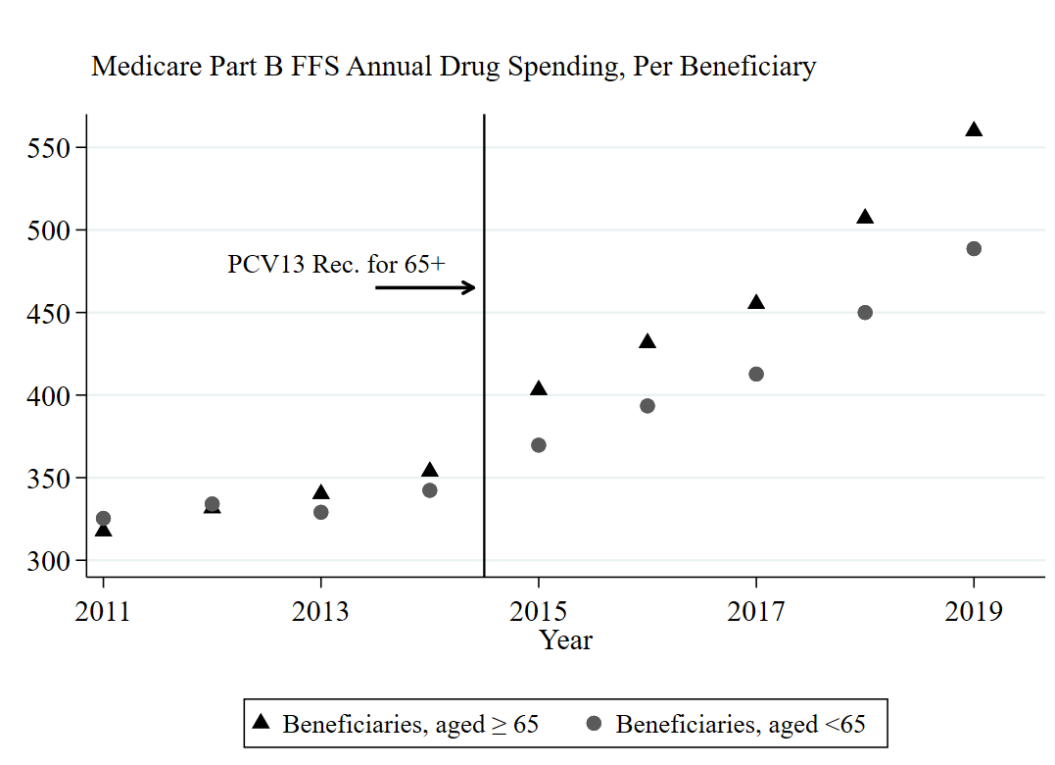
Source: Medicare Part B Average Sales Price Drug Pricing Files, 2011-2019
Note: Panel A plots the annual percent change in the average sale price of PCV13 (black triangles) and PPSV23 (grey circles) relative to the prior year. Panel B plots the demeaned sales price for PCV13 (black triangles) and PPSV23 (grey circles).

Appendix Figure 13: Average Sales Price of Medicare Part B-Covered Vaccines Over Time



