Appendix

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Vaccination and voting patterns in the United States: analysis of COVID-19 and flu surveys from 2010 to 2022

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Appendix Table 1. Description of vaccination data included in the analysis.

Dataset	Vaccination	Population	Years	Timeframe used in the analysis	Age used	Geography used	Outcome used	Survey methodology summary
CDC Surveillance[1]	Covid-19	Total population	2020-Ongoing	**Analysis 1:** By month, from Janaury 2021 to November 2022	Total population	State	End of month vaccine uptake coverage at state-level Monthly aggregate estimate determined by the last date data are available for a given month which may or may not correspond to the last day of the month	Administrative Surveillance
NIS-ACM [2]	Covid-19	General population	2021-Ongoing	**Analysis 1:** By month, from May 2021 to November 2022	18+	State	Monthly Vaccine uptake coverage at state-level Monthly aggregate estimates are approximate, and do not necessarily represent a full calendar month (e.g. April 22 – May 29, 2021 estimate was used for May 2021)	Phone interview
NIS-FLU [3] **BRFSS**	Flu	General population	2008-Ongoing[a]	**Analysis 1** By flu season, 2020-2021 and 2021-2022 **Analysis 3** By flu season, from 2000-2001 to 2021-2022	18+ 6 months+	State	Last vaccination coverage measure available of each flu season (May) at state-level	Phone interview. The two surveys are merged and joint results presented
CTIS[4]	Flu Covid-19	General population with Facebook account.	2020-2022	**Analysis 1** **CV:** By month, from January 2021 to June 2022 **FLU: B**y flu season, 2020-2021 and 2021-2022 **Analysis 2** Responses between May – June 2022	18+	County, State,	Received any flu or any COVID-19 vaccination[b] County and State defined by the respondent's FIPS	Survey administered on Facebook

Footnote:

a) We omitted year 2009-2010 when two vaccines were available: the seasonal influenza vaccine and vaccine against the H1N1 strain, and the publicly available data for 2009-2010 flu season included people aged 50 and over only.

b) Uptake of flu vaccine for season 2020-2021 was in the survey for January 2021-August 2021, and a question about flu vaccine uptake for season 2021-2022 was in the survey for January-June 2022.

Flu vaccination data

The US Surgeon General recommended annual influenza vaccination at-risk people 1960.[5] Annual flu vaccine is currently recommended by Centers for Disease Control and Prevention (CDC) for all people over 6 months of age.[6] Two data sources were used to examine flu vaccination coverage:

i. We used a publicly available database,[3] which combined data from National Immunization Surveys (NIS) and Behavioral Risk Factor Surveillance System (BRFSS); both are nationally telephone-based interviews. The component for influenza vaccination, NIS-FLU, has publicly available data with aggregate estimates of flu vaccine coverage over time for people 6 months to 17 years, by state, age and race/ethnicity.[3] BRFSS has data of flu vaccine coverage for people aged 18 and over. Data were used from flu seasons 2010-2011 to 2021-2022. We examined coverage by age given the small sample sizes in the race/ethnicity groups by state.
ii. The US COVID-19 Trends and Impact Survey (CTIS) is an online survey, implemented by the Delphi Group at Carnegie Mellon University, which recruited responses using the Facebook active user base of people aged 18 and older.[1] The individual-level responses included a question about flu vaccination uptake during the 2020-2021 and 2021-2022 flu seasons.

