The Effect of College Vaccine Mandates on Local COVID-19 and Economic Outcomes

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Riley K. Acton
Miami University & IZA

Wenjia Cao
Michigan State University

Emily E. Cook
Tulane University

Scott Imberman
Michigan State University, CES-ifo, & NBER

Michael Lovenheim
Cornell University, CES-ifo, & NBER

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Abstract

This study explores the effects of college mandated COVID-19 vaccinations on cases and severe outcomes of COVID-19 in the local area along with measures of local economic activity. Using data on college vaccine mandates, semester start dates, and county-level COVID-19 and economic outcomes, we compare college counties with and without a mandate, before and after the college semester start date in an event-study framework combined with week-by-region and week-by-baseline vaccine status fixed effects to account for COVID-19 trends. After adding these controls, residual baseline vaccine rates and pre-opening COVID outcomes equalize and show little evidence of non-parallel trends. We find that college vaccine mandates reduced COVID-19 cases by 630 per 100,000 county residents, and new deaths by 7.3 per 100,000 residents in the first 12 weeks of the semester. We estimate the value of lives saved from college COVID-19 vaccine mandates are between $13.1 million and $37 million per 100,000 residents in a county. We also find suggestive evidence that these mandates lead to more economic activity in the form of higher consumer spending relative to January 2020 and more trips to restaurants during that same period.

Keywords: Higher education, vaccine mandates, COVID-19

Riley K. Acton: Corresponding author. Department of Economics, Miami University. 800 E. High St., Oxford, OH 45056. actonr@miamioh.edu

Wenjia Cao: Department of Economics, Michigan State University. 486 W Circle Dr. East Lansing, MI 48824. caowenj1@msu.edu

Emily E. Cook: Department of Economics, Tulane University. 6823 St. Charles Avenue, New Orleans, LA 70118. ecook4@tulane.edu

Scott Imberman: Department of Economics, Michigan State University. 486 W Circle Dr. East Lansing, MI 48824. imberman@msu.edu

Michael Lovenheim: Department of Economics, Cornell University. 418 Uris Hall, Ithaca, NY 14853. mfl55@cornell.edu

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1 Introduction

Mandates requiring vaccination for COVID-19 are among the most controversial but widespread policies that have been implemented to control the spread of the SARS-Cov2 virus. The basis for these mandates is that COVID-19 is a highly-communicable and deadly disease, which creates sizable externalities associated with individual infections. These externalities increase the risk of infecting others, potentially leading to increases in hospitalizations and deaths. Further, beyond the health impacts, there are potentially sizable effects of increased COVID-19 infection on the economy through stresses on the health care sector, less economic activity as people avoid social activities and supply chain disruptions emerge, and lower productivity from people missing work (Hershbein and Holzer 2021; Coibion, Gorodnichenko, and Weber 2020; Guan et al. 2020; Rojas et al. 2020). Clinical trials have demonstrated that FDA-approved vaccines help protect people from being infected with the COVID-19 virus, and conditional on being infected, they reduce the likelihood of hospitalization and death (Baden et al. 2021; Falsey et al. 2021; Polack et al. 2020). Widespread vaccination thus can reduce the externalities and public health costs associated with the COVID-19 pandemic. However, opponents of these mandates raise concerns about forced medical interventions and curtailments of individual freedom. Understanding how vaccine mandates impact COVID-19 infection rates, hospitalizations, deaths, and economic activity is a critical aspect of this debate. We provide the first evidence in the literature on this question, focusing on the context of colleges and universities.

Our study examines the effect of college- and university-imposed COVID-19 vaccine mandates for students on COVID-19 infections, hospitalizations, and deaths among those in the communities that surround the colleges, as well as on local economic activity. We focus on college mandates 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 on their local communities. For example, colleges that brought students back to campuses following spring break in March 2020 saw increased levels of COVID-19 spread in their counties (Mangrum and Niekamp 2020), and those that opened in-person during the Fall 2020 semester contributed to increased case rates and hospi-

talizations (Andersen et al. 2021). Students interact extensively with those in the local community, which allows us to measure how college vaccine mandates on the student population affect those living near colleges and universities. College students are an interesting population to consider as well: although they tend to live in congregate settings that are ripe for spread of contagious diseases, their age group has a considerably lower risk for severe outcomes, conditional on COVID-19 infection, than the surrounding population (Levin et al. 2020). Thus, the primary benefit from college vaccine mandates come from externalities imposed by infection among students spreading to other members of the community, rather than benefits to the students themselves. Further, individuals of college age also tend to have lower take-up of vaccination generally —as of August 15, 2021, only 47% of US residents aged 18- 4 were fully vaccinated for COVID-19 compared to 61% of 40-49 year olds and 84% of 65-79 year olds —leaving substantial room for these mandates to have an impact on vaccine take-up.[1] The college context therefore offers a powerful lens through which to understand how vaccine mandates can affect health and economic externalities from infectious disease.

Second, there is extensive variation across colleges in their vaccine mandate policies that provide variation for identification. As the Fall 2021 semester approached and vaccines became more widely available, many institutions mandated that students, and sometimes faculty and staff, be vaccinated against SARS-Cov2. In some cases these mandates were driven by institutional decisions and in others they were state-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.

Third, the return of students in Fall 2021 had the potential to generate large spikes in local infection rates. This was particularly the case at residential colleges that enroll a more nationally- and internationally-representative student body, as well as those where students live together in close quarters in dorms and high density off-campus housing. Institutions start their fall terms at different times, allowing for time-varying shocks in when local communities were exposed to heightened exposure risk from returning students. This variation allows us to account for secular

[1] https://covid.cdc.gov/covid-data-tracker/#vaccination-demographics-trends

trends in COVID-19 outcomes that are the central concern in identifying the effect of college vaccine mandates on these outcomes.