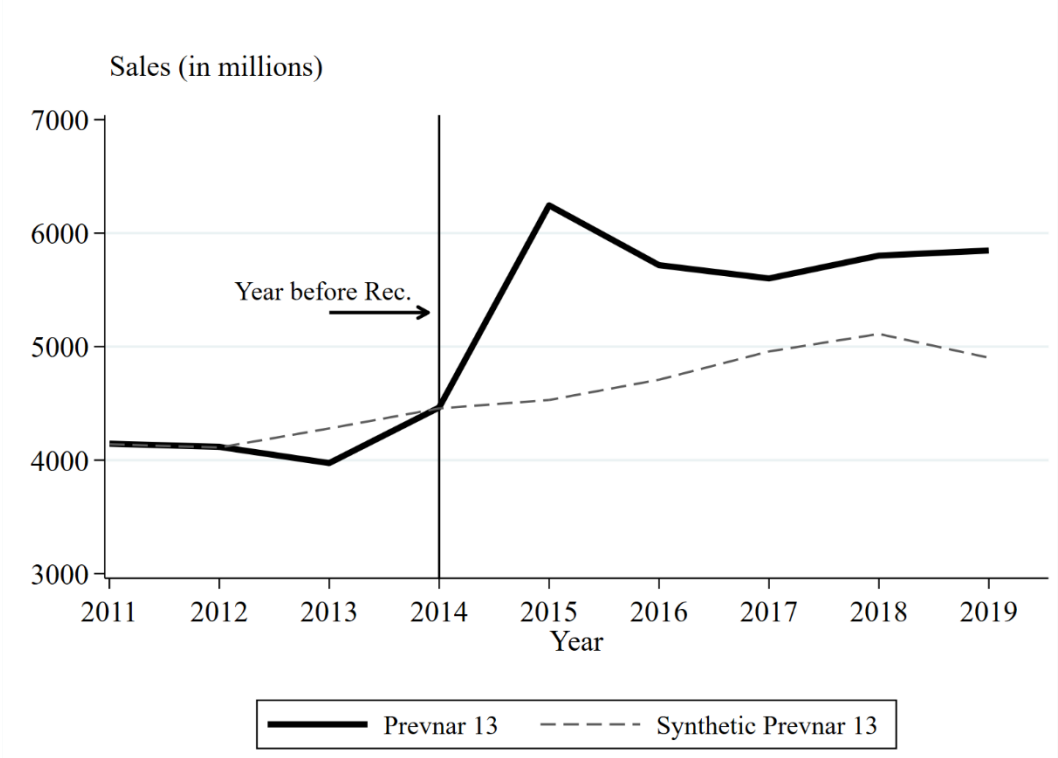
Source: Medicare Part B Average Sales Price Drug Pricing Files, 2011-2019
Note: The figure plots the average sales prices for the drugs used in our analyses.

Appendix Figure 14: Trends in Medicare Part B Drug Spending



Source: Medicare Geographic Variation Public Use Files, 2011-2019
Note: The figure plots the annual per beneficiary Medicare Part B expenditure on drugs for Fee-For-Service beneficiaries aged 65 or older (black triangles) and under 65 (grey circles).

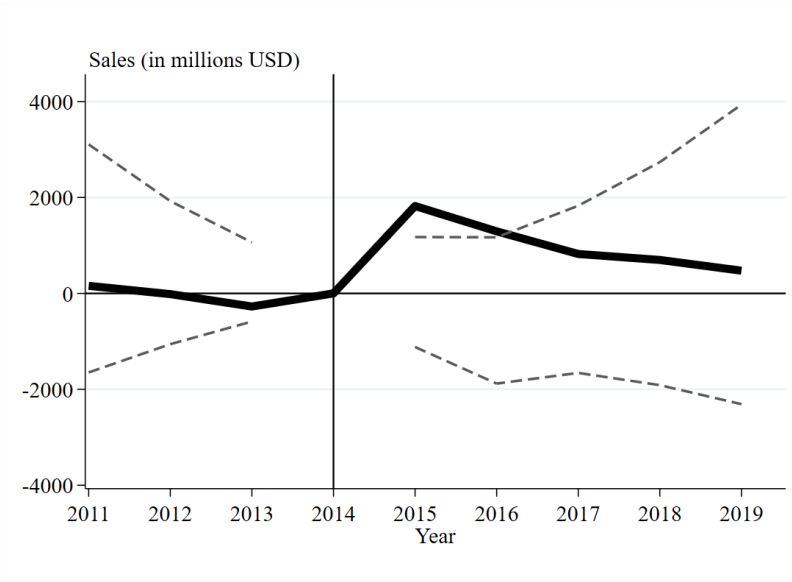
Appendix Figure 15: Dynamic Effects of ACIP's Recommendation on Prevnar Sales, Synthetic Control Approach



