A1 Other Analyses Referenced in the Text

Table A1: Recommended vaccinations from birth to 24 months.

| Birth	1 month	2 months	4 months	6 months	12 months	15 months	18 months	19-23 months
HepB	HepB	HepB		HepB	HepB	HepB	HepB	
		RV	RV					
		Hib	Hib	Hib	Hib	Hib		
		Pneumo	Pneumo	Pneumo	Pneumo	Pneumo		
		DTaP	DTaP	DTaP		DTaP	DTaP	
		Polio	Polio	Polio	Polio	Polio	Polio	
				Influenza (Yearly)	Influenza (Yearly)	Influenza (Yearly)	Influenza (Yearly)	Influenza (Yearly)
					MMR	MMR		
					Varicella	Varicella		
					HepA	HepA	HepA	HepA

Notes: DTaP is a diphtheria, tetanus, and pertussis vaccine; HepA is a hepatitis A vaccine; HepB is a hepatitis B vaccine; Hib is a Haemophilus influenzae type b vaccine; MMR is a measles, mumps, and rubella vaccine; Pneumo is a pneumococcal vaccine; and RV is a rotavirus vaccine. Source: Centers for Disease Control and Prevention.

Figure A1: Median Monthly Price Per Dose for Leading Hib Vaccines
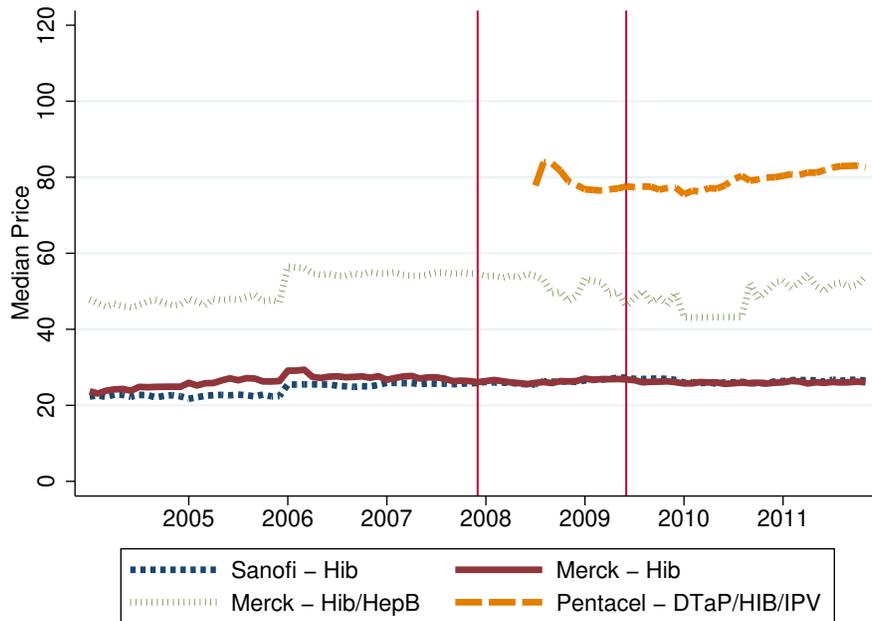
Notes: Median monthly prices in nominal dollars (not adjusted for inflation) for Hib-containing vaccines, as observed in the MarketScan database. Sanofi introduced Pentalcel in June 2008.

Figure A2: Number of Hib doses per child administered per month
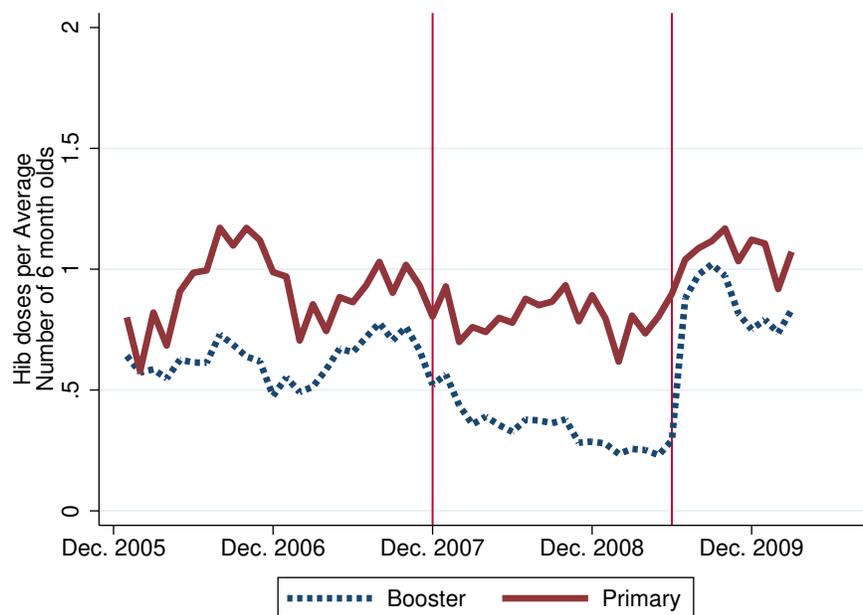
Notes: The outcome variable is Hib doses administered in a given month, divided by the average number of 6-month-old children in the MarketScan data in a year. The vertical axis is scaled by the number of doses in each series, so the value of one approximates a child being up-to-date in the series. A series is two primary doses of the Merck vaccine, three primary doses of the Sanofi Pasteur vaccine, or one booster dose.

Table A2: Effect of the Shortage on Hib Vaccine Up-to-Date Rates, including county-level controls

	(1) Any doses 9 months	(2) Any doses 62 months	(3) Primary UTD 9 months	(4) Primary UTD 62 months	(5) Booster UTD 18 months	(6) Booster UTD 62 months
Panel A						
Shortage Exposed	-0.008**	-0.002	-0.038***	-0.001	-0.254***	-0.038***
	(0.002)	(0.002)	(0.005)	(0.002)	(0.022)	(0.008)
	[0.014]	[0.502]	[0.000]	[0.776]	[0.000]	[0.000]
Mean	0.92	0.95	0.72	0.90	0.53	0.79
Observations	263069	263069	263069	263069	263069	263069
Panel B						
Pre-Trend	-0.000	0.000	-0.000	-0.001*	-0.000	-0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	(0.001)
	[0.876]	[0.420]	[0.179]	[0.061]	[0.872]	[0.233]
Pre-Shortage Mean	0.92	0.95	0.72	0.89	0.63	0.77
Observations	88740	88740	88740	88740	45594	45594

Notes: Each column of each panel presents coefficient estimates from a separate regression using MarketScan data aggregated to the child level; the outcome variable is given in the column header and captures receipt of a given dose of the Hib vaccine. In Panel A, the indicator variable *Shortage Exposed* captures if a child's birth cohort was of age to receive a given vaccine dose during the shortage. See Figure 3 for details. In Panel B, the reported estimate is the coefficient on a month-level time trend, estimated using only pre-shortage cohorts. Robust standard errors, shown in parentheses, are clustered at the month-year of birth level. Wild clustered bootstrapped p-values are reported in brackets.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A3: Summary Statistics for Pneumococcal Vaccine Outcomes