We study the effects of college vaccine mandates on local public health and economic outcomes by leveraging several rich sources of data. First, we obtain information on vaccine mandates, vaccine incentive programs, and vaccine encouragements for the fall 2021 semester, along with institutions' semester start dates, from the College Crisis Initiative (C2i) at Davidson College. C2i's staff collected this 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. We then merge these college-level data with publicly available data from the Centers for Disease Control (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, weekly data on SafeGraph restaurant foot traffic from the Carnegie Mellon University Delhi Group's COVIDcast,[2] and data on consumer spending and mobility from the Opportunity Insights Economic Tracker.[3]

We then estimate event study specifications that examine how these outcomes evolve before and after students return to campus as a function of the vaccine mandate regime in place. The identification assumption underlying our approach is that areas without college vaccine mandates provide an accurate counterfactual for what COVID-19 outcomes would have been absent the college mandates. Of primary concern is that counties with college mandates have populations that were otherwise more likely to be vaccinated or that more stringently followed public health advice. There is a strong geographic component to vaccination rates and public health compliance. Hence, we include not only county and week fixed effects in our models but also region-by-week fixed effects and interactions between week fixed effects and the baseline (August 1, 2021, before all schools' semesters in our data began) county vaccination rate. That there is variation in college start times also helps separate causal effects of mandates from broader secular variation in outcomes during the late summer and early fall of 2021. Furthermore, we present evidence that our results

[2] `https://delphi.cmu.edu/covidcast/export/`

[3] `https://www.tracktherecovery.org/`. Data on consumer spending are provided by Affinity Solutions. Data on mobility are from Google Trends.

are unlikely to be confounded by other policies, such as masking and social distancing.

Our results show consistent evidence that college vaccine mandates reduced COVID-19 infections, hospitalizations, and deaths in the surrounding population. In order to summarize our results, we sum estimates over the first 10 weeks post-reopening. Since our outcomes are cumulative in nature, we estimate total effects of mandates mid-way through the fall term. In our preferred models, a college vaccine mandate reduces total new cases by 629 per 100,000 over 13 weeks following students' return to campuses. This estimate is significantly different from zero at the 1% level. COVID-19 related emergency room (ER) visits decline by 170 per 100,000 and new hospitalizations decrease by 3 per 100,000. However, only the former estimate is statistically significantly different from zero at the 5% level. Ultimately, vaccine mandates lead to 7.3 fewer deaths per 100,000 in the county, which is significant at the 1% level. Taken together, these results suggest that college COVID-19 vaccine mandates had an economically and statistically significant effect on infections and health outcomes.

These health effects translate into large potential monetary savings for the health care sector from the mandates, given that the average cost of an in-patient hospital stay related to COVID-19 is $12,046 (Di Fusco et al. 2021). Even more important, however, may be the amount of value gained from saved life-years. Estimates for the average years of life lost when a person dies from COVID-19 range from 9 to 14.5 (Elledge 2020; Quast et al. 2021; Goldstein and Lee 2020; Arolas et al. 2020). Aldy and Viscusi (2008) estimate a value of a statistical life-year (VSLY) at age 62 of $350,000. Given that in 2021, 69% of COVID-19 deaths were for people over age 65,[4] we approximate that the value of lives saved from college COVID-19 vaccine mandates are between $13.1 million and $37 million per 100k residents in a county.[5]

In addition to the positive health effects, we find suggestive evidence of increased economic activity in the local community from college vaccine mandates post-opening. Our results point to positive effects on restaurant visits and overall consumer spending, however the estimates are not statistically significant at conventional levels. Consistent with the college vaccine mandates

[4] `https://www.cdc.gov/nchs/covid19/mortality-overview.htm`

[5] These use our estimates in Table 2 of 7.3 deaths per 100k people saved over 12 weeks following semester starts multiplied by a lower bound of $200k $\times$ 9 years of life saved and an upper bound of $350k $\times$ 14.5 years of life saved.

affecting local communities largely through the behavior of college students, there is no effect of mandates on the likelihood of remote work or time spent at home. We conclude from this evidence that college COVID-19 vaccine mandates had positive health spillovers to the local community while also likely stimulating economic activity.

Our paper contributes to multiple strands of the literature. First and foremost, while there are estimates of how vaccine mandates have affected health for other diseases (Carpenter and Lawler 2019; Lawler 2017), to our knowledge we are the first to estimate the causal effect of COVID-19 vaccine mandates on public health and economic activity. Given the enormous cost of the ongoing COVID-19 pandemic and the contentious nature of vaccine mandates, this is an important contribution.

We also contribute to a growing body of work that examines the interaction between postsecondary education and COVID-19.[6] Mangrum and Niekamp (2020) 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. (2021) show that college reopenings led to higher student mobility and increased infection rates.[7] Our paper extends these analyses to identify the mitigating effects of vaccine mandates when students returned to campus.

Finally, our work contributes to the literature examining vaccine mandates more broadly. Vaccine mandates, especially in schools, are not new: students across the US are required to be vaccinated against a variety of illnesses, such as smallpox, measles, and polio.[8] Carpenter and Lawler (2019) show that the introduction of the Tdap mandate in middle schools had a large effect on vaccine takeup and significantly reduced the incidence of pertussis. The mandate also induced positive spillovers to the takeup of other vacccines. Lawler (2017) presents evidence that school mandates for the hepatitis A vaccine increased takeup and reduced population incidence of the disease. Abrevya and Mulligan (2011) show positive effects of chickenpox vaccine mandates on takeup, however the takeup effects dissipate over time. Holtkamp et al. (2021) uses the staggered

[6] A growing 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 (Chatterji and Li 2021; Musaddiq et al. 2021; Bacher-Hicks, Goodman, and Mulhern 2021), reduced academic achievement (Azevedo et al. 2021; Bailey et al. 2021; Kilbride et al. 2021), and reduced bullying (Bacher-Hicks et al. 2022). See Hinrichs (2021) for a review of the literature on COVID-19 and schooling.

[7] 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; Goldhaber et al. 2020; Harris, Ziedan, and Hassig 2021).

[8] See Hodge Jr and Gostin (2001) for a history of school-based vaccine mandates.

rollout of smallpox vaccine mandates in the late 19th and early 20th centuries in the US and finds that the mandates increase vaccine takeup and have large long-run effects on affected students.

We contribute to this research along three dimensions. First, we provide novel evidence on the effect of vaccine mandates for COVID-19, which presents unique challenges due to the politicized nature of the vaccines. Second, our analysis is rather unique in the literature in showing effects of vaccine mandates on infections and health outcomes of the broader population not affected by the mandate. With a highly-infectious disease such as COVID-19, estimating the spillover and population health effects of vaccine mandates are of primary importance. Third, we present new evidence on the effects of vaccine mandates on local economic activity.

Our results suggest that college vaccine mandates for COVID-19 have sizable positive effects on health of the population living near colleges and universities while also facilitating increased economic activity. 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 and potential economic benefits of COVID-19 college vaccine mandates.

2 Data

We obtain information on college-level vaccine mandates and semester start dates from C2i. These data were collected between July 21, 2021 and August 5, 2021, allowing us to identify whether a college had a vaccine mandate in place just prior to the start of the fall 2021 semester. 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 COVID-19 cases, emergency room visits, hospitalizations, deaths, and vaccination counts by county and week from the Center for Disease Control and Prevention (CDC).[9] In addition, we collect county-level, weekly test positivitity rates from CovidActNow.org and weekly data on doctors' visits from insurance claims. We obtained

[9]These data are publicly available at `https://data.cdc.gov`.