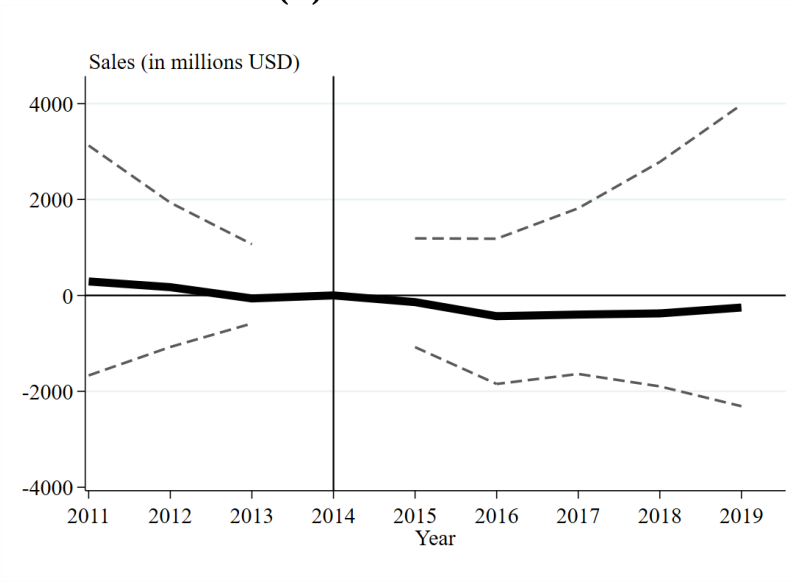
Source: Annual Reports, 2011-2019

Note: The solid black line plots annual sales for Prevnar 13. The grey dashed line plots annual sales for 'Synthetic Prevnar' which is constructed by determining the weighted average of placebo sales which best approximates sales for 'Prevnar' during the pre-period. Synthetic Prevnar is determined by matching on sales data in 2012 and 2014.

Appendix Figure 16: Dynamic Effects of Prevnar 13 Recommendation on US and International Prevnar Sales



(A) US Prevnar Sales



(B) International Prevnar Sales

Source: Annual Reports, 2011-2019

Note: Panels A and B plot the event study coefficients obtained from equation (1), and the dependent variable is annual pharmaceutical sales. Panel A uses US Prevnar sales and Panel B international Prevnar sales. The comparison pharmaceuticals are global sales. The independent variables are indicators for being *j* years away from ACIP recommending PCV13 for adults 65 or older. The solid black line plots the point estimates obtained from equation (1). The dashed gray lines plot the 95 percent placebo intervals generated from iteratively assuming each of the 47 comparison pharmaceuticals received ACIP's recommendation in August of 2014, estimating equation (1), and saving the placebo coefficients. The regression includes fixed effects for each product, as well as year fixed effects.

Appendix Table 1: Comparison Group Products and Terms

	(1)	(2)	(3)
	Ad$pender	Google Trends	Sales
Abilify	Y	Y	Y
Aciphex	Y	Y	
Actemra	Y	Y	
Aczone	Y	Y	
Advair	Y	Y	Y
Allegra	Y	Y	
Amitiza	Y	Y	
Ampyra	Y	Y	Y
Androgel	Y	Y	Y
Asclera	Y	Y	
Atelvia	Y	Y	
Auvi-Q	Y	Y	
Axiron	Y	Y	
Belviq	Y	Y	
Beyaz	Y	Y	
Boniva	Y	Y	
Botox	Y	Y	Y
Brovana	Y	Y	
Cialis	Y	Y	Y
Cimzia	Y	Y	Y
Crestor	Y	Y	Y
Cymbalta	Y	Y	Y
Daytrana	Y	Y	
Dexilant	Y	Y	
Diovan	Y	Y	Y
Dulera	Y	Y	Y
Eloric	Y	Y	
Epiduo	Y	Y	
Essure	Y	Y	
Evista	Y	Y	Y
Exelon Patch	Y	Y	Y
Flovent	Y	Y	Y
Flumist	Y	Y	Y
Fluzone	Y	Y	
Gardasil	Y	Y	Y
Gilenya	Y	Y	Y
Horizant	Y	Y	
Humalog	Y	Y	Y
Humira	Y	Y	Y
Incivek	Y	Y	Y
Intermezzo	Y	Y	
Intuniv	Y	Y	

