

**Online Appendix for
The Effect of Vaccine Mandates on Disease Spread:
Evidence from College COVID-19 Mandates**

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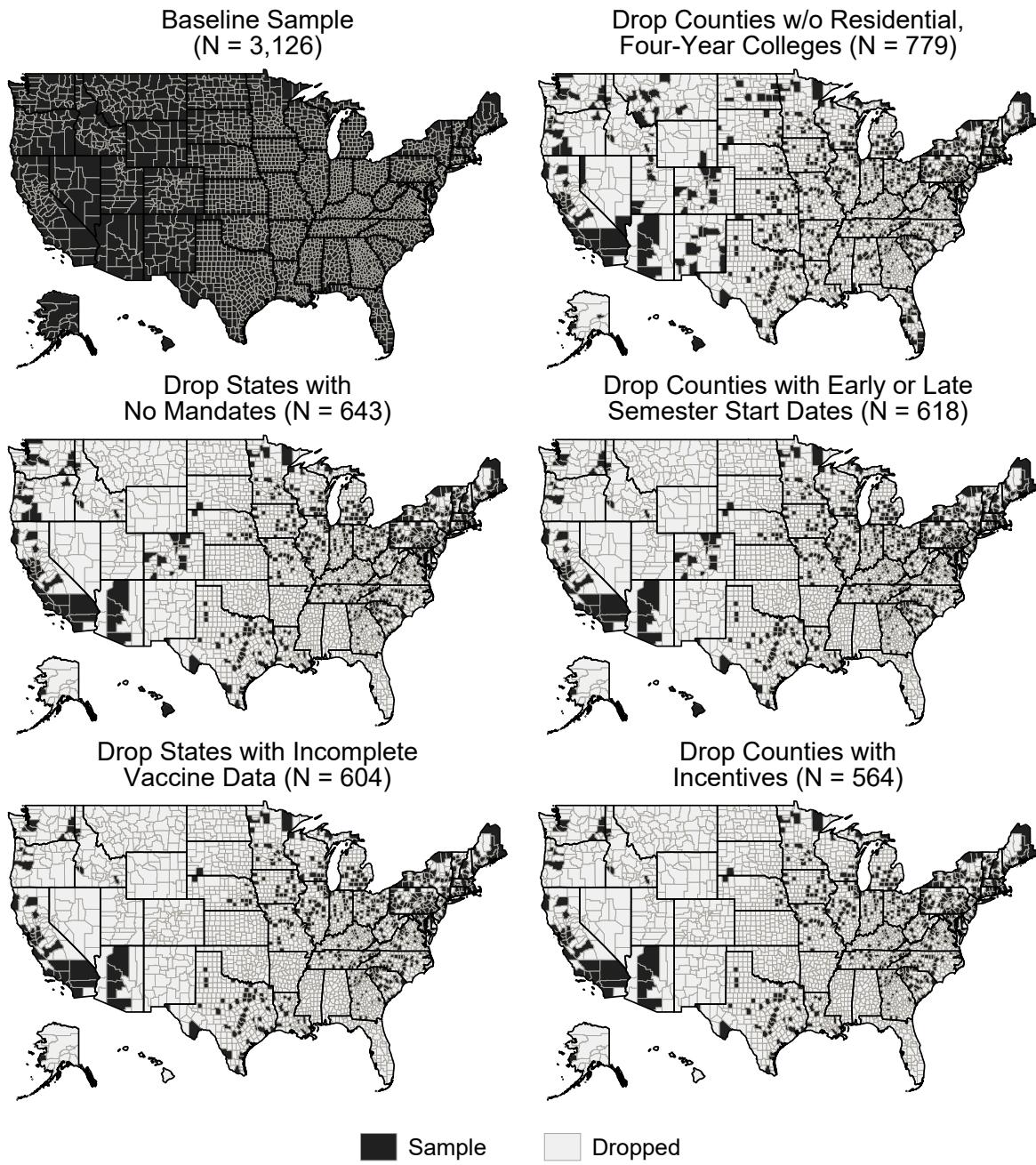
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A Additional Figures & Tables

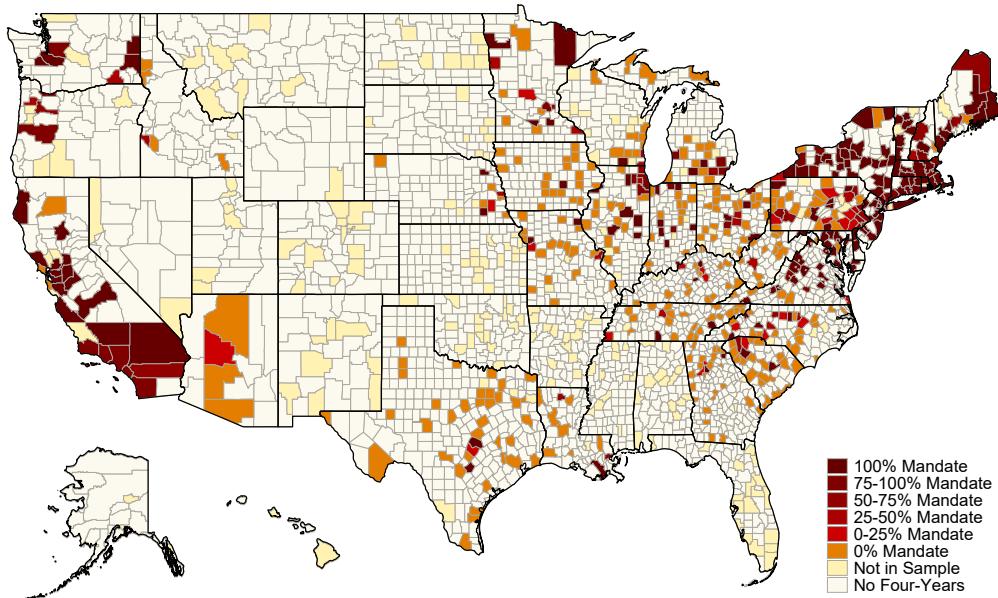
Figure A.1: Sample Construction



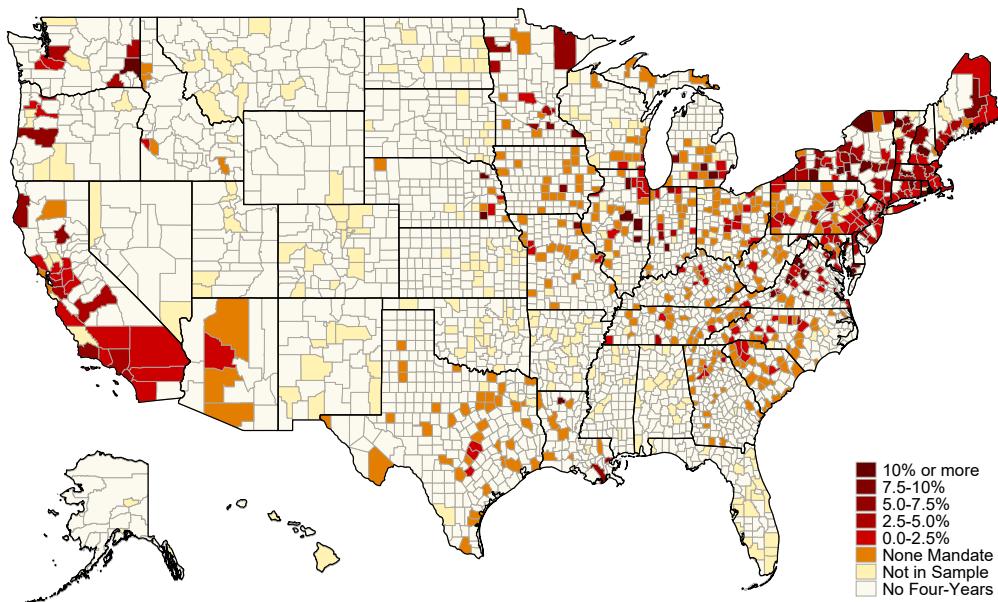
Note: This county-level map shows how the sample evolves as restrictions are imposed. Counties included in the sample are shaded in black. The count of counties remaining in the sample is provided in the header for each subplot.

Figure A.2: Map of Students Covered by Vaccine Mandates

(a) As Share of Students

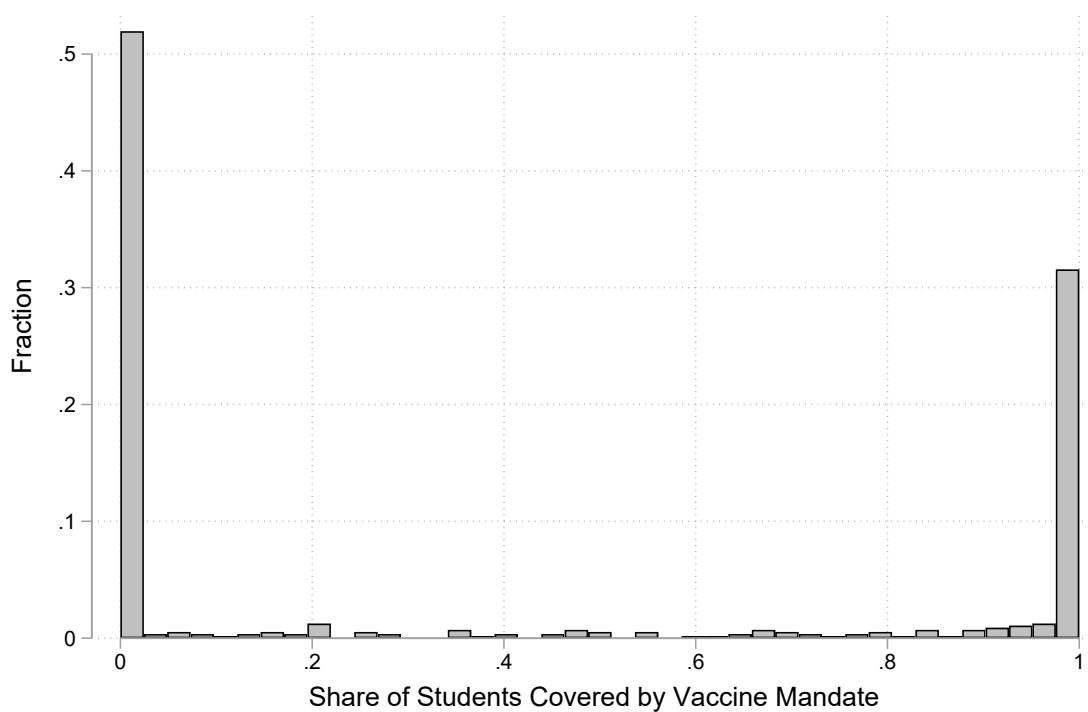


(b) As Share of Population



Note: This county-level map shows the four-year students covered by a mandate as a fraction of the total number of four-year college students or the population in each county.