SafeGraph restaurant foot traffic data from the Carnegie Mellon University Delhi Group's COVIDcast, and data on consumer spending and mobility come from the Opportunity Insights Economic Tracker. Together, these data sources provide rich information on public health and economic outcomes at the local level throughout the summer and fall of 2021.

Our analysis sample includes all U.S. counties with at least one four-year college that offers on-campus residential facilities. We further restrict the sample to counties where the first fall 2021 semester start date fell between August 7th and September 9th.[10] 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.[11]

Table 1 summarizes the 237 counties with a mandate and the 354 counties without a mandate in our sample. The table shows large and statistically significant differences in the demographic, geographic and college characteristics between the mandate and non-mandate counties. Mandate counties on average are more populous, more urban, have a higher share minority population, have higher average incomes, and have higher college attainment than do non-mandate counties. The baseline vaccination rate, defined as the vaccination rate in the last week of June, 2021, is also higher in mandate counties, which are more likely than non-mandate counties to be located in the Northeast, Mid-Atlantic, and West. 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 (18,359) than in non-mandate counties (7,660).

Given these differences, we rely on the timing of semester starts in summer 2021 across mandate and non-mandate counties in a difference-in-differences framework. To facilitate this approach, C2i provided a unique dataset of web-scraped and hand-collected data on semester start dates. Figure 1 shows the cumulative distributions of semester start date for colleges with and without a mandate. Ultimately, 75% of colleges in our sample began their semesters between August 15th and September 1st and more than 90% did so between August 15 and September 7. However,

[10] Only 24 out of 763 counties (3.1%) with four-year residential colleges start outside these dates.

[11] Although it is possible that different colleges in the same county can make different mandate decisions, 81% of colleges in mandate counties have a mandate, and these mandates cover 82% of students in these counties. Nevertheless, we also estimate specifications that omit counties where some colleges mandated vaccination and others in the same county did not and find similar results.

colleges without a mandate typically started earlier than colleges without a mandate. This may reflect other underlying differences between the colleges, such as location (recall that colleges without a mandate are more likely to be located in the South and Midwest).

3 Empirical Strategy

Our goal is to estimate the causal effect of college vaccine mandates for COVID-19 on COVID-related health outcomes and economic activity among the local population. We limit the sample to counties with four-year colleges that we observe for at least eight weeks before and eleven weeks after the first college begins its fall semester. We then estimate event study models that compare how outcomes change in counties with no college mandate to counties with any college mandate surrounding the reopening of the college. Note that the "event" in these models is the college reopening, and all colleges experience this event. We then estimate the hetereogenous impact of reopening on the outcomes of interest by college mandate status. The event study specifications take the following form:

$$Y_{crt} = \sum_{\substack{k=-8 \\ k\neq -2}}^{11} \beta_k * 1\left[t - t_c^* = k\right] + \sum_{\substack{k=-8 \\ k\neq -2}}^{11} \gamma_k * 1\left[t - t_c^* = k\right] * Mandate_c + \theta_c + \delta_t + \varepsilon_{crt} \quad (1)$$

where Y_{crt} is an outcome of interest for county c in region r during week t (e.g., the number of new COVID-19 cases, hospitalizations, or deaths), and t_c^* is the earliest week that a four-year college in county c begins its fall semester. $Mandate_c$ is a dummy variable equal to one if any four-year college in county c required vaccination as of the start of the fall semester. We include both county fixed effects (θ_c) and week fixed effects (δ_t). Throughout the analysis, we cluster all standard errors at the county level.

The β_k coefficients trace out how COVID-19 outcomes were changing in the eight weeks before and the eleven weeks after the start of colleges' fall semesters across all counties with four-year colleges. The γ_k coefficients then capture differences in these pre- and post-reopening coefficients in counties where colleges implemented vaccine mandates. For both sets of coefficients, we omit the period $k = -2$, i.e., two weeks before semesters begin, as we anticipate that students may arrive

on-campus prior to a college's official semester start date, which could generate treatment effects as early as period $k = -1$.

As with any difference-in-difference estimator, we invoke the identification assumption that counties without a college mandate are an accurate counterfactual for counties with a college mandate. This assumption can be broken down into two parts. The first is that counties with and without a mandate were on the same trend prior to college openings. To test this assumption, we estimate γ_k coefficients when $k < -1$. These estimates show pre-opening trends by mandate status. If college vaccine mandates are not passed in areas that are experiencing different trends in COVID-related outcomes, then we expect these coefficients to be zero: the mandates should have no effect until after colleges begin their semesters.

Examining raw trends, there is some evidence that mandate and non-mandate counties were trending differently prior to reopening. The first panel in each row of Figure 2 (panels a, c, e, and g) show raw COVID-19 outcome measures at the county level by mandate status and week relative to college semester start. Vaccination levels are higher in mandate counties, consistent with evidence shown above, but the trend in the vaccination rate appears similar across mandate status. However, cases, hospitalizations, and deaths per 100,000 resident are increasing at a faster rate in counties without a mandate than in counties with a mandate even prior to the semester start date.

The second part of the identification assumption is that there are no shocks that occur at the same time as college reopenings that deferentially affect mandate versus non-mandate counties. While it is impossible to completely rule these contemporaneous shocks, the most important potential issue is that mandate and non-mandate counties get hit by COVID 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.

To address these lingering threats to identification, we use the following estimation model:

$$\begin{aligned} Y_{crt} &= \sum_{\substack{k=-8 \\ k\neq -1}}^{11} \beta_k * 1\left[t - t_c^* = k\right] + \sum_{\substack{k=-8 \\ k\neq -1}}^{11} \gamma_k * 1\left[t - t_c^* = k\right] * Mandate_c + \theta_c + \delta_t \\ &+ \phi_t * Vaxrate_c + \nu_t * Region_c + \varepsilon_{crt}, \end{aligned} \tag{2}$$

where we add controls for the baseline vaccination rate as of July 1, 2021 ($Vaxrate$) and region indicators from the Bureau of Labor Statistics ($Region_c$), both interacted with the calendar week. The basis for these additional variables comes from case dynamics of COVID-19. First, for vaccination rates, while we see parallel trends in vaccination rates in the first column of 2, *growth* in COVID-19 during ensuing waves is itself likely to be a function of vaccine *levels*. Thus, it is important that we compare counties that have similar pre-opening vaccination rates but differ in their mandate policies. Pre-opening vaccination rates also are likely to be correlated with other preventive measures adopted by the local population, such as social distancing and mask-wearing. These controls help account for such unobserved heterogeneity in other behaviors. Since the simultaneous vaccination rate is itself an outcome, and thus inclusion could lead to collider bias, we instead interact the baseline vaccination with time indicators. Second, region-week interactions allow us to account for differences locations on the epidemic curve during COVID waves, particularly the Delta variant wave that propagated through the United States during our period of study. Allowing for the week fixed effects to vary flexibly by region help to ensure that the background level of disease absent the mandates is similar across mandate and non-mandate counties.