	(1)	(2)	(3)	(4)
		Exposed	Exposed	
	Full	during	during	Never
	Sample	Primary	Booster	Exposed
Any Pneumo Doses, 9 Months	0.896	0.893	0.890	0.900
	(0.305)	(0.309)	(0.313)	(0.300)
Pneumo UTD Primary, 9 Months	0.720	0.715	0.709	0.724
	(0.449)	(0.452)	(0.454)	(0.447)
Pneumo UTD Booster, 18 Months	0.663	0.657	0.646	0.671
	(0.473)	(0.475)	(0.478)	(0.470)
Any Pneumo Doses, 62 Months	0.930	0.927	0.925	0.932
	(0.255)	(0.260)	(0.264)	(0.252)
Pneumo UTD Primary, 62 Months	0.884	0.889	0.884	0.880
	(0.321)	(0.314)	(0.320)	(0.324)
Pneumo UTD Booster, 62 Months	0.809	0.831	0.819	0.794
	(0.393)	(0.375)	(0.385)	(0.404)
Observations	177351	60636	54475	95303

Notes: Summary statistics for outcomes and treatments for different samples using MarketScan data aggregated to the child level. The mean is listed with the standard deviation in parentheses below. Children could have been exposed during the primary series and the booster series, so columns 2-4 do not add up to the full sample of observations. See Figure 3 for details. For this table, we drop states that implemented pneumococcal mandates between 2006 and 2008. "UTD" indicates up to date.

Table A4: Summary Statistics for Other Demographics

|	(1) Full Sample	(2) Exposed during Primary	(3) Exposed during Booster	(4) Never Exposed
Family Size	3.777	3.801	3.797	3.764
	(1.189)	(1.216)	(1.216)	(1.171)
Income ($10,000s)	6.823	6.817	6.775	6.845
	(1.471)	(1.460)	(1.442)	(1.489)
% Rural	0.208	0.207	0.212	0.207
	(0.239)	(0.237)	(0.240)	(0.239)
% African American	0.141	0.140	0.141	0.140
	(0.129)	(0.129)	(0.129)	(0.129)
% Hispanic	0.146	0.146	0.148	0.145
	(0.155)	(0.155)	(0.156)	(0.155)
% College	0.609	0.609	0.606	0.610
	(0.104)	(0.104)	(0.104)	(0.104)
% High School	0.800	0.799	0.801	0.801
	(0.079)	(0.079)	(0.078)	(0.079)
PCPs	89.376	89.390	87.968	89.912
	(42.700)	(43.002)	(41.622)	(43.010)
Teen Births	42.526	42.462	43.359	42.160
	(17.495)	(17.420)	(17.578)	(17.455)
% Diabetic Screening	0.824	0.824	0.823	0.825
	(0.038)	(0.038)	(0.039)	(0.038)
Merck Share	0.414	0.417	0.413	0.414
	(0.402)	(0.400)	(0.399)	(0.404)
Observations	322784	107833	98739	175470

Notes: The mean is listed with the standard deviation in parentheses below. Source: Authors' using Marketscan and Robert Wood Johnson County Health Rankings.

Table A5: Balance Tests: Comparing Demographics For Exposed and Non-Exposed Cohorts

	Sample Mean	(1) Primary Series	(2) Booster Series
Family Size	3.777	0.042***	0.023*
		(0.011)	(0.011)
		[0.000]	[0.085]
Income ($10,000s)	6.823	-0.026*	-0.032**
		(0.011)	(0.011)
		[0.048]	[0.012]
% Rural	0.208	0.001	0.003
		(0.002)	(0.002)
		[0.796]	[0.160]
% African American	0.141	0.001	-0.002*
		(0.001)	(0.001)
		[0.197]	[0.039]
% Hispanic	0.146	-0.002	0.007**
		(0.002)	(0.002)
		[0.336]	[0.004]
% College	0.609	-0.001	-0.004***
		(0.001)	(0.001)
		[0.429]	[0.000]
% High School	0.800	-0.001	0.002**
		(0.000)	(0.001)
		[0.095]	[0.016]
PCPs	89.376	-0.259	-1.902***
		(0.467)	(0.362)
		[0.634]	[0.000]
Teen Births	42.526	0.137	0.886***
		(0.139)	(0.095)
		[0.392]	[0.000]
% Diabetic Screening	0.824	-0.000	-0.003***
		(0.000)	(0.000)
		[0.359]	[0.000]
% Merck Share	0.414	0.002	-0.005
		(0.003)	(0.003)
		[0.520]	[0.132]

Notes: Each column and row is the result of a different regression where the outcome variable is shown in the first column of the table. For each regression, we present the coefficient on an indicator for being shortage exposed, either in the primary series or booster series. The regression also includes an indicator for being shortage adjacent and birth month of year fixed effects. Source: Authors' using Marketscan and Robert Wood Johnson County Health Rankings.

Figure A3: Hib Vaccination Up-to-Date Rates, Cumulative Distribution

Primary Series

Booster Dose
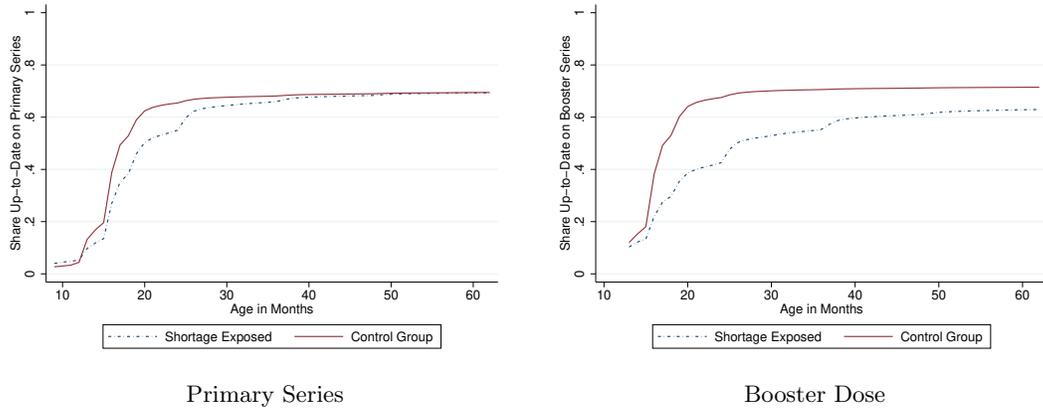
Notes: These figures present a cumulative distribution of up-to-date rates for the Hib vaccine for the shortage exposed cohort and our control cohorts. The y-axis is the share of children in that cohort who are up-to-date on the primary or booster series. The x-axis is the age for those children. These graphs show how long the gap in vaccination rates persisted for shortage exposed children.

