The Effect of Vaccine Mandates on Disease Spread: Evidence from College COVID-19 Mandates

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Abstract

Nearly 700 4-year U.S. colleges mandated students receive COVID-19 vaccinations in fall 2021. Using data on college policies and county health, we estimate how mandates affect surrounding communities. Event studies from August to November 2021 show that mandates covering all colleges in a county reduced COVID-19 deaths by 5.6 per 100,000 persons, a 4.6% reduction in the U.S. total during this period. Mandates reduced COVID cases by 504 and ICU admissions by 16.2 per 100,000, though we see no statistically significant impact on hospitalizations. Impacts are larger in counties with larger college populations and low estimated ex-ante student vaccination rates.

JEL Codes: H75, I18, I23

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Data Replication Statement: Most of the data we use for this project are publicly available, except for the data that were collected by C2i: vaccine mandates, school opening dates, mask mandates, and testing policies. Interested researchers can request these data directly from C2i. All data and code except for the data collected by C2i are included in a replication package hosted in the IDSC Dataverse: https://doi.org/10.15185/jhr2024.1.

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I. Introduction

Mandates requiring vaccination in educational settings for deadly and communicable diseases such as smallpox, measles, polio, and Hepatitis, are widespread in the U.S. and throughout the world.[1] Laws mandating that students receive a range of vaccines have been used extensively to help fight the spread of epidemic diseases. Despite their widespread use, vaccine mandates remain controversial. In the wake of the COVID-19 pandemic, public opposition to school-based mandates for other diseases has increased (Lopes et al. 2022) while, in some states, laws that would weaken mandates for diseases other than COVID-19 are under consideration (Allsop 2023; Kekatos 2023; Lawlor 2023).

At base, these mandates represent a tradeoff between the public health benefits of vaccinating a large population and the loss of autonomy in deciding one's own medical care as well as any adverse health impacts of the vaccines themselves. With communicable and deadly diseases, there are likely to be large, positive public health externalities from mandating vaccinations to reduce individual infections and the spread of the disease to others that dramatically increase the benefits from mandated medical interventions. These externalities can be particularly large for students because of their extensive interactions with one another and with the wider community. It therefore is important to quantify the public health benefits of vaccine mandates in order to assess the tradeoff between public health and reduced autonomy over medical decisions. Currently, little work has been done that examines the public health benefits of vaccine mandates, especially in a pandemic setting.

We provide novel evidence on the public health effects of vaccine mandates in the specific setting of college- and university-imposed COVID-19 vaccine mandates for students that were used to control the spread of the SARS-Cov2 virus that causes COVID-19. Besides understanding the role of mandates on COVID-19 specifically, the college context during the COVID-19 pandemic provides an excellent natural experiment to better understand the benefits of vaccine mandates more broadly given the widespread and rapid adoption of mandates across many parts of the U.S. in 2021.

Clinical trials have demonstrated that vaccines approved by the U.S. Food and Drug Administration (FDA) help protect people from being infected with the SARS-Cov2 virus, and, conditional on being infected, reduce the likelihood of hospitalization and death (Polack et al. 2020; Baden et al. 2021; Falsey et al. 2021). Barro (2022) estimates that one life was saved per 248 vaccinations, with a marginal cost per life saved of $55,000. Widespread COVID-19 inoculation driven by vaccine mandates thus could have significant public health benefits during the pandemic, which then need to be balanced with the costs of forced medical interventions and curtailments of individual freedom. Studying the extent of externalities in the context of mandating a younger population like college students is particularly important as COVID-19—like many other vaccine mitigated diseases such as influenza and chicken pox—leads to disproportionately severe outcomes among the elderly. Thus the costs of mandates are borne primarily by people who benefit less from them. As a result, understanding how vaccine mandates impact community-level public health is a critical aspect of the debate over the role of government intervention during a pandemic.

Our study examines the effect of college- and university-imposed COVID-19 vaccine mandates for students on county-level COVID-19 infections, hospitalizations, deaths, and other health outcomes. We focus on college mandates at four-year residential colleges for several reasons. First, other decisions made by higher education institutions during the COVID-19 pandemic have had large effects on both their students and their local communities. For example, colleges that brought students back to their campuses after spring break in March 2020 experienced an increase in COVID-19 case rates and higher mortality rates in their counties (Mangrum and Niekamp 2022). Similarly, counties that hosted NCAA men's basketball games in March 2020 also saw increased spread of the virus and increased COVID-19 deaths (Carlin et al. 2021). In the fall 2020 semester, colleges that opened in-person rather than online contributed to increased case rates and hospitalizations (Andersen et al. 2022). Additional research has revealed genetic links between campus outbreaks of COVID-19 and deaths among elderly residents in local nursing homes (Richmond et al. 2020). These spillover effects from college-level decisions and events to broader, community-level public health outcomes are unsurprising, given the extent to which college students may interact with those in the local community (for example, through visiting bars, restaurants, and local businesses), including faculty and staff, and the speed at which the COVID-19 virus can spread. Thus, college vaccine mandates on the student population may reasonably affect the health outcomes of non-students who live and work on or near college campuses, including faculty and staff.

Because of their age, college students themselves have a considerably lower risk for severe outcomes, conditional on COVID-19 infection, than the surrounding population (Levin et al. 2020). This is despite the fact that they tend to live in congregate settings that are ripe for the spread of contagious diseases. One of the primary arguments for college vaccine mandates comes from externalities imposed by infection among students spreading to other members of the community, rather than benefits to the students themselves.[2] This includes those unaffiliated with the colleges as well as university employees not covered by the mandates. Furthermore, college-aged individuals have consistently taken up the COVID-19 vaccine at lower rates than older groups—as of August 15, 2021, only 47% of U.S. residents aged 18-24 were fully vaccinated, compared to 61% of 40-49 year olds and 84% of 65-79 year olds. This leaves substantial room for these mandates to impact vaccination rates.[3] The college context therefore offers a powerful lens through which to understand how vaccine mandates, and the act of vaccination itself, can affect health externalities from infectious disease.

Second, extensive variation across colleges in their vaccine mandate policies provides a useful source of identification. As the fall 2021 semester approached and vaccines became more widely available, 668 two-year and four-year institutions mandated that students, and sometimes faculty and staff, be vaccinated against SARS-Cov2 (Botelho et al. 2021). In some cases, these mandates were driven by institutional decisions, and in others, they were state or county-level decisions. As a result, there is variation among observationally-similar people who live near postsecondary institutions in terms of whether the college students in their community had to be vaccinated.

We study the effects of college vaccine mandates on local public health outcomes by leveraging several rich sources of data. We obtain information on vaccine mandates for the fall 2021 semester, along with institutions' semester start dates, mask mandates, and required COVID-19 testing policies from the College Crisis Initiative (C2i) at Davidson College (Berick et al. 2021; Botelho et al. 2021). C2i's staff collected vaccine mandate information through a combination of data-scraping and directly visiting colleges' websites between July 21, 2021 and August 5, 2021—just prior to the start of colleges' fall semesters—with follow-up collection in late October and early November. These data are then merged with publicly available information from the Centers for Disease Control and Prevention (CDC) on county-level COVID-19 case rates, vaccinations, hospitalizations, and deaths. We also acquire data on county test positivity rates from CovidActNow.org, data on doctors' visits from insurance claims, and data on individual vaccination status from the Census Bureau's Household Pulse Survey.[4]

We estimate event study specifications that examine how these outcomes evolve before and after students return to campus by the share of students in a county covered by a vaccination mandate. The identification assumption underlying our approach is that the share of college students in a county covered by COVID-19 vaccination mandates is uncorrelated with changes in a county's COVID-19 outcomes, except for the vaccination mandates themselves and other determinants included in our controls. Of primary concern is that counties with colleges that decided to implement vaccine mandates have other protective policies in place or have populations that were otherwise more likely to be vaccinated or that more stringently followed public health advice. There are strong geographic and political components to vaccination rates, public health measures, and compliance with these measures (Gollwitzer et al. 2020; Adolph et al. 2021; Clinton et al. 2021; Fraser, Juliano, and Nichols 2021; Murthy et al. 2021; Yuan et al. 2021; Ye 2023). Hence, we include not only county and calendar week fixed effects in our models but also region-by-week fixed effects, interactions between week fixed effects and the Democratic vote share in the 2016 presidential election, and interactions between week fixed effects and the baseline county vaccination rate (measured during the last week of June 2021, before any college in our data began fall classes). Furthermore, we present evidence that our results are (1) robust to controlling for differences in colleges' masking and COVID-19 testing policies, and (2) unlikely to be confounded by other policy or behavioral changes that alter community-level vaccination rates or mobility, as neither of these outcomes differentially change in counties with vaccine mandates after college semesters begin.

Our results show consistent evidence that college vaccine mandates reduced COVID-19 cases and deaths in the surrounding population. In order to summarize our results, we sum estimates over 13 weeks, beginning with the week prior to semester start when students are likely to return to college campuses and ending about two-thirds of the way through the fall term, prior to the Thanksgiving holiday. In our preferred specifications, we find that a mandate covering 100% of college students in a county (as opposed to 0%) reduces COVID-19 cases by 504 per 100,000, an estimate that is statistically significant at the 1% level. In counties with a vaccine mandate, an average of 84.5% of students were in fact mandated to receive a COVID-19 vaccine. Thus, we can scale the numbers above by 84.5% to determine the total effect of the mandates as implemented in Fall 2021. The scaled estimates suggest that the mandates reduced total new cases in a county by 426 per 100,000 (approximately 12% of the baseline mean) over these 13 weeks. This estimate is largest in areas where we would expect mandates to have the largest effects on local public health: counties where colleges have low predicted vaccination rates based on their demographic composition and where colleges are large relative to the county population. Further, we show that results are similar regardless of whether faculty and staff are included in the mandates, which highlights that it is student behavior that likely drives the estimates.

Hospital-based measures, such as the number of ICU patients and hospitalizations, contain error because they are based on hospital locations rather than on patients' counties of residence. Nonetheless, while our findings for overall hospitalizations are generally statistically indistinguishable from zero, mandates significantly reduce intensive care unit (ICU) admissions with a 100% mandate reducing admissions by 16 per 100,000 people in the county.

Deaths are measured by county of residence and likely contain less noise. Mandating that 100% of students in a county receive the COVID-19 vaccine reduces COVID-19 deaths by 5.6

per 100,000 in the county, an estimate that is significant at the 10% level. Mandates as implemented—with 84.5% of students covered by a mandate—reduced deaths by 4.7 per 100,000 county population. Again, this effect is larger in counties where we would expect college vaccine mandates to have the largest effect on student vaccination rates, and therefore, on local public health.

Taken together, these results suggest that college COVID-19 vaccine mandates had meaningful and statistically significant effects on infections and health outcomes. We estimate that four-year college vaccine mandates during the 13 weeks we consider avoided 6,358 deaths, which is about 4.6% of total deaths in the United States from COVID-19 during this period. The value gained from saved life-years is substantial. Using estimates of life-years lost from the average COVID death (Elledge 2020; Goldstein and Lee 2020; Arolas et al. 2021; Quast et al. 2022) and value of a statistical life-year (Aldy and Viscusi 2008) we provide a back-of-the-envelope estimate that the value of lives saved from college COVID-19 vaccine mandates is between $14.9 million and $24.0 million per 100k residents in a county—$73-$118 million in the average county with a mandate. Applying this to our estimate of total deaths avoided nationwide in fall 2021 implies a reduction in economic losses from avoided deaths of $11.4 billion to $32.3 billion.

Our paper contributes to multiple strands of the literature. First, we contribute to the literature examining vaccine mandates in educational settings. Vaccine mandates, especially in schools and colleges, are not new: students across the U.S. are required to be vaccinated against a variety of illnesses, such as smallpox, measles, and polio. Carpenter and Lawler (2019) show that the introduction of the Tdap mandate in middle schools had a large effect on vaccine take-up and significantly reduced the incidence of pertussis. The mandate also induced positive spillovers to the take-up of other vaccines. Lawler (2017) presents evidence that school mandates for the hepatitis A vaccine increased take-up and reduced population incidence of the disease. Abrevaya and Mulligan (2011) show positive effects of chickenpox vaccine mandates on take-up, however the take-up effects dissipate over time. Additionally, Holtkamp (2021) uses the staggered roll-out of smallpox vaccine mandates in the late 19th and early 20th centuries in the U.S. and finds that the mandates increased vaccine take-up and had large long-run effects on affected students.

Second, while there are estimates of how various types of COVID-19 vaccine mandates increased vaccine take-up (Walkowiak, Walkowiak, and Walkowiak 2021; Karaivanov et al. 2022; Mills and Rüttenauer 2022), as well as prior research on how vaccine mandates have affected health outcomes for other diseases (Lawler 2017; Carpenter and Lawler 2019), we are among the first to estimate the causal effect of COVID-19 vaccine mandates on public health. Given the enormous cost of the COVID-19 pandemic and the contentious nature of vaccine mandates, this is an important contribution.

Third, we contribute to a growing body of work that examines the interaction between postsecondary education and COVID-19.[5] Mangrum and Niekamp (2022) show that institutions that had earlier spring breaks at the onset of the pandemic experienced higher growth rates of cases due to more infections from spring break travel. Andersen et al. (2022) show that college re-openings led to higher student mobility and increased infection rates.[6] Most closely related to our work, Ghaffarzadegan (2022) finds that, among a subsample of 94 colleges and universities, institutions that mandated COVID-19 vaccines reported lower student COVID-19 cases in fall 2021 than institutions that did not. We extend these analyses to identify the mitigating effects of vaccine mandates on community-level outcomes when students returned to campus.

We contribute to this research along two dimensions. First, our analysis is unique in the literature in showing the effects of vaccine mandates on infections and health outcomes of the broader population not affected by the mandate. To our knowledge, no studies of education-based vaccine mandates have considered the externality benefits of mandates and few in other contexts have either. White (2021) is a rare exception, showing that influenza vaccine mandates for healthcare workers reduce influenza incidence among hospital patients. Our study provides evidence of the effects of vaccination mandates beyond the healthcare setting and for a different highly-infectious disease. Given the prevalence of vaccine mandates in educational settings, estimating the spillover and population health effects of these policies is of primary importance. Second, we provide novel evidence on the effect of vaccine mandates for COVID-19 specifically, which is important not only due to the ongoing costs of the pandemic but also because of the intense politicization of support for vaccination. It thus is of high value to obtain estimates of the public health impacts of COVID-19 vaccine mandates in order to inform this debate.

Our results indicate that college vaccine mandates for COVID-19 have sizable positive effects on the health of the population living near colleges and universities. These benefits must be balanced against curtailments of individual freedoms associated with these mandates as well as any adverse effects of the vaccines themselves. Our results show that these costs must be substantial in order to overcome the large public health benefits of COVID-19 college vaccine mandates.

II. Data

A. Data Sources

We obtain information on college-level vaccine mandates (Botelho et al. 2021), semester start dates (Berick et al. 2021), and masking (Bernhardt et al. 2022b) and testing (Bernhardt et al. 2022a) policies as of the start of the fall 2021 semester from C2i. The vaccine mandate data were first collected between July 21, 2021 and August 5, 2021, with follow-up collection between November 5, 2021 and November 24, 2021. We define an institution as having a vaccine mandate if they announced a mandate prior to the start of their fall 2021 semester.[7] We merge these data with institutional characteristics, such as location, enrollment, and public/private control, from the National Center for Education Statistics' Integrated Postsecondary Education Data System (IPEDS).