COVID-19 vaccination data

COVID-19 vaccination started in December 2020, and vaccination is now recommended for all people 6 months and older.[7] Since January 2021, vaccine eligibility expanded from the older age groups and at-risk groups to essential workers and to younger age groups at varied pace across the country, but all states offered COVID-19 vaccine to all adults by April 19, 2021.[8] In October 29, 2021, Food and Drug Administration authorized emergency use of the Pfizer/BioNTech COVID-19 Vaccine for children aged 5-11 years old.[9]

Definition of coverage was having received at least one dose of COVID-19 vaccine, which represents the most widespread estimate of achieved vaccination coverage. Three data sources of COVID-19 vaccination coverage were used:

i. NIS Adult COVID-19 Module (NIS-ACM) estimates COVID-19 vaccination coverage. Public data are available for people aged 18 and older by state.[2]
ii. CTIS self-reported COVID-19 vaccination coverage, with individual-level responses received between January 2021 – June 2022 included in the analyses. Survey includes people aged 18 and older.[4]

iii. Aggregated data from the Centers for Disease Control and Prevention (CDC) on COVID-19 vaccination at state level using percent of population with at least one dose based on the jurisdiction where recipient lives.[1]

Voting patterns in presidential elections

Presidential election vote share at state- and county-level was obtained from the MIT Data Lab.[10] The results from the most recent preceding election as the nearest indicator of political influence preceding each outcome, e.g. the 2020 presidential election vote share was used for 2020 and 2021 vaccination coverage data. Vote share was defined as percentage of votes for the main Democratic candidate over total votes given in that geographic area. Vote share for the Democratic candidate was chosen as this portrays the positive association with vaccination coverage (higher vote share is associated with higher coverage).

Urban-Rural Classification Scheme for Counties

Rural-urban classification for counties was obtained from National Center for Health Statistics' 2013 Urban-Rural Classification Scheme for Counties.[11]

Analyses

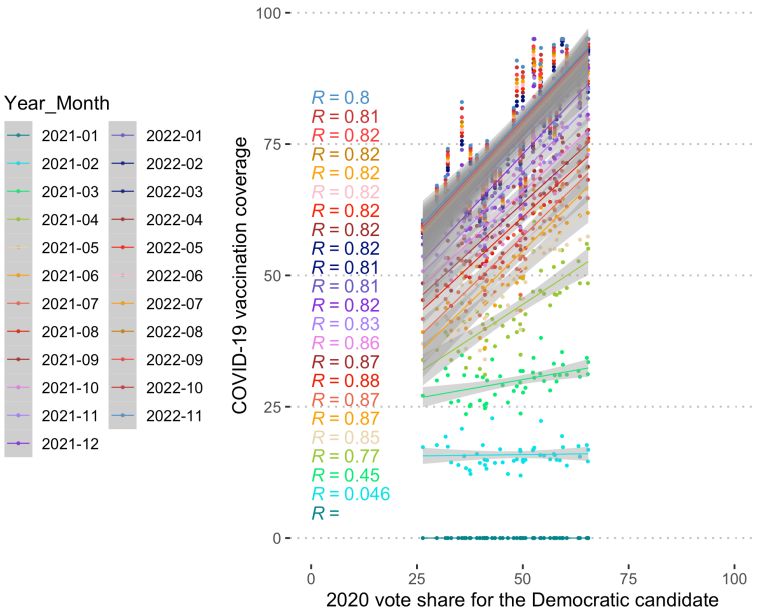
Analyses i) described the overall patterns of correlation between COVID-19 and flu vaccination against voting patterns during the pandemic (2020-2022), ii) examined the similarities and differences in individual-level characteristics associated with vaccination status for COVID-19 and for flu in 2022, and iii) examined the longer time trend for flu vaccination coverage and voting patterns using flu surveys from 2010 onwards. Analyses were done in R.