The benefits of this strategy can be seen in panels b, d, f, and h of Figure 2, where we plot the residuals from a regression of the COVID-19 outcome measure on all the fixed effects and interactions in equation 3. 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 vaccination rate gaps do not exceed 0.1% in any pre-opening period, while the COVID outcome gaps are less than 20 cases, 0.8 hospitalizations, and 0.3 deaths per 100k people per week. Below, we present event-study estimates that confirm the lack of pre-trends.

We present several other pieces of evidence that support our empirical approach. Our results are robust to directly controlling for a county's vaccination rate over time, and we find little effect of mandates on vaccination rates of county populations. This finding suggests that mandate counties are not trending differently in terms of this key underlying response to the pandemic. It is important

to note, however, that a lack of impacts on vaccination rates in mandate counties does not imply that the mandates failed to increase vaccinations. These mandates were known to students prior to the start of the semester and usually students were required to provide proof of vaccination prior to arriving on campus. Thus, most additional vaccinations were likely to have occurred in students' home counties rather than the county where the college is located.

A final set of identification concerns relates to alternative policies and behaviors that could be correlated with a college passing a mandate. As discussed above, the initial vaccination rate by week fixed effects help control for this unobserved heterogeneity, to the extent that places with higher vaccination rates also were more likely to have these other policies. We also find no evidence from placebo tests that 2021 mandates are associated with differences in outcomes surrounding opening in fall 2020. Since these other policies are likely to have been in effect over that time period as well, these findings suggest that we are not picking up latent differences in how communities addressed the risk from COVID-19. Finally, for a limited set of counties we have information on mask-wearing behavior.[12] Among the overlap counties, the correlation between mask-wearing behavior and a college-level vaccine mandate is only 0.27. Hence, variation in masking, to the extent it is not handled by the other controls in the model, is unlikely to cause a bias in our estimates.

4 Results

4.1 Vaccinations

We start our analysis by considering how colleges' vaccine mandates affect local vaccination rates.[13] We note several important features of these data that are important for interpreting these results. First, we are unable to acquire data on vaccinations of college students directly or even of college-age individuals. Thus, we use total weekly vaccinations in each county. Second, since most mandates were announced prior to students' arrival on campus and often required students

[12]The data on mask wearing are from the Carnegie Mellon University Delhi Group's COVIDcast, which is only available for 164 out of 591 (27.7%) counties in our sample. The mask-wearing measure is constructed by asking Facebook users if they wear a mask for most or all of the time while in public.

[13]Specifically, we use the countywide share of population that received at least one dose of the COVID-19 vaccine.

to get vaccinated before arrival, a large portion —potentially a substantial majority —of students would have been vaccinated in a county other than the one in which their college is located. Both of these factors add a substantial amount of noise to our vaccination estimates. Nonetheless, we provide estimated impacts on county vaccination rates in the interest of completeness.

The effects of the mandates on county-wide vaccinations can be seen in panel (a) of Figure 3. While there is a slight indication of an upwards trend prior to adoption, the point estimates are very small —the estimate for vaccination rate differential in week -8 is only -0.3 percentage points. Ultimately, we see little impact of the mandates on county-wide vaccination rates. Turning to Table 2, in column (8) of the first row, we estimate an average impact of mandates on vaccination rates over the 12 weeks following semester start of -2.3 percentage points. This estimate is not statistically significant at even the 10% level. Overall, we conclude that college vaccine mandates had a negligible impact aggregate vaccinations in the county. This result is important as well because it suggests that mandate and non-mandate counties were trending similarly in terms of vaccinations after college students came back. 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 mandates per se. We also see little evidence of meaningful differences in levels or trends of vaccinations prior to semester start by mandate status after conditioning on the fixed-effects and interactions in equation 3, which further supports our identification strategy.

4.2 COVID-19 Outcomes

We now turn to assessing how the mandates affect the spread of COVID-19 and related severe health outcomes. Unlike for vaccinations, our interest goes beyond the college enrolled population itself to capture spillovers from vaccinating college students to the wider community. We present our main event study results in panels (b) through (f) of Figure 3.

First, in panel (b), we show that COVID-19 cases per 100,000 residents were trending similarly in counties with and without college mandates prior to semester start dates. Cases then begin to decline in counties with mandates, relative to counties without mandates, in the week prior to the

start of the semester, when students began to arrive on college campuses. Cases continue to decline in the first five weeks of the semester and level out at approximately 50 fewer weekly cases per 100,000 residents beginning in week 6. Panel (c) shows that these effects are not primarily driven by differences in testing across counties with and without mandates: there is a small negative effect on the test positivity rate that matches the decline in cases.[14] We again see parallel pre-trends prior to semester start dates, with declines in the test positivity rate in mandate counties in weeks -1 to 5 and a leveling off beginning in week 6.

Panels (d) and (e) show the effects of college mandates on more severe COVID-19 outcomes, namely weekly COVID-related emergency department visits per 100,000 residents and weekly COVID-related hospitalizations per 100,000 residents. In both measures, we include both suspected and confirmed cases of COVID-19. Panel (d) shows a reduction of emergency department visits of approximately 10 visits per 100,000 county residents per week beginning two weeks after colleges semesters start. The results for hospitalizations in panel (e) are noisy but suggestive of a reduction in hospitalizations in weeks 2-4 following college reopenings. In Section 4.4, we show that these effects are much larger when we weight by county size, indicating that we see reductions in hospitalizations in larger counties. This finding is not surprising because the hospitalization data reflect the locations where patients are hospitalized rather than where they reside. Thus, there is likely to be more measurement error in small counties with low hospital capacity, where severely ill patients may be hospitalized outside of their county of residence. We therefore caution that the unweighted hospitalization results should be interpreted with this measurement error in mind.

Finally, panel (f) 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 in the first 5 weeks following the start of semesters, which is unsurprising given the well-documented lag between COVID-19 cases and deaths. Beginning six weeks after colleges resume instruction, there is a reduction in deaths of approximately 5 deaths per 100,000 county residents per week.

[14]The test positivity rate is the number of positive tests in a county divided by the total number of tests.