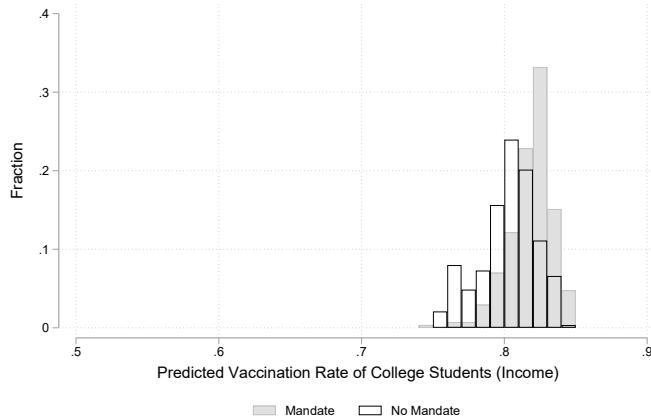
Figure A.3: County-Level Distribution of Share of Students Covered by Vaccine Mandates



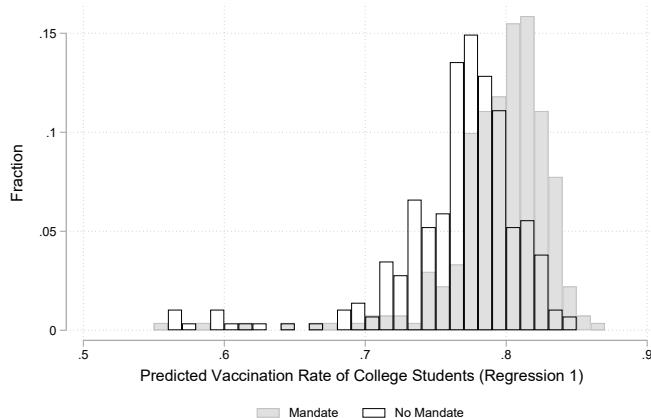
Note: This figure shows the distribution of the share of four-year, residential college students covered by a vaccine mandate across counties in our analysis sample.

Figure A.4: Distribution of Predicted Vaccination Rates by Mandate Status

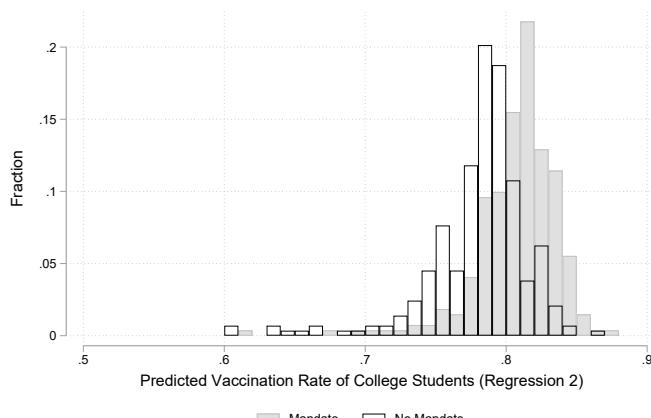
(a) Prediction Based on Income Only



(b) Prediction Based on Income and Race



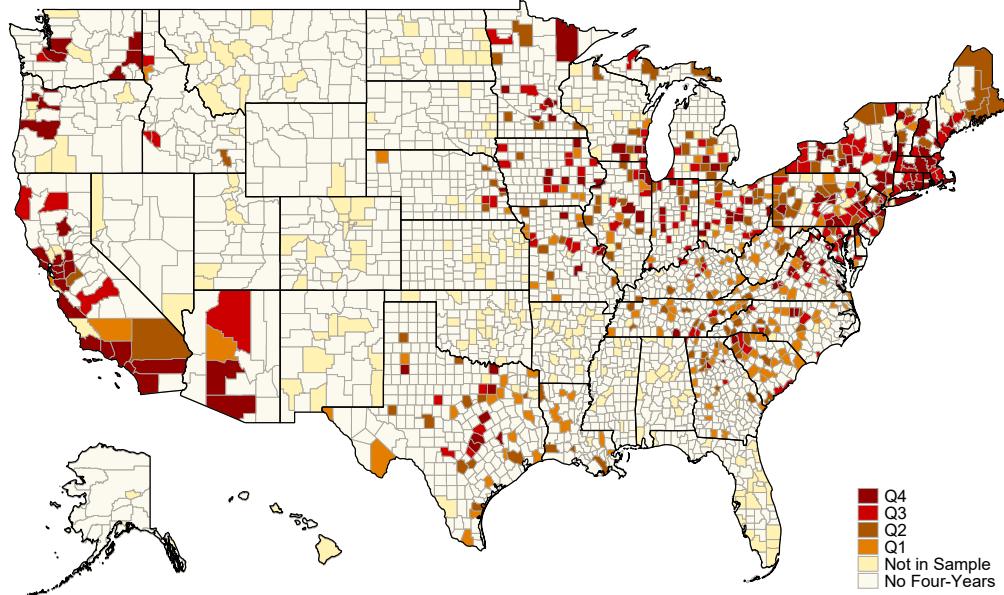
(c) Prediction Based on Income, Race, and Interactions



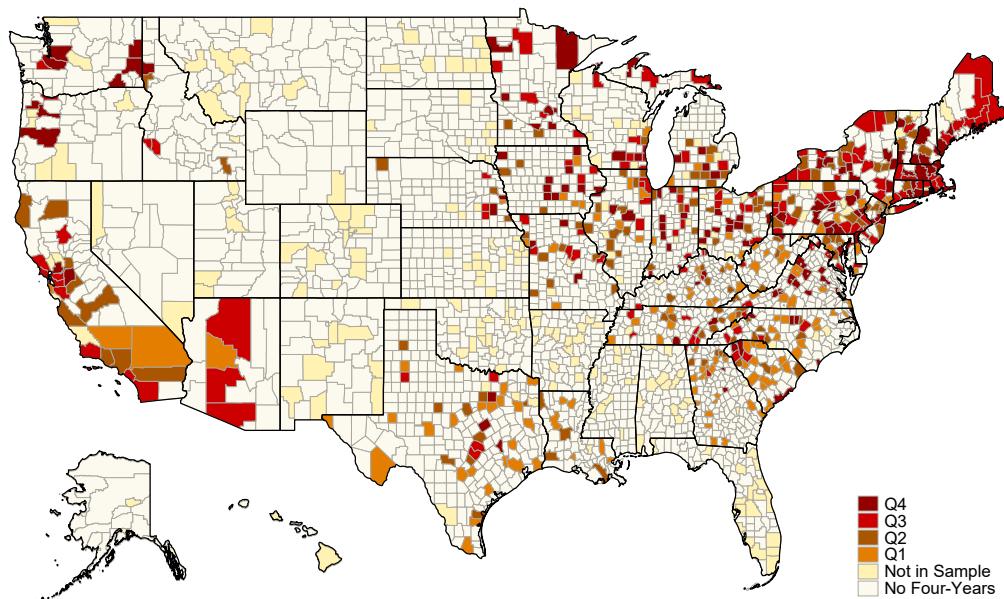
Note: The figures show the distribution of the predicted vaccination rate among college students based on regressions of Pulse Survey vaccination responses on income, race and interactions as described in Section III.B. The three panels vary in the characteristics included in the regression. In Panel (a), the regression includes only income. In Panels (b) and (c), we add race and the interactions between race and income, respectively.