We further combine these college-level data with county-level COVID-19 cases, hospitalizations, deaths, and vaccination counts by county and week from the Center for Disease Control and Prevention (CDC).[8] In addition, we collect county-week-level data on per capita COVID-19 tests from the National Institute of Environmental Health Sciences' COVID-19 Pandemic Vulnerability Index (PVI) and test positivity rates from CovidActNow.org.[9] Together, these data sources provide rich weekly information on public health outcomes at the local level throughout the summer and fall of 2021.

While we have access to extensive information on county-level health outcomes, we do not observe vaccination or COVID-related outcomes specifically for the student body on each college campus. Due to this data limitation, we cannot directly measure the "first-stage" effect—the effect of college vaccine mandates on the number of vaccinated students relative to the county population. Instead, we use a more indirect approach to demonstrate that our results are driven by the first-stage effect of the mandates: we show that the reduced-form effect of mandates on local health outcomes is larger for counties in which we expect mandates to have a larger first-stage effect, that is, where we would expect the college student population to have a lower vaccination rate absent the mandate. The details of this exercise are described in Section III.B. To determine which colleges have the largest expected first-stage effect, we use the Census Bureau's Household Pulse Survey among 18-24 year olds who are either high school graduates or are enrolled in college, which collects vaccination attitudes and outcomes along with demographic characteristics at the individual level. We combine this information with demographic information on colleges' student bodies from both IPEDS and Opportunity Insights.

B. Analysis Sample

Our analysis sample includes all U.S. counties with at least one four-year college that offers on-campus residential facilities in states where at least one four-year residential college mandated COVID-19 vaccinations for the fall 2021 semester.[10] We further restrict the sample to counties where the first fall 2021 semester start date fell between August 7th and September 9th. In addition, we omit counties in Colorado and Hawaii due to a lack of accurate, county-level COVID-19 vaccination data. We then distinguish between "mandate" and "non-mandate" college counties by whether any four-year college in the county had a COVID-19 vaccination mandate for students. To ensure clean comparisons between these mandate and non-mandate counties, we further drop 40 counties that do not have any college mandates, but in which colleges offered incentives for students to get vaccinated.[11]

Figure 1 maps the counties in our data and in our analysis sample by mandate status, and Online Appendix Figure A.2 displays the number of students covered by a vaccine mandate as a share of the total number of students at four-year residential colleges in the county (Panel A) and the total county population (Panel B). On average, 85% of students in a mandate county are covered by a vaccine mandate. However, Online Appendix Figure A.3 shows that, in most counties, either all students or no students are covered by a mandate. As such, while our primary empirical approach leverages differences in the share of students covered by a mandate across counties, we also estimate specifications using a county's binary mandate (vs. no mandate) status and present some specifications where we limit our sample only to counties where either all colleges or no colleges within the county implement a mandate.

Table 1 summarizes the 272 counties with a mandate and the 292 counties without a mandate in our sample. The table shows large and statistically significant differences in the demographic, geographic, and college-level characteristics between the mandate and non-mandate counties. Mandate counties, on average, are more populous, more urban, have a larger non-white population, have higher average incomes, and have higher educational attainment than do non-mandate counties. The baseline vaccination rate, defined as the vaccination rate in the last week of June 2021, also is higher in mandate counties, which are more likely than non-mandate counties to be located in the Northeast, Mid-Atlantic, and West. Moreover, counties with mandates tend to lean more liberal than non-mandate counties. On average, mandate counties are home to 2.5 four-year colleges, while non-mandate counties are home to 1.2 colleges. This difference corresponds to more college students in mandate counties (17,938) than in non-mandate counties (7,776). Mandate counties are also much more likely than non-mandate counties to have at least one college that required regular COVID-19 testing or required masking indoors for at least some students at the start of the fall 2021 semester. Among mandate counties, 20.6% have a college that requires testing of some students, and 94.9% have a college that requires masks indoors for some students. For non-mandate counties, these numbers are 3.8% and 69.2%, respectively.

Given these differences in county and college characteristics, our empirical approach compares within-county *changes* in COVID-19 outcomes as a function of the share of students covered by a mandate, before and after the fall 2021 semester begins. In the section that follows, we discuss how the time-invariant demographic and geographic differences in mandate and non-mandate counties may affect trends in health outcomes over time and the steps we take to account for these correlations.

III. Empirical Strategy and Identification

Our goal is to estimate the causal effect of college COVID-19 vaccine mandates on COVID-related health outcomes in college counties. The reduced-form effect of a vaccine mandate on local outcomes derives from a two-stage process: first, the mandate affects student vaccinations, then student vaccinations reduce the local spread of COVID-19 as students mix with county residents after semesters begin. We focus on the reduced-form effect of a mandate policy but also demonstrate that our estimated reduced-form effects are consistent with this two-stage mechanism.

A. Empirical Framework

Our main approach is to estimate event study specifications to identify the effect of a college vaccine mandate. We provide a general discussion of this framework and the associated identification concerns before moving to the specifics of our first-stage and reduced-form analyses. We limit the sample to counties with four-year, residential colleges, for which we observe outcomes for at least eleven weeks before and eleven weeks after the first college begins its fall semester.[12] Then, we use an event study approach in which we compare changes in outcomes for counties with colleges when colleges reopen by the share of students covered by a mandate. Note that the "event" in these specifications is the college reopening, and all colleges experience this event. Fall 2021 coincided with the spread of the Delta variant, leading to high case rates from students moving back to campus at most colleges and universities. Our empirical approach examines how the effect of reopening differs by the share of college students in the county covered by a vaccine mandate.

Our event study specifications take the following form:

$$(1)\ Y_{ct} = \sum_{\substack{k=-11 \\ k\neq -2}}^{11} \beta_k * 1[t - t_c^* = k] + \sum_{\substack{k=-11 \\ k\neq -2}}^{11} \gamma_k * 1[t - t_c^* = k] * ShareMandate_c + \theta_c + \delta_t + \varepsilon_{ct}$$

where Y_{ct} is the outcome of interest in county c during week t, and t_c^* is the earliest week that a four-year, residential college in county c begins its fall semester. $ShareMandate_c$ is the proportion of students at four-year colleges in county c that were required to be vaccinated as of the start of the fall semester. We also estimate a version of this model in which we use a dummy variable for any mandate in the county, instead of the share of students in a county that are covered by a mandate. Equation 1 includes both county fixed effects (θ_c), which capture time invariant differences between counties with different levels of mandate coverage, and week fixed effects (δ_t), which account for secular changes in COVID-19 health outcomes in college counties over time. Throughout the analysis, we cluster all standard errors at the county level.

The β_k coefficients trace how COVID-19 outcomes were changing in the eleven weeks before and after the start of colleges' fall semesters across all counties with four-year colleges. The γ_k coefficients then capture how these outcomes evolve differently across counties by the share of students covered by vaccine mandates. These are the coefficients of interest in this study. For both sets of coefficients, we omit the period $k = -2$, that is, two weeks before semesters begin. We anticipate that students may arrive on or near campus prior to a college's official semester start date, which could generate treatment effects as early as period $k = -1$.

The specification in Equation 1 represents a difference-in-differences (DID) framework with a continuous treatment. The identification assumption in this setting is that counties' COVID-19 outcomes would evolve on parallel trends in the absence of the treatment, at all levels of the mandate share, conditional on our controls (Callaway, Goodman-Bacon, and Sant'Anna 2021). This assumption can be broken down into two parts. The first part of this assumption is that COVID-19 outcomes were evolving in parallel prior to the start of the semester across counties with different levels of vaccine mandate coverage. While it is not possible to test parallel trends prior to semester start across all levels of vaccine mandate coverage, the γ_k coefficients for $k \leq -2$ provide a test of this assumption, assuming a linear relationship between pre-treatment effects and a county's vaccine mandate coverage. We also test for parallel trends in settings with a binary treatment, either by dichotomizing all counties to either "mandate" or "non-mandate" counties or only including counties with 0% or 100% vaccine mandate coverage. Across these specifications, we expect these pre-period coefficients to equal zero: the mandates should have no effect until students return to begin the semester.

The second part of the identification assumption is that there are no changes in unobserved determinants of our outcome measures that occur concurrently with college reopenings and that differently affect counties with varying levels of mandate coverage. Violations of this assumption most likely come from three sources:

1. *Correlated COVID Shocks:* Counties with different levels of mandate coverage could be hit by COVID-19 waves at systematically different times, possibly because they

are not uniformly distributed across the country—non-mandate counties tend to be more concentrated in the South, Southwest, and the Midwest (see Table 1).

2. *College Selection of Mandate Policies:* Colleges decide whether to impose vaccine mandates or not, and these decisions could potentially be driven by factors such as local COVID spread, the political environment on campus or in the community, or even the likelihood that students would be vaccinated without a mandate.[13]
3. *Other Policies:* Other local or college-level policies and social norms, such as masking and social distancing policies and compliance, could be correlated with the mandate share and have independent effects on the outcomes we examine. This pattern could result from the college selection discussed above, or it could be generated through other mechanisms.

To address the identification concerns related to regional variation in COVID spread, we include region-by-week fixed effects, separating the country into eight regions defined by the Bureau of Labor Statistics (BLS). It still is possible that there is within-region variation in the timing of COVID waves that is systematically correlated with mandate coverage. We view this as unlikely given strong evidence of parallel trends in COVID outcomes across counties with and without mandates as well as by the share of mandate coverage prior to semester start. We discuss this evidence below.

To the extent that colleges are responding to student or community factors when making vaccine mandate decisions, underlying variation in baseline attitudes and behaviors among the student or community population may drive both mandate decisions and COVID outcomes. A few specific examples of this type of concern include: 1) a college could impose a mandate only if students are already favorable towards vaccination, or 2) colleges may impose mandates based on community concerns, which may be correlated with other local policies. To address these concerns in the regression analysis, we include weekly fixed effects interacted with the county's Democratic vote share in the 2016 presidential election. Because of the politicized nature of the response to the pandemic, the Democratic vote share is strongly correlated with community behaviors and policies (Canes-Wrone, Rothwell, and Makridis 2022). It also is correlated with student behaviors to the extent that students sort into colleges with communities that match their political beliefs. In addition, we control for baseline vaccination rates interacted with weekly fixed effects. Communities in which there were more aggressive public health responses and where people followed public health guidelines more carefully had higher vaccination rates, especially in August 2021. These controls thus help capture community attitudes and behaviors around COVID as well. Any bias from unobserved policies or local behaviors must be orthogonal to *both* the Democratic vote share and the baseline COVID vaccination rate. While possible, we present evidence below that these controls account powerfully for local heterogeneity.

The third identification concern is that other local or college-level COVID-19 policies could be correlated with a college implementing a mandate. As discussed above, the vote-share and baseline vaccination rate-by-week fixed effects help control for this unobserved heterogeneity. In the section that follows, we show that there are no differential trends in county-wide vaccination rates before or after the start of fall semesters in counties by college mandate status, suggesting that there were no concurrent policies implemented that increased vaccine take-up among the general public. Any other policies or unobserved heterogeneity residual to our controls would have to impact outcomes without being correlated with vaccination rates of the county populations. We also find no evidence from placebo tests that 2021 mandates are associated with differences in outcomes surrounding semester starts in fall 2020 among colleges that were operating in person. Since other norms and policies, such as masking and social distancing, are likely to have been in effect over that time period as well, these findings further suggest that we are not picking up latent differences in how communities addressed the risk from COVID-19. Furthermore, we control directly for institutions' mask and testing policies during the fall 2021 semester and find that doing so makes little difference in our cumulative estimates.

Taking into account all of the controls discussed above, our final estimating equation is the following:

$$(2)\ Y_{ct} = \sum_{\substack{k=-11 \\ k\neq -2}}^{11} \beta_k * 1[t - t_c^* = k] + \sum_{\substack{k=-11 \\ k\neq -2}}^{11} \gamma_k * 1[t - t_c^* = k] * ShareMandate_c + \theta_c + \delta_t$$

$$+ \nu_t * Region_c + \mu_t * VoteShare_c + \phi_t * BaseVaxrate_c + \varepsilon_{ct}$$

where we have augmented Equation 1 with week-by-region, week-by-2016 Democratic presidential vote share, and week-by-baseline vaccination rate fixed effects. We present results with and without the week-by-baseline vaccination rate controls to demonstrate that they do not substantially alter the results after accounting for regional and political differences in our outcomes over time. Given the close relationship between community COVID-19 responses and vaccination rates, this evidence strongly supports our claim that our controls account for unobserved local heterogeneity in other policies and prevention behavior.

In essence, our augmented regression compares the evolution of COVID-19 outcomes of counties in the same region, with similar political leanings and baseline vaccination rates, that did and did not mandate that students receive COVID-19 vaccines. There are numerous examples of these types of county pairs in our data. For instance, in the Midwest, Champaign County, Illinois, home to the University of Illinois Urbana-Champaign, had a 60% Democratic vote share in 2016 and a 58% baseline vaccination rate as of July 2021. Similarly, Story County, Iowa, where Iowa State University is located, had a 57% Democratic vote share and a 54% baseline vaccination rate. However, the University of Illinois had a vaccine mandate, whereas Iowa State did not. Likewise, the counties housing the Universities of Connecticut, Rhode Island, and New Hampshire all had Democratic vote shares ranging from 53% to 55% and baseline vaccination rates between 57% and 60%. The University of Connecticut and the University of Rhode Island implemented vaccine mandates, while the University of New Hampshire did not. More formally, in Online Appendix Table A.1 we predict a county's mandate status as a function of its region, 2016 Democratic vote share, and baseline vaccination rate. We find that these variables explain at most 43% of the observed variation in county-level mandate status. Thus, there is substantial variation in mandate policies even among similar counties, which allows us to estimate Equation 2 after accounting for an extensive set of control variables.

B. First-Stage

A key parameter of interest in our policy setting is the extent to which college vaccine mandates increase the vaccination rate of a county's college students. Colleges that implemented vaccine mandates reported very high compliance with their mandates and, therefore, very high student vaccination rates ex-post. Ghaffarzadegan (2022) reports that, in a sample of 49 colleges with student vaccination rates available online, those with mandates reported an average student vaccination rate of 95% while those without mandates reported an average of 75%. The latter value is notably close to the predicted vaccination rates for non-mandated colleges that we estimate below and are shown in Online Appendix Figure A.4.

We also collected data on the final reported vaccination rates for 145 randomly-selected institutions with vaccine mandates in our sample. For 106 of these institutions, we were able to find information on campuses' final vaccination rates and, within this sample, the median reported final vaccination rate was 95.2%. However, the counterfactual student vaccination rates for these campuses had they not implemented mandates are unknown.

Ideally, we would directly estimate the first-stage effect of vaccination mandates on vaccination rates among students using our event-study framework with student vaccination rates as the outcome measure. However, this approach is infeasible for two reasons. First, we cannot observe vaccinations specifically among a county's college student population, or even more generally at the county-by-age level. Second, even if we could observe vaccination rates at the county-by-age level, it is not obvious that we would detect a larger increase in vaccination rates for college-aged individuals in counties with mandates (vs. without) in anticipation of the fall semester. This is because vaccinations are recorded where individuals receive them and most students would have received their vaccines in their home counties and not in their colleges' counties.[14] Most vaccine mandates were announced towards the end or following the conclusion of the spring 2021 semester, when many students would not have been on or near campus, and required students to arrive on-campus for the fall semester fully vaccinated (for example, receiving both doses of a two-dose vaccine series).[15] In Online Appendix B, we provide examples of vaccine mandate language across a variety of institutions. These mandates support our contention that students needed to arrive on-campus in the fall having already been fully vaccinated.