1. Correlations between vaccination coverage and presidential election vote share.

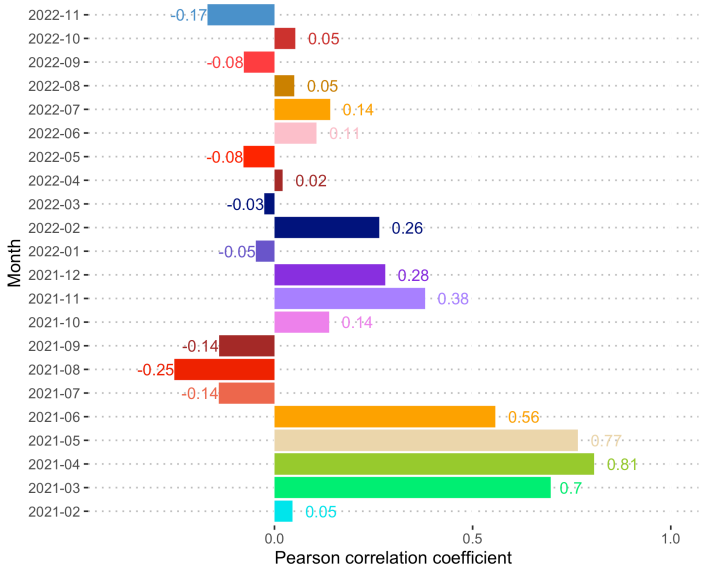
Surveys that rely on convenience sampling are less representative of the underlying population.[12] To examine the consistency of relationship between COVID-19 vaccination coverage and vote share, the strength and consistency of correlation across different datasets was evaluated using the Pearson correlation coefficient. For COVID-19 vaccination coverage measures were calculated by month and for flu vaccination coverage by flu season. In CTIS data the cross-tabulation between flu and COVID-19 vaccination status was evaluated, categorizing people in one of the following states: not vaccinated for COVID-19 nor for flu ("none"), only received flu vaccine ("only flu"), only received COVID-19 vaccine ("only COVID-19"), or vaccinated against both COVID-19 and flu ("both vaccinations"). Weighted estimates, adjusting for sampling and non-response in CTIS, are presented.

Appendix Figure 1 Comparison of correlation coefficient between state-level COVID-19 vaccination estimates by month and the 2020 vote share for the Democratic party candidate. We have omitted Washington D.C. as an outlier. Pearson correlation coefficient (R) shown by month in panels A,C,D, and as a bar plot in panel B. R values are ordered bottom-up from oldest to newest

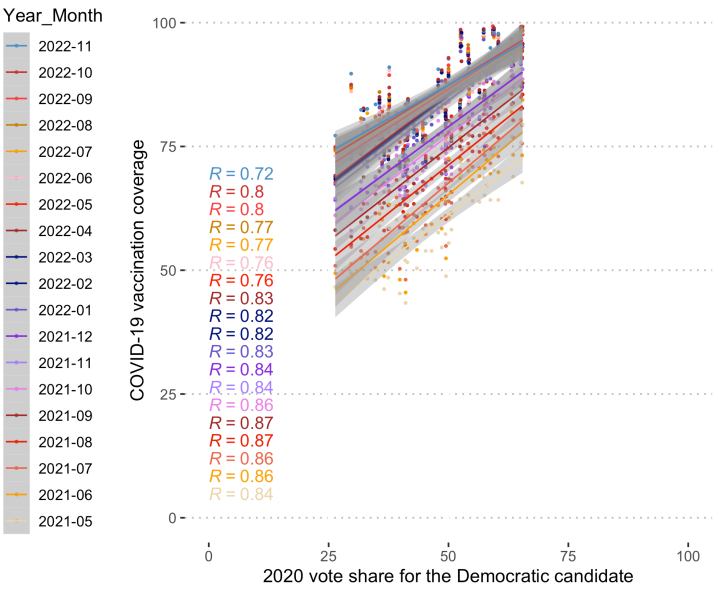
A) COVID-19 vaccination coverage in CDC surveillance [a]