Figure A.5: Map of Predicted Vaccination Rates of College Students

(a) Vaccine Status Measured in July/August

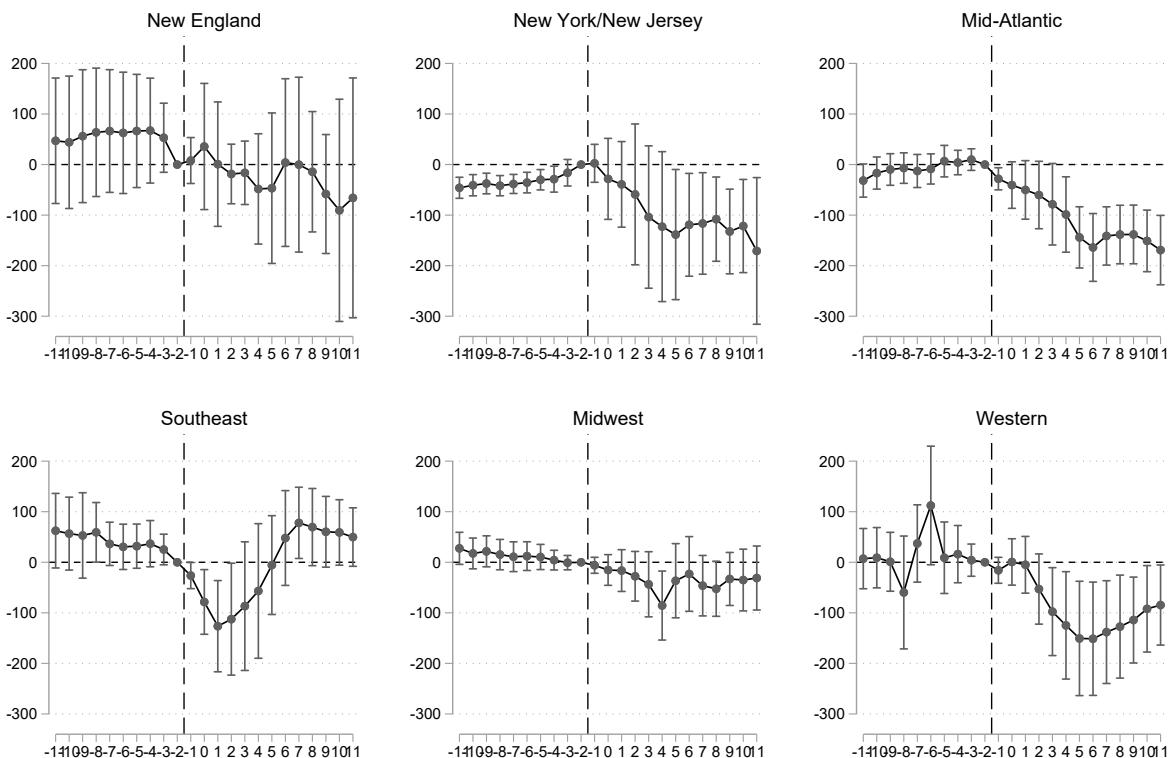


(b) Vaccine Status Measured in April/May



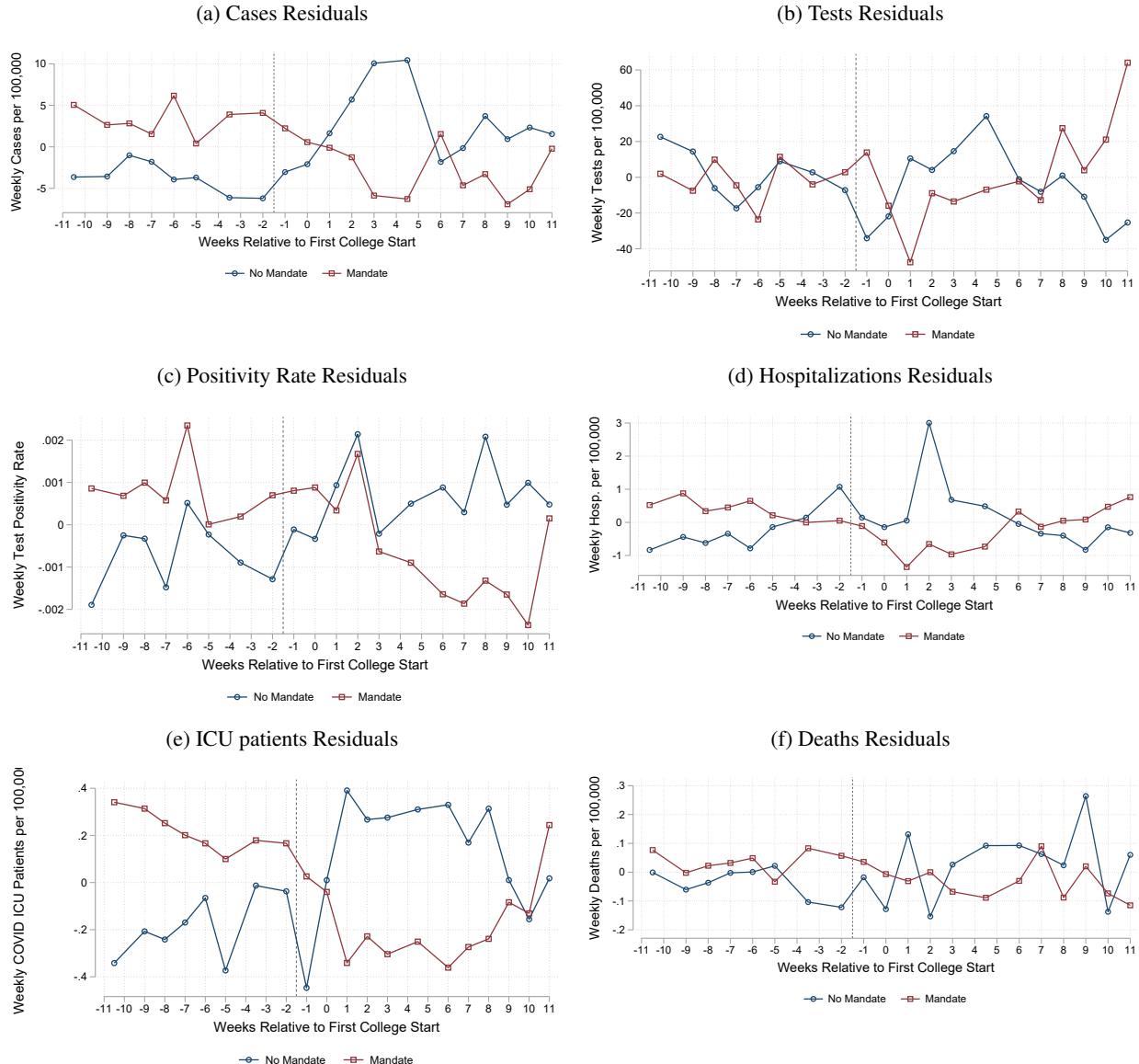
Note: This map shows the predicted vaccination rate among college students based on a regression of Pulse Survey vaccination responses on income, race and interactions as described in Section III.B.

Figure A.6: Event Study of COVID-19 Cases by Region, No Controls



Note: Each figure shows the result of an event study specification that includes county and week fixed effects in the six BLS-defined regions with the greatest number of mandate counties in our sample. We omit figures for the Southwest (6 mandate counties) and Mountain-Plains (5 mandate counties) regions as they have very few mandate counties. The line in each figure shows the effect of 100% mandate coverage relative to college counties without mandates. We cluster standard errors at the county level and include 95% confidence intervals.

Figure A.7: Residual Plots



Note: These figures plot the residuals from a regression of COVID-19 outcome measures on county and week fixed effects, week-by-region fixed effects, week-by-baseline vaccination rate fixed effects, and week-by-vote share fixed effects, where the vote share is the county-level Democratic vote share in the 2016 presidential election. The levels for college counties with (without) a mandate are given by the square (circular) markers. Captions provide the outcome measure for each panel.