As further evidence that most students likely did not receive their vaccines in their college counties, we estimate the effect of vaccine mandates on the institution's county-wide vaccination rate. This rate is defined as the share of the population that has received at least one dose of a COVID-19 vaccine. In Panel (a) of Figure 2, we first plot the county-wide vaccination rates for counties with and without vaccine mandates, before and after the start of the fall 2021 semester. While vaccination rates are consistently higher in counties with mandates (as we documented in Table 1), there is little evidence that vaccination rates increase more rapidly in counties with mandates as the fall semester approaches—as we would expect to be the case if students were receiving their vaccines in these counties to comply with the mandates. In Panel (b), we present the γ coefficients from Equation 2 for county-wide vaccination rates in Figure 2. While there is some indication of an upward trend in counties with greater mandate coverage relative to counties with lower coverage prior to the start of the fall 2021 semester, the point estimates are very small—the estimate for vaccination rate differential in week -11 is only -0.4 percentage points, suggesting that in the weeks leading up to the fall 2021 semester, counties with 100% mandate coverage saw an increase in vaccination rates of 0.4pp more than counties with 0% coverage. Moreover, after the fall semester begins, we see little impact of the mandates on county-wide vaccination rates. Averaging across the 13 weeks following the start of the fall semester in our preferred specification with both vote share and baseline vaccination by week fixed effects, we estimate that counties with 100% mandate coverage had 0.002pp lower vaccination rates than counties with no mandates in the post-reopening period. This estimate is not statistically significant at even the 10% level. Overall, we conclude that college vaccine mandates had a negligible impact on aggregate vaccinations in the county. In addition to providing evidence that college students likely did not receive their vaccines in their colleges' counties, this result is important for our identification assumption because it suggests that, conditional on our controls, counties with different levels of mandate coverage were trending similarly in terms of vaccinations before and after college students returned to campuses. Since vaccination rates are correlated with other dimensions of response to COVID risk, the null result on overall vaccinations is consistent with our model identifying the causal effect of college vaccine mandates rather than other policy or behavioral differences.

While vaccine mandates did not meaningfully affect colleges' counties' vaccination rates among the general population, we provide evidence that is suggestive of a strong first-stage effect of the mandates on college students' vaccination rates. We do so by assessing whether our reduced-form estimates are heterogeneous in ways that are consistent with a strong first stage effect. In particular, we examine patterns of heterogeneity to confirm that they align with the following hypotheses:

Hypothesis 1: *Vaccine mandates have a larger effect on local health outcomes where college students make up a larger share of the population.*

Hypothesis 2: *Vaccine mandates have a larger effect on local health outcomes where students are less likely to be vaccinated in absence of a vaccine mandate.*

Testing the first hypothesis is straightforward: we examine whether the estimated reduced-form effects are larger for counties where students make up a larger share of the population (for example, those with "college towns"). Testing the second hypothesis is more difficult because we have to measure which colleges enroll students who are likely to be vaccinated in absence of a mandate. We perform this test using information from the Census Bureau's Household Pulse Survey on 18-24 year-olds to estimate the relationship between vaccination status, race, and income. We then use these relationships along with college demographics to estimate counterfactual vaccine take-up rates in absence of a mandate. Finally, we examine whether our reduced-form effects are stronger at institutions with lower predicted vaccine take-up absent a vaccine mandate.

For our analysis of the Pulse data, we use the sample of 18-24-year-olds surveyed between July 21 and August 16, 2021 who report that they have completed high school, but have not yet earned a postsecondary degree. We estimate the following regression to identify the relationship between vaccination status, race, and income:

$$(3)\ Vax_{jqr} = \alpha + \sum_{q} \beta_q Income_q + \sum_{r} \gamma_r Race_r + \sum_{q}\sum_{r} \pi_{rq} Income_q * Race_r + \varepsilon_{jqr},$$

where Vax_{jqr} is a dummy variable indicating whether respondent j in household income quintile q and racial group r reports being vaccinated.[16] We use the coefficients from this regression to predict vaccination rates at each college using college-level income quintile shares from Opportunity Insights and racial shares from IPEDS.[17] For some analyses, we also present versions in which we only include income, or include income and race without their interactions. In addition, we present specifications where we use survey responses from April 28 to May 21, to ensure that our estimates of vaccination rates across demographic groups are not driven by compliance with college vaccine mandates themselves.

Online Appendix Figure A.5 shows the distribution of predicted vaccination rates by county using the full set of predictors, both using our main July/August sample and our alternative April/May sample. Online Appendix Figure A.4 further shows the distribution of predicted vaccination rates by mandate status using either income alone, race and income, or race, income, and their interactions. In both figures, we caution that these predicted vaccination rates are likely higher than colleges' true vaccination rates at the start of the fall 2021 semester, due to the fact that the Household Pulse Survey overestimated U.S. vaccine take-up (Bradley et al. 2021). However, there is substantial variation in these predicted rates and, although college counties with no mandate have lower predicted vaccination rates than college counties with a mandate on average, there is considerable overlap in these distributions. Thus, we are able to estimate how vaccine mandates affect outcomes separately in counties with relatively low versus high predicted student vaccination rates.

C. Raw Trends and Fixed Effects

Figure 3 presents average weekly per-capita cases at the county level by mandate status and region.[18] Our use of region-by-week fixed effects in the event study models means that we are identifying the main effects off of the within-region variation we show here. In each region, COVID-19 cases in mandate and non-mandate counties are moving along a similar trend but split off from each other after the semester start, suggesting that vaccine mandates generate a relative drop in case rates. The same patterns can be seen in Online Appendix Figure A.6, which shows event study estimates of cases by region without controls.

Our event-study estimates include the week-by-vote share and week-by-baseline vaccination rate effects discussed above. The variation we use after accounting for all of our fixed effects is shown in Online Appendix Figure A.7, where we plot the residuals from a regression of each COVID-19 outcome measure on all the fixed effects and interactions in Equation 2. After residualizing the data, differences in COVID-19 outcomes and vaccinations between mandate and non-mandate counties during the pre-opening periods are small and show little indication of non-parallel trends. It is important to note that the magnitudes themselves are very small: residualized average positivity rate gaps do not exceed 0.4% in any pre-opening period, while the COVID outcome gaps are less than 13 cases, 2 hospitalizations, and 0.5 deaths per 100k people per week. Our event-study estimates using 11 weeks prior to semester start confirm the lack of pre-trends.

IV. Results

We now turn to assessing how college vaccine mandates affect the spread of COVID-19 and related health outcomes. We emphasize that all of our estimates provide the net effect of vaccine mandates on local outcomes of interest, inclusive of any changes in behavior or outcomes of college students themselves.

A. Main Results

We present our main event study results in Figure 4.[19] Panel (a) shows the effect of vaccine mandates on cases. Our pre-period estimates indicate that the degree of mandate coverage was not related to COVID-19 outcomes, on average, before students came back for the semester start. Beginning the week prior to semester start, cases decline in counties with greater mandate coverage relative to counties with less mandate coverage. The difference in weekly COVID-19 cases between counties with 100% mandate coverage and no mandates grows to about 50 cases per 100,000 by the fifth week after the semester begins. This difference remains at a similar level through the end of our analysis time period.

When interpreting the case rate reductions in Panel (a), it is important to recognize that reported case counts are endogenous to the number of COVID-19 tests administered. If mandate counties engage in more testing, then the negative effects we find on cases are even more striking. If they have less testing, then we should observe an increase in the test positivity rate. In Panel (b), we present event study estimates of the number of tests performed per 100,000 residents. We find that, if anything, counties with more mandate coverage slightly *increase* their testing throughout the semester, as compared to counties with less mandate coverage. As such, in Panel (c), we find a reduction in the test positivity rate—defined as the number of positive COVID-19 tests in a county over a 7-day period divided by the total number of reported tests.

Together, we interpret our results as evidence that there were fewer COVID-19 infections in counties where mandate coverage was higher after opening.

Next, Panels (d) and (e) show the effects of college mandates on the number of new hospitalizations and ICU patients with COVID-19. Both measures include suspected and confirmed cases of COVID-19. The results for hospitalizations in Panel (c) are noisy but suggestive of a reduction in hospitalizations in weeks 2-4 following college re-openings, rising after week 4. Panel (d) shows a reduction in the number of ICU cases per 100,000 county residents beginning the week after college semesters start with recovery beginning in week 9. Hospitalization data reflect the locations where patients are hospitalized rather than where they reside. There is likely to be misclassification error in small counties with low hospital capacity, where severely ill patients may be hospitalized outside of their county of residence and thus reported as occurring in a different county. The hospitalization and ICU results should therefore be interpreted with caution.

Last, Panel (f) of Figure 4 shows the effects of colleges' vaccination mandates on COVID-19 deaths. As with prior figures, there is little evidence of a pre-opening trend in COVID-19 deaths per 100,000 residents prior to the start of colleges' fall semesters. There additionally is only a small effect on deaths at the beginning of the semester, which is unsurprising given the well-documented lag between COVID-19 cases and deaths (Testa et al. 2020; Jin 2021). The estimated effect of 100% mandate coverage (as opposed to 0%) then grows slightly to a reduction of approximately 0.5 deaths per 100,000 county residents per week in weeks eight and nine of the semester.

We summarize these event study estimates in Table 2. For all outcomes that are measured on a per capita basis, we sum the post-period event study coefficients ($k = -1$ to $k = 11$) to present a cumulative effect over the 13 weeks since students likely began returning to campus. For the test positivity rate, which is measured on a percentage basis, we present the average of the post-period event study coefficients.

The results in Panel A show the effects of increasing the share of students covered by a vaccine mandate from 0% to 100%. Beginning with column (1), we find that 100% mandate coverage reduces COVID-19 cases by 504 per 100,000—a 14.7% reduction off of the mean. Tests increase by a statistically insignificant 716 per 100,000 (2.1% of mean) and positivity rates decrease by 0.8 percentage points, an 8% decline off of the mean (significant at the 10% level). Aligned with Figure 4, column (4) shows noisy cumulative effects on hospitalizations. However, we estimate that 100% mandate coverage of college students reduces the number of ICU patients by 16.2 per 100,000 (16.6% of mean). Finally, the results in column (6) indicate a reduction in COVID-19 deaths of 5.6 per 100,000 over thirteen weeks, a 13.2% decrease (also significant at the 10% level).[20] Taken together, these findings demonstrate that colleges' vaccination mandates reduced the health-related toll of COVID-19 in their local communities during the fall 2021 semester.

Thus far, we have measured counties' vaccine mandate exposure as the share of students within a county who are covered by a college mandate. In Panel B of Table 2, we instead use a binary treatment variable indicating whether *any* college within a county has a vaccine mandate. Panel C repeats this specification, dropping counties with multiple colleges that differ in their mandate status (that is, restricting the sample only to colleges where all or no colleges implement vaccine mandates).[21] The resulting estimates are consistent with our preferred specification. In the full sample, counties with a vaccine mandate experience case reductions of 337 per 100,000 and a reduction of deaths of 4.8 per 100,000. In the restricted sample, counties where all colleges implement vaccine mandates experience a reduction of cases of 581 per 100,000, and deaths decline by 6.8 per 100,000. Broadly, the results in all three panels of Table 2 show sizable public health benefits of college vaccine mandates regardless of how we measure mandate exposure.

We motivated our analysis by suggesting that college student vaccinations may have spillover effects on the non-college student population. In Figure 5, we test this assertion by estimating effects on cases by age group. While we do not have data on cases by detailed ages and week, we are able to examine effects at the monthly level for three broad age groups: 0-17, 18-64, and 65+. The majority of students, as well as faculty and staff on college campuses, will fall within the 18-64 year old age range, so reductions in cases in the 0-17 and 65+ age groups can be interpreted primarily as externality effects. We estimate a monthly event study by age group using the same controls as the weekly event studies, except with month fixed effects substituted for week fixed effects. We omit the month prior to the start of the fall semester (for example, July for colleges beginning semesters in August) and measure outcomes as the number of cases per 100,000 population within the relevant age group.

The results in Figure 5 indicate that case rates decline by statistically significant amounts for all age groups in mandate counties relative to non-mandate counties after the semester starts. In Online Appendix Table A.3, we estimate the cumulative effects by age group. Over the first four months of the fall semester, going from 0% to 100% of students covered by a mandate reduces cases by the largest amount—563 cases per 100,000—for those aged 18-64, who would have been the most directly affected by a mandate. However, we also see reductions of 407 cases per 100,000 among children (age 0-17) and 406 cases per 100,000 among the elderly (65+). Hence, the reduction in cases we document for the county population as a whole is not solely driven by differences in case levels among the college student population. Furthermore, 99.5% of

COVID deaths are among those over the age of 24. Thus, we believe the reductions in deaths we document come almost entirely from the non-college population and also reflect the externality benefits of college vaccine mandates.

B. Heterogeneity

In this section, we test whether heterogeneity in the estimated effects of vaccine mandates aligns with our hypotheses surrounding the "first-stage" effect of mandates on student vaccination rates. We do not observe vaccinations among students directly, so we are unable to implement a direct test of the first-stage effect. Instead, as discussed in Section III.B, we test whether our reduced-form estimates are consistent with a strong first stage.

We first assess whether our estimated effects are larger at colleges where baseline vaccination take-up is likely to be low. Our primary approach to identifying colleges where vaccination rates would otherwise be lower is to use the Census Bureau's Household Pulse Survey to estimate a function relating vaccination status among 18-24 year-olds to income and race and use this function to predict vaccination rates at the campus level (see Section III.B for details). We then split the sample by high (above median) and low (below median) predicted vaccination rates.

Figure 6 shows event study estimates by predicted vaccination rates using the Pulse Survey data.[22] These figures provide evidence of stronger effects in counties where colleges are predicted to have lower underlying vaccination rates. The estimates for cases, positivity rates, ICU admissions, and deaths are particularly striking: all of the effects are driven by counties with colleges that are predicted to have low vaccination rates based on their demographic composition. Put differently, our results are strongest in areas with colleges that enroll a higher percentage of non-white and lower-income students, since students from these backgrounds tend to have lower vaccination rates on average. In order for this result to be affected by omitted variable bias, it would have to be the case that communities with such colleges are more likely to have other mitigating policies or have populations that more closely follow public health guidance.

Figure 7 shows cumulative event study estimates by predicted vaccination rates using three methods for the prediction: only income, income and race, and income, race, and their interactions. Regardless of the method chosen to predict vaccination rates, the estimated effects are much stronger for colleges with below-median predicted vaccination rates. Online Appendix Figure A.11 repeats this analysis using quartiles of predicted vaccination rates. Generally, the effects across our outcomes of interest are strongest for the counties that contain the lowest-quartile predicted vaccination colleges.

Because our results show that the effects are largest where predicted vaccination rates are lowest, and because increasing the percent of students who are vaccinated through means other than mandates (for instance, incentives or informational campaigns) may be of interest to policymakers, we quantify the effect of a one percentage point increase in the student vaccination rate on health outcomes. To do so, we estimate event study specifications where we interact the pre- and post-indicators with the expected vaccination rate of college students in a given county at the start of the semester. For institutions with mandates, we set this rate to 90%, 95%, or 100%, in order to illustrate the effect of different assumptions about mandate compliance.[23] For institutions without mandates, we set this rate to the predicted vaccination rate from the Pulse Survey data, using the most saturated predicted specification that includes race and income interactions. We also consider specifications where we subtract 30 percentage points from these predicted vaccination rates, because the average reported vaccination rates in the Pulse data are about 30 percentage points higher than the true vaccination rate in the 18-24 year old population at the time of the survey, though as noted above our predicted vaccination rates for non-mandate colleges are, on average, similar to those found in Ghaffarzadegan (2022).[24] For counties containing multiple four-year colleges, we then average expected start-of-semester vaccination rates over colleges within a county, weighting by each college's enrollment.