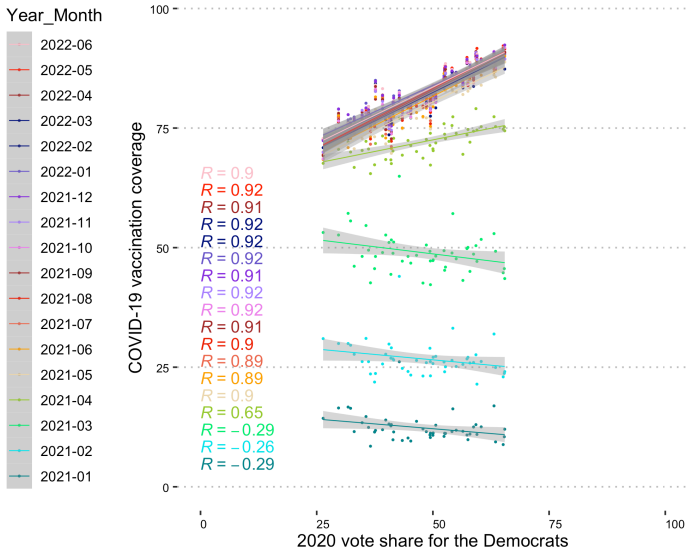
B) Correlation with monthly increase in COVID-19 vaccination coverage in CDC surveillance[a,b]



C) COVID-19 vaccination coverage in NIS-ACM [c]



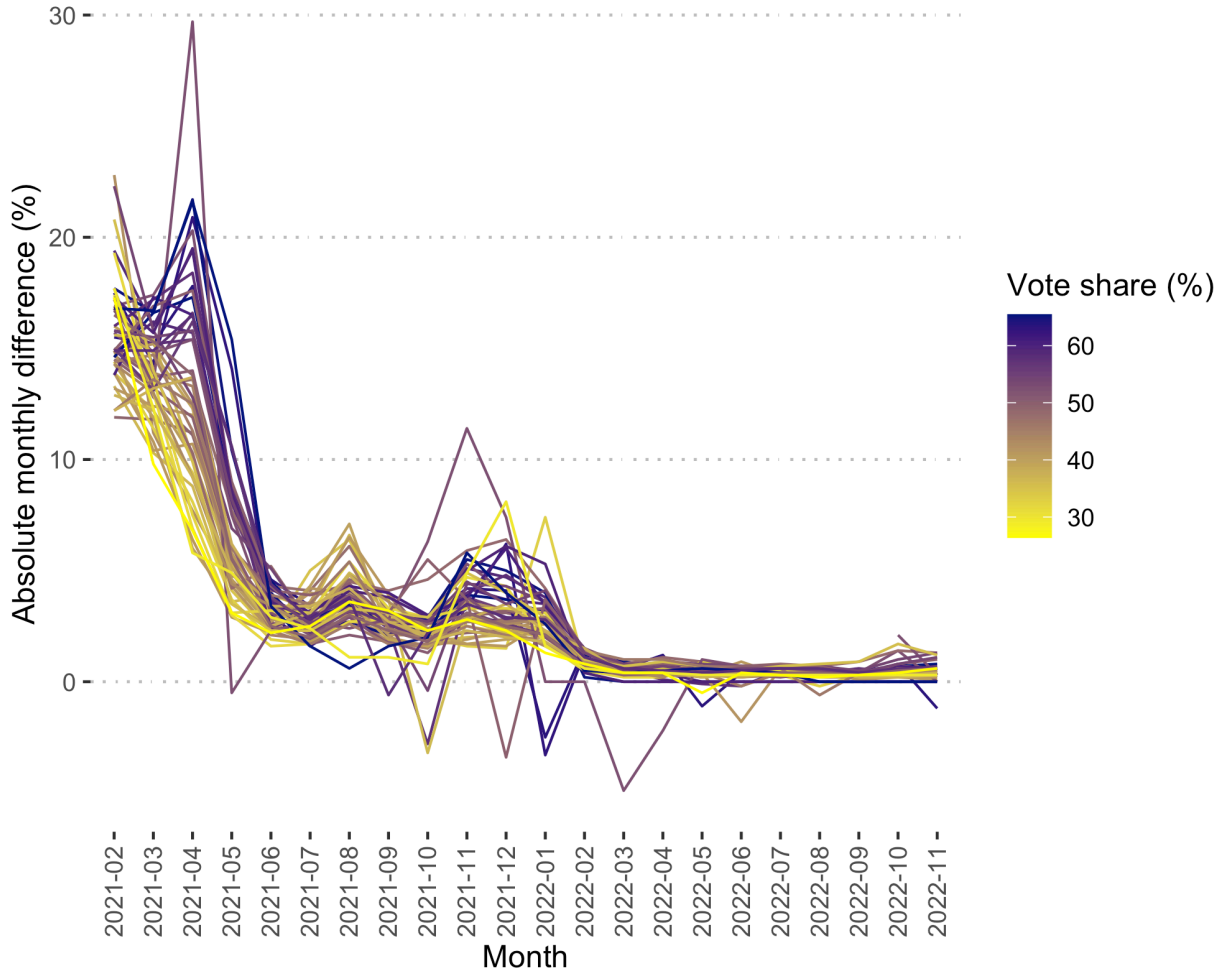
D) COVID-19 vaccination coverage in CTIS survey [d]