Figure A.8: Event Studies with Binary Treatment

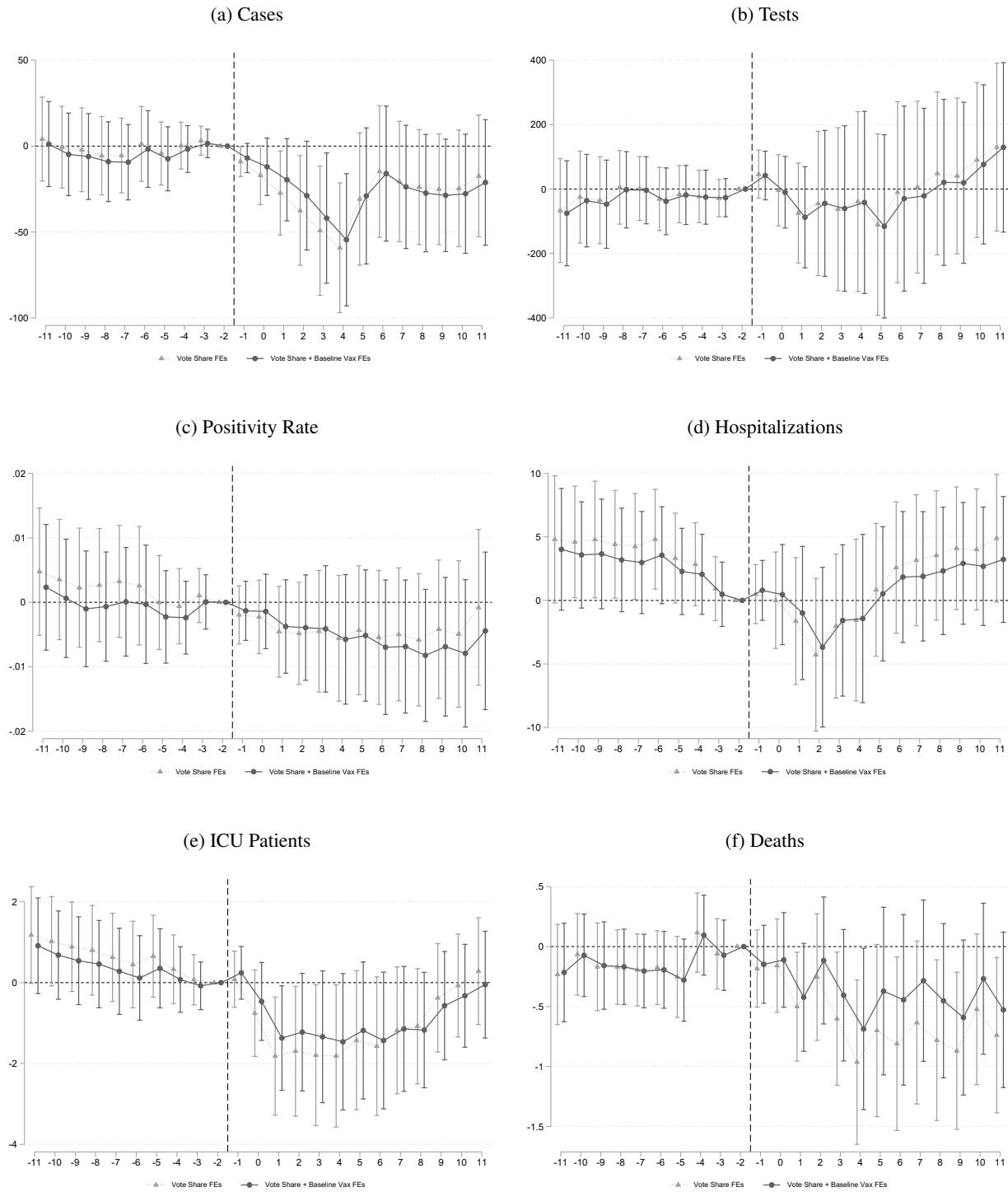
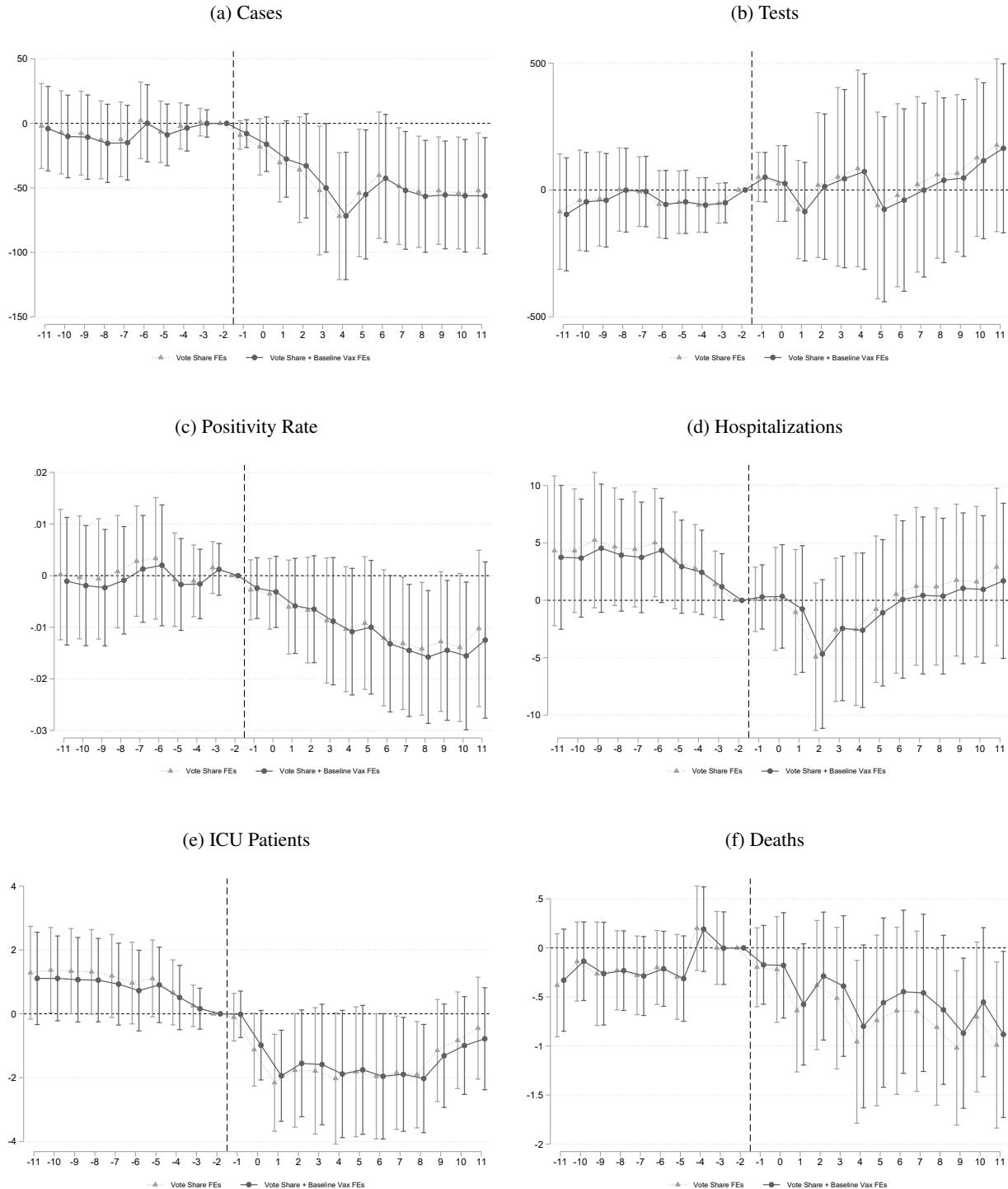
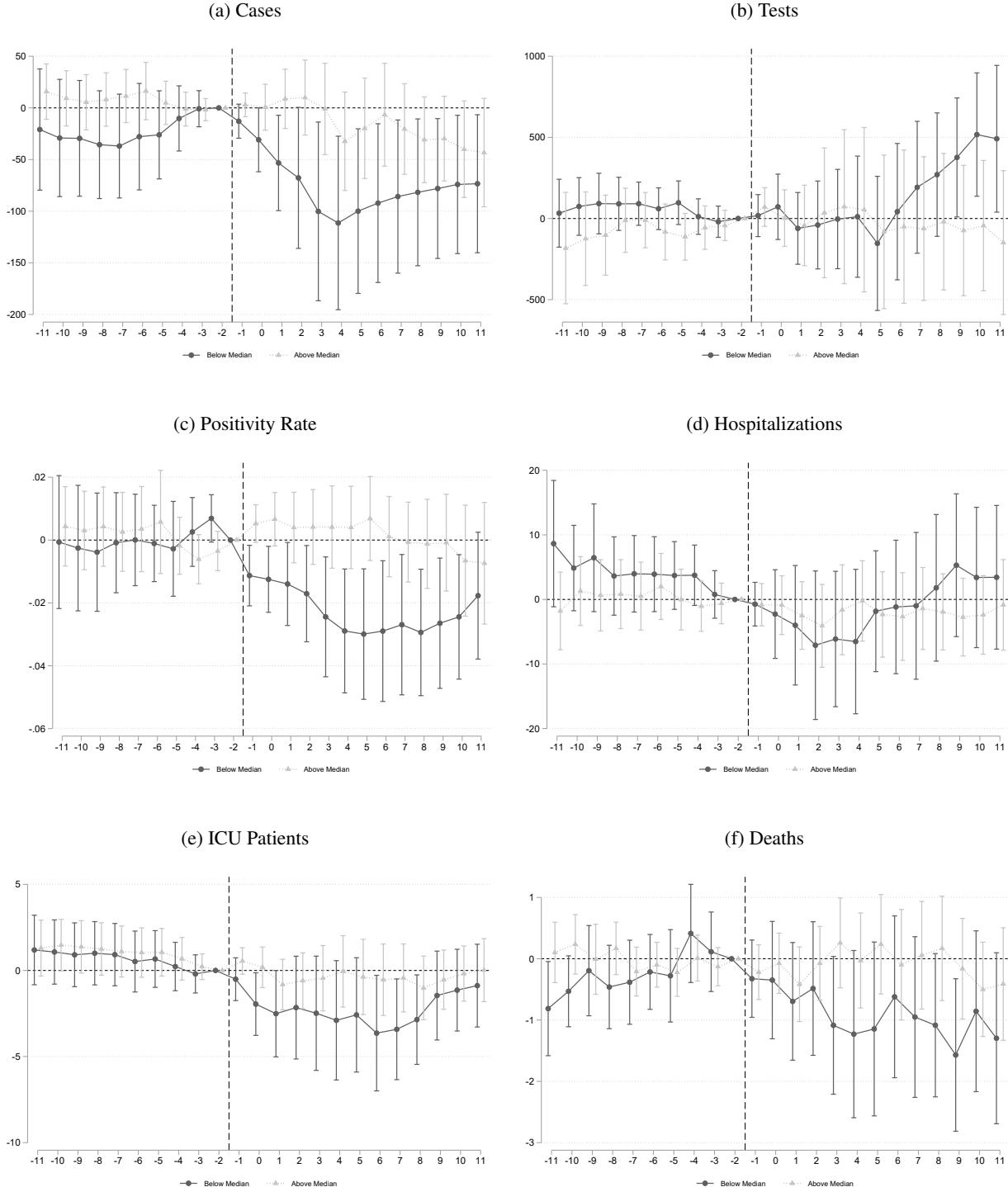


Figure A.9: Event Studies, Dropping Partially Treated Counties



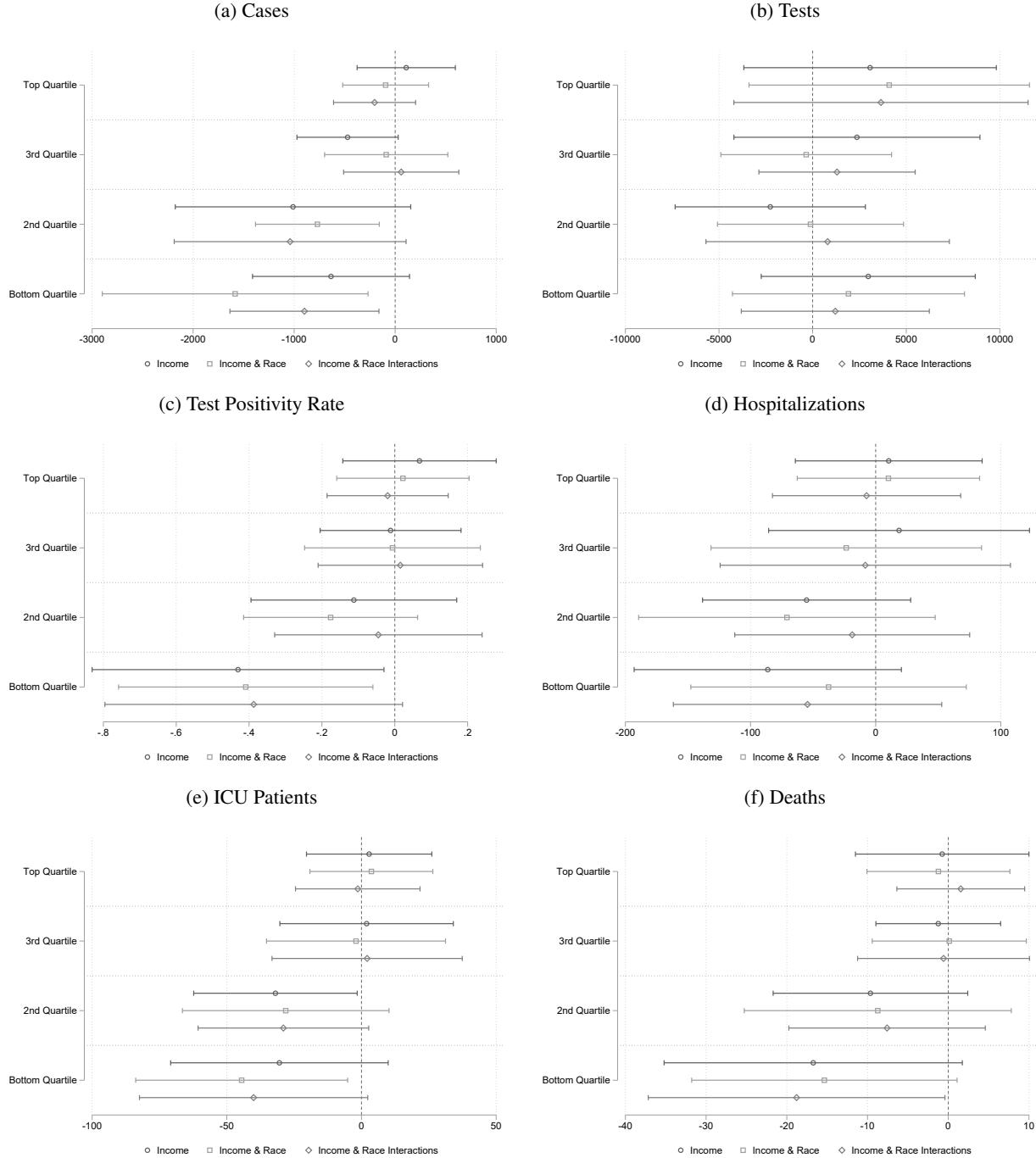
Note: These figures show the results of event studies that include county and week fixed effects, week-by-region fixed effects, week-by-baseline vaccination rate fixed effects, and week-by-vote share fixed effects, where the vote share is the county-level Democratic vote share in the 2016 presidential election. The line shows the effect of the mandate relative to college counties without mandates. We cluster standard errors at the county level and include 95% confidence intervals. Panels are labeled by the outcome measure. Outcomes are measured on a weekly basis.