We summarize these effects —as well as those for the share of doctors' office visits and emergency department visits that are COVID-19 related —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 all outcomes that are measured on a percentage basis, we present the average of the post-period event study coefficients. The results in panel A mirror those in the event study, while those in panel B further control for a county's vaccination rate over time. In general, these two specifications produce very similar results. To contextualize the size of our results, we present the average cumulative or weekly average value of the outcome across weeks $k = -1$ to $k = 11$ and scale our estimates relative to these values.

Beginning with column (1), we find that college-level COVID-19 mandates reduced COVID-19 cases by 619-629 cases per 100,000 —an approximately 18% reduction off of the mean. In column (2), we show a corresponding weekly average reduction in the test positivity rate of 1.1 percentage points (an 11% decrease), and in column (3) we show that college mandates reduce the share of doctors' visits that are COVID-19 related by 0.13 percentage points on average (a 12% decrease). The estimated coefficients in columns (4) and (5) indicate that mandates reduce the total number of COVID-related emergency department visits by 168-169 per 100,000 residents (a 9% decrease) or by 2.1 percentage points on average (a 13% decrease). Column (6) shows a noisy reduction in hospitalizations of 2.6-3.6 per 100,000 and, finally, column (7) shows that college mandates reduce the total number of COVID-19 deaths in a county by 7.3 per 100,000 over thirteen weeks, a 17% decrease. Taken together, these findings indicate that colleges' vaccination mandates substantially reduced the health-related toll of COVID-19 in their local communities during the fall 2021 semester.

4.3 Economic Outcomes

We next turn to estimating the effects of colleges' vaccination mandates on local economic outcomes. If mandating vaccination amongst college students either (1) reduces periods of quarantine and isolation for local residents and/or (2) makes local residents more comfortable engaging in

higher-risk activities like shopping and indoor dining, we would expect to see consumer spending and related measures of economic activity increase in mandate counties, relative to non-mandate counties, after colleges' semesters begin. We test for these effects by again estimating event study specifications, which we present in Figure 4.

Panel (a) shows the effects of mandates on weekly visits to grocery stores and pharmacies, relative to January 2020. Similar to the health outcomes in Figure 3, there is little evidence of a differential pre-trend in mandate counties prior to colleges' start dates. After opening, there is a small increase in foot traffic at these establishments over the course of the semester. Panel (b) shows a similar pattern for retail and recreation facilities, including restaurants.

Panel (c) presents event study estimates of total consumer spending in a county, normalized against January 2020. There once again is little evidence of a pre-opening trend, and post-opening the mandate counties experience an increase in spending of 3-4% in the latter weeks of the semester, relative to non-mandate counties. Finally, in panel (d), we show estimates for the weekly number of visits to restaurants per 100,00 residents. There are no pre-opening trends, and followin reopening there is an increase of up to 100 more visits per 100,000 residents in mandate counties relative to non-mandate counties.

We summarize these effects, as well as those for other mobility-related outcomes, in Table 3. As for the health outcomes, we show cumulative effects for per capita outcomes and average effects for percentage outcomes. We also present results with and without a time-varying vaccination rate control. These results are, in general, imprecise but positive, indicating that COVID-19 vaccination mandates had a modest, positive effect on local spending and related activities. At the very least, we can rule out any concerns that these mandates substantially reduced local economic activity.

4.4 Robustness

The results we have presented thus far indicate that college-level COVID-19 mandates protected local public health during the fall 2021 semester, which had modest positive effects on counties' local economies. These findings rely on the assumption that counties where colleges did not implement vaccination mandates serve as a valid counterfactual for those that did. We now present

several tests of this assumption, concentrating on five primary per capita outcomes of interest: the number of COVID-19 cases, emergency department visits, hospitalizations, and deaths per 100,000 residents, as well as the county's vaccination rate.

Figure 5 shows the results of a placebo event study using the same specification as in our baseline event study but with COVID-19 outcomes measured in fall 2020, before vaccines were widely available. If mandate- and non-mandate counties have different COVID-19 patterns that are not accounted for using our fixed effects and controls, we might expect to see these patterns show up after the Fall 2020 semester start among colleges that re-opened in person. This is particularly important for assessing whether mandate counties had other policies in place that protected against COVID-19 infection. These policies are likely to have been in place prior to the rollout of the vaccine as well. The results show no indication of differences in outcomes across mandate and non-mandate counties in 2020.[15]

We also test the sensitivity of our results to several specification choices. Panel A of Table 4 shows the main specification, while Panel B shows the results when we weight the regressions by the county population size. Panel C weights the regressions by the student share of the county population. In the weighted regressions, we obtain larger and in many cases more statistically significant effects for cases, ER visits, hospitalizations, and deaths, while the vaccination rate effects remain small and are not statistically significant at conventional levels. In Panel D, we include week fixed effects interacted with an indicator for remote re-opening in 2020 —this is to address the concern that mandate colleges may have systematically different attitudes and responses to COVID-19 than non-mandate colleges. However, these controls have little impact on our results. Panel E shows the estimates when we drop any negative COVID-19 counts in the CDC data, which occur due to revisions of the data. Panel F shows the estimates when we drop any counties that have multiple colleges with different vaccine mandate statuses in Fall 2021. Our results and conclusions are robust to these measurement issues.

Table A.2 addresses the concern that our results could be driven by one specific state. We

[15]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, Figure A.5 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.

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.

One final econometric issue is that our main specification relies on event studies from two-way fixed effect regressions with staggered adoption. This can be a problem if the treatment effects are dynamic and heterogeneous (Goodman-Bacon 2021; Sun and Abraham 2021). However, while our adoption is staggered, there is actually little difference in the timing of when semesters start as seen in Figure 1. Indeed, about 90% of schools started in a three week period between August 15 and September 7, making our setup close to a more standard event-study with uniform adoption timing.[16] Nonetheless, 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 Table 5.[17] For each outcome, the estimates are qualitatively similar and, with the exception of hospitalizations, are in the same direction across semester start weeks. Furthermore, in column (6) we provide a weighted average of these separate start-week estimates, where the weights are equal to the share of institutions that start the semester in each week. The results are very similar to our main estimates.

5 Conclusions

Mandates for COVID-19 vaccination have become a politically controversial issue. While we have excellent experimental and population data on how vaccines themselves affect individual health outcomes, the justification for mandates rely primarily on the extent to which vaccinations can reduce the externalities imposed on others from communicable illness in terms of additional disease spread and reduced economic activity. To better understand the externality-correcting benefits of vaccine mandates, we focus on the context of colleges and estimate the impact of residential

[16] While we define the start time of treatment as the start of the semester, it is worth noting that 21% of institutions with mandates announced them after the start of the semester. However, this would tend to bias our estimates towards zero as we would be treating some post-opening periods without mandates as actually having mandates. Indeed, when we estimate models that drop any county whose first mandate is after the semester start, our results are very similar.