Footnote:

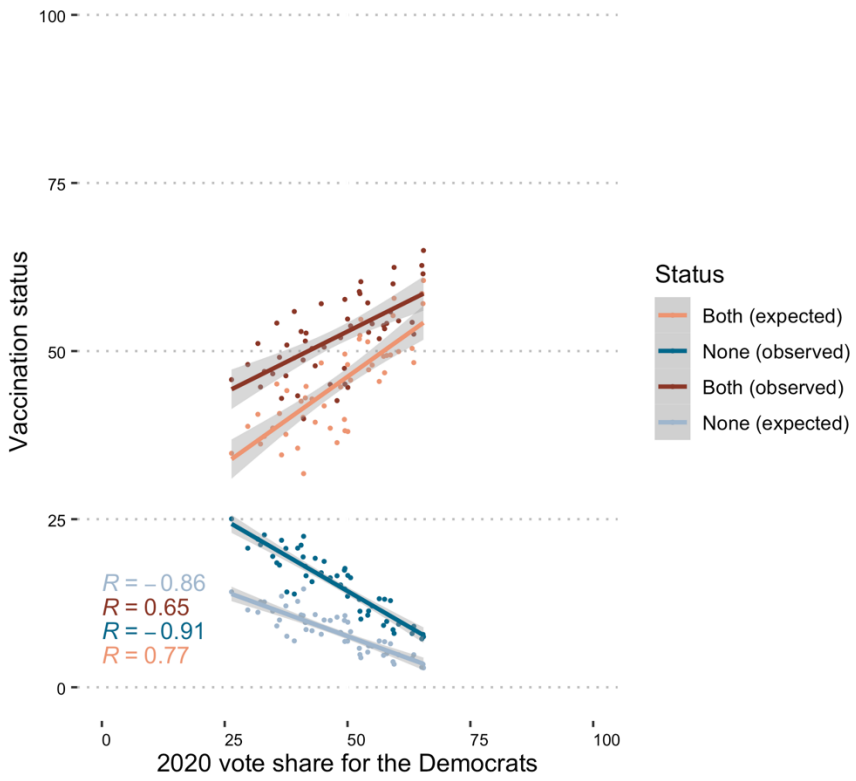
a) Percent of *total* population with at least 1 dose
b) Absolute within state difference in COVID-19 vaccination coverage compared to the previous month in the CDC surveillance
c) Received at least 1 dose, among people aged 18 and older
d) Received at least 1 dose, among people aged 18 and older

Appendix Figure 2. Absolute monthly difference in COVID-19 vaccination coverage, compared at state-level to previous month. Shading represents 2020 vote share for the Democratic party candidate. Data: CDC Surveillance



Footnote
The data are presented as they were reported, and no data cleaning were done to adjust for potential reporting changes and/or errors; e.g. reductions in population level vaccination coverage observed in some states.