Figure A.10: Event Studies by Predicted Vaccination Rate, Earlier Pulse Data



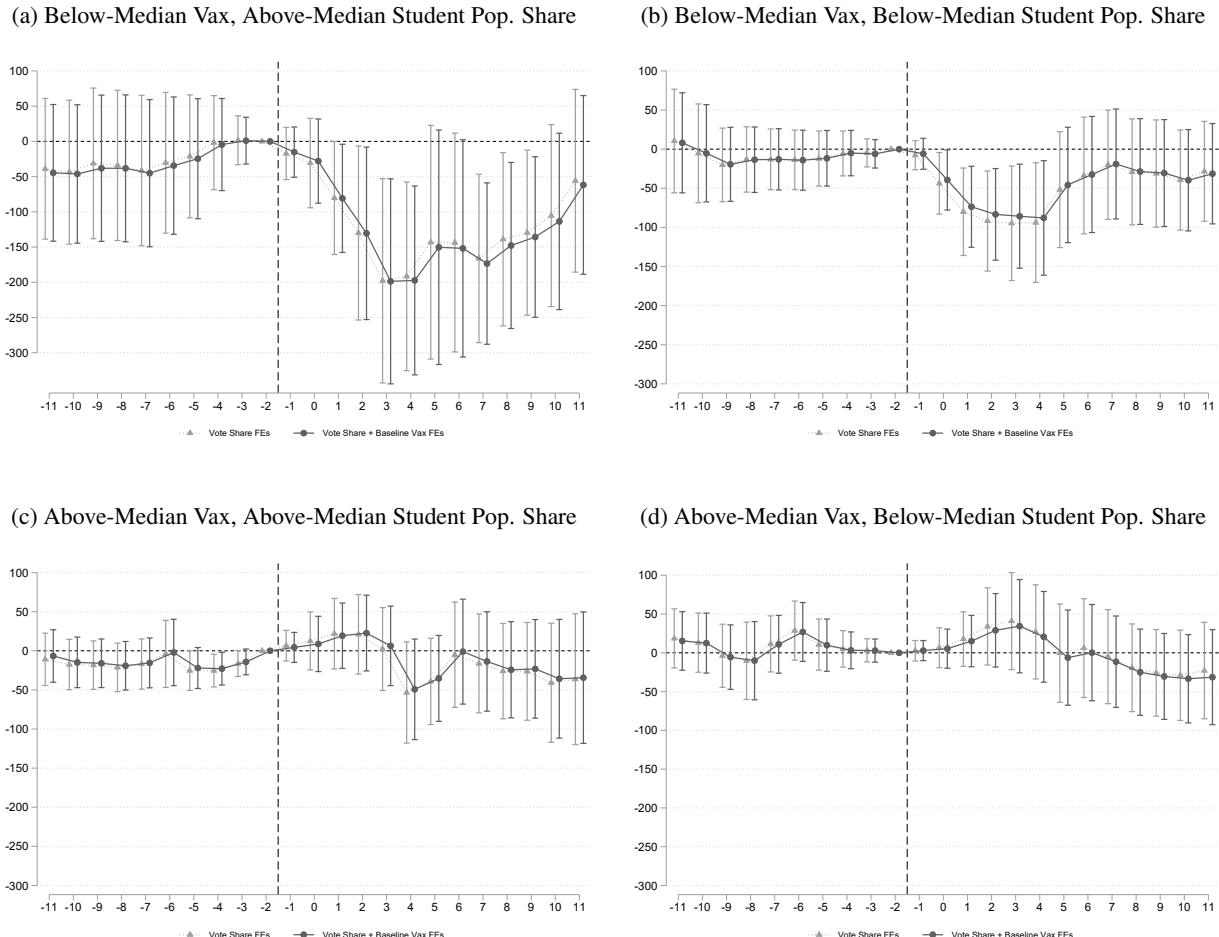
Note: Note: These figures show the results of event studies that include county and week fixed effects, week-by-region fixed effects, week-by-baseline vaccination rate fixed effects, and week-by-vote share fixed effects, where the vote share is the county-level Democratic vote share in the 2016 presidential election. The lines show the effect of 100% mandate coverage of four-year, residential college students relative to college counties without mandates. The dark line with circular markers indicates the effects for counties with colleges that have below-median predicted student vaccination rates, while the light gray line with triangular markers indicates the effects for counties with colleges that have above-median predicted student vaccination rates (median = 64.9%). Predicted vaccination rates are based on regressions of Pulse Survey vaccination responses in April and May 2021 on income, race and interactions as described in Section III.B. We cluster standard errors at the county level and include 95% confidence intervals. Panels are labeled by the outcome measure. Outcomes are measured on a weekly basis.

Figure A.11: Cumulative Estimates by Predicted Vaccination Rate Quartile



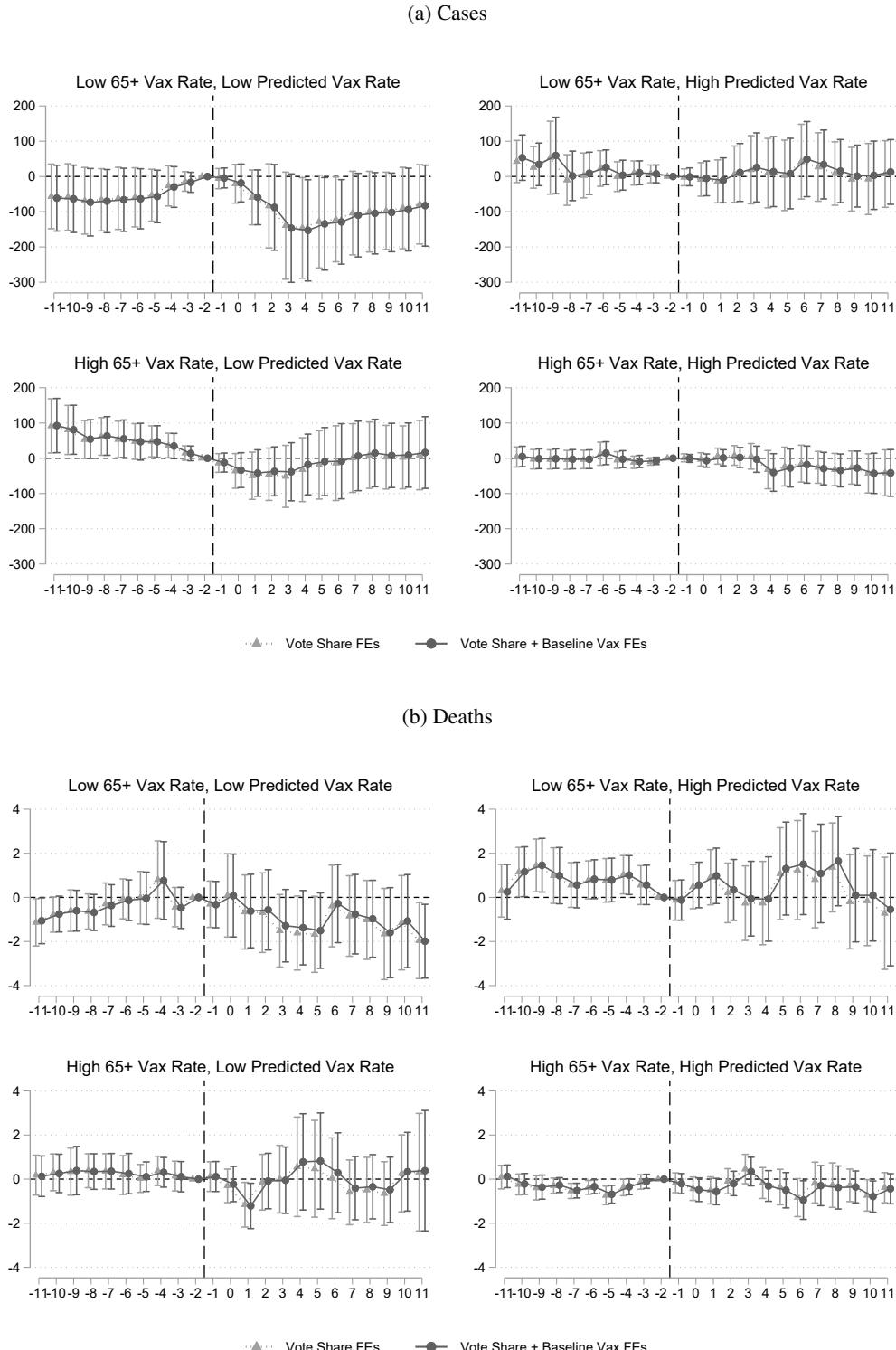
Note: These figures show cumulative and average effects of vaccine mandates on COVID-19 outcomes from the week prior to semester start through the 12th week of the semester. These effects are computed separately for college counties by quartile of predicted vaccination rate. The predicted vaccination rates are based on the regression shown in Equation 3, where the included regressors are either income, income and race, or income and race plus their interactions, as labeled in the figure. All values per 100k are sums of the event study estimates from -1 through 11. All percentage values are averages of these coefficients. The event studies include county and week fixed effects, week-by-region fixed effects, week-by-baseline vaccination rate fixed effects, and week-by-vote share fixed effects, where the vote share is the county-level Democratic vote share in the 2016 presidential election. We cluster standard errors at the county level and include 95% confidence intervals. Panels are labeled by the outcome measure. Outcomes are measured on a weekly basis.