Invega Sustenna	Y	Y	Y
Invokana	Y	Y	Y
Jalyn	Y	Y	Y
Januvia	Y	Y	Y
Juvederm	Y	Y	
Lantus	Y	Y	
Latisse	Y	Y	Y
3Levemir Flexpen	Y	Y	
Livalo	Y	Y	
Lo Loestrin	Y	Y	Y
Lovaza	Y	Y	Y
Lunesta	Y	Y	
Mirena	Y	Y	
Nasonex	Y	Y	Y
Nexium	Y	Y	Y
Nexplanon	Y	Y	Y
Niaspan	Y	Y	
Novolog	Y	Y	
Nuedexta	Y	Y	
Nuvaring	Y	Y	Y
Nuvigil	Y	Y	Y
Omnaris	Y	Y	
Onglyza	Y	Y	Y
Oracea	Y	Y	
Orencia	Y	Y	Y
Osphena	Y	Y	
Paragard	Y	Y	
Plavix	Y	Y	
Pradaxa	Y	Y	
Prolia	Y	Y	Y
Provenge	Y	Y	
Radiesse	Y	Y	
Rapaflo	Y	Y	
Reclast	Y	Y	
Restasis	Y	Y	Y
Sculptra Aesthetic	Y	Y	
Seasonique	Y	Y	
Seroquel	Y	Y	Y
Simponi	Y	Y	Y
Sklice	Y	Y	
Staxyn	Y	Y	
Stelara	Y	Y	Y
Strattera	Y	Y	Y
Suboxone	Y	Y	
Symbicort	Y	Y	Y

Synvisc One	Y	Y	
Tamiflu	Y	Y	
Tradjenta	Y	Y	
Ulesfia	Y	Y	
Vesicare	Y	Y	
Victoza	Y	Y	
Viibryd	Y	Y	
Vimovo	Y	Y	Y
Voltaren Gel	Y	Y	Y
Vyvanse	Y	Y	Y
Xarelto	Y	Y	Y
Xiaflex	Y	Y	Y
Zetia	Y	Y	Y

Appendix Table 2: NHIS Summary Statistics

	(1)	(2)	(3)
	Full Sample	Below Recommended Age	Above Recommended Age
Pneumococcal Vaccination	0.431	0.225	0.645
Health Insurance	0.935	0.880	0.994
Male	0.437	0.460	0.412
Less than High School	0.148	0.120	0.178
High School Degree	0.278	0.265	0.291
Some College	0.288	0.310	0.266
College Degree	0.286	0.305	0.265
White	0.727	0.693	0.762
Black	0.125	0.139	0.110
Hispanic	0.095	0.111	0.079
Asian	0.041	0.042	0.040
Other	0.012	0.014	0.010
Northeast	0.176	0.173	0.180
Midwest	0.221	0.219	0.224
South	0.362	0.364	0.359
West	0.241	0.245	0.237

Source: National Health Interview Survey, 2011-2019

Note: The summary statistics indicate the shares of the samples with each characteristic based on whether the adult was 65 or older.