Figure 8 displays the results from this exercise, summing the event study coefficients over the 13 post-period weeks in our data, beginning with the week before the semester begins and dividing by 100. As such, the estimates display the expected effect of beginning the semester with a 1 percentage point higher vaccination rate among college students within a county, equivalent to an increase of 65 students per 100,000 population on average. The effects are larger when we assume a smaller difference in vaccination rates between institutions with and without mandates but consistently show that an increase in the student vaccination rate reduces county-level cases and deaths by statistically significant amounts. Specifically, we estimate that a 1 percentage point increase in the college student vaccination rate (65 students per 100,000) reduces cumulative cases by 21-32 per 100,000 and cumulative deaths by 0.3-0.6 per 100,000 in specifications without the 30 percentage point adjustment. With such an adjustment, we find that a 1 percentage point increase in the college student vaccination rate reduces cumulative cases by 10-12 per 100,000 and cumulative deaths by 0.1-0.2 per 100,000.

We also examine heterogeneity by the size of the college population relative to the county population. We construct the following relative size measure:

$$(4)\ RelativeSize_c = \frac{\sum_{Jc} Enrollment_j}{Population_c},$$

where Jc represents the set of colleges located in county c.[25] We divide the sample into counties that are above- and below-median by this measure and show differences in the estimated effects across these two sets of counties. We use this measure because it is likely that the externality effects of the vaccine mandates will be larger when students make up a larger share of the local population (for instance, counties with "college towns").

Table 3 presents estimates by above/below median predicted vaccination rate and student population share. The estimates in Panel A suggest that effects are strongest for counties that have both below-median predicted vaccination rates and above-median student population share. For these counties, going from 0% vaccine mandate coverage to 100% coverage reduces cumulative case counts by 1,585 per 100,000 and deaths by 20.9 per 100,000. The first estimate is statistically significant at the 5% level, while the latter is significant at the 10% level. We further observe reductions in hospitalizations of 109.4 per 100,000 and in ICU patients of 54.2 per 100,000, the latter of which is statistically significant at the 10% level. Effects for the other groups shown in the table are more modest and are not statistically significant at conventional levels, although generally they are in the same direction. Online Appendix Figure A.12 shows event studies for cases for each of these groups and aligns with the findings from Table 3.[26]

A central implication of our estimates being produced by spillover effects is that they should be larger in areas where the population is more vulnerable. In Online Appendix Figure A.13, we show event study estimates by above/below median predicted student vaccination rate *and* above/below median vaccination rate among the 65+ population, measured in the CDC data as of the last week of June 2021. For both cases and deaths, the estimates are localized to areas where the predicted vaccination rate among college students is low (and thus the treatment intensity is high) and where there is a lower vaccination rate among those who are 65 or older. We find similar results when examining heterogeneity by above/below median vaccination rate of the over 25 population.[27] These results align with spillovers as a central mechanism driving our results.

C. Robustness

The results presented in Sections IV.A and IV.B indicate that college-level COVID-19 mandates protected local public health during the fall 2021 semester. These findings rely on the assumption that college counties' COVID-19 outcomes are unrelated to vaccine mandate coverage except through the mandates themselves, conditional on our controls. We now present several tests of this assumption.

As previously discussed, a central identifying assumption in our event study approach is that our controls are sufficient to account for unobserved policies or behaviors that could be correlated with mandates but have independent effects on outcomes. To provide further evidence that our estimates are not being driven by these factors, we conduct a placebo test surrounding fall 2020 reopenings. In fall 2020, COVID-19 vaccines were not yet available to the public, but patterns of county-level heterogeneity with respect to alternative policies and behaviors were likely similar in fall 2020 and fall 2021. If these alternative policies and behaviors are sources of bias, they should differentially affect outcomes in fall 2020 as well, before vaccine mandates were in place.

Figure 9 shows the results of a placebo event study using the same specification as in our baseline model but with COVID-19 outcomes measured in fall 2020. The sample is restricted to counties in which colleges re-opened for in-person instruction in fall 2020.[28] The results show no indication of differences in outcomes across mandate and non-mandate counties in 2020.[29] This evidence supports our identification strategy and indicates that mandate counties did not differ from non-mandate counties in terms of health outcomes in the first year of the pandemic, conditional on our set of controls.

To further ensure that our results are not driven by alternative policies or behaviors, we test the robustness of our results to the inclusion of additional week fixed effects interacted with college-level policies. Panel A of Table 4 shows the results from our preferred main specification, while Panel B shows the results when we include week fixed effects interacted with an indicator for remote re-opening in 2020.[30] This specification addresses the concern that mandate colleges may have systematically different attitudes and responses to COVID-19 than non-mandate colleges across both the 2020 and 2021 academic years. The estimates are very similar to those in Panel A, suggesting that this is not a relevant source of bias. Panels C and D of Table 4 then use data on college COVID-19 testing and masking requirements to control directly for such policies. In Panel C, we augment our baseline model with week fixed effects interacted with the share of college students covered by a campus mask mandate. Adding these controls barely moves the estimated effect of the vaccine mandate. Similarly, adding week fixed effects interacted with the share of students facing COVID-19 testing policies does not change our results (Panel D). Taken together, these estimates provide strong evidence that our main results are driven by vaccine mandates themselves, as opposed to other correlated policies.

Variation in college masking policies also allows us to estimate the effect of college masking policies directly and determine whether impacts of these policies contaminate our vaccine policy estimates. Among college counties without vaccine mandates, 69.2% have a college with a mask requirement, while nearly all (94.9%) college counties with a vaccine mandate also have a masking requirement. Thus, we focus on the sample of 292 counties with no vaccine mandate to estimate the effect of a mask mandate. Using this sample, we estimate event studies analogous to our baseline model, but interact the event time indicators with the share of students covered by a mask mandate rather than a vaccine mandate. We then sum the event study estimates to obtain the cumulative effect of 100% mask mandate coverage (as opposed to 0% coverage). The results are shown in Online Appendix Table A.4. The estimated effect of mask mandates on all measures of COVID-19 spread are small and not statistically significant at conventional levels. Furthermore, most estimates are positive—the opposite direction of our estimates for vaccine mandates.[31] These null results provide further evidence that our findings for vaccine mandates are not picking up the effects of masking policies.

In the remainder of Table 4, we test the sensitivity of our results to several additional specification choices. In Panel E, we interact our week fixed effects with county-level population densities to account for the potential for COVID-19 to spread differently in dense relative to sparse areas. Our results hardly change when we include this additional interaction. Panel F then shows the results when we weight the regressions by the county population size, while Panel G weights the regressions by the student share of the county population. Weighting by county population does not meaningfully change our results, while weighting by the student share increases the magnitude and, in the case of hospitalizations, the statistical significance, of our estimates. The latter results are consistent with mandates having larger effects in counties where students make up a large share of a county's population, as we find in Section IV.B.

In Table 5, we further show how our results vary when we alter the counties included in our sample. First, Panel B shows that our results are robust to limiting the sample to a subset of counties that share a common support of population density values.[32]

Panels C and D then show how our estimates change if we drop counties with colleges that have staff mandates or instead limit our mandate counties to only those that include both student and staff mandates.[33] While we lose some statistical power, our estimates are similar in size and direction when we drop counties with student but not staff mandates, suggesting that our effects are driven primarily by student mandates rather than faculty and staff mandates. The effects on cases are larger for counties that have both student and faculty staff mandates, while effects on deaths and hospitalizations are larger in areas with just student mandates. The estimates are less precise, and they are not statistically distinguishable from one another. We interpret them as showing that including faculty and staff in the mandate does not meaningfully change the results. The similarity of the estimates suggests that faculty and staff mandates are not a main driver of the public health effects. Rather, it is student vaccinations and behavior that are critical to determining the public health benefits of vaccine mandates. Because it is the student mandates that matter, we consider effects flowing through faculty and staff as contributing to the community-level spillover.

Panel E of Table 5 drops colleges that announce a vaccination mandate mid-semester and again produces very similar results to our main specification.[34] Similarly, in Panel F, we treat all counties with mid-semester mandates as having a mandate. In doing so, we expand our sample to include four additional states (Alaska, New Mexico, Nevada, and Utah) where at least one college has a mid-semester vaccine mandate. Once again, our results are very similar to our preferred specification.[35] Finally, in Panel G, we restrict our sample to the regions where the most mandate counties are located: New England, New Jersey/New York, the Mid-Atlantic, and the West. The results for this subset of counties are broadly similar to our main results, although we see a reduction in testing in mandate counties in these regions.

As an additional test of the assumption that our results are driven by mandates and not other policy or behavioral changes—such as business or K-12 school closures, establishment capacity limits, or voluntary changes in social distancing measures when students return to campuses—we estimate effects on a variety of measures related to mobility and economic activity. Table 6 shows the estimated cumulative effect of 100% vaccine mandate coverage on (1) weekly restaurant visits per 100,000 residents, (2) weekly consumer spending relative to January 2020, and (3) weekly visits to different types of establishments, also measured relative to January 2020.[36] Panel A shows that, across the full sample, college vaccine mandates do not result in decreased economic activity after students return to campus. Moreover, Panels B through E show that, even in counties where we document the largest effects of mandates on COVID-19 health outcomes (those that have low predicted vaccination rates of college students and large college student populations), mandates are not associated with a decline in mobility or spending. If anything, we observe a small *increase* in restaurant visits and use of public transit in these counties. Thus, it is unlikely that our results for health-related outcomes are driven by other contemporaneous policy or behavioral changes that may have reduced the local COVID-19 burden.

Online Appendix Table A.5 addresses the concern that our results could be driven by one specific state. We estimate our main specification leaving out one state at a time for all states in the analysis. The table shows percentiles of the distribution of estimated cumulative effects. Hospitalizations continue to be a noisy measure—in some specifications the coefficient is positive—but on the whole, the results are consistent with our main specification.

Finally, our main specification relies on event studies from two-way fixed effect regressions with staggered adoption. This approach can be a problem if the treatment effects are dynamic and heterogeneous (Goodman-Bacon 2021; Sun and Abraham 2021). While openings are staggered, there is actually little difference in the timing of when semesters start as seen in

Online Appendix Figure A.16. Indeed, about 90% of colleges started in a three week period between August 15 and September 7, making our setup closer to a more standard event study with uniform adoption timing.[37] Since we know the start dates of each institution regardless of whether they are treated with a mandate, a simple way to address this concern is to estimate our models separately by semester start week. These results are shown in Online Appendix Table A.6.[38] For each outcome, the estimates are qualitatively similar across semester start weeks, although they remain somewhat noisy for tests and hospitalizations. Furthermore, in column (6) we provide a weighted average of these separate start-week estimates, where the weights are equal to the share of counties whose first semester start date falls within each week. The results are very similar to our main estimates, indicating that our estimates are not affected by the use of staggered start dates.

V. Conclusions

Mandates for vaccination are politically controversial. While we have excellent experimental and population data on how vaccines themselves affect individual health outcomes, the justification for mandates relies primarily on the extent to which vaccinations can reduce the externalities imposed on others from communicable illness in terms of additional disease spread. To better understand the externality-correcting benefits of vaccine mandates, we focus on the context of colleges and estimate the impact of COVID-19 vaccine mandates at residential, four-year colleges and universities on a variety of community-level COVID-19 health outcomes. Residential colleges and universities provide an excellent case study of spillover effects from vaccine mandates as they contain large, concentrated populations of young individuals who are at relatively low individual risk from serious COVID-19 complications themselves but may spread infections to the broader community—a similar epidemiological situation to other vaccine preventable diseases that often have mandates attached to them. Individuals of college age also tend to have lower vaccination take-up generally, and hence there is substantial scope for mandates to improve these rates.

Our analysis uses an event study estimation strategy that examines changes in COVID-19 related outcomes within counties before and after fall 2021 semester start dates as a function of the percentage of students covered by a college vaccine mandate. To account for differences across counties in mitigation behaviors, regional variation in the timing of COVID waves, colleges' selection into mandate status, and variation in baseline community vaccination rates, we also include county and calendar week fixed-effects, interacting the latter with region indicators, Democratic vote shares in the 2016 presidential election, and baseline vaccination rates.

Our primary focus is on the combination of direct and indirect effects of the mandates on health outcomes, though for severe outcomes like ICU admission and death—since students are at an age level when such outcomes are very unlikely—we argue that most of the effects are indirect. We estimate that, over the first thirteen weeks after students returned to campus in fall 2021, cases of COVID-19 in counties where all students in 4-year residential colleges were mandated to receive the COVID-19 vaccine fell by 504 per 100,000 people relative to counties with only non-mandate colleges. This reduction in cases, in turn, resulted in 16.2 per 100,00 fewer ICU admissions and 5.6 per 100,000 fewer deaths. We find no significant impacts on hospitalizations, but these, like ICU admissions, are measured in the county of hospitalization rather than residence, adding measurement error.

Overall, we estimate that four-year college vaccine mandates over the 13 weeks of fall 2021 saved 6,358 lives across the country, reducing deaths from COVID-19 by about 4.6%.[39] To get a back-of-the-envelope estimate of the economic benefits from these reduced deaths, we apply a value of a statistical life-year estimate at age 62 between $200,000 and $350,000[40] (Aldy and Viscusi 2008) and estimates of each COVID death resulting in 9-14.5 lost life years (Elledge 2020; Goldstein and Lee 2020; Arolas et al. 2021; Quast et al. 2022), we approximate that the economic benefit accrued from reductions in deaths from college COVID-19 vaccine mandates ranges from $14.9 million and $24.0 million per 100k residents in a county—or $73-$118 million for the average-sized county with a vaccine mandate in our sample. Applying these to our estimate of total deaths avoided during Fall 2021 from mandates indicates a reduction in economic losses of $11.4 billion to $32.3 billion nationwide.

In total, our findings indicate that college vaccine mandates led to substantial reductions in disease burden well beyond college campuses themselves. Our results have important implications for the role of government intervention to impose vaccine mandates, especially during a public health crisis. In the absence of any government oversight, many universities would (and did) decide to impose a vaccine mandate on students as well as faculty and staff in order to protect the university community. That colleges are able to internalize the benefits of vaccines makes it optimal for many of them to mandate vaccination on their own. Indeed, this was a main justification for many colleges and universities to independently adopt a mandate. However, our finding of spillover effects to the broader local population also argues for a role for government intervention. This role is particularly strong in places where the spillovers were largest, such as areas with a large student body relative to the size of the local population. Of course, the government also must weigh the public health benefits of vaccine mandates against the costs of forcing people to obtain possibly unwanted medical interventions as well as any costs of the vaccines themselves. These are difficult costs to measure, but the large health benefits to local communities from COVID-19 vaccine mandates suggests that such costs must be quite high in order to make these mandates undesirable.