Figure A.12: Event Study of COVID-19 Cases, by Predicted Student Vaccination Rate and Student Population Share



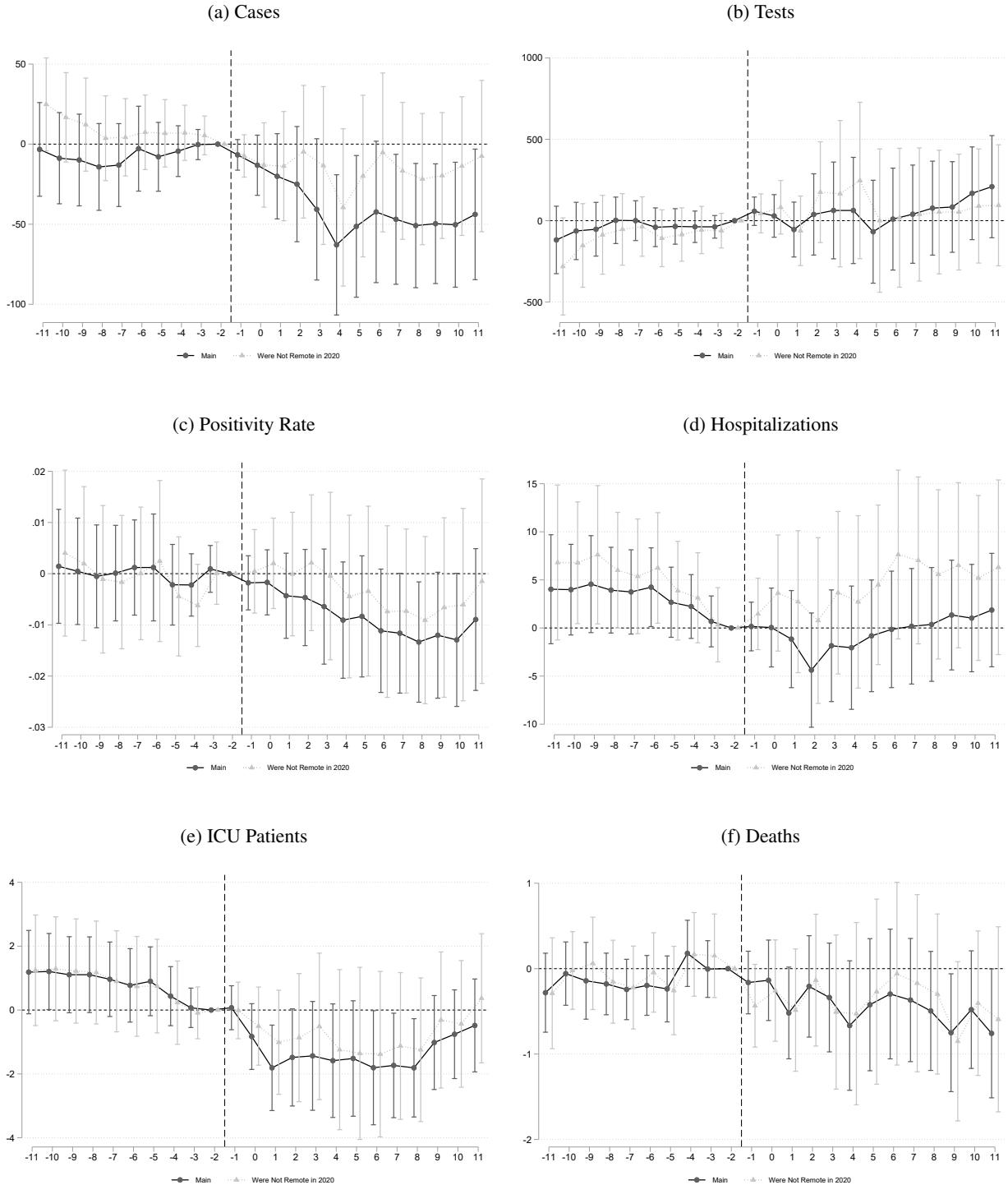
Note: These figures show the results of event studies with cases per 100k as the outcome measure, splitting the sample into above- vs. below-predicted student vaccination rates (median = 79.4%) and above- or below-median student population share (median = 3.85%). Predicted vaccination is based on income, race and the interactions of income and race. Each event study includes county and week fixed effects, week-by-region fixed effects, week-by-baseline vaccination rate fixed effects, and week-by-vote share fixed effects, where the vote share is the county-level Democratic vote share in the 2016 presidential election. The lines show the effect of the mandate relative to college counties without mandates. We cluster standard errors at the county level and include 95% confidence intervals.

Figure A.13: Event Studies by Baseline Vaccination Rate of 65+ Population and Predicted Student Vaccination Rate



Note: These figures show the results of event studies with cases per 100k (panel a) and deaths per 100k (panel b) as the outcome measures, splitting the sample into above- vs. below- predicted student vaccination rates and above- or below-median vaccination rate of the 65+ population in the county. Predicted vaccination is based on income, race and the interactions of income and race. The vaccination rate of the 65+ population is measured using Household Pulse Survey data from before semester start. Each event study includes county and week fixed effects, week-by-region fixed effects, week-by-baseline vaccination rate fixed effects, and week-by-vote share fixed effects, where the vote share is the county-level Democratic vote share in the 2016 presidential election. Standard errors are clustered at the county level and include 95% confidence intervals.

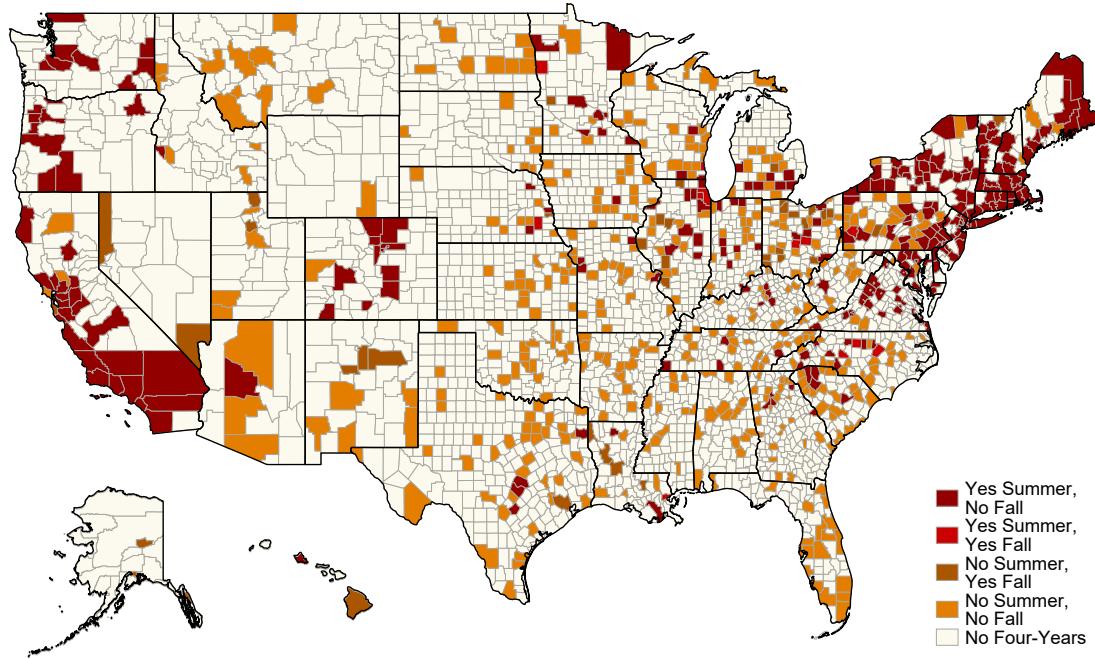
Figure A.14: 2021 Event Studies by 2020 Instruction Mode



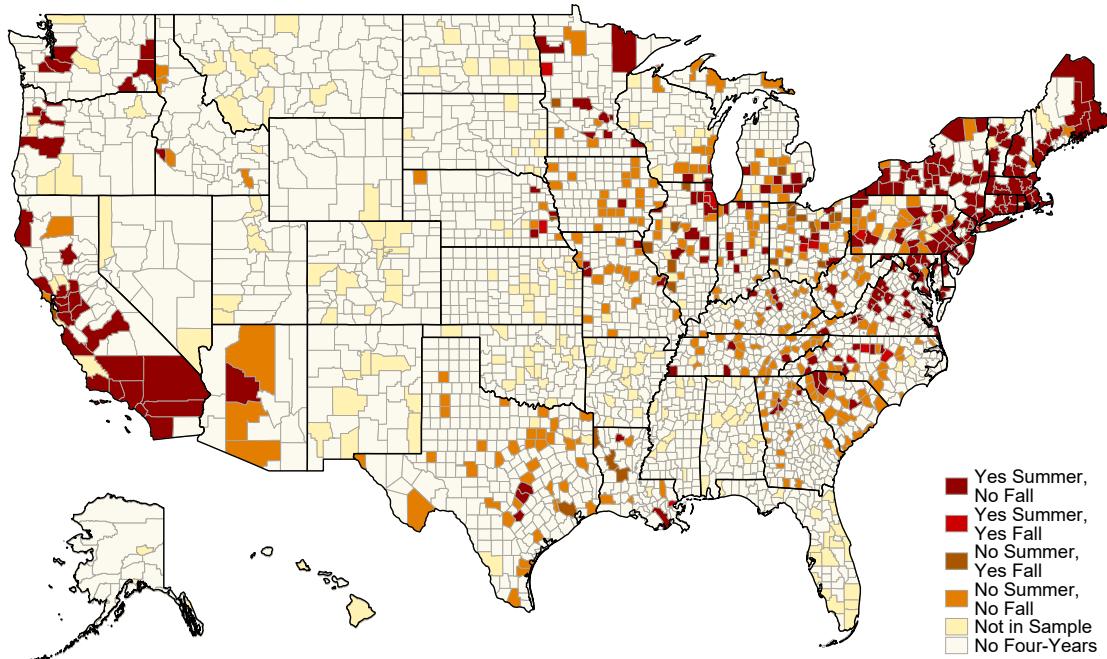
Note: These figures show the results of a placebo event study in which we regress 2020 outcomes on 2021 mandates, for colleges that re-opened in person in 2020. All regressions include county and week fixed effects, week-by-region fixed effects, week-by-baseline vaccination rate fixed effects, and week-by-vote share fixed effects, where the vote share is the county-level Democratic vote share in the 2016 presidential election. The line shows the effect of the mandate relative to college counties without mandates. We cluster standard errors at the county level and include 95% confidence intervals. Panels are labeled by the outcome measure.