Table A6: Effect of Shortage on Age at Receipt of a Hib Dose, Conditional on Receipt

	(1) Age 1st Dose	(2) Age 2nd Dose	(3) Age Booster Dose
Panel A			
Shortage Exposed	0.277***	0.346***	5.086***
	(0.041)	(0.052)	(0.571)
	[0.000]	[0.000]	[0.000]
Mean	2.89	5.02	17.18
Observations	307973	293297	230472
Panel B			
Pre-Trend	0.012***	0.014***	0.023*
	(0.003)	(0.003)	(0.010)
	[0.000]	[0.000]	[0.068]
Pre-Shortage Mean	2.72	4.93	14.82
Observations	84599	80463	32630

Notes: Each column presents coefficient estimates from a separate regression using MarketScan data aggregated to the child level; the outcome variable is the age in months of a child receiving the dose of the Hib vaccine referenced in the header. In Panel A, the indicator variable *Shortage Exposed* captures if a child's birth cohort was of age to receive a given vaccine dose during the shortage. See Figure 3 for details. In Panel B, the reported estimate is the coefficient on a month-level time trend, estimated using only pre-shortage cohorts. Robust standard errors, shown in parentheses, are clustered at the month-year of birth level. Wild clustered bootstrapped p-values are reported in brackets.

Table A7: The Effect of the Shortage on Hib Vaccine Up-to-Date Rates, Dropping the Post Period

	(1)	(2)	(3)	(4)	(5)	(6)
			Primary	Primary	Booster	Booster
	Any doses	Any doses	UTD	UTD	UTD	UTD
	9 months	62 months	9 months	62 months	18 months	62 months
Panel A						
Shortage Exposed	-0.008***	-0.002	-0.028***	0.005*	-0.292***	-0.004
	(0.002)	(0.002)	(0.005)	(0.002)	(0.020)	(0.007)
	[0.001]	[0.476]	[0.000]	[0.054]	[0.000]	[0.607]
Mean	0.92	0.95	0.72	0.90	0.53	0.79
Observations	222173	222173	222173	222173	173598	173598
Panel B						
Pre-Trend	-0.000	0.000	-0.000	-0.001*	-0.000	-0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	(0.001)
	[0.884]	[0.409]	[0.184]	[0.074]	[0.847]	[0.249]
Pre-Shortage Mean	0.92	0.95	0.72	0.89	0.63	0.77
Observations	88740	88740	88740	88740	45594	45594

Notes: This table presents similar results as Table 3, but we drop the children born after the shortage from our control group. Observation counts differ for the primary and booster doses because fewer children in our sample are born after the shortage cleared for the booster dose. Each column of each panel presents coefficient estimates from a separate regression using MarketScan data aggregated to the child level. The outcome variable is given in the column header and captures receipt of a given dose of the Hib vaccine. In Panel A, the indicator variable *Shortage Exposed* captures if a child's birth cohort was of age to receive a given vaccine dose during the shortage. See Figure 3 for details. In Panel B, the reported estimate is the coefficient on a month-level time trend, estimated using only pre-shortage cohorts. Robust standard errors, shown in parentheses, are clustered at the month-year of birth level. Wild clustered bootstrapped p-values are reported in brackets.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A8: Effect of Shortage on Diagnosed Hib Cases Within 5 Years of Birth

	(1) Exposed for Primary Series	(2) Exposed for Booster Series
Shortage Exposed	-0.00004	-0.00003
	(0.00008)	(0.00009)
	[0.700]	[0.815]
Mean	0.00069	0.00069
Observations	222173	173598

Notes: Each column presents coefficient estimates from a separate regression using MarketScan data aggregated to the child level; the outcome variable is an indicator for whether a child received a Hib diagnosis within 5 years of their birth. Robust standard errors, shown in parentheses, are clustered at the month-year of birth level. Wild clustered bootstrapped p-values are reported in brackets.

Figure A4: Share of Children with Hib Cases
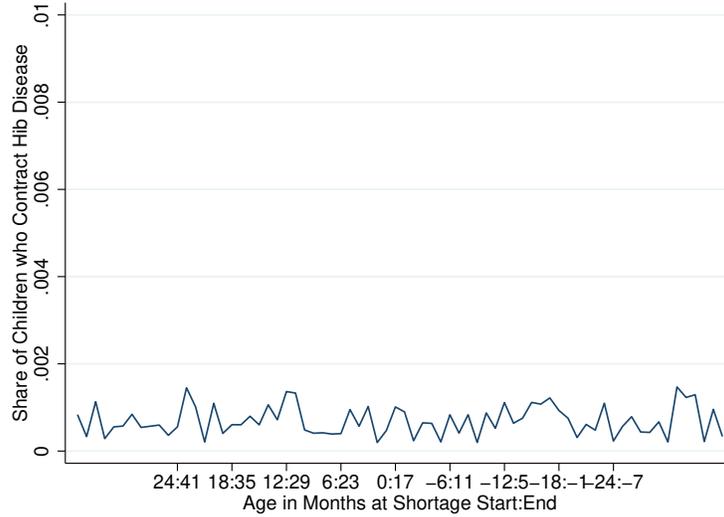
Notes: This figure presents the share of children who we observe to have a Hib diagnosis within 5 years of their birth, by birth cohort.

A11

Figure A5: Up-to-Date Rates Netting Out Birth Month for Pneumococcal Vaccine

(a) Primary Series

(b) Booster Series
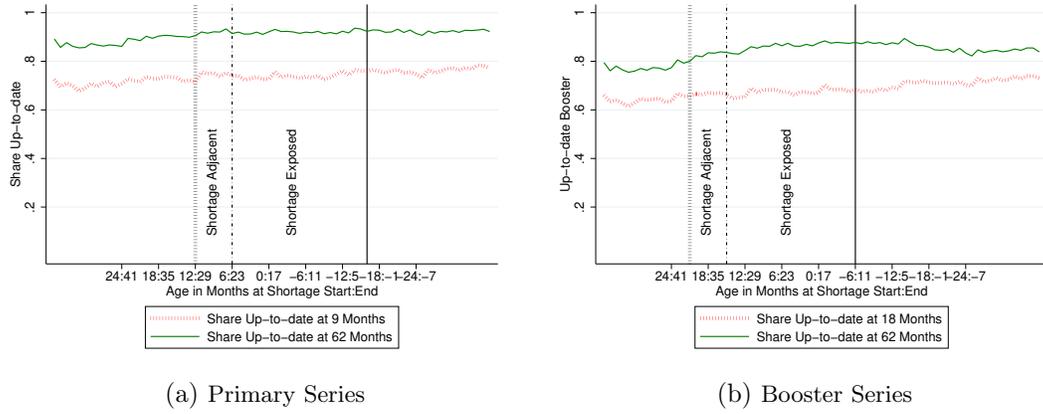
Notes: This figure presents variation in up-to-date rates for the pneumococcal vaccine (which was *not* in shortage) for children born in different month-years in the MarketScan data. We present results after netting out birth month effects. In Panel (a), the dotted orange line and the solid green line are share up-to-date for primary series at 9 months and 62 months, respectively. In Panel (b), the dotted orange line and the solid green line are share up-to-date for booster series at 18 months and 62 months, respectively.