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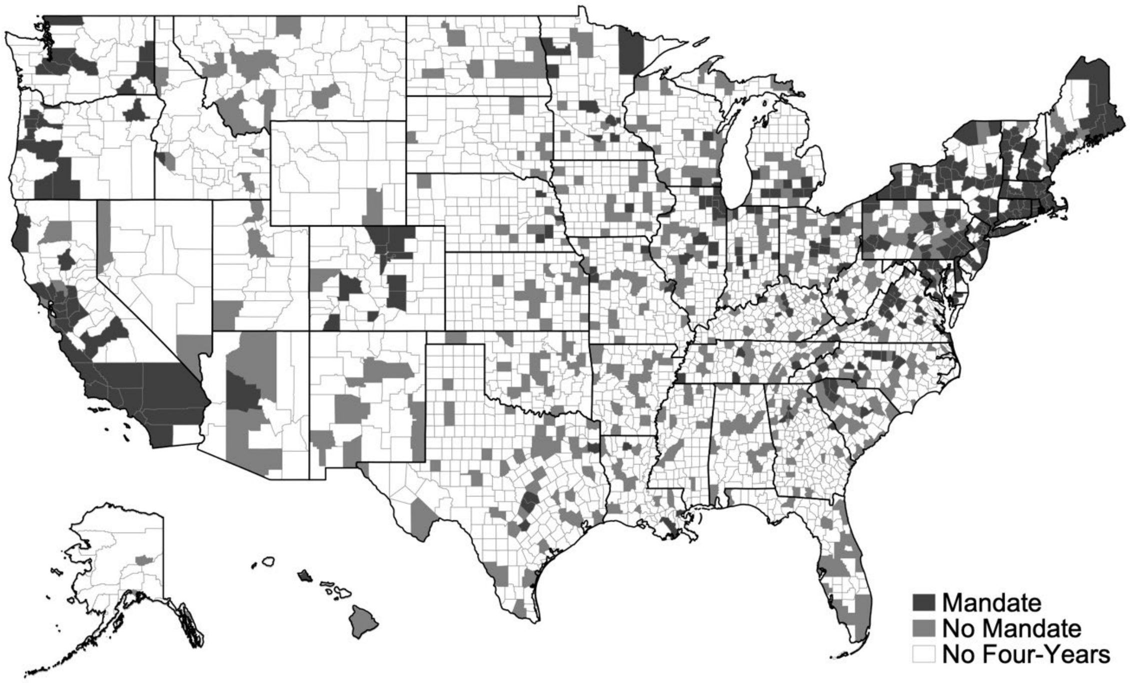
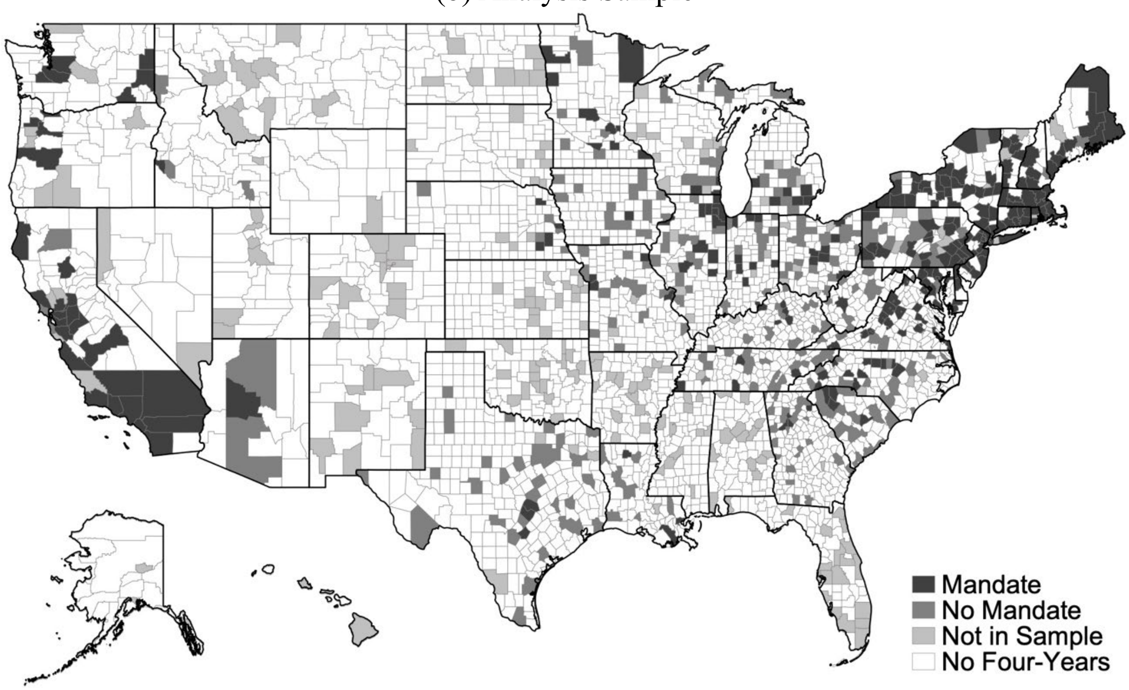
Figures

Figure 1: Map of College Vaccine Mandates

(a) All U.S. Counties



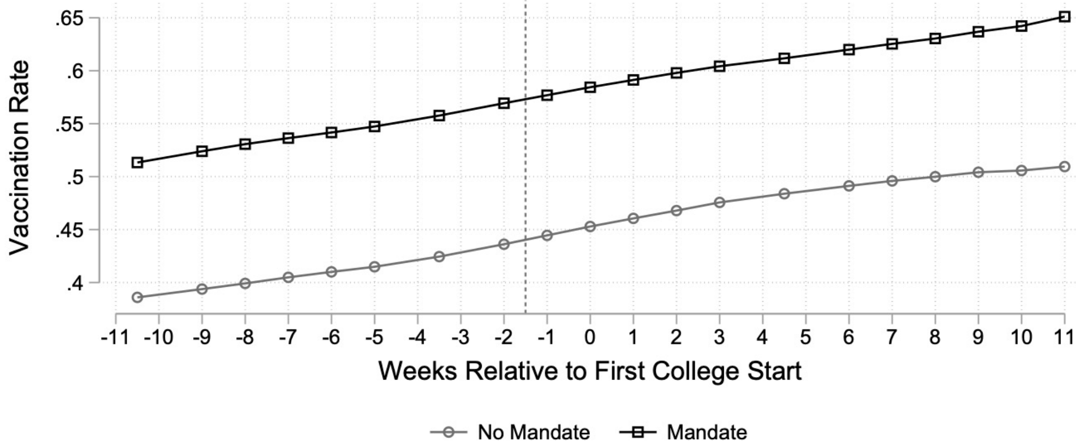
(b) Analysis Sample



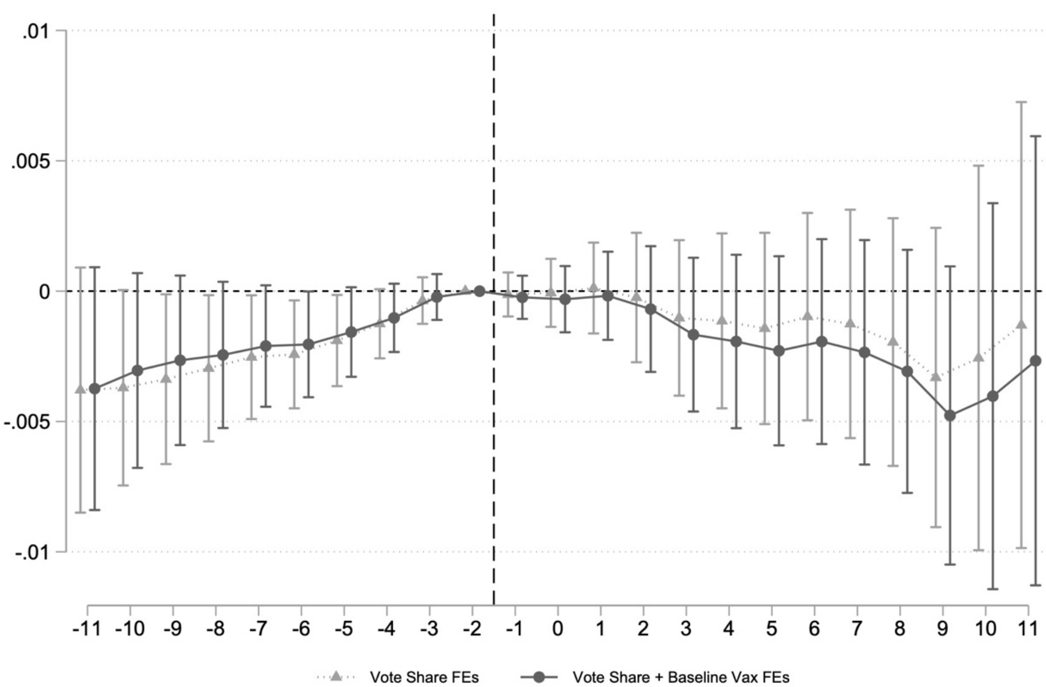
Note: This county-level map shows whether a county has a four-year college and whether any of these colleges had a vaccine mandate. Panel A includes all U.S. counties, while Panel B only includes those in our analysis sample.

Figure 2: County-Wide Vaccination Rates

(a) Plot by County Mandate Status

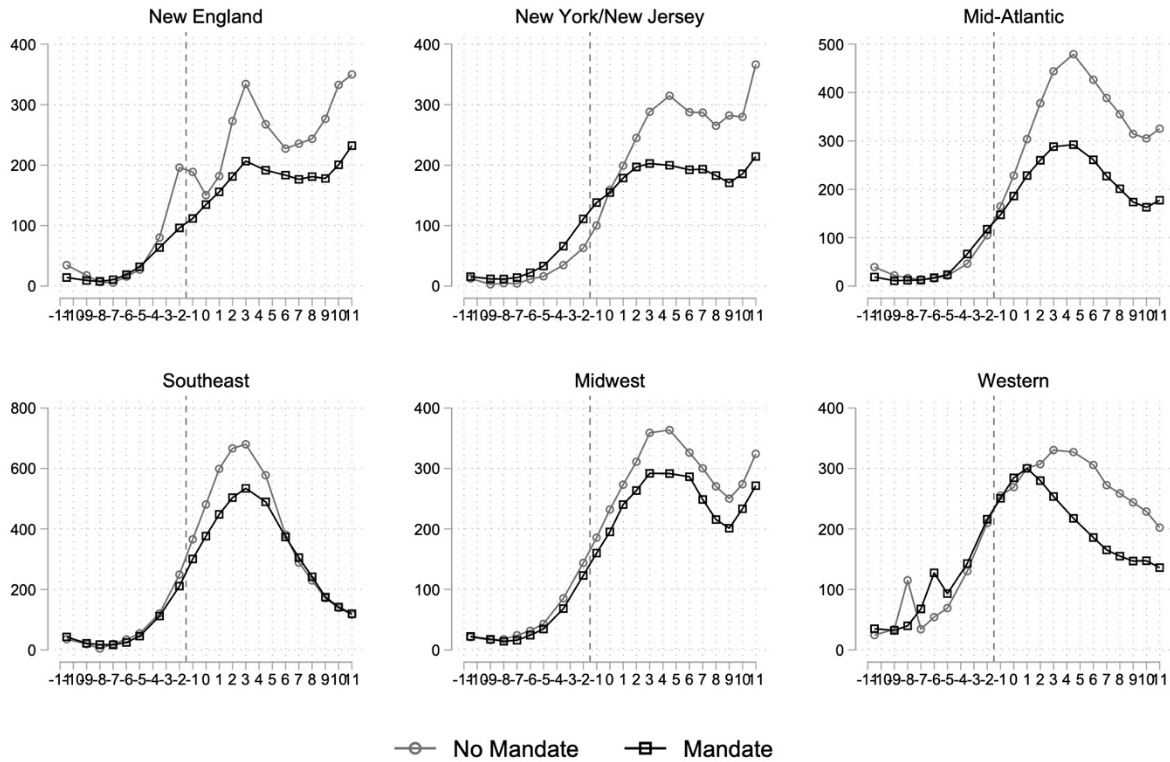


(b) Event Study Specification



Note: In Panel A, we show the vaccination rate in mandate and non-mandate counties by week relative to semester start. In Panel B, the dark line shows the results of an event study that 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 light gray line shows the estimated effects when we exclude the week-by-baseline vaccination rate fixed effects. The estimates show the effect of 100% mandate coverage of four-year, residential college students relative to college counties without mandates. The outcome measure is the vaccination rate in the county. We cluster standard errors at the county level and include 95% confidence intervals.

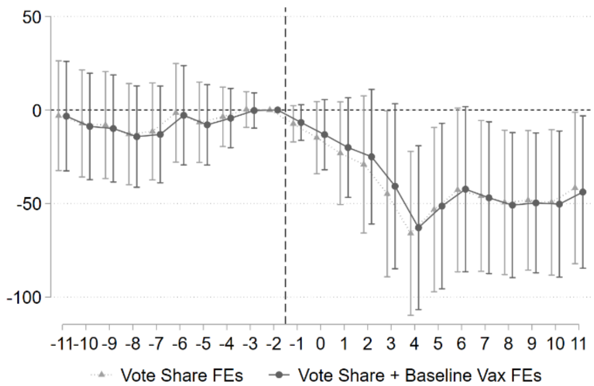
Figure 3: COVID-19 Cases by Region and Mandate Status



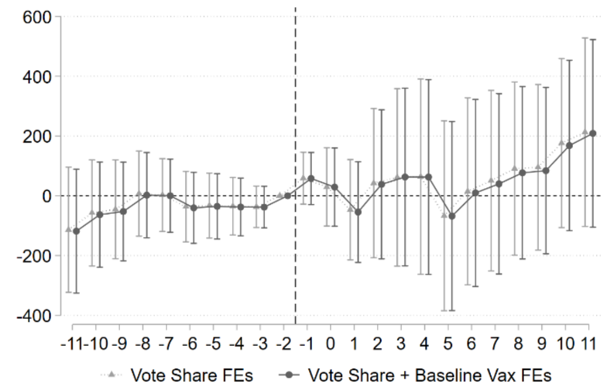
Note: These figures show average weekly COVID-19 cases per 100k population at the county level in the six BLS-defined regions with the greatest number of mandate counties in our sample, by week relative to semester start. We omit figures for the Southwest (6 mandate counties) and Mountain-Plains (5 mandate counties) regions as they have very few mandate counties. The levels for college counties with (without) a mandate are given by the square (circular) markers.