Figure A.15: Map of Mid-Semester Mandates

(a) All U.S. Counties

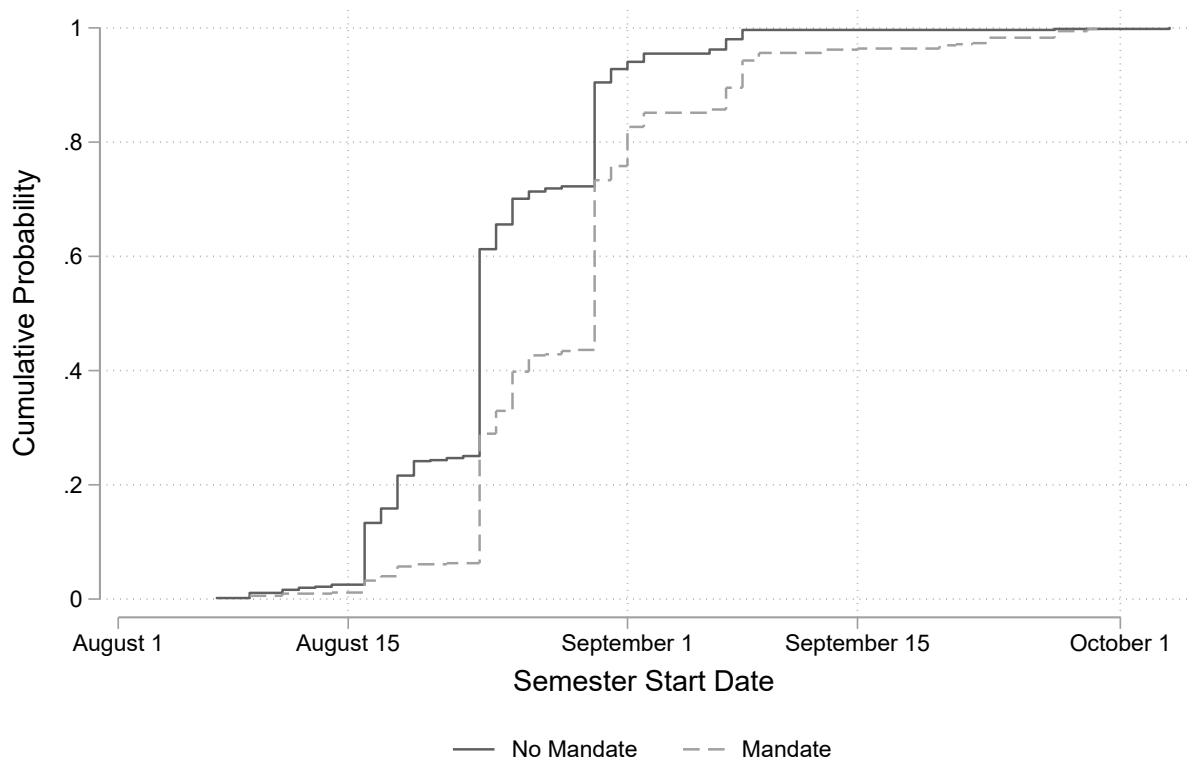


(b) Analysis Sample



Note: This county-level map shows whether the county has a four-year college in the sample, and whether any of these colleges had a vaccine mandate in summer 2021 and/or in fall 2021 ("mid-semester").

Figure A.16: Semester Start Dates



Note: This figure shows the cumulative probability that a college's semester has started by the date indicated on the X axis, among colleges with and without a mandate.

Table A.1: Predicted County Mandates

	Any Mandate			% of Students w/ Mandate		
	(1)	(2)	(3)	(4)	(5)	(6)
NY/NJ	0.008 (0.043)	0.050 (0.046)	0.058 (0.047)	0.046 (0.048)	0.077 (0.048)	0.081* (0.049)
Mid-Atlantic	-0.293*** (0.059)	-0.201*** (0.058)	-0.159*** (0.059)	-0.365*** (0.061)	-0.319*** (0.060)	-0.301*** (0.061)
Southeast	-0.724*** (0.051)	-0.571*** (0.057)	-0.470*** (0.066)	-0.760*** (0.048)	-0.646*** (0.052)	-0.603*** (0.059)
Midwest	-0.610*** (0.052)	-0.485*** (0.054)	-0.444*** (0.057)	-0.613*** (0.052)	-0.520*** (0.053)	-0.502*** (0.055)
Southwest	-0.830*** (0.058)	-0.660*** (0.063)	-0.588*** (0.069)	-0.804*** (0.054)	-0.676*** (0.059)	-0.646*** (0.063)
Mountain Plains	-0.714*** (0.099)	-0.526*** (0.093)	-0.450*** (0.098)	-0.727*** (0.084)	-0.586*** (0.081)	-0.554*** (0.085)
West	-0.185** (0.073)	-0.187** (0.073)	-0.169** (0.075)	-0.212*** (0.075)	-0.214*** (0.071)	-0.206*** (0.072)
2016 D Vote Share		0.839*** (0.109)	0.605*** (0.115)		0.628*** (0.094)	0.529*** (0.106)
Base Vax Rate			0.638*** (0.166)			0.271* (0.153)
Constant	0.952*** (0.033)	0.468*** (0.073)	0.227** (0.103)	0.895*** (0.038)	0.532*** (0.068)	0.430*** (0.092)
Observations	564	552	552	564	552	552
R-squared	0.323	0.388	0.404	0.380	0.428	0.431

Note: This table presents estimate coefficients from regressions of county-level mandate status on region dummy variables, a county's 2016 Democratic vote share, and a county's baseline vaccination rate. The Northeast is the excluded region. Robust standard errors are shown in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.2: Event Study Estimates

	Cases per 100k (1)	Tests per 100k (2)	Positivity Rate (3)	Hosp. per 100k (4)	ICU patients per 100k (5)	Deaths per 100k (6)
Pre: -11	-3.299 (14.888)	-118.393 (105.528)	0.001 (0.006)	4.028 (2.885)	1.188* (0.664)	-0.282 (0.235)
Pre: -10	-8.778 (14.493)	-63.205 (89.572)	0.000 (0.005)	3.986* (2.399)	1.207** (0.606)	-0.058 (0.189)
Pre: -9	-9.908 (14.577)	-52.733 (84.077)	-0.001 (0.005)	4.558* (2.565)	1.106* (0.606)	-0.142 (0.229)
Pre: -8	-14.230 (13.799)	2.211 (72.622)	0.000 (0.005)	3.932* (2.270)	1.107* (0.603)	-0.179 (0.184)
Pre: -7	-13.069 (13.176)	0.158 (62.218)	0.001 (0.005)	3.747* (2.229)	0.964 (0.593)	-0.244 (0.180)
Pre: -6	-2.829 (13.496)	-40.436 (60.534)	0.001 (0.005)	4.240** (2.083)	0.773 (0.585)	-0.196 (0.178)
Pre: -5	-7.907 (10.939)	-35.383 (55.559)	-0.002 (0.004)	2.676 (1.855)	0.900 (0.549)	-0.237 (0.197)
Pre: -4	-4.374 (8.065)	-37.523 (49.170)	-0.002 (0.003)	2.233 (1.688)	0.435 (0.471)	0.179 (0.197)
Pre: -3	-0.273 (4.795)	-37.930 (35.421)	0.001 (0.002)	0.684 (1.347)	0.070 (0.314)	-0.004 (0.169)
Post: -1	-6.692 (4.870)	57.865 (44.413)	-0.002 (0.003)	0.156 (1.288)	0.073 (0.350)	-0.162 (0.187)
Post: 0	-13.184 (9.565)	29.172 (66.598)	-0.002 (0.003)	0.049 (2.087)	-0.830 (0.524)	-0.136 (0.240)
Post: 1	-20.080 (13.545)	-54.479 (85.795)	-0.004 (0.004)	-1.156 (2.570)	-1.810*** (0.681)	-0.519* (0.273)
Post: 2	-24.977 (18.309)	38.308 (127.100)	-0.005 (0.005)	-4.379 (3.023)	-1.483* (0.775)	-0.208 (0.302)
Post: 3	-40.748* (22.458)	62.796 (151.292)	-0.006 (0.006)	-1.845 (2.956)	-1.435* (0.867)	-0.338 (0.324)
Post: 4	-62.912*** (22.294)	62.734 (166.041)	-0.009 (0.006)	-2.050 (3.262)	-1.585* (0.905)	-0.666* (0.386)
Post: 5	-51.353** (22.524)	-67.922 (160.934)	-0.008 (0.006)	-0.817 (2.956)	-1.517* (0.920)	-0.422 (0.394)
Post: 6	-42.337* (22.475)	9.636 (159.372)	-0.011* (0.006)	-0.145 (3.082)	-1.806** (0.910)	-0.297 (0.387)
Post: 7	-46.933** (20.655)	39.879 (153.495)	-0.012* (0.006)	0.176 (3.057)	-1.734** (0.833)	-0.368 (0.367)
Post: 8	-50.853** (19.751)	76.932 (146.887)	-0.013** (0.006)	0.368 (3.011)	-1.810** (0.783)	-0.495 (0.355)
Post: 9	-49.684*** (19.030)	84.031 (141.687)	-0.012* (0.006)	1.345 (2.904)	-1.017 (0.749)	-0.750** (0.351)
Post: 10	-50.319** (19.857)	168.156 (145.042)	-0.013* (0.007)	1.030 (2.842)	-0.757 (0.707)	-0.480 (0.351)
Post: 11	-43.870** (20.749)	208.790 (159.715)	-0.009 (0.007)	1.863 (3.002)	-0.482 (0.740)	-0.758** (0.384)
Obs.	12,690	12,690	12,117	12,117	11,588	12,690
R-Squared	0.776	0.788	0.813	0.716	0.719	0.570

Note: This table shows the event study estimates that correspond to those shown in Figure 4. The rows are labeled by the number of weeks pre- or post-semester start. The estimates are relative to non-mandate college counties. All regressions include county and week fixed effects, week-by-region fixed effects, week-by-baseline vaccination rate fixed effects, and week-by-vote share fixed effects, where the vote share is the county-level Democratic vote share in the 2016 presidential election.