Table A9: Effect of Shortage on Age of Dose – Pneumococcal, Conditional on Receipt

	(1) Age 1st Dose	(2) Age 2nd Dose	(3) Age 3rd Dose	(4) Age Booster Dose
Panel A				
Shortage Exposed	0.205***	0.216***	0.266***	1.535***
	(0.047)	(0.044)	(0.056)	(0.078)
	[0.001]	[0.000]	[0.000]	[0.000]
Mean	3.11	5.14	7.79	15.19
Observations	302753	289919	276970	244335
Panel B				
Pre-Trend	0.027***	0.031***	0.030***	0.044***
	(0.003)	(0.004)	(0.003)	(0.008)
	[0.000]	[0.000]	[0.000]	[0.000]
Pre-Shortage Mean	3.21	5.20	7.83	14.83
Observations	81875	77943	73840	31746

Notes: Each column presents coefficient estimates from a separate regression using MarketScan data aggregated to the child level; the outcome variable is the age in months of a child receiving the dose of the pneumococcal vaccine referenced in the header. In Panel A, the indicator variable *Shortage Exposed* captures if a child's birth cohort was of age to receive a given vaccine dose during the shortage. See Figure 3 for details. In Panel B, the reported estimate is the coefficient on a month-level time trend, estimated using only pre-shortage cohorts. Robust standard errors, shown in parentheses, are clustered at the month-year of birth level. Wild clustered bootstrapped p-values are reported in brackets.

Table A10: Effect of the Shortage on Up-to-Date Rates for DTaP

	(1) Any doses 9 months	(2) Any doses 62 months	(3) Three doses 9 months	(4) Three doses 62 months	(5) Four doses 21 months	(6) Four doses 62 months
Panel A						
Shortage Exposed	-0.006*	-0.010***	-0.007	-0.007*	-0.016***	-0.014***
	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)
	[0.027]	[0.002]	[0.092]	[0.055]	[0.000]	[0.000]
Mean	0.91	0.97	0.75	0.89	0.85	0.89
Observations	322784	322784	322784	322784	322784	322784
Panel B						
Pre-Trend	-0.000	0.000	-0.000	-0.000	-0.001	-0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
	[0.660]	[0.833]	[0.786]	[0.669]	[0.231]	[0.389]
Pre-Shortage Mean	0.90	0.96	0.73	0.88	0.84	0.88
Observations	88740	88740	88740	88740	45594	45594

Notes: Each column of each panel presents coefficient estimates from a separate regression using MarketScan data aggregated to the child level; the outcome variable is given in the column header and captures receipt of a given dose of the DTaP vaccine. In Panel A, the indicator variable *Shortage Exposed* captures if a child's birth cohort was of age to receive a given vaccine dose during the shortage. See Figure 3 for details. In Panel B, the reported estimate is the coefficient on a month-level time trend, estimated using only pre-shortage cohorts. Robust standard errors, shown in parentheses, are clustered at the month-year of birth level. Wild clustered bootstrapped p-values are reported in brackets.// * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A11: Effect of the Shortage on Up-to-Date Rates for Polio

	(1) Any doses 9 months	(2) Any doses 62 months	(3) Two doses 9 months	(4) Two doses 62 months	(5) Three doses 21 months	(6) Three doses 62 months
Panel A						
Shortage Exposed	-0.009***	-0.009*	-0.011	-0.008**	-0.008*	-0.008
	(0.002)	(0.004)	(0.007)	(0.003)	(0.003)	(0.005)
	[0.000]	[0.029]	[0.165]	[0.014]	[0.030]	[0.136]
Mean	0.90	0.84	0.77	0.97	0.91	0.86
Observations	322784	322784	322784	322784	322784	322784
Panel B						
Pre-Trend	-0.000	0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	[0.754]	[0.914]	[0.486]	[0.563]	[0.367]	[0.378]
Pre-Shortage Mean	0.89	0.95	0.82	0.89	0.74	0.83
Observations	88740	88740	88740	88740	88740	88740

Notes: Each column of each panel presents coefficient estimates from a separate regression using MarketScan data aggregated to the child level; the outcome variable is given in the column header and captures receipt of a given dose of the polio vaccine. In Panel A, the indicator variable *Shortage Exposed* captures if a child's birth cohort was of age to receive a given vaccine dose during the shortage. See Figure 3 for details. In Panel B, the reported estimate is the coefficient on a month-level time trend, estimated using only pre-shortage cohorts. Robust standard errors, shown in parentheses, are clustered at the month-year of birth level. Wild clustered bootstrapped p-values are reported in brackets.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure A6: Number of Vaccination Visits
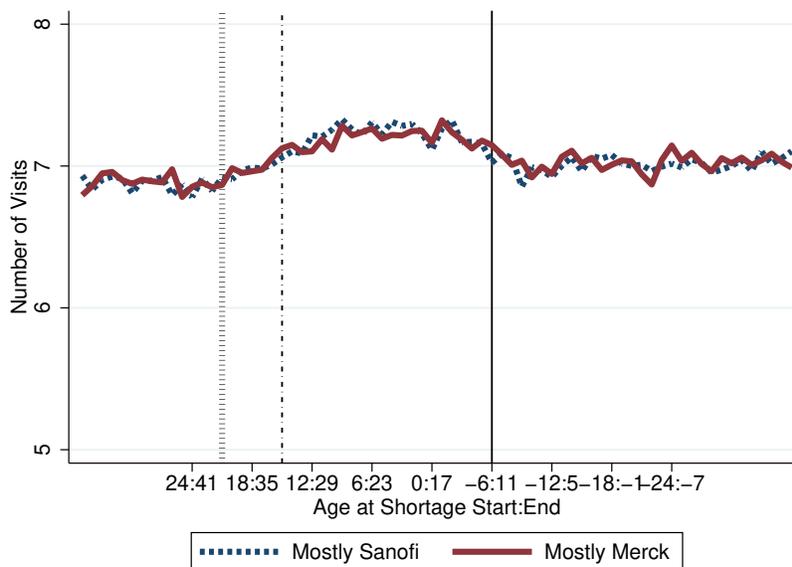
Notes: This figure plots the average number of visits at which a child in a given birth cohort received at least one dose of the hepatitis A, Hib, pneumococcal, or DTaP vaccine, net of calendar month of birth fixed effects. Inclusion in the sample is conditional on being up-to-date on Hib and pneumococcal at 62 months, to avoid counting fewer visits for those missing vaccines. The dashed blue line represents children whose provider primarily administered Sanofi Hib vaccines during the pre-shortage period; the solid red line represents children whose provided primarily administered Merck manufactured Hib vaccines during the pre-shortage period.