Appendix Table 3: Estimated Effects on Monthly Prevnar Advertising Expenditures, by Type

	(1)	(2)	(3)	(4)	(5)
Outcome →	Total Dollars (000s)	TV Dollars (000s)	Print Dollars (000s)	Internet Dollars (000s)	Radio Dollars (000s)
Panel A: Total Advertising					
1{Drug= Prevnar}×	8,146.8**	6,437.1**	1,632.9*	49.64	8.185
1{Rec. for Age ≥ 65}	(276.2)	(219.3)	(97.93)	(14.67)	(3.694)
	[0.03]	[0.02]	[0.09]	[0.67]	[0.18]
R^2	0.588	0.601	0.348	0.244	0.109
Mean for Prevnar in 2013	5.650	0	0	5.650	0
Observations	10,777	10,777	10,777	10,777	10,777
Panel B: National Advertising					
1{Drug= Prevnar}×	7,967.0**	6,379.1**	1,522.8*	47.58	1.905
1{Rec. for Age ≥ 65}	(264.4)	(212.1)	(91.41)	(14.26)	(1.901)
	[0.03]	[0.02]	[0.07]	[0.69]	[0.74]
R^2	0.590	0.601	0.354	0.240	0.0941
Mean for Prevnar in 2013	5.650	0	0	5.650	0
Observations	10,777	10,777	10,777	10,777	10,777
Panel C: Local Advertising					
1{Drug= Prevnar}×	179.8	58.00	110.0*	2.068	6.280*
1{Rec. for Age ≥ 65}	(41.62)	(13.78)	(35.95)	(0.683)	(3.198)
	[0.16]	[0.23]	[0.08]	[0.35]	[0.06]
R^2	0.226	0.217	0.192	0.204	0.114
Mean for Prevnar in 2013	0	0	0	0	0
Observations	10,777	10,777	10,777	10,777	10,777

Source: Ad$pender, 2011-2019

Note: The estimates are obtained using the difference-in-differences specification shown in equation (1), with the vector of indicator variables capturing calendar quarters relative to the recommendation adoption replaced with the single indicator, **1**{Rec. for Age ≥ 65}, which is equal to one in 9/2014 and all subsequent months and is zero otherwise. All specifications include a quadratic in product age (in months), and year-month and product fixed effects. Robust standard errors are shown in parentheses, and p-values obtained from β-randomization inference are in square brackets.

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

Appendix Table 4: Effects of ACIP's Prevnar 13 Recommendation on Internet Search Behavior for 'Pneumovax' and 'Pneumonia'

	(1)	(2)
Outcome →	Google Trends Index for 'Pneumovax'	Google Trends Index for 'Pneumonia'
1{Drug= Prevnar}×	25.338	18.006
1{Rec. for Age ≥ 65}	(9.427)	(2.086)
	[0.19]	[0.45]
R^2	0.577	0.575
Mean for Outcome in 2013	36.583	42.417
Observations	10,908	10,908

Source: Google Trends, 2011-2019

Note: The estimates are obtained using the difference-in-differences specification shown in equation (1), in which the vector of indicator variables capturing calendar quarters relative to the recommendation adoption is replaced with the single indicator, **1**{Rec. for Age ≥ 65}, which is equal to one in 9/2014 and all subsequent months and is zero otherwise. Column 1 includes a linear and quadratic in product age (in months). Both columns include year-month and search term fixed effects. Robust standard errors are shown in parentheses, and p-values obtained from β-randomization inference are in square brackets.

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

Appendix Table 5: Effect of ACIP's Prevnar 13 Recommendation on Pneumococcal Vaccine, by Demographic Group

	(1)	(2)	(3)	(4)	(5)	(6)
Sample Restriction →	Health Insurance	Male	Female	White	Black	Hispanic
1{Age ≥ 65}×	0.069***	0.077***	0.065***	0.057***	0.074***	0.065***
1{Rec. for Age ≥ 65}	(0.005)	(0.007)	(0.006)	(0.006)	(0.014)	(0.016)
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.002]
R^2	0.202	0.211	0.216	0.238	0.142	0.123
Observations	130,712	61,025	78,717	101,559	17,484	13,307
	(7)	(8)	(9)	(10)	(11)	(12)
Sample Restriction →	Asian	Other	Less than HS	HS Graduate	Some College	College Graduate
1{Age ≥ 65}×	0.057***	0.111	0.057***	0.060***	0.056***	0.072***
1{Rec. for Age ≥ 65}	(0.023)	(0.052)	(0.013)	(0.009)	(0.009)	(0.009)
	[0.001]	[0.144]	[0.000]	[0.000]	[0.000]	[0.000]
R^2	0.200	0.163	0.206	0.217	0.217	0.266
Observations	5,749	1,643	20,716	38,805	40,304	39,917