Appendix Figure 3. CTIS data vaccination coverage for flu and COVID-19 by state and state's vote share for the Democratic party in 2020 presidential election. CTIS data for June 2022. Vaccination status at state-level: expected[a] and observed compared to each other.



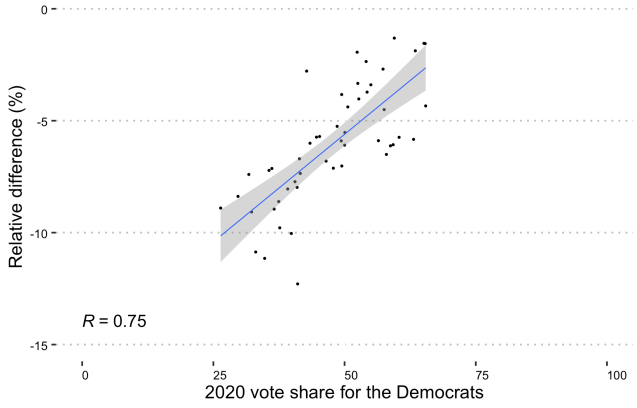
Footnote

a) Expected calculated based on individual vaccination coverage assuming independence: coverage of flu vaccine * coverage of COVID-19 vaccine.

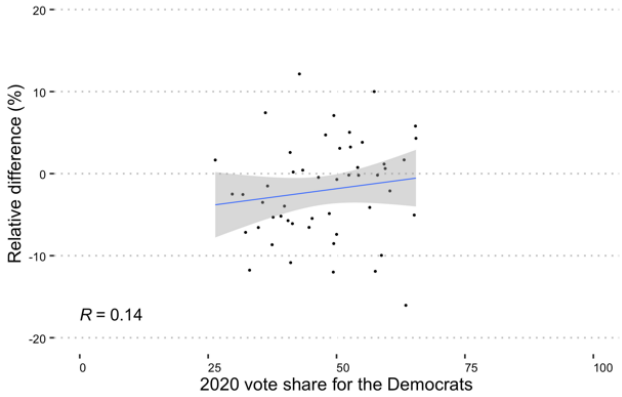
Status defined as
Both = received both flu and COVID-19 vaccine
None = has not received flu nor the COVID-19 vaccine

Appendix Figure 4. Relative difference in flu vaccine covearge by state between flu seasons: flu season 2021-2022 compared against 2020-2021