A2 National Immunization Survey-Child data and methods

Data: We supplement our primary analyses using data from the National Immunization Survey-Child (NIS-Child), 2005-2015. The NIS-Child is a nationally representative survey that targets children aged 19 to 35 months old. This survey is conducted in two parts: (1) a household survey that collects information on household and child characteristics, and (2) a survey of the child's healthcare provider(s) that collects detailed information on the child's vaccination history. The vaccination information collected from providers includes number and type of vaccine doses received at the time of survey, as well as age in days for each of the doses. Although these data are available through 2019, due to changes in the availability of individual level characteristics over time, for our regression analyses we

restrict out sample to the 2005-2015 survey waves;[50] this corresponds to children born from 2002 through 2014. We also restrict our sample to exclude Alaskan residents, as Alaskan natives are considered to be a high risk group for Hib and therefore were not included in the CDC recommendation to delay the booster series (CDC, 2007). Overall, in our final sample there are approximately 14,500 to 21,000 children each year with both a completed household survey and adequate provider data.

Descriptive trends in the outcome variables across birth cohorts are plotted in Figure A7. This figure shows a sharp drop in the share of children receiving 3+ Hib doses by age 18 months, corresponding with the timing of the shortage. Notably, Hib vaccination rates are relatively stable before and after the shortage.

Methods: For these analyses we estimate the following modified version of Equation 1:

$$Y_{cm} = \beta_0 + \beta_1 \mathbb{1}(Exposed_m) + \beta_2 X_c + \gamma_s + \epsilon_{cm} \tag{1}$$

Where our outcome, Y_{cm}, is an indicator variable capturing whether child c in birth cohort m has had at least one, two, or three Hib containing vaccinations at the age of 18 months old.[51] $\mathbb{1}(Exposed_m)$ is an indicator for whether the child is in the shortage-exposed cohort, defined as being born in either 2007 or 2008. In this specification we omit the $\mathbb{1}(Shortage\ Adjacent_m)$ indicator because birth cohorts are measured less precisely, relative to MarketScan. X_c is a vector of child-level characteristics observed at the time of survey, including measures of household demographics and socioeconomic status;[52] γ_s are state fixed effects. All results use survey weights and standard errors are clustered by birth year. We also compute p-values using a wild clustered bootstrap. As in our baseline model, identification is based on the assumption that, in the absence of the shortage, the outcomes would have been similar for shortage-exposed and non-exposed cohorts.

To test for heterogeneity in the effects of the shortage, we additionally include the interaction between $\mathbb{1}(Exposed_m)$ and a measure of a given individual-level characteristic, Z_c, as follows:

---

[50]Specifically, family income is only available after 2005. The mother's binned age is not available after 2015.

[51]We limit to 18 months old because children begin to be interviewed at 18 months. If we used an older age (e.g. 21 months), then we might miss children vaccinated between 18 and 21 months, but interviewed at 18 months. We focus on 3 doses because many do not receive a 4th dose due to Merck not requiring it.

[52]We use the following variables as controls: education of the mother, the race of the child, family income (binned as below poverty, above poverty but below $75k, and above $75k), the number of people in the household, whether the child was breast fed, whether the child received WIC, the language the interview was conducted in, and the mother's age. We do not include insurance variables as controls because they only began being asked in 2007, limiting our pre-period. However, we do check for heterogeneity by insurance status.

$$Y_{cm} = \beta_0 + \beta_1 \mathbb{1}(Exposed_m) + \beta_2 \mathbb{1}(Exposed_m) \times Z_c + \beta_3 X_c + \gamma_s + \epsilon_{cm} \qquad (2)$$

Where Z_c represents one characteristic out of the vector X_c. The coefficient on the interaction term, β_2, measures whether certain groups were differentially affected by the shortage.

Figure A7: Number of Hib Doses per Child in the NIS Data
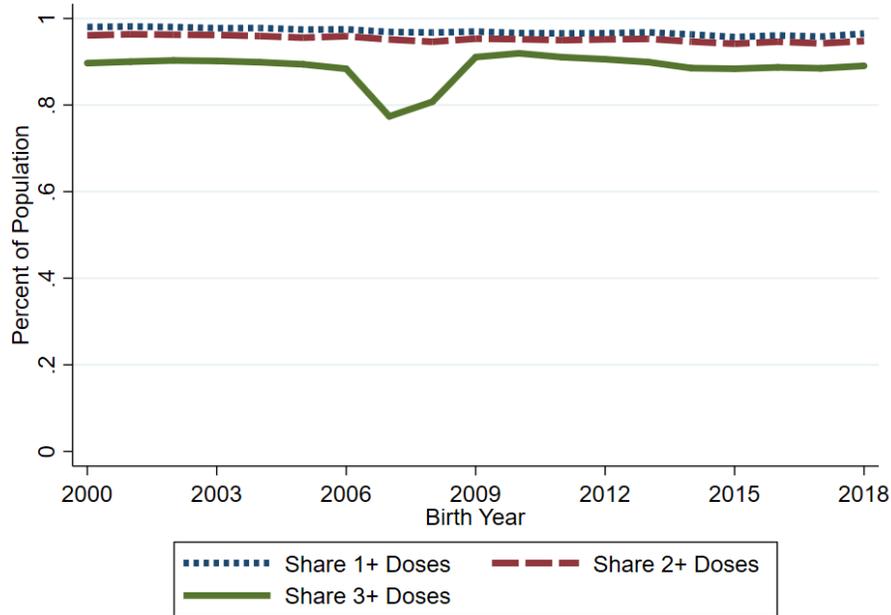
Notes: This figure presents variation in the share of children having received 1, 2, or 3 of the Hib vaccine in the NIS data. Number of doses is measured at 18 months because some children were interviewed as early as 19 months old. Birth year is fuzzy as only age in months at time of interview is reported in 6 month bins and we only know the interview year.

Table A12: Effect of the Shortage on Hib Vaccine Receipt Including Demographic Controls, NIS-Child

	1+ Doses 18 months	2+ Doses 18 months	3+ Doses 18 months
Shortage Exposed	-0.000129	-0.00139	-0.0986***
	(0.001)	(0.003)	(0.010)
	[0.893]	[0.677]	[0.000]
Education:			
Shortage Exposed	0.000250	-0.00322	-0.0836***
	(0.005)	(0.006)	(0.010)
	[0.982]	[0.598]	[0.018]
Shortage Exposed × ≥12 years	0.000229	0.00376	-0.0125
	(0.006)	(0.008)	(0.009)
	[0.957]	[0.657]	[0.268]
Shortage Exposed × College Grad	-0.00146	-0.00000583	-0.0266
	(0.005)	(0.007)	(0.015)
	[0.852]	[0.989]	[0.135]
Income:			
Shortage Exposed	-0.00349	-0.00556**	-0.115**
	(0.002)	(0.001)	(0.025)
	[0.069]	[0.098]	[0.000]
Shortage Exposed × Above			
Poverty, <= $75k	0.00303	0.00776	0.0243
	(0.002)	(0.005)	(0.028)
	[0.329]	[0.262]	[0.521]
Shortage Exposed ×			
Below Poverty	0.00689	0.00385	0.0213
	(0.005)	(0.005)	(0.019)
	[0.404]	[0.618]	[0.601]
Race:			
Shortage Exposed	-0.000127	-0.00187	-0.103***
	(0.001)	(0.003)	(0.009)
	[0.886]	[0.570]	[0.000]
Shortage Exposed × Black Only	0.00200	0.00839**	0.0154
	(0.002)	(0.002)	(0.012)
	[0.387]	[0.094]	[0.436]
Shortage Exposed × Other/Multi	-0.00230	-0.00571	0.0147
	(0.006)	(0.005)	(0.007)
	[0.657]	[0.573]	[0.073]
Health Insurance:			
Shortage Exposed	0.00402	-0.00397	-0.0909***
	(0.002)	(0.004)	(0.007)
	[0.196]	[0.396]	[0.008]
Shortage Exposed ×			
Covered by Medicaid	-0.00399	0.00530	-0.00442
	(0.003)	(0.004)	(0.008)
	[0.231]	[0.271]	[0.694]
Shortage Exposed ×			
Covered by Private Insurance	-0.00590	0.00249	-0.0122
	(0.003)	(0.003)	(0.010)
	[0.155]	[0.339]	[0.516]
Sample Mean	0.98	0.96	0.89
Observations	130260	130260	130260