Source: National Health Interview Survey, 2011-2019

Note: The dependent variable is an indicator for reporting receipt of the pneumococcal vaccine. The independent variable of interest is an indicator for whether ACIP recommended the pneumococcal vaccine for adults aged 65 or older. The regression includes the full set of controls from equation (2). Each column restricts the sample to a specific group: column 1 limits the sample to those with health insurance, column 2 to men, column 3 to women, column 4 to white individuals, column 5 to Black individuals, column 6 to Hispanic individuals, column 7 to Asian individuals, and column 8 to those classified as 'other.' Similarly, column 9 limits the sample to those with less than a high school degree, column 10 to those with a high school degree, column 11 to those with some college education, and column 12 to those with a college degree. Robust standard errors are shown in parentheses, and wild bootstrapped p-values obtained after clustering standard errors at the age group-year level are reported in brackets.

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

Appendix Table 6: Differential Effects of ACIP's Prevnar 13 Recommendation on Pneumococcal Vaccine, by Demographic Group

	(1)	(2)	(3)
Group →	Male	White	College Educated
1{Age ≥ 65}×	0.065***	0.073***	0.064***
1{Rec. for Age ≥ 65}	(0.006)	(0.009)	(0.006)
	[0.001]	[0.000]	[0.000]
1{Group = j} × **1**{Age ≥ 65}	0.012	-0.015	0.008
× **1**{Rec. for Age ≥ 65}	(0.010)	(0.011)	(0.011)
	[0.307]	[0.188]	[0.374]
R^2	0.216	0.222	0.219
Mean for Age ≥ 65 in 2013	0.593	0.593	0.593
Observations	139,742	139,742	139,742

Source: National Health Interview Survey, 2011-2019

Note: The dependent variable is an indicator for whether the respondent reported receiving the pneumococcal vaccine. The estimates are obtained using a modified version of difference-in-differences specification shown in Table 3 column 2 whereby the righthand side variables are fully interacted with an indicator for the group of interest shown in the column header. Column 1 interacts the righthand side variables with an indicator for being male, column 2 for being white, and column 3 for being college educated. Robust standard errors are shown in parentheses, and wild bootstrapped p-values obtained after clustering standard errors at the group-year level are reported in brackets.

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

Appendix Table 7: Effect of ACIP's Prevnar 13 Recommendation on Pneumococcal Vaccination, BRFSS Data

	(1)	(2)	(3)
1{Age ≥ 65}×	0.027***	0.026***	0.026***
1{Recommended for Age ≥ 65}	(0.001)	(0.001)	(0.003)
	[0.000]	[0.000]	[0.000]
R^2	0.193	0.216	0.210
Mean	[0.605]	[0.605]	[0.605]
Observations	1,788,994	1,788,994	1,788,994
Covariates?		Y	Y
Survey Weights?			Y

Source: Behavioral Risk Factor Surveillance System, 2011-2019

Note: The dependent variable is an indicator for whether the respondent reported receiving the pneumococcal vaccine. The independent variable of interest indicates whether individuals were treated by ACIP's August 2014 PCV13 recommendation. Column 1 utilizes a sparse framework including only indicators for being over the recommended age, being in the post-recommendation period, and the interaction of these terms. Column 2 adds state fixed effects, year and month fixed effects, and indicators for each age group (50-54, 55-59, 60-64, 65-69, 70-74, 75-79 with 80+ omitted), race/ethnicity (white, black, Hispanic, Asian with 'other' omitted), educational attainment (less than high school, high school degree, some college with college degree omitted), and sex (male with female omitted). Column 2 also fully interacts the age indicators with an indicator for whether the state had expanded Medicaid as part of the Affordable Care Act at the time of survey. Column 3 utilizes the survey weights. Robust standard errors are shown in parentheses, and wild bootstrapped p-values obtained after clustering standard errors at the group-year level are reported in brackets.