Figure 4: Event Studies

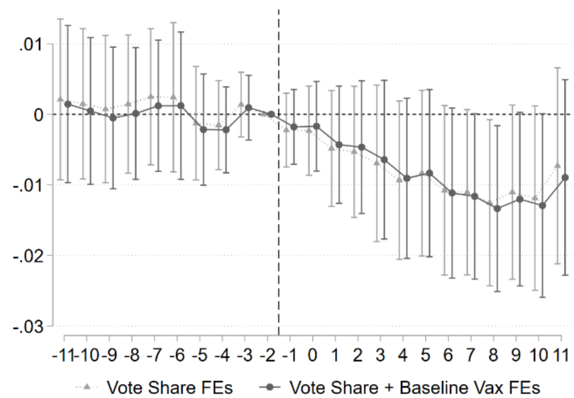
(a) Cases per 100,000



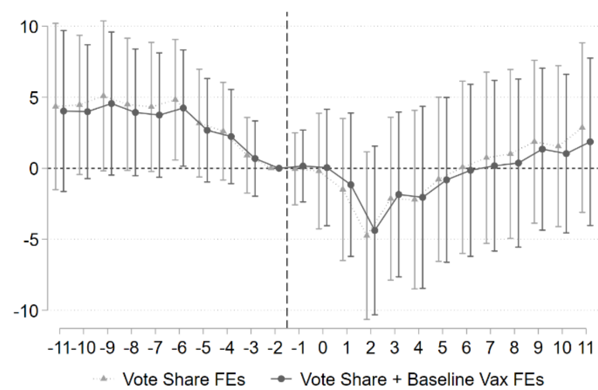
(b) Tests per 100,000



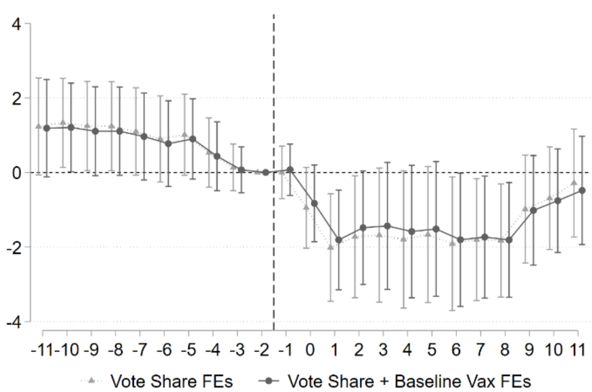
(c) Test Positivity Rate



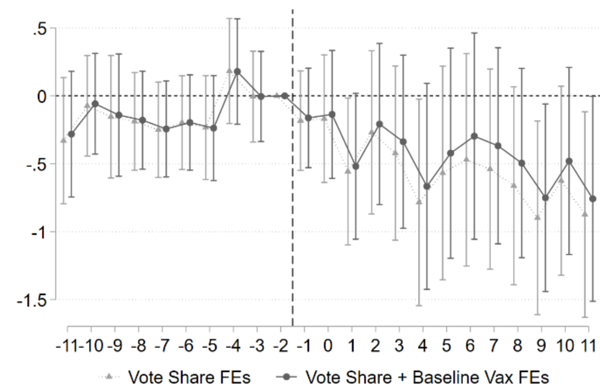
(d) Hospitalizations per 100,000



(e) ICU patients per 100,000



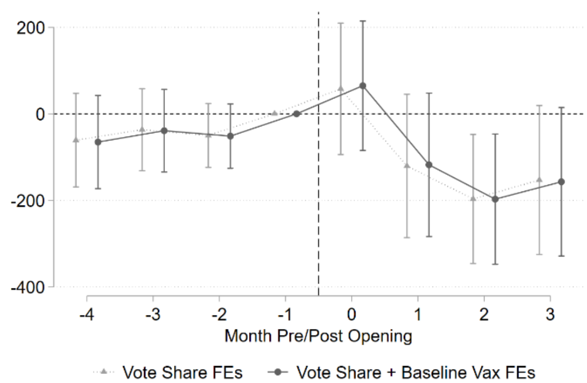
(f) Deaths per 100,000



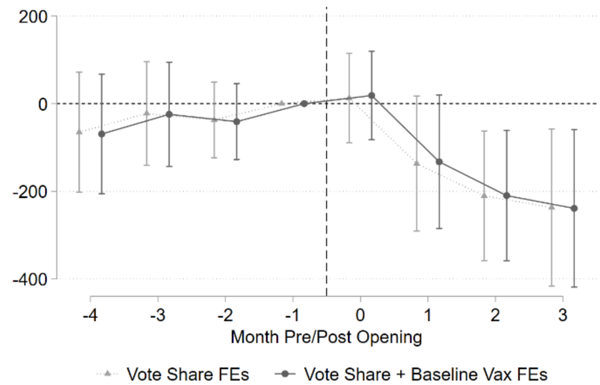
Note: These figures show the results of event studies that include county and week fixed effects, week-by-region fixed effects, week-by-baseline vaccination rate fixed effects, and week-by-vote share fixed effects, where the vote share is the county-level Democratic vote share in the 2016 presidential election. The line shows the effect of 100% mandate coverage of four-year, residential college students 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 5: Event Study of Monthly Cases by Age Group

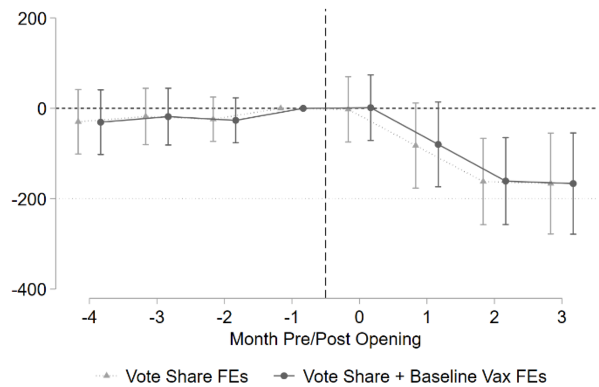
(a) Age 0-17



(b) Age 18-64

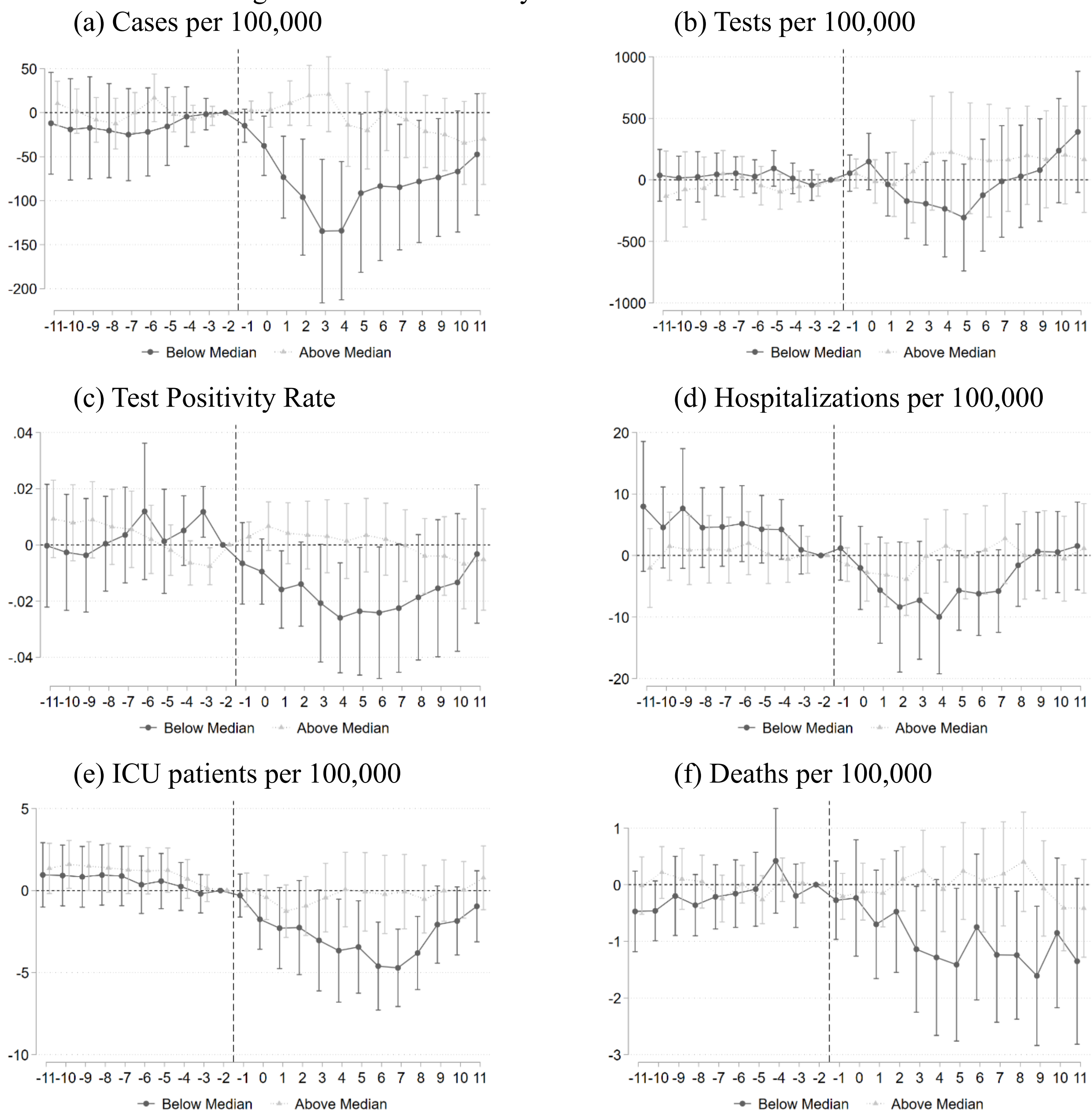


(c) Age 65+



Note: These figures show the results of an event study by age group with cases per 100k population (within age group) per month as the dependent variable. The event study includes county and month fixed effects, month-by-region fixed effects, month-by-baseline vaccination rate fixed effects, and month-by-vote share fixed effects, where the vote share is the county-level Democratic vote share in the 2016 presidential election. The estimates show the effect of 100% mandate coverage of four-year, residential college students relative to college counties without mandates. We cluster standard errors at the county level and include 95% confidence intervals.

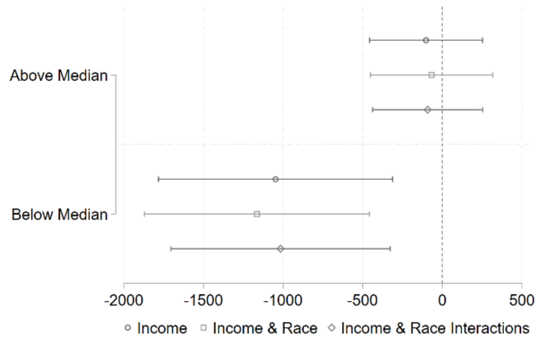
Figure 6: Event Studies by Predicted Vaccination Rates



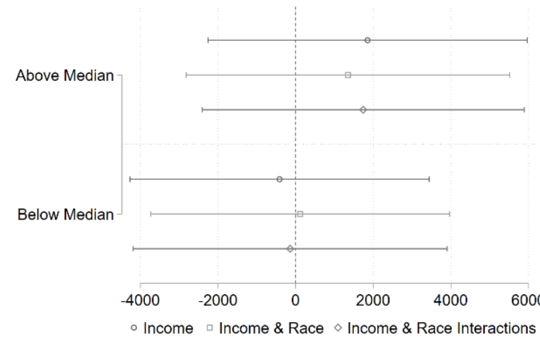
Note: These figures show the results of event studies that include county and week fixed effects, week-by-region fixed effects, week-by-baseline vaccination rate fixed effects, and week-by-vote share fixed effects, where the vote share is the county-level Democratic vote share in the 2016 presidential 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 = 79.4%). 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 7: Cumulative Estimates by Predicted Vaccination Rates

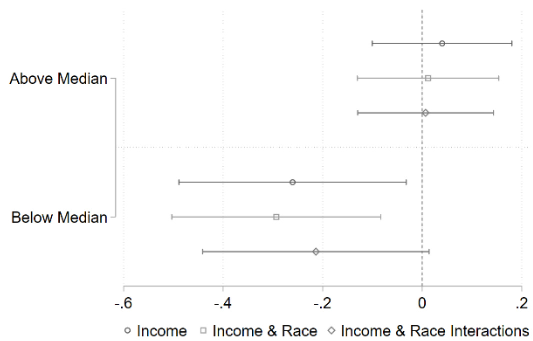
(a) Cases



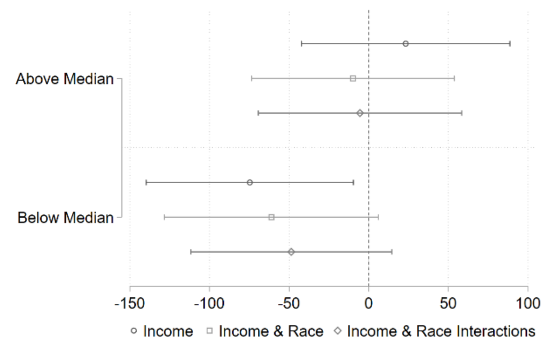
(b) Tests per 100,000



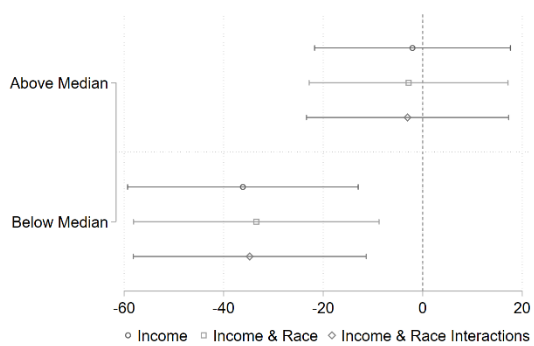
(c) Test Positivity Rate



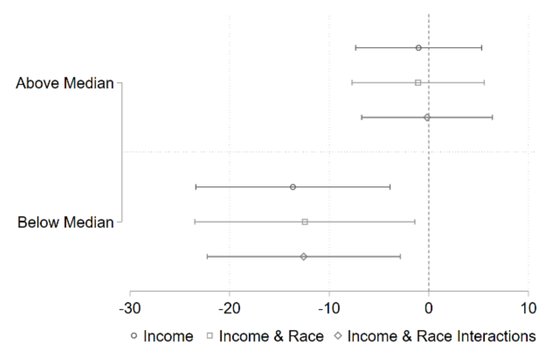
(d) Hospitalizations



(e) ICU patients

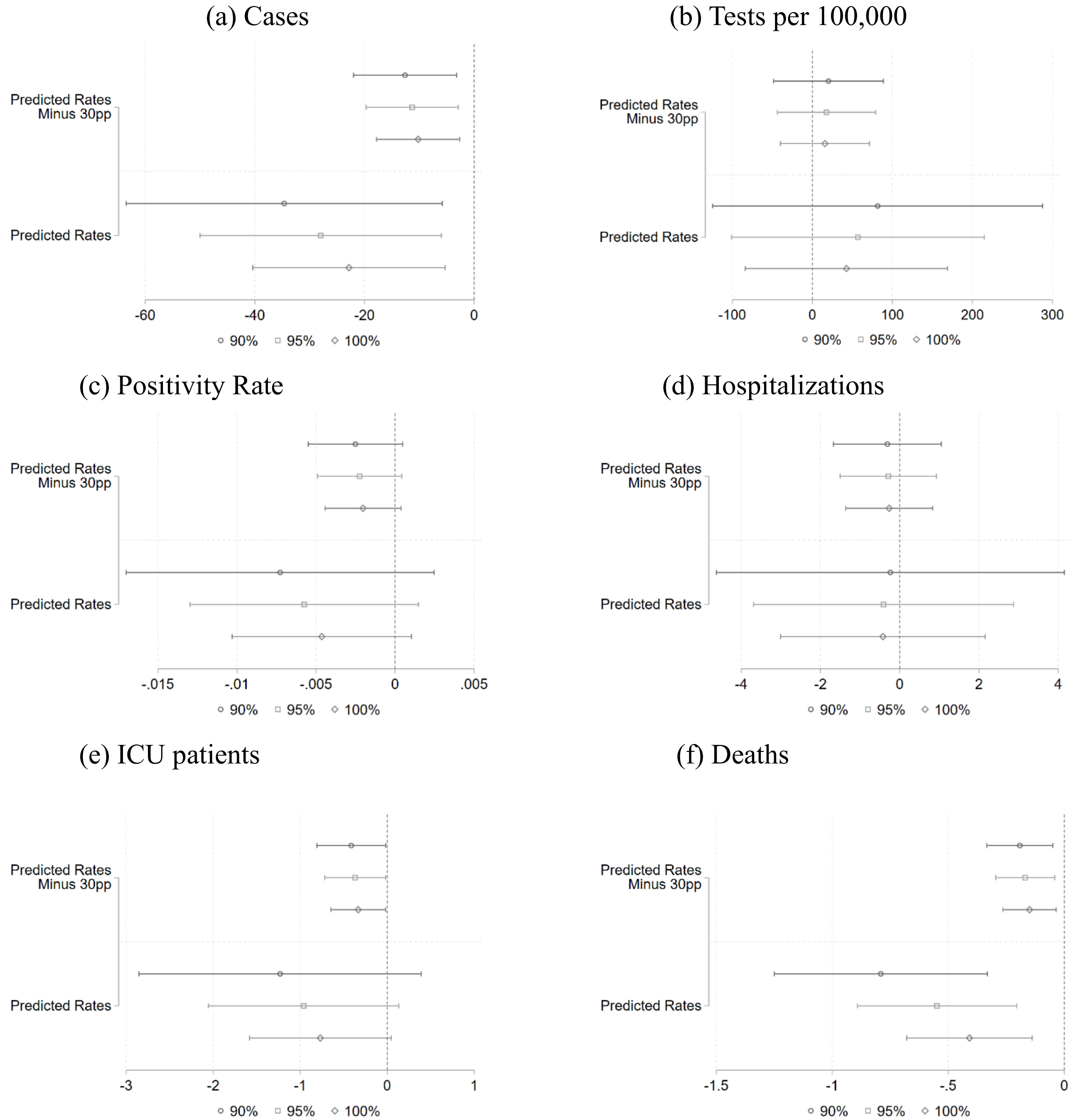


(f) Deaths



Note: These figures show cumulative and average effects of vaccine mandates on COVID-19 outcomes from the week prior to semester start through the 12^{th} week of the semester. These effects are computed separately for college counties with above- or below-median predicted student vaccination rates (median = 79.4%). 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.