A19

Notes: This is the same as Table 4, except we include the observed demographic variables as controls in each regression. Each column presents coefficient estimates from a separate regression using NIS data at the child level. The outcome variable is an indicator for whether a child has received at least the number of Hib doses as specified in the column header. Shortage exposed means that a child was born in 2007 or 2008, based on our fuzzy assignment of birth years. Robust standard errors, shown in parentheses, are clustered at the birth year. Wild clustered bootstrapped p-values are reported in brackets.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A13: Effect of the Shortage on Hib Vaccine Receipt: Heterogeneity by State VFC Policy
Omitted Category: Not in Universal VFC state

	1+ Doses	1+ Doses	2+ Doses	2+ Doses	3+ Doses	3+ Doses
Shortage Exposed	-0.00138	-0.000829	-0.00390	-0.00278	-0.0900***	-0.0877***
	(0.002)	(0.002)	(0.004)	(0.004)	(0.008)	(0.008)
	[0.619]	[0.757]	[0.563]	[0.651]	[0.000]	[0.000]
Shortage Exposed × Universal VFC	-0.00460*	-0.00470*	-0.00506	-0.00548	-0.0786***	-0.0790**
	(0.002)	(0.002)	(0.003)	(0.004)	(0.017)	(0.018)
	[0.145]	[0.138]	[0.261]	[0.411]	[0.000]	[0.000]
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Other Controls	No	Yes	No	Yes	No	Yes
Sample Mean	0.98	0.98	0.96	0.96	0.89	0.89
Observations	182407	182405	182407	182405	182407	182405

Notes: Each column presents coefficient estimates from a separate regression using NIS data at the child level. The outcome variable is an indicator for whether a child has received at least the number of Hib doses as specified in the column header. Odd columns only include state fixed effects, while even columns include additional control variables. Shortage exposed means that a child was born in 2007 or 2008, based on our fuzzy assignment of birth years. Robust standard errors, shown in parentheses, are clustered at the birth-year. Wild clustered bootstrapped p-values are reported in brackets.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

A3 Difference-in-differences analyses using pneumococcal as a control

In this section, we estimate the effects of the Hib vaccine shortage using a difference-in-differences framework, in which the change in uptake of the pneumococcal vaccine over time is explicitly treated as the counterfactual for how uptake of the Hib vaccine would have evolved in the absence of the shortage. This approach has the advantage of allowing us to relax the identification assumption of our baseline model that the *level* of Hib vaccination uptake would have remained constant in the absence of the shortage. However, if the Hib shortage had negative spillovers to uptake of the pneumococcal vaccine (because, for example, households delayed all vaccinations until Hib was available), then our coefficient estimates from the difference-in-differences model will *understate* the true impacts of the shortage on uptake of the Hib vaccine.

A3.1 Methods

For these analyses, we use data from MarketScan and estimate the effect of the Hib vaccine shortage by comparing changes in uptake of the Hib vaccine to concurrent changes in uptake of the pneumococcal vaccine. Our difference-in-differences specification is as follows, where the unit of observation is at the child-vaccine level:

$$Y_{cvm} = \beta_0 + \beta_1 \mathbb{1}(Hib\ Vaccine_v) + \beta_2 \mathbb{1}(Adjacent_m) \times \mathbb{1}(Hib\ Vaccine_v) \qquad (3)$$
$$+ \beta_3 \mathbb{1}(Exposed_m) \times \mathbb{1}(Hib\ Vaccine_v) + \beta_4 X_c + \epsilon_{cvm}$$

Y_{cvm} represents the vaccination outcome measure for child c in birth month-year cohort m for vaccine type $v \in \{Hib, pneumococcal\}$. The outcome variables of interest are indicators for having at least one dose of the specified vaccine, being up to date on the primary series, and being up to date on the booster series. $\mathbb{1}(Hib\ Vaccine_v)$ is an indicator variable equal to one if the given observation is for the Hib vaccine, and is equal to zero otherwise; X_c is a vector of birth cohort fixed effects (defined at the month-year level), which flexibly controls for cross-cohort differences in vaccination behavior, and census region fixed effects. Standard errors are clustered at the birth-month cohort level. We also report wild cluster bootstrapped p-values.

This empirical strategy leverages variation in shortage exposure across birth cohorts and across vaccines. The identifying assumption in this model is that changes in the pneumococcal conjugate vaccination (PCV) outcomes represent a valid counterfactual for how Hib vaccination would have evolved in the absence of the shortage. Descriptive trends in up-to-date rates for the two vaccines, shown in Figure A8, provide empirical support for this assumption by showing that for cohorts not exposed to the shortage, PCV and Hib