A) CTIS data



B) NIS/BRFSS data



Footnote

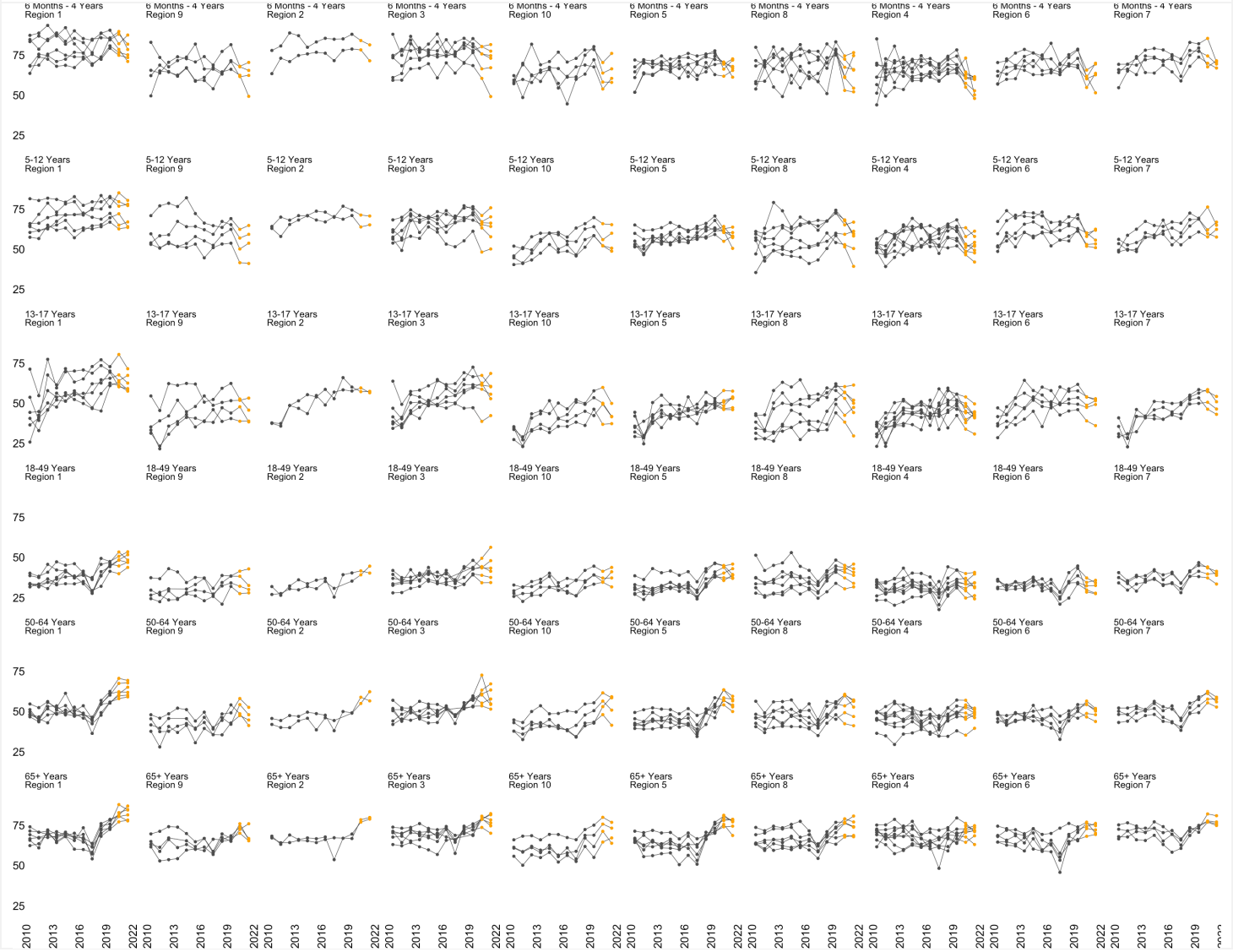
Relative difference calculated as (b-a)/b with a=state-level coverage in flu season 2020-2021 and b = state-level coverage in flu season 2021-2022

Appendix Table 2. Adjusted odds ratios (aOR), and 95% CI from logistic regression models