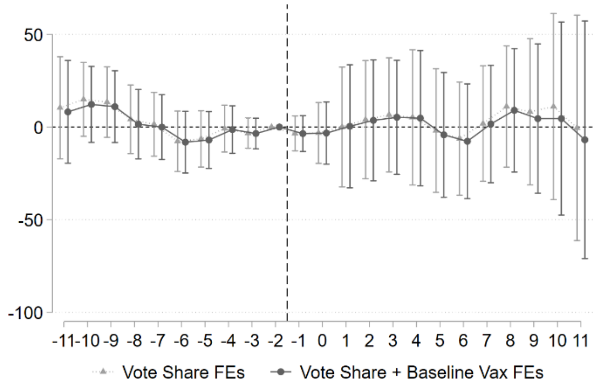
Figure 8: Effect of Increasing the Student Vaccination Rate



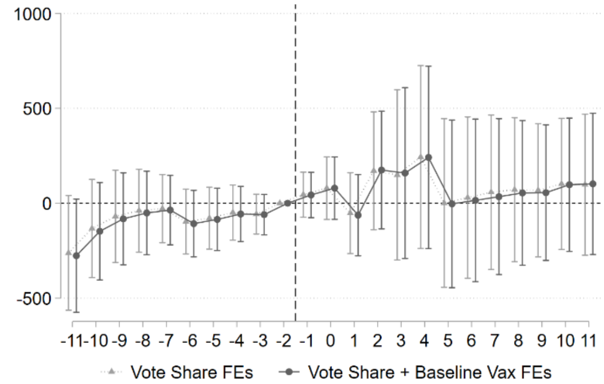
Note: The figures show the effect of a 1pp increase in student vaccinations on each outcome under multiple assumptions. The shading indicates the assumption about vaccination mandate compliance – either a 90%, 95%, or 100% vaccination rate in the mandated student population. We also show two different assumptions about the vaccination rate in absence of the mandate. The predicted rate is the prediction from the Household Pulse Survey using income, race, and their interactions. This survey overstates vaccination rates relative to other data sources for this age group by approximately 30pp, so we show an alternative set of estimates that assumes vaccination rates without a mandate are 30pp lower than those predicted by the Pulse Survey regressions. 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 9: Placebo Event Studies with 2020 Outcomes

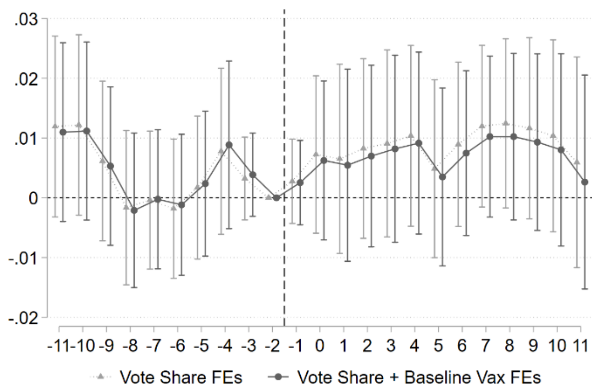
(a) Cases



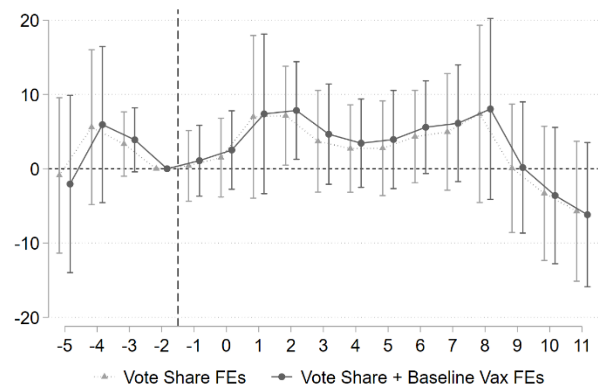
(b) Tests



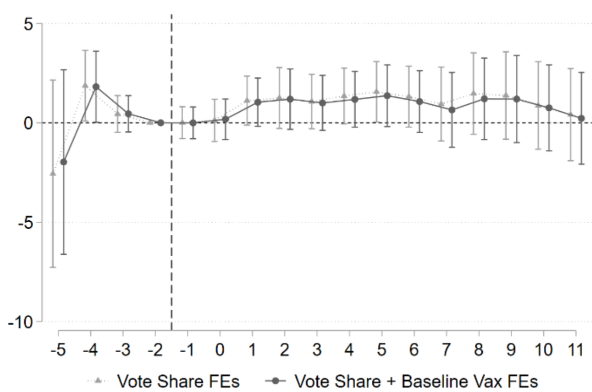
(c) Positivity Rate



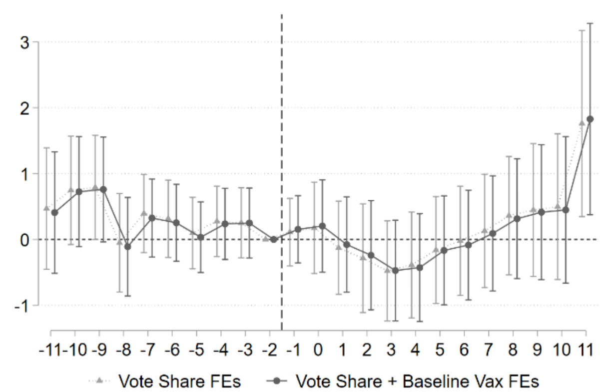
(d) Hospitalizations



(e) ICU patients



(f) Deaths



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 lines show the effect of 100% mandate coverage of four-year, residential college students 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.

Tables

Table 1
Summary Statistics

	Mandate	No Mandate	Difference	
Population	494,016	188,212	305,805	(57,109)
Population Density	1,685.0	282.5	1,402.5	(340.8)
% White	77.41	82.06	-4.649	(1.320)
Median Household Income	65,947	53,762	12,185	(1,248)
% Bachelor's Degree	33.55	25.96	7.589	(0.820)
Baseline Vaccination Rate	0.530	0.401	0.130	(0.010)
2016 Democrat Vote Share	0.527	0.377	0.150	(0.013)
New England	0.147	0.007	0.140	(0.022)
New Jersey/New York	0.180	0.007	0.173	(0.024)
Mid-Atlantic	0.228	0.110	0.118	(0.031)
Southeast	0.099	0.312	-0.212	(0.033)
Midwest	0.184	0.329	-0.145	(0.036)
Southwest	0.022	0.147	-0.125	(0.023)
Mountain Plains	0.018	0.055	-0.036	(0.016)
West	0.121	0.034	0.087	(0.023)
Number of Four-Year Colleges	2.559	1.223	1.336	(0.161)
% of Colleges w/ Mandate	83.6	0.0	83.6	(1.5)
% of Colleges Remote in 2020	40.6	20.2	20.4	(3.3)
Number of College Students	17,938	7,776	10,162	(1,797)
Students as Share of Population	0.061	0.072	-0.011	(0.007)
% of Students w/ Mandate	84.5	0.0	84.5	(1.7)
% of Students Remote in 2020	44.0	20.5	23.6	(3.5)
% of Students Living On-Campus	51.0	48.9	2.1	(2.4)
% with Any College Testing Requirement	20.6	3.8	16.8	(2.7)
% with Any College Mask Requirement	94.9	69.2	25.7	(3.0)
Observations	272	292	564	

Note: This table presents mean characteristics of the counties in the analysis. Mandate counties are those with at least one four-year college with a vaccine mandate. Non-mandate counties are home to at least one four-year college, but none of these colleges mandate a COVID-19 vaccine. Standard errors of the difference between mandate and non-mandate counties are given in parentheses. The baseline vaccination rate is measured in the last week of June, 2021, which is prior to any start date in our sample. It is the vaccination rate for the entire county, not just the student population.

Table 2
Cumulative Estimates of Vaccine Mandates

	Cases per 100k	**Tests per 100k**	**Positivity Rate**	**Hosp. per 100k**	**ICU patients per 100k**	**Deaths per 100k**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Panel A. Effect of 100% Mandate Coverage of College Students						
Effect	-503.9***	715.9	-0.008*	-5.406	-16.19**	-5.599*
	(189.7)	(1,448)	(0.005)	(29.11)	(7.668)	(2.853)
Obs.	12,690	12,690	12,550	12,117	11,588	12,690
Panel B. Effect of Any Vaccine Mandate in County						
Effect	-337.4**	-122.6	-0.005	8.996	-11.49	-4.828*
	(165.3)	(1,293)	(0.004)	(25.88)	(7.303)	(2.520)
Obs.	12,690	12,690	12,550	12,117	11,588	12,690
Panel C. Effect of Any Mandate, Dropping Partially Treated						
Effect	-580.5***	368.4	-0.010**	-6.404	-18.69**	-6.807**
	(213.0)	(1,663)	(0.005)	(32.42)	(8.486)	(3.196)
Obs.	10,457	10,457	10,363	9,912	9,498	10,457
Mean	3,431	34,718	0.100	378.8	97.64	42.34
Estimate Type	Sum	Sum	Average	Sum	Sum	Sum

Note: The table shows cumulative effects of vaccine mandates on COVID-19 outcomes from the week prior to semester start through the 12^{th} week of the semester. The cumulative measure of the positivity rate, which is the percentage of positive tests, is an average over the event study estimates through week 11. For other outcomes, 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 3
Cumulative Estimates by Predicted Student Vaccination Rate and Student Population Share

	Cases per 100k	**Tests per 100k**	**Positivity Rate**	**Hosp. per 100k**	**ICU patients per 100k**	**Deaths per 100k**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Panel A. Below-Median Vax, Above-Median Student Population Share						
Effect	-1,585**	-2,398	-0.027	-109.4	-54.15*	-20.89*
	(592.8)	(3,517)	(0.018)	(58.36)	(21.50)	(10.26)
Obs.	3,145	3,145	3,143	2,859	2,744	3,145
Panel B. Below-Median Vax, Below-Median Student Population Share						
Effect	-603.0	1,572	-0.010	-1.624	-11.72	-3.738
	(306.7)	(2,663)	(0.008)	(35.39)	(13.10)	(5.251)
Obs.	3,194	3,194	3,194	3,102	2,917	3,194
Panel C. Above-Median Vax, Above-Median Student Population Share						
Effect	-155.4	3,231	0.006	-15.76	-7.619	-5.819
	(230.1)	(4,068)	(0.008)	(43.05)	(14.70)	(5.224)
Obs.	3,238	3,238	3,169	3,119	3,073	3,238
Panel D. Above-Median Vax, Below-Median Student Population Share						
Effect	-30.40	1,604	-0.004	14.18	2.173	4.595
	(250.6)	(1,762)	(0.008)	(45.60)	(11.92)	(4.054)
Obs.	2,985	2,985	2,916	2,908	2,724	2,985
Estimate Type	Sum	Sum	Average	Sum	Sum	Sum

Note: The table shows cumulative effects from event studies by predicted student vaccination rate (median = 79.4%) and student population share (median = 3.85%). The predicted vaccination rates are based on the regression shown in Equation 3, where the dependent variables include income and race plus their interactions. 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 4
Cumulative Estimates from Robustness Checks

	Cases per 100k	Tests per 100k	Positivity Rate	Hosp. per 100k	ICU patients per 100k	Deaths per 100k
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Main Specification						
Effect	-503.9***	715.9	-0.008*	-5.406	-16.19**	-5.599*
	(189.7)	(1,448)	(0.005)	(29.11)	(7.668)	(2.853)
Obs.	12,690	12,690	12,550	12,117	11,588	12,690
Panel B. Remote in 2020-by-Week FEs						
Effect	-492.7***	578.5	-0.008*	-4.229	-16.22**	-5.766**
	(183.1)	(1,484)	(0.005)	(29.33)	(7.815)	(2.902)
Obs.	12,690	12,690	12,550	12,117	11,588	12,690
Panel C. Mask Requirement-by-Week Controls						
Effect	-484.6***	551.8	-0.008*	-8.168	-16.02**	-5.160*
	(183.9)	(1,443)	(0.005)	(29.39)	(7.724)	(2.862)
Obs.	12,690	12,690	12,550	12,117	11,588	12,690
Panel D. Test Requirement-by-Week Controls						
Effect	-446.4**	783.3	-0.008	-17.67	-16.41**	-6.094**
	(198.1)	(1,560)	(0.005)	(27.62)	(7.641)	(3.025)
Obs.	12,690	12,690	12,550	12,117	11,588	12,690
Panel E. Population Density-by-Week Controls						
Effect	-507.0***	665.8	-0.008*	-5.848	-16.00**	-5.627**
	(189.8)	(1,448)	(0.005)	(29.20)	(7.655)	(2.861)
Obs.	12,690	12,690	12,550	12,117	11,588	12,690
Panel F. Weighted by County Population						
Effect	-571.0***	3,886	-0.010**	-30.41	-11.86*	-5.233**
	(164.3)	(2,548)	(0.005)	(18.56)	(6.376)	(2.409)
Obs.	12,690	12,690	12,550	12,117	11,588	12,690
Panel G. Weighted by % Students						
Effect	-958.2***	-1,253	-0.013	-114.7**	-31.20**	-15.74*
	(238.1)	(3,380)	(0.008)	(48.94)	(12.40)	(9.181)
Obs.	12,690	12,690	12,550	12,117	11,588	12,690
Estimate Type	Sum	Sum	Average	Sum	Sum	Sum

Note: The table shows cumulative effects from the robustness checks 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.