vaccination outcomes are very similar in terms of both trends *and* levels. Notably prior to the shortage 95% of infants received their pneumococcal and Hib vaccines on the same day, for the first two doses.
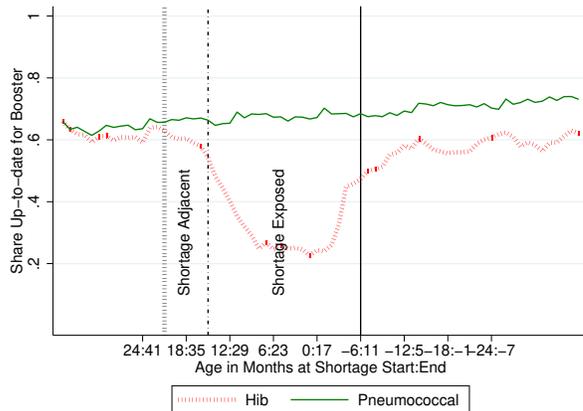
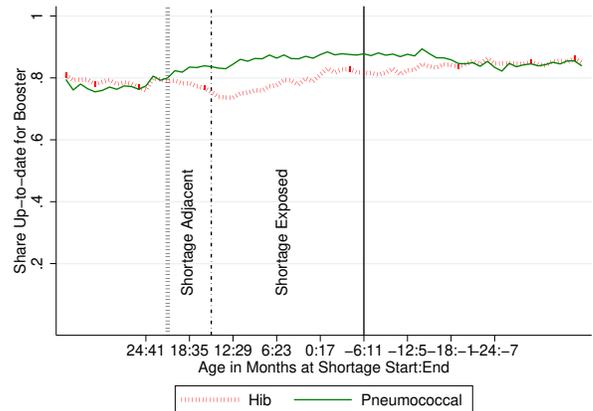Figure A8: Share of birth cohort up-to-date, Hib and Pneumococcal Vaccines
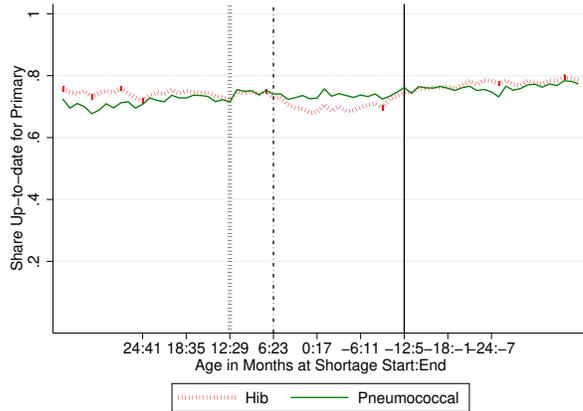
(a) Primary series at 9 months
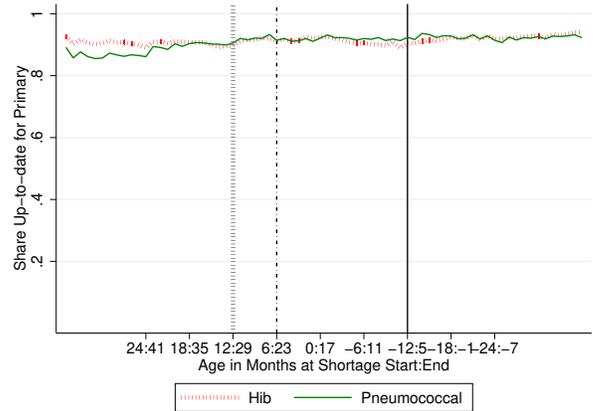
(b) Primary series at 62 months

(c) Booster series at 18 months

(d) Booster series at 62 months

Notes: This figure presents variation in up-to-date rates for the Hib and Pneumococcal vaccine for children born in different month-years in the Marketscan data. In all figures, we present results after netting out birth month effects.

A22

A4 Provider-Level Analysis Methods

To characterize the dynamics of the shortage and supply-side factors influencing the shortage depth, we conduct provider-level analyses. For these analyses, we compare provider-level Hib vaccination rates during the shortage to their rates during the two prior years. Since the Hib vaccine and the pneumococcal vaccine are recommended to be received on the same vaccination schedule, the number of pneumococcal doses administered approximates the number of Hib-vaccine eligible children visiting a providers practice in a given quarter. Thus, we approximate the Hib vaccination rate by dividing the number of Hib doses by the number of pneumococcal vaccine doses the provider administers over the same time period. Motivated by Figure 1, we allow for different effects in the first two quarters (six months) of the shortage versus the remaining shortage period (quarters 3 through 6 of the shortage).

We formalize the provider-level analyses by estimating the following regression equation:

$$
\begin{aligned}
\text{Hib to Pneumococcal Ratio}_{pq} =& \beta_0 + \beta_1 \mathbb{1}(ShortageQuarters1-2_q) \\
&+ \beta_2 \mathbb{1}(ShortageQuarters3-6_q) + \gamma_r + \gamma_p + \epsilon_{pq},
\end{aligned}
\tag{4}
$$

where the dependent variable is the ratio of Hib to pneumococcal doses administered by physician p in quarter q, defined separately for the primary and booster series. We aggregate the data to the quarterly level because for some providers we see only a small number of monthly doses.[53] As previously discussed, we allow the shortage to have a different effect in the very short-run, thus, $\mathbb{1}(ShortageQuarters1-2_q)$ is an indicator for the first two quarters of the shortage and $\mathbb{1}(ShortageQuarters3-6_q)$ is an indicator for the rest of the shortage; we exclude post-shortage observations from these analyses. Each indicator variable captures the average effect of the shortage on vaccine administration, relative to the two years prior to the shortage. γ_r is a vector of calendar quarter fixed effects, and controls for seasonality; γ_p are physician fixed effects and control for time invariant physician characteristics. Standard errors are clustered at the quarter-year, although since we have relatively few clusters we also report p-values from the wild cluster bootstrap procedure described in Cameron, Gelbach, and Miller (2008). The regressions are weighted by the number of pneumococcal doses administered by a given physician in a given quarter, to account for the fact that there is variation across physicians in practice size.[54]

To decompose the impact of physician-level factors on the realized depth of the shortage, we augment the above equation with interactions between the *Shortage Quarters* indicators and the following two pre-shortage provider characteristics: percent of Hib vaccines ad-

---

[53]We shift our quarter definition up by one month to account for the shortage starting in December 2007. Therefore, December 2007 to February 2008 is the first quarter of the shortage.

[54]Results are robust when we do not include weights. They are also similar when leaving the data at the monthly level.

ministered by the provider that were manufactured by Merck and percent of Hib vaccines administered in the county that were manufactured by Merck (omitting that provider's own doses). Providers tend to only use one type of vaccine: prior to the shortage 77% percent of providers used at least 80% Merck vaccines or 80% Sanofi Pasteur vaccines. The provider's vaccine manufacturer at the start of the shortage directly impacts their short-run access to the vaccine, and therefore also their incentives to reduce booster administration. It also influences the probability that they experienced frictions at the start of the shortage, for example due to negotiating a new contract or joining a new physician buying group. Geographic-specific variation might affect vaccination rates if it changes the degree of information about the shortage and the rationing policy or if it changes access to Sanofi Pasteur doses for patients and providers.

A5 Counterfactuals

To draw policy implications from our analysis of the shortage and rationing, we report two sets of counterfactual calculations. Our counterfactual calculations focus on the short-run effects of the CDC rationing policy on primary series vaccination, conditional on the shortage occurring. For these analyses, we compare the actual outcome to a best-case counterfactual in which providers perfectly comply with the rationing recommendation, and to a worst-case counterfactual in which providers continue administering booster doses as usual. These two counterfactuals demonstrate that the actual market outcome much more closely resembled the best case (full compliance) scenario.
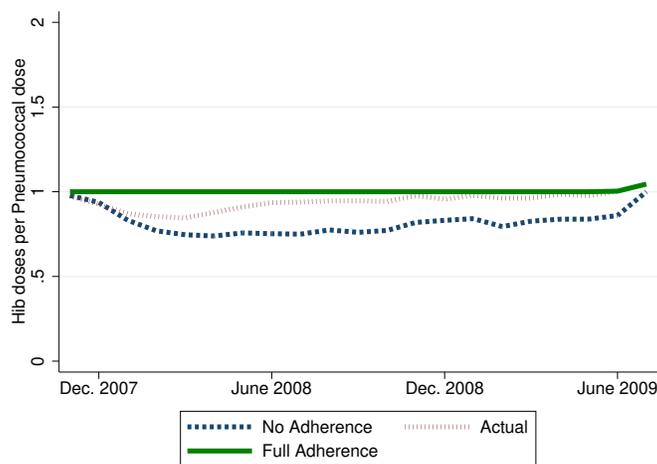
A5.1 Full adherence counterfactual

First, we compare the actual outcome to an ideal counterfactual in which providers perfectly comply with the rationing recommendation. This allows us to examine whether there was sufficient supply for the realized 4.5 percentage point reduction in Hib primary dose receipt to have been avoided with reduced administration of the booster dose. Given that the vaccination guidelines recommend individuals receive two to three times as many primary Hib doses as booster doses, it is possible that even with reallocation of all booster doses there would not have been sufficient supply.