	COVID-19				FLU	
	aOR	95%	CI	aOR	95%	CI
Alaska	Not included			Not included		
Alabama	1			1		
Arkansas	1.24	1.06	1.44	1.19	1.06	1.33
Arizona	0.79	0.70	0.90	0.89	0.80	0.98
California	1.45	1.30	1.62	1.17	1.08	1.26
Colorado	1.49	1.31	1.7	1.38	1.26	1.52
Connecticut	1.87	1.56	2.25	1.43	1.29	1.59
District of Columbia	3.57	2.10	6.09	2.27	1.81	2.83
Delaware	1.21	0.94	1.55	1.42	1.21	1.66
Florida	1.02	0.92	1.13	0.76	0.70	0.82
Georgia	1.03	0.91	1.16	1.04	0.95	1.14
Hawaii	1.41	1.08	1.84	1.11	0.95	1.29
Iowa	1.21	1.05	1.39	1.63	1.47	1.80
Idaho	1.04	0.89	1.20	1.22	1.08	1.38
Illinois	1.34	1.20	1.50	1.30	1.20	1.41
Indiana	1.12	0.99	1.26	1.25	1.14	1.36
Kansas	1.23	1.07	1.42	1.35	1.21	1.50
Kentucky	1.34	1.18	1.52	1.18	1.07	1.30
Louisiana	0.98	0.86	1.12	1.03	0.93	1.14
Massachusetts	2.07	1.75	2.44	1.70	1.54	1.87
Maryland	2.29	1.95	2.70	1.63	1.47	1.81
Maine	2.18	1.79	2.65	1.54	1.36	1.75
Michigan	1.11	1.00	1.24	1.33	1.22	1.44
Minnesota	1.48	1.29	1.70	1.70	1.54	1.87
Missouri	1.19	1.06	1.34	1.43	1.31	1.57
Mississippi	1.11	0.95	1.29	0.92	0.82	1.04
Montana	1.11	0.93	1.33	1.47	1.27	1.69
North Carolina	1.24	1.10	1.39	1.32	1.21	1.45
North Dakota	1.27	1.02	1.57	1.58	1.32	1.89
Nebraska	1.44	1.20	1.71	1.58	1.38	1.81
New Hampshire	1.79	1.41	2.26	1.51	1.32	1.74
New Jersey	1.65	1.42	1.90	1.13	1.03	1.25
New Mexico	1.52	1.27	1.83	1.32	1.16	1.50
Nevada	0.80	0.67	0.96	0.77	0.68	0.87
New York	1.91	1.70	2.15	1.32	1.21	1.43
Ohio	1.06	0.95	1.18	1.22	1.12	1.33
Oklahoma	1.19	1.03	1.36	1.19	1.08	1.32
Oregon	1.45	1.26	1.67	1.05	0.95	1.15

Pennsylvania	1.32	1.19	1.47	1.35	1.25	1.47
Rhode Island	1.45	1.10	1.90	1.50	1.27	1.79
South Carolina	1.09	0.96	1.24	1.07	0.97	1.17
South Dakota	1.51	1.23	1.85	1.84	1.56	2.17
Tennessee	1.01	0.89	1.13	1.11	1.01	1.22
Texas	0.97	0.87	1.08	1.01	0.94	1.10
Utah	1.47	1.25	1.73	1.28	1.15	1.43
Virginia	1.65	1.46	1.88	1.50	1.37	1.64
Vermont	2.89	2.16	3.88	1.77	1.49	2.09
Washington	1.73	1.52	1.97	1.24	1.13	1.35
Wisconsin	1.41	1.25	1.60	1.63	1.49	1.78
West Virginia	1.44	1.23	1.68	1.37	1.22	1.54
Wyoming	1.10	0.88	1.37	1.21	1.00	1.46

Appendix Figure 5. State-level flu vaccination coverage on y-axis by age (rows) and by HHS region (columns), over time (x-axis). HHS regions* are ordered by 2020 vote share**: Region 1 has the highest share for Democratic candidate and Region 7 has the lowest vote share. The seasons during the COVID-19 pandemic (2020-2021, 2021-2022) are highlighted with orange. Data: NIS-FLU, BRFSS



Footnote

***) HHS Regions**

Region 1: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont
Region 2: New Jersey, New York (not included: Puerto Rico, and the Virgin Islands)
Region 3: Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, and West Virginia
Region 4: Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee
Region 5: Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin
Region 6: Arkansas, Louisiana, New Mexico, Oklahoma, and Texas
Region 7: Iowa, Kansas, Missouri, and Nebraska
Region 8: Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming
Region 9: Arizona, California, Hawaii, Nevada (not included: American Samoa, Commonwealth of the Northern Mariana Islands, Federated States of Micronesia, Guam, Marshall Islands, and Republic of Palau)
Region 10: Alaska, Idaho, Oregon, and Washington

**) 2020 vote share used in this instance to demonstrate the ranking of HHS regions

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