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

Appendix Table 8: Effect of ACIP's Prevnar 13 Recommendation on Incidence of Pneumococcal Disease and Pneumonia-Related Mortality

	(1)	(2)	(3)	(4)
Outcome →	IHS(Incidence per 100K)	IHS(Incidence per 100K)	IHS(Incidence per 100K)	Pneumonia-Related Mortality per 100K
1{Age ≥ 65}×	0.013	-0.767***	0.018	-0.936
1{Rec. for Age ≥ 65}	(0.052)	(0.087)	(0.059)	(0.582)
	[0.772]	[0.002]	[0.741]	[0.226]
R^2	0.974	0.965	0.987	0.998
Mean for Age ≥ 65 in 2013	30.4	30.4	30.4	27.92
Observations	184	92	736	27
Age in Sample	All	65+	All	45-74
Disease in Sample	Pneumonia	All	All	Pneumonia
Age FE?	Y			
Year FE?	Y	Y		Y
Disease FE?		Y		Y
Age-by-Year FE?			Y	
Age-by-Disease FE?			Y	
Year-by-Disease FE?			Y	

Source: Active Bacterial Core Surveillance 1998-2019; CDC WONDER 2011-2019

Note: The dependent variable in columns 1-3 is the inverse hyperbolic sine of the disease incidence rate per 100,000. The estimates in column 1 are obtained using a difference-in-differences specification comparing changes in pneumococcal disease incidence for eight age groups (<1, 1 year old, 2-4 years old, 5-17 years old, 18-34 years old, 35-69 years old, 50-64 years old, and ≥ 65 years old) over time. Column 2 reports the difference-in-differences coefficient obtained by comparing changes in pneumococcal incidence for adults aged 65+ to the associated changes in three other diseases (Group A Streptococcus, Group B Streptococcus, and Haemophilus Influenzae) among this age group over time. Column 3 presents the triple-difference estimate obtained from including all four diseases and eight age groups in a single specification and including age-by-year, age-by-disease, and year-by-disease fixed effects. All columns control for the approval of PCV7 and PCV13 for children < 5 and adults aged 50 or older. Column 4 uses CDC WONDER mortality data and includes age group fixed effects (45-54, 55-64, with 65-74 omitted) and year fixed effects. Robust standard errors are shown in parentheses, and wild bootstrapped p-values obtained after clustering standard errors at the group-year level are reported in brackets.

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

Appendix Table 9: Effect of ACIP's 2014 Prevnar 13 Recommendation on Average Vaccine Prices

Outcome →	(1) Average Price of PCV13	(2) Average Price of PPSV23
1{Treated Group}×	38.189***	18.991***
1{PCV13 Rec.}	(2.363)	(2.997)
	[0.000]	[0.000]
R^2	0.974	0.972
Mean for Treated group in 2013	143.30	70.71
Observations	290	290
Time Fixed Effects?	Y	Y
Product Fixed Effects?	Y	Y

Source: Medicare Part B Average Sales Price, 2011-2019

Note: The dependent variable in column 1 is the average price of PCV13, in column 2 the average price of PPSV23, and in column 3 the annual Medicare Part B drug spending per beneficiary. The columns compare changes in outcomes for PCV13 and PPSV23 to the concurrent changes in outcomes of other vaccines covered by Medicare Part B (hepatitis B, rabies, and tetanus). These columns include year fixed effects and product fixed effects. Robust standard errors are shown in parentheses and wild bootstrapped p-values obtained after clustering standard errors at the group-year level are reported in brackets.

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