Table 5
Cumulative Estimates from Sample Changes

	Cases per 100k	Tests per 100k	Positivity Rate	Hosp. per 100k	ICU patients per 100k	Deaths per 100k
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Main Specification						
Effect	-503.9***	715.9	-0.008*	-5.406	-16.19**	-5.599*
	(189.7)	(1,448)	(0.005)	(29.11)	(7.668)	(2.853)
Obs.	12,690	12,690	12,550	12,117	11,588	12,690
Panel B. Population Density Common Support						
Effect	-511.2***	688.1	-0.008	-5.032	-15.73**	-6.042**
	(191.7)	(1,488)	(0.005)	(29.79)	(7.801)	(2.952)
Obs.	12,001	12,001	11,862	11,428	10,945	12,001
Panel C. Drop Counties with Staff Mandates						
Effect	-386.2	936.1	-0.007	-5.381	-19.181*	-8.915*
	(311.4)	(1,893)	(0.007)	(34.56)	(10.932)	(4.541)
Obs.	8,801	8,801	8,800	8,307	7,962	8,801
Panel D. Drop Mandate Counties without Staff Mandates						
Effect	-643.3***	588.6	-0.011**	-3.458	-14.30	-3.220
	(157.0)	(1,908)	(0.005)	(35.41)	(8.925)	(2.886)
Obs.	10,551	10,551	10,411	10,128	9,668	10,551
Panel E. Drop Counties with Fall Mandates						
Effect	-529.0***	732.3	-0.008*	-4.778	-16.63**	-6.249**
	(197.7)	(1,472)	(0.005)	(30.71)	(7.908)	(2.985)
Obs.	11,885	11,885	11,745	11,335	10,967	11,885
Panel F. Treat Fall Mandates as Treated						
Effect	-416.2**	889.1	-0.003	-0.631	-13.17*	-5.537**
	(190.0)	(1,263)	(0.005)	(27.75)	(7.467)	(2.605)
Obs.	13,081	13,081	12,941	12,508	11,979	13,081
Panel G. Restrict to Northeast, Mid-Atlantic, and West						
Effect	-632.2***	-4,194*	-0.002	-47.35	-11.76	-4.516
	(167.6)	(2,507)	(0.006)	(31.98)	(10.06)	(4.074)
Obs.	5,012	5,012	4,874	4,789	4,789	5,012
Estimate Type	Sum	Sum	Average	Sum	Sum	Sum

Note: The table shows cumulative effects from the robustness checks 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.

Table 6
Cumulative Estimates for Economic Outcomes

	Restaurant Visits (1)	Cons. Spend. (2)	GPS Retail (3)	GPS Grocery (4)	GPS Parks (5)	GPS Transit (6)	GPS Work (7)	GPS Resid. (8)	GPS Not Home (9)
Panel A. Main Specification									
Effect	866.5	0.001	-0.003	0.003	0.032	0.003	-0.006	-0.001	0.002
	(771.1)	(0.012)	(0.006)	(0.006)	(0.054)	(0.013)	(0.004)	(0.001)	(0.001)
Obs.	12,231	9,360	11,708	11,138	6,032	8,197	12,161	11,839	11,839
Panel B. Below-Median Vax, Above-Median Student Population Share									
Effect	2,448	-0.017	-0.005	-0.030	0.130	0.043	-0.014	-0.010	0.014
	(2,832)	(0.039)	(0.030)	(0.025)	(0.124)	(0.030)	(0.019)	(0.005)	(0.007)
Obs.	2,878	2,046	2,303	2,483	617	1,345	2,800	2,613	2,613
Panel C. Below-Median Vax, Below-Median Student Population Share									
Effect	1,040	0.025	0.009	0.024	0.185*	0.050	0.001	-0.001	0.002
	(1,065)	(0.018)	(0.013)	(0.015)	(0.075)	(0.029)	(0.004)	(0.002)	(0.002)
Obs.	3,083	2,538	2,870	3,033	1,520	2,056	3,102	3,059	3,059
Panel D. Above-Median Vax, Above-Median Student Population Share									
Effect	203.0	-0.042	-0.003	-0.022*	-0.143	0.002	-0.014	0.001	-0.000
	(1,169)	(0.030)	(0.011)	(0.011)	(0.097)	(0.035)	(0.008)	(0.001)	(0.002)
Obs.	3,179	2,311	2,870	3,100	1,749	2,261	3,146	3,054	3,054
Panel E. Above-Median Vax, Below-Median Student Population Share									
Effect	48.76	0.004	0.001	-0.008	0.080	-0.016	0.001	0.001	-0.001
	(1,769)	(0.016)	(0.008)	(0.008)	(0.109)	(0.019)	(0.003)	(0.001)	(0.001)
Obs.	2,965	2,324	2,937	2,962	2,059	2,380	2,985	2,985	2,985
Estimate Type	Sum	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.

Note: The table shows cumulative effects on economic outcomes from event studies by predicted student vaccination rate (median = 79.4%) and student population share (median = 3.85%). The predicted vaccination rates are based on the regression shown in Equation 3, where the dependent variables include income and race plus their interactions. 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.

[1] See Hodge Jr and Gostin (2001) for a history of school-based vaccine mandates.
[2] Carlin et al. (2022) find that even private returns to the COVID-19 vaccine were undervalued in the U.S. population, including among 18-39 year-olds. While externalities are one argument for vaccine mandates, it also is possible to justify such mandates in a behavioral model with undervalued private returns.
[3] https://covid.cdc.gov/covid-data-tracker/#vaccination-demographics-trends.
[4] All data on outcomes and control variables are publicly available. College vaccine mandate data can be requested from C2i.
[5] An expanding literature also examines the effect of the COVID-19 pandemic on K-12 schooling, showing that it changed the demand for different types of schooling environments (Bacher-Hicks, Goodman, and Mulhern 2021; Chatterji and Li 2021; Musaddiq et al. 2022), reduced academic achievement (Azevedo et al. 2021; Bailey et al. 2021; Kilbride et al. 2021; Halloran et al. 2023; Strunk et al. 2023), and reduced bullying (Bacher-Hicks et al. 2022). See Hinrichs (2021) for a review of the literature on COVID-19 and schooling.
[6] In the K-12 sector there is evidence that under certain conditions, in-person schooling led to more COVID-19 spread relative to remote schooling (Courtemanche et al. 2021; Ertem et al. 2021; Harris, Ziedan, and Hassig 2021; Goldhaber et al. 2022).
[7] If an institution announced a vaccine mandate between the summer and fall data collection periods, we hand-collected information on the announcement date from their website to determine the timing of the announcement relative to the start of the fall 2021 semester. In Section IV.C, we test the sensitivity of the analysis to different definitions of treatment based on the mandate timing and find that it makes little difference in the estimates.
[8] These data are publicly available at https://data.cdc.gov.
[9] County-level testing counts are publicly available at: https://github.com/COVID19PVI/data and test positivity data are publicly available at: https://covidactnow.org/data-api#coverage.
[10] No colleges in Alaska, Alabama, Arkansas, Florida, Kansas, Mississippi, Montana, North Dakota, New Mexico, Nevada, Oklahoma, South Dakota, Utah, or Wyoming mandated vaccinations prior to the fall 2021 semester.
[11] Online Appendix Figure A.1 shows the counties that are dropped during each step of our analysis sample construction.
[12] For the earliest college reopening counties in our sample, we observe outcomes beginning the week of May 21*st*. For the latest reopening counties, we observe outcomes through the week of November 19*th*. Thus, restricting the sample period to eleven weeks before and after college reopenings limits the likelihood that our results are affected by (1) the end of the spring 2021 semester or (2) student travel and changes in instructional mode following Thanksgiving in the fall 2021 semester.
[13] Acton, Cook, and Luedtke (2022) and Collier et al. (2022) analyze factors that contribute to college instruction mode decisions in fall 2021, demonstrating that these decisions depend upon political preferences, local COVID severity, and peer institution decisions. Grossmann et al. (2021) and Christian, Jacob, and Singleton (2022) show some similar influences in K-12 reopening decisions. College vaccine mandate decisions are likely to be influenced by similar factors.
[14] Publicly available data from the National Center for Education Statistics' Beginning Postsecondary Students (BPS) survey shows that in 2011-12, the average four-year college student traveled 233 miles to their first institution, while the median student traveled 55 miles. Our sample is limited to institutions with residence halls on campus, while the BPS data include all four-year institutions, so these distances are likely under-estimated for our sample of institutions. Either way, the statistics show that the majority of students would not reside in the same county as the institution implementing a mandate.
[15] Even if colleges announced vaccine mandate plans for the fall semester during the spring 2021 semester, over 60% of four-year colleges were operating primarily online or in a hybrid environment in spring 2021, suggesting that many students would not have been on-campus. See: https://collegecrisis.shinyapps.io/dashboard/.
[16] The Household Pulse Survey asks individuals "Have you received a COVID-19 vaccine?" and "Did you receive (or do you plan to receive) all required doses?" regarding vaccination status. Individuals can respond "1) Yes, received all required doses", "2) Yes, plan to receive all required doses", and "3) No, don't plan to receive all required doses". We assign a value of one to individuals who selected the first two responses, and zero to all others. We aggregate income ranges from the Pulse survey to income quintiles based on the U.S. household income distribution in 2019 (https://www.taxpolicycenter.org/statistics/household-income-quintiles). The ranges of the

income quintile bins are less than $25,000, $25,000 to $49,999, $50,000 to $74,999, $75,000 to $149,999, and $150,000 and above, respectively.

[17] The Opportunity Insights data use the universe of U.S. tax records to estimate the share of students from each income quintile at each higher education institution (Chetty et al. 2020). We use the most recent data available, which capture students enrolled in colleges and universities in 2013. For institutions with insufficient data to provide quintiles, we use the estimates from Chetty et al. (2020) of the income distribution among all students attending the colleges with insufficient data.

[18] For ease of exposition, we show figures for the six BLS-defined regions with the greatest number of mandate counties in our sample and omit figures with very few mandate counties—the Southwest (6 mandate counties) and the Mountain-Plains (5 mandate counties) regions. No regions are omitted from the regression specifications.

[19] Estimates are also available in tabular form in Online Appendix Table A.2.

[20] Our results imply a case fatality rate of approximately 1.1% (5.599/503.9 = 0.011), which is in line with estimates of the overall U.S. case fatality rate. Indeed, Johns Hopkins University's Coronavirus Resource Center estimated a case fatality rate of 1.1% from the pandemic's onset to March 2023: https://coronavirus.jhu.edu/data/mortality.

[21] Online Appendix Figures A.8 and A.9, respectively, present event study specifications for these samples and treatment definitions. We continue to estimate parallel pre-trends between mandate and non-mandate counties prior to the start of colleges' fall 2021 semesters.

[22] Online Appendix Figure A.10 repeats these event study specifications using Pulse data from April and May to construct our predicted vaccination rates. During this period, it is unlikely that respondents to the Pulse data would be aware of any vaccine mandates for the Fall. Using April and May data thus rules out the possibility that vaccination rate predictions are affected by the presence of vaccination mandates. The results are nearly identical to those in Figure 6, suggesting that differential exposure to college vaccine mandates across demographic groups is unlikely to be driving our predictions.

[23] As reported in Section III.B, to inform these rates we collected data on the final reported vaccination rates for 145 randomly-selected institutions with vaccine mandates. For 106 of these institutions, we were able to find information on campuses' final vaccination rates. Within this sample, the median reported final vaccination rate was 95.2%. The 25th and 75th percentiles were 91% and 98%, respectively.

[24] For the U.S. adult population overall, Bradley et al. (2021) find that the Pulse Survey overstates vaccination rates by 14% in May 2021, with gaps widening between January and May.

[25] We construct this measure using colleges' total full-time equivalent enrollments from the 2019 IPEDS data collection. Branch campuses of the Pennsylvania State University (PSU) System are not included separately in this collection and for these institutions, we instead use fall 2019 unduplicated headcount enrollments from the PSU website: https://datadigest.psu.edu/student-enrollment/.

[26] Event study figures for other outcomes are available from the authors upon request.

[27] These results are available from the authors by request.

[28] We obtain data on colleges' fall 2020 instructional modes from C2i. We include all counties where at least 50% of colleges operated primarily or fully in-person in fall 2020.

[29] The contrast between the 2020 and 2021 results is not driven by the fact that we have limited our sample to colleges that re-opened in person in 2020. For comparison, Online Appendix Figure A.14 presents a version of our 2021 results in which the sample is limited to colleges that re-open in person in fall 2020. The estimates are similar to baseline.

[30] For computational ease, we dichotomize the choices of colleges within a county, interacting the week fixed effects with a dummy variable indicating that more than 50% of colleges in a county operated remotely in the fall 2020 semester.

[31] We note that this null effect differs from work on local and state mask mandates in the early stages of the pandemic (Karaivanov et al. 2021; Hansen and Mano 2023), as well as work on mask mandates in K-12 schools (Cowger et al. 2022; Hughes et al. 2022), which find reductions in COVID-19 incidence as a result of mask mandates. This difference may be explained by the fact that college mask mandates in the fall of 2021 typically only applied to on-campus spaces, such as classrooms, and state-level mask mandates were no longer in place in most states (see: https://www.aarp.org/health/healthy-living/info-2020/states-mask-mandates-coronavirus.html). Thus, students may not have masked in off-campus spaces, such as living spaces and bars and restaurants, where COVID-19 is likely to spread. Indeed, research by Condra et al. (2023) finds that college students were less likely to mask off-campus than on-campus, especially when there was no mask mandate in the broader community.

[32] We implement the common support restriction by dropping all counties with population density values smaller than the minimum value in the sample of mandate counties and larger than the maximum value in the sample of non-mandate counties.
[33] Only two colleges in our sample have faculty/staff mandates but no student mandates.
[34] Online Appendix Figure A.15 identifies counties with mid-semester mandates, announced in Fall 2021 after colleges began their semesters.
[35] As an additional robustness test, we drop any observations with negative counts, reflecting data revisions. Estimates that drop these observations differ little from our main estimates. These results are available from the authors upon request.
[36] We obtain restaurant visit data from Carnegie Mellon University's Project Delphi (https://delphi.cmu.edu/covidcast/export/) and all other measures from Opportunity Insights, (https://www.tracktherecovery.org/), which in turn collects data on consumer spending from Affinity Solutions and data on mobility from Google.
[37] While we define the start time of treatment as the start of the semester, 8.1% of institutions in our analysis sample that began the fall semester without a vaccine mandate announced one by mid-November. We code these institutions as not having a mandate (since they do not begin the semester with one), which likely biases our estimates towards zero because we are treating some post-opening periods with mandates as not having mandates. When we estimate models that drop any county whose first mandate is after the semester start in Table 4, our results are very similar.
[38] For this analysis, we drop the 5% of institutions in our sample that began their semesters during week 32 or 36 of the calendar year. In the second column of Online Appendix Table A.6, we show that the main estimates do not change in a meaningful way when we restrict the sample in this way.
[39] We calculate that 6,358 lives were saved by multiplying the cumulative reduction in deaths per 100,000 under 100% coverage (5.6 from Panel A of Table 2) by the average share of students covered (0.845), the average size of counties with a mandate (494,016 from Table 1) and by the number of mandate counties (272 from Table 1): 5.6*84.5*4.94*272=6,358. During this period (August 16 to November 14), there were 139,711 deaths from COVID-19 per CDC figures: 6,358/139,711=0.046.
[40] Aldy and Viscusi (2008) only provide estimates up to age 62. Nonetheless, in 2021, 69% of COVID-19 deaths were for people over age 65 (https://www.cdc.gov/nchs/covid19/mortality-overview.htm) hence we believe this is a reasonable age to use.