To construct this counterfactual, in each sample month we hypothetically reallocate Hib vaccine doses that were given as boosters to be primary doses. This reallocation continues until the number of Hib primary doses per month match the number of primary series pneumococcal doses actually administered, or until all Hib booster doses have been reallocated to the primary series. The number of pneumococcal primary series doses administered serves as our proxy for the number of infants needing a Hib primary dose in a given month. The dashed red line in Figure A9 shows the actual number of Hib primary series doses given

A24

per pneumococcal primary series dose during each month of the shortage. The solid green line shows the result of reallocating booster doses to primary doses under the full adherence counterfactual. Across all shortage months, we find that there were sufficient doses available to give one Hib primary series dose for every pneumococcal primary dose. Thus, the green line is always at or above one. To achieve full primary series vaccination, about half of the booster doses given in the first six months of the shortage would have needed to be reallocated to primary doses. Later in the shortage, the amount of hypothetical reallocation is smaller as doctors appear to have independently reallocated more vaccine doses to the primary series.
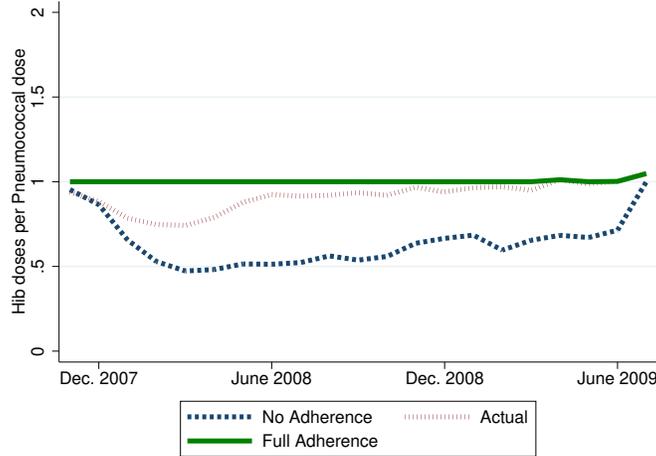
Figure A9: Counterfactual Primary Series Vaccination

Notes: The dashed red line shows the number of Hib primary series doses per pneumococcal dose in the MarketScan data. The solid green line shows the full adherence counterfactual, where we hypothetically reallocate Hib doses from booster to primary series until the number of Hib primary series doses matches the number of pneumococcal primary series doses or until there are no remaining booster doses. For the no adherence counterfactual, which is the blue dotted line, we assume that Sanofi Pasteur providers did not shift any doses to Merck providers and Merck providers used Hib primary and booster doses in the same ratio as pneumococcal primary and booster doses.

A5.2 No adherence counterfactual

Second, in Figure A10 we compare the actual outcome to a worst-case counterfactual in which providers continue administering booster doses as usual. In this counterfactual, we assume that health-care providers that used Sanofi Pasteur Hib doses prior to the shortage do not decrease administration of booster doses and do not reallocate doses to health-care providers that had used Merck Hib doses. Instead, we assume that those providers give as many Hib doses (primary and booster) as pneumococcal doses. In this counterfactual, we

also assume that health-care providers that used Merck Hib doses prior to the shortage do not prioritize primary doses, but instead administer Hib primary and booster doses in the same ratio as pneumococcal primary and booster doses.

Figure A10: Counterfactuals for Merck Providers Only

Notes: The dashed red line show the number of primary series doses a "Merck provider" gave. For the no adherence counterfactual, which is the blue dotted line, we assume that Sanofi Pasteur providers did not shift any doses to Merck providers and Merck providers used Hib primary and booster doses in the same ratio as pneumococcal primary and booster doses. The solid green line shows the full adherence counterfactual, where we hypothetically reallocate Hib doses from booster to primary series until the number of Hib primary series doses matches the number of pneumococcal primary series doses or until there are no remaining booster doses.

Across the entire shortage, we estimate that providers would have given only 0.8 Hib primary series doses per pneumococcal primary series dose if there had been no adherence with the CDC-recommended reallocation of doses from booster to primary series. In reality, providers gave 0.93 Hib primary series doses per pneumococcal primary series dose. Hence, the reallocation increased primary doses by 13 percentage points. Notably, the difference between the actual outcome and the no adherence counterfactual was smaller during the first six months of the shortage: during this period providers gave 0.88 primary series doses for each pneumococcal primary series dose, representing only an 8 percentage point improvement over the no adherence counterfactual. Additionally, if we focus on providers who used mostly Merck vaccines prior to the shortage (and therefore were most directly impacted by the supply shock), we estimate that the primary series vaccination rate would have been 20 percentage points lower than the realized rate under the no adherence counterfactual.

Using these estimates, we calculate that over the shortage period, full adherence would have

A26

corresponded to 1.2 million additional primary doses given, relative to what we actually observed. On the other hand, had there been no adherence, we calculate that 2.2 million fewer primary series doses would have been administered than actually were.[55] This, in turn, translates to at least seven hundred thousand children not receiving the full primary series in the absence of adherence to the rationing recommendation (2.2 million doses ÷ 3 primary doses per child).

Based on this counterfactual analysis, we find that the actual outcome of this shortage was much closer to the full adherence case, compared to no adherence case. This demonstrates the impact of the CDC rationing plan that prioritized the primary doses. Notably, however, for the first six months, the actual outcome was closer to the no adherence case, potentially suggesting supply chain or information frictions which eventually subsided.

While the number of doses given was closer to the full adherence counterfactual, it is worth noting that the consequences of these counterfactuals may not be symmetric. Limited evidence of large increases in Hib infection may be because most children still received the primary series on time or with minimal delay (Centers for Disease Control and Prevention, 2009b). The risk of a serious outbreak and associated morbidity and mortality might have been greatly increased in the no adherence case.

---

[55]In the no adherence case primary series doses decreased by 13 percentage points. In the full adherence case, doses increased by 7 percentage points. If 3.75 million children are born each year and needed three primary series Hib vaccine doses during the shortage, then that would translate to 16.875 million doses during the 1.5 year shortage. Therefore, a 7 percentage point increase in doses represents 1.2 million additional doses (0.07 × 16.875 million); a 13 percentage point decrease translates to 2.2 million fewer doses.