[17] Note that 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 Table 5, we show that the main estimates do not change in a meaningful way when we restrict the sample in this way.

college vaccine mandates on a variety of COVID-19 health outcomes and indicators of local economic activity. Residential colleges and universities provide an excellent case study of spillover effects from vaccine mandates as they are large, concentrated populations of young individuals who are at relatively low individual risk from serious COVID-19 complications themselves. Individuals of college age also tend to have lower take-up of vaccination generally, and hence there is substantial scope for mandates to improve these rates.

Our analysis uses an event study estimation strategy comparing counties with schools that had mandates to those that did not before and after fall 2021 semester start dates. To account for differences across counties in mitigation behaviors, regional variation in the timing of COVID waves, and existing vaccination rates, we also include county and week of the calendar year fixed-effects while interacting the latter with baseline vaccination rates and region indicators.

While we do not find impacts of mandates on county-wide vaccination rates for the counties the institutions are located in, this is likely due to the college population being a relatively small portion of each county and most students receiving their vaccinations in their county of residence rather than in the county in which the college is located.

Our primary focus is on the combination of direct and indirect effects of the mandates on health and the local economy. We estimate that, over the first thirteen weeks after students returned to campus in Fall 2021, cases of COVID-19 in counties with mandate schools fell by 629 per 100,000 people relative to counties with non-mandate schools. This reduction in cases, in turn, resulted in 169 per 100,000 fewer emergency room visits, and 7.3 per 100,000 fewer deaths. A back-of-the-envelope calculation applying the value of a statistical life-year estimate at age 62 of $350,000 from Aldy and Viscusi (2008) and estimates of each COVID death resulting in 9 to 14.5 lost life years (Elledge 2020; Quast et al. 2021; Goldstein and Lee 2020; Arolas et al. 2020), we approximate that the value of lives saved from college COVID-19 vaccine mandates could be as large as $37 million per 100,000 residents in a county.

We then turn to economic outcomes using data on consumer spending and various indicators of mobility in the county via mobile phone tracking. Event studies show that mandate counties see a slight but insignificant increase in restaurant visits shortly after the semester starts, suggesting that

additional illness in the area has a drag on dining out either through people getting ill or becoming more cautious as cases rise. Notably, while consumer spending is initially unaffected, by week 11 mandate counties experience consumer spending that is about 4 percentage points higher than in non-mandate counties relative to their January 2020 baselines. While the exact mechanism for this delayed impact is unclear, it may be a result of time needed for the impacts of the disease to propagate through the economy as people reduce spending due to lost work (and hence, wages).

In total, our findings indicate that college vaccine mandates led to substantial reductions in disease burden well beyond college campuses themselves. As of now, it is unclear how the COVID-19 pandemic will continue as new potential variants emerge. However, public health officials and governments likely willcontinue to need to be nimble in how they try to reduce disease burden. This study shows that vaccine mandates, even in a young population, can be an effective tool towards achieving that goal.

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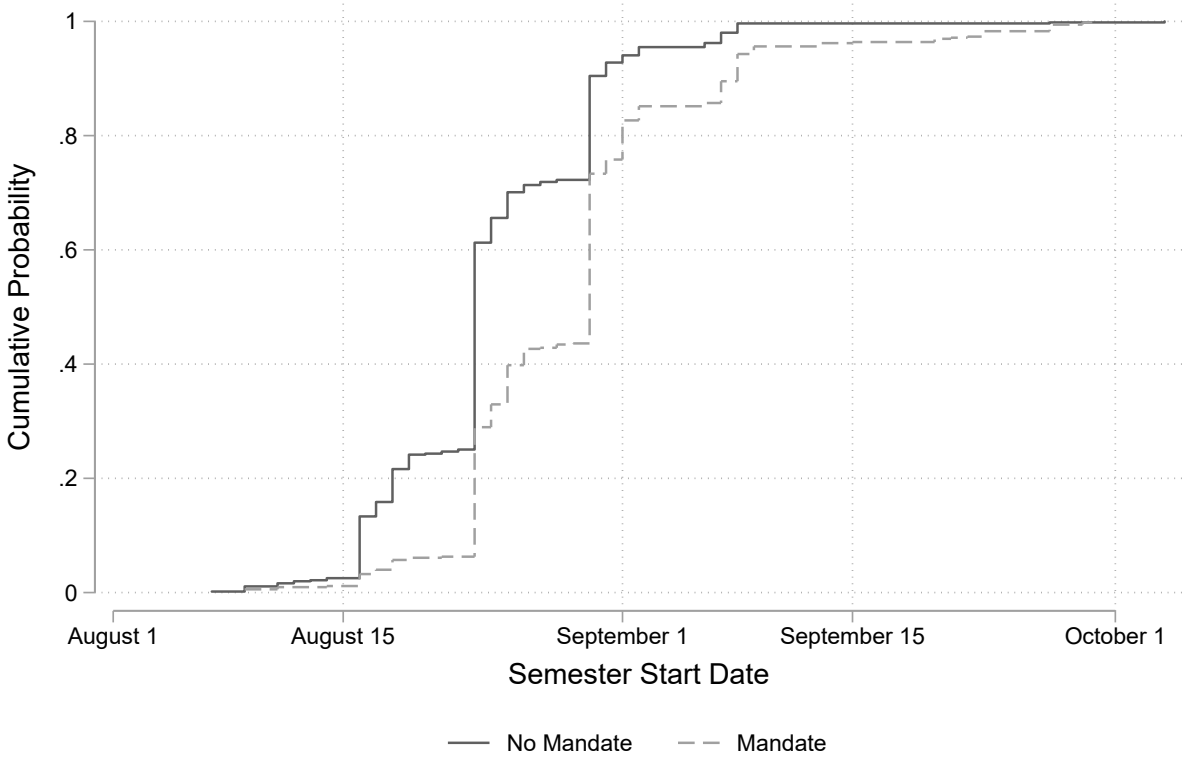
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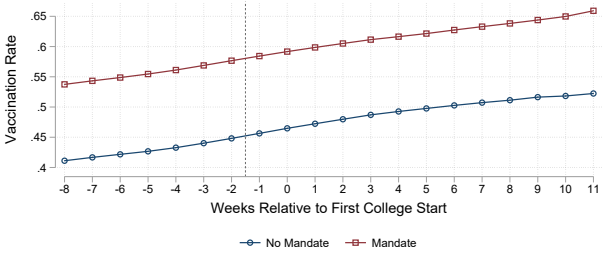
Figure 1: Semester Start Dates



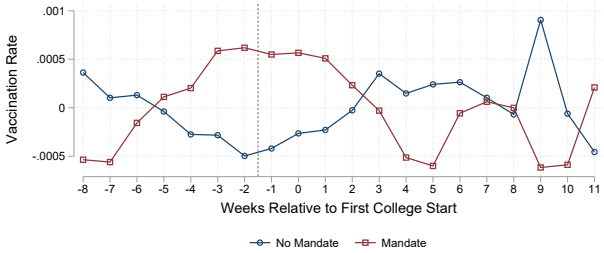
Note: This figure shows the cumulative probability that university's semester has started by the date indicated on the X axis, among colleges with and without a mandate.