Table A.3: Cumulative Effects on Cases by Age Group

	Ages 0-17 (1)	Ages 18-64 (2)	Ages 65+ (3)
<i>Panel A. Effect of 100% mandate coverage of college students</i>			
Effect	-407.1* (216.8)	-562.6** (226.8)	-405.8*** (143.8)
Obs.	4,169	4,169	4,169
<i>Panel B. Effect of any vaccine mandate in county</i>			
Effect	-354.1* (190.3)	-356.7* (200.1)	-255.0* (132.7)
Obs.	4,169	4,169	4,169
<i>Panel C. Effect of any mandate, dropping partially treated</i>			
Effect	-491.8** (232.5)	-610.6*** (234.8)	-477.6*** (155.6)
Obs.	3,441	3,441	3,441
Mean	681.2	711.5	418.7
Estimate Type	Sum	Average	Sum

Note: The table shows cumulative effects of vaccine mandates on COVID-19 cases from the week prior to semester start through the 12th week of the semester. The cumulative measure is the sum of the event study coefficients. The specification in Panel A considers the share of college students in a county covered by a mandate. Panel B considers the effect of having any vaccine mandate in a county. Panel C repeats the specification in Panel B but drops counties where some, but not all, students are covered by a mandate. All specifications include county, week, week-by-region, week-by-baseline vaccination rate, and week-by-vote share fixed effects. All standard errors are clustered at the county level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.4: Cumulative Effects of Mask Mandates

	Cases per 100k (1)	Tests per 100k (2)	Positivity Rate (3)	Hosp. per 100k (4)	ICU patients per 100k (5)	Deaths per 100k (6)
Effect	68.88 (238.5)	3,153** (1,306)	0.008 (0.005)	48.85 (44.85)	0.906 (12.71)	-0.984 (3.781)
Obs.	6,659	6,659	6,658	6,314	6,038	6,659
Estimate Type	Sum	Sum	Average	Sum	Sum	Sum

Note: The table shows the cumulative effect of college mask mandates, estimated using the sample of college counties with no vaccination requirement. The cumulative effects are calculated by summing event study coefficients from the week prior to semester start through the 12th week of the semester. All event study regressions include county and week fixed effects, week-by-region fixed effects, week-by-baseline vaccination rate fixed effects, and week-by-vote share fixed effects, where the vote share is the county-level Democratic vote share in the 2016 presidential election. All standard errors are clustered at the county level.
^{*} $p < 0.10$, ^{**} $p < 0.05$, ^{***} $p < 0.01$.

Table A.5: Distribution of Effects with One State Left Out

Outcome	max	p75	p50	p25	min
Cases	-328.1 (136.4)	-490.2 (200.2)	-502.7 (190.0)	-520.9 (194.8)	-591.6 (198.1)
Tests	1,829 (1,429)	870.3 (1,455)	728.0 (1,491)	576.9 (1,450)	-801.7 (1,230)
Positivity Rate	-0.007 (0.005)	-0.008 (0.005)	-.0008 (0.005)	-0.009 (0.005)	-0.010 (0.005)
Hospitalizations	4.838 (30.13)	-1.121 (28.27)	-5.100 (29.19)	-7.184 (29.43)	-27.137 (26.67)
ICU Patients	-12.43 (7.660)	-15.85 (7.731)	-16.21 (7.898)	-16.67 (8.152)	-19.15 (8.185)
Deaths	-3.994 (2.934)	-5.430 (2.859)	-5.595 (2.899)	-5.770 (2.965)	-7.408 (2.899)

Note: The table shows percentiles from the distribution of estimated effects using our main specification but leaving out one state from the analysis at a time. All standard errors are clustered at the county level.

Table A.6: Difference in Differences Estimates by Week of Semester Start

	Main (1)	Weeks 33-35 (2)	Week 33 (3)	Week 34 (4)	Week 35 (5)	Weighted Avg. (6)
Panel A. Cases						
Effect	-503.9*** (189.7)	-529.2*** (197.3)	-1,158.6 (739.3)	-336.4* (180.3)	-109.205 (239.1)	-461.8** (188.9)
Obs.	12,690	12,004	2,576	6,808	2,576	12,006
Panel B. Tests						
Effect	715.9 (1,448)	1,143 (1,504)	926.9 (3,755)	-628.2 (1,973)	4869 (3,647)	1014 (1,548)
Obs.	12,690	12,004	2,576	6,808	2,576	12,006
Panel C. Positivity Rate						
Effect	-0.008* (0.005)	-0.007 (0.005)	-0.019 (0.019)	-0.004 (0.006)	-0.007 (0.008)	-0.008 (0.006)
Obs.	12,550	11,864	2,576	6,760	2,484	11,866
Panel D. Hospitalizations						
Effect	-5.406 (29.11)	-19.12 (26.72)	-114.8* (63.03)	-20.51 (27.28)	61.71 (110.3)	-21.57 (31.57)
Obs.	12,117	11,513	2,415	6,623	2,431	11,515
Panel E. ICU patients						
Effect	-16.19** (7.668)	-19.02** (7.638)	-49.93*** (18.65)	-8.772 (9.734)	-11.761 (11.94)	-18.45*** (6.995)
Obs.	11,588	10,984	2,323	6,232	2,385	10,986
Panel F. Deaths						
Effect	-5.599* (2.853)	-6.545** (2.930)	-6.676 (12.74)	-3.329 (3.332)	-4.732 (6.517)	-4.391 (3.509)
Obs.	12,690	12,004	2,576	6,808	2,576	12,006

Note: The table shows cumulative effects by the week of semester start as described in Section IV.C. All regressions include county and week fixed effects, week-by-region fixed effects, week-by-baseline vaccination rate fixed effects, and week-by-vote share fixed effects, where the vote share is the county-level Democratic vote share in the 2016 presidential election. All standard errors are clustered at the county level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

B Examples of Vaccine Mandate Language

Institution	State	Date	Language
Bentley University	MA	May 17, 2021	<p>“As we prepare for a fully open and operational 2021-2022 academic year, consistent with state and federal guidance, all undergraduate and graduate students who will be on campus this fall will be required to be vaccinated against COVID-19 before the start of the fall 2021 semester.”</p>
Boston University	MA	April 9, 2021	<p>“Boston University will require all students enrolled in classes on our campuses to be vaccinated before the start of classes in the fall of 2021.”</p>
Duke University	NC	April 9, 2021	<p>“Looking ahead, we know that widespread vaccination will be the only way to facilitate a return to normal and robust campus life. With this in mind, we plan to require all new and returning Duke students to present proof of vaccination to Student Health before they can enroll for the Fall 2021 semester.”</p>
Elon University	NC	June 17, 2021	<p>“Undergraduate students must submit vaccine documentation no later than Friday, July 30. Unvaccinated undergraduates should plan to get their first dose of any two-dose vaccine (Pfizer or Moderna) by July 1, so they can get their second dose by July 29. Students may alternately choose to receive the single-dose Johnson & Johnson vaccine by July 15 to meet this requirement. Please keep in mind that full vaccination is not achieved until two weeks after the final dose of the vaccine.”</p>

James Madison University	VA	Unknown	<p>“To help ensure the health of our community and following the guidance and directives from the Governor’s Office, State Council of Higher Education for Virginia (SCHEV), Centers for Disease Control and Prevention (CDC) and American College Health Association, students will be required to provide verification that they have been fully vaccinated for COVID-19 before returning to campus for Fall 2021 except as otherwise noted below.”</p>
Rice University	TX	May 28, 2021	<p>“So, we are announcing today that we expect all students who come to campus, except those with an approved waiver for medical or religious reasons, to be fully vaccinated against COVID-19 in order to start the fall 2021 semester.”</p>
Salem State University	MA	April 26, 2021	<p>“Prior to the beginning of the fall semester and following state, federal and legal guidance, the Massachusetts State Universities will require all students to be fully immunized before returning to campus.”</p>
Stanford University	CA	April 22, 2021	<p>“Based on these recommendations from the CDC and from our Vaccine Governance Committee, Stanford plans to require all undergraduate, graduate and professional students coming to campus this fall to be fully vaccinated for COVID-19. All students will be asked about their vaccine status prior to their arrival on campus for the fall quarter.”</p>
Syracuse University	NY	April 8, 2021	<p>“All new and returning students as well as faculty and staff will be required to be vaccinated prior to the Fall 2021 semester.”</p>

University of
Delaware

DE May 5, 2021

“To continue protecting the health and safety of our community while transitioning to more normal academic operations and campus life, the University will require all students — undergraduate, graduate and professional — who will be on UD campuses this fall to be fully immunized against COVID-19 **before their arrival to campus, and no later than Aug. 15, 2021.**

University of
Virginia

VA Unknown

“All students who live, learn, or work in person at the University during the next academic year must be fully **vaccinated before returning to Grounds**, starting July 1.”

Western
Washington
University

WA May 5, 2021

“After careful consideration and assessing the direction taken by several public and private universities both within Washington state and nationally, Western will require COVID vaccinations for students, faculty, and staff **before returning to campus for the fall 2021 quarter.**”