Figure 2: Health Outcome Measures, Raw and Residualized

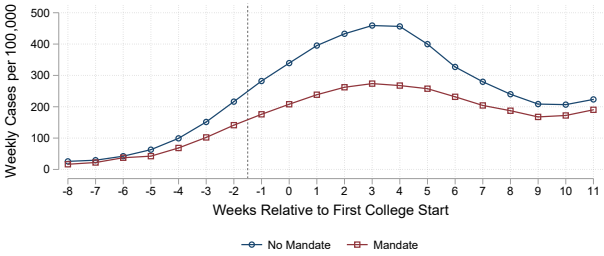
(a) Vaccination Rate



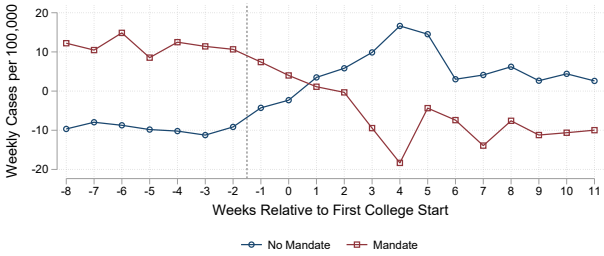
(b) Vaccination Rate Residuals



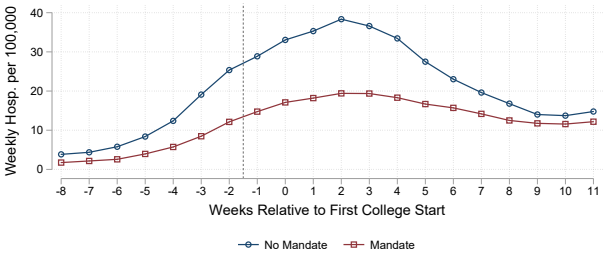
(c) Cases



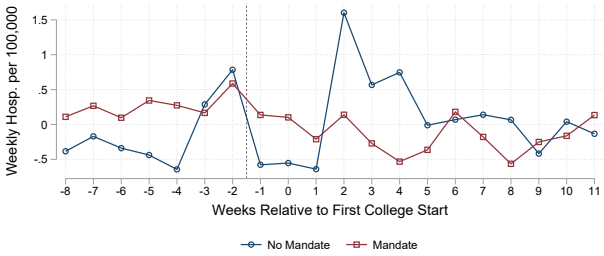
(d) Cases Residuals



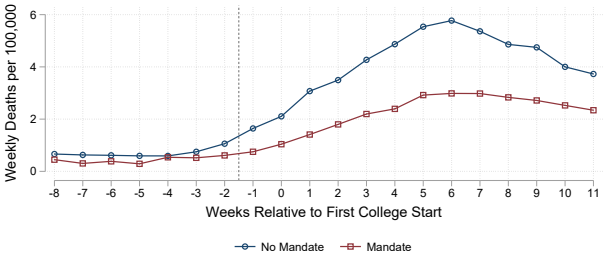
(e) Hospitalizations



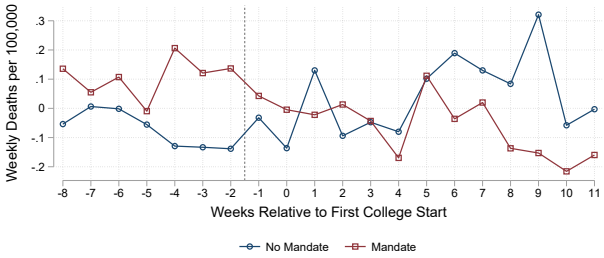
(f) Hospitalizations Residuals



(g) Deaths

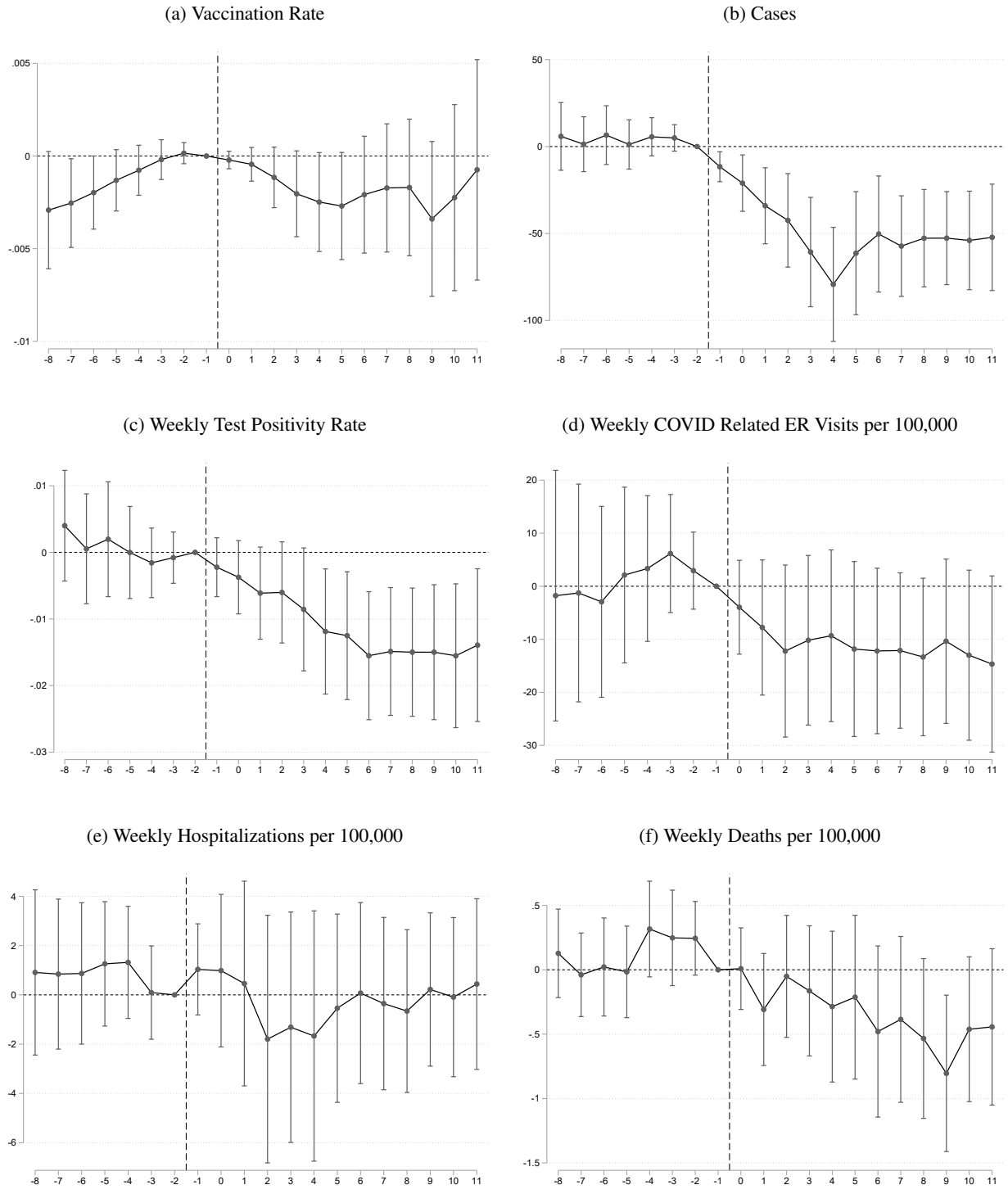


(h) Deaths Residuals



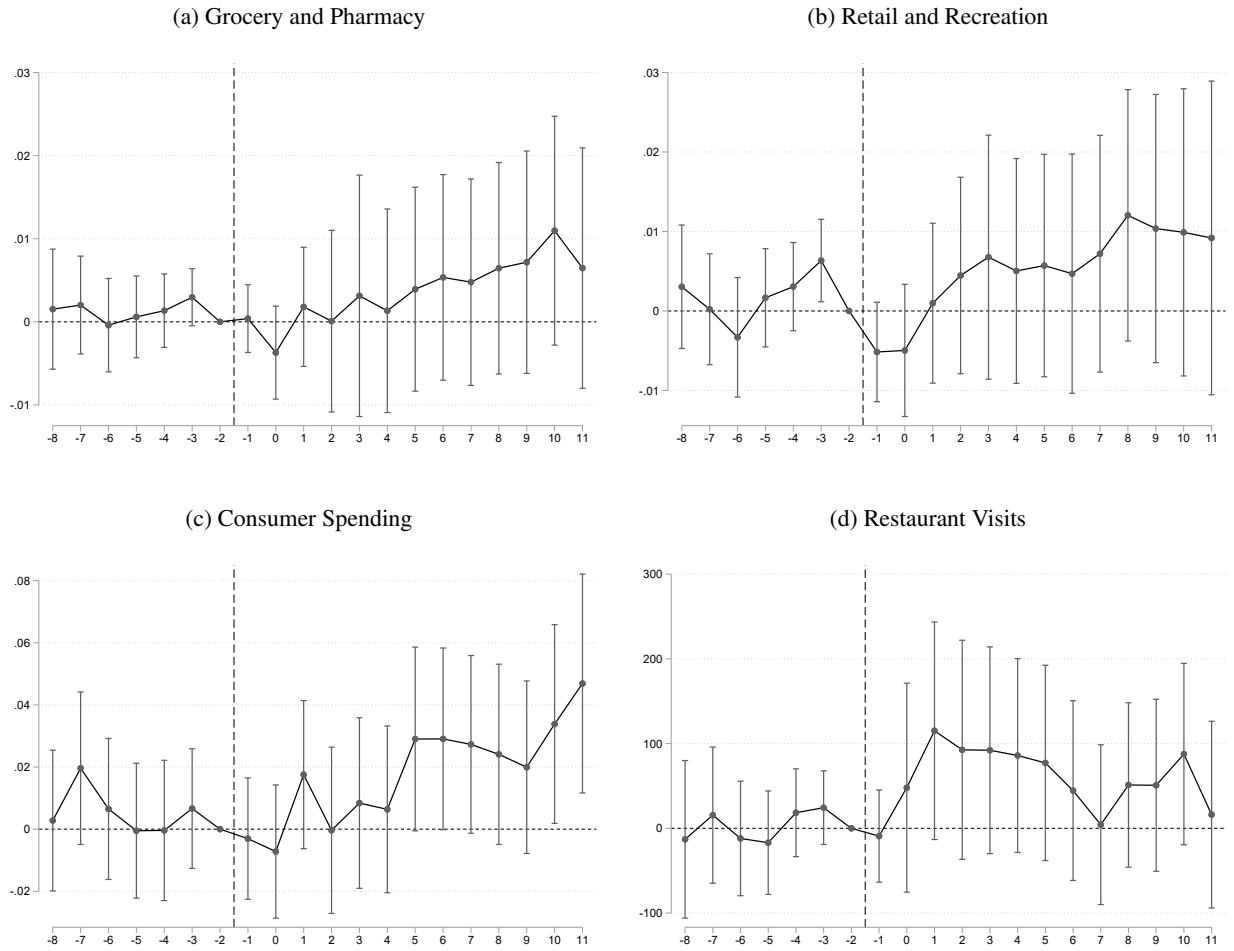
Note: These figures show raw COVID-19 outcome measures at the county level and the residuals from a regression of the COVID-19 outcome measures on county and week fixed effects, week-by-region fixed effects, and week-by-baseline vax rate fixed effects. The levels for college counties with (without) a mandate are given by the square (circular) markers. Subfigures (a) and (b) show the raw and residualized vaccination rate, measured as the proportion of the county population with at least one dose of a COVID-19 vaccine. Subfigures (c) and (d) show the raw and residualized weekly number of cases per 100,000 county residents. Subfigures (e) and (f) show the raw and residualized weekly number of hospitalizations per 100,000 population, and subfigures (g) and (h) show the raw and residualized deaths per 100,000 population, respectively.

Figure 3: Event Studies with Health Outcomes



Note: These figures show the results of event studies that include county and week fixed effects, week-by-region fixed effects, and week-by-baseline vaccination rate fixed effects. The line shows the effect of the mandate relative to college counties without mandates. We include 95% confidence intervals. Panels are labeled by the outcome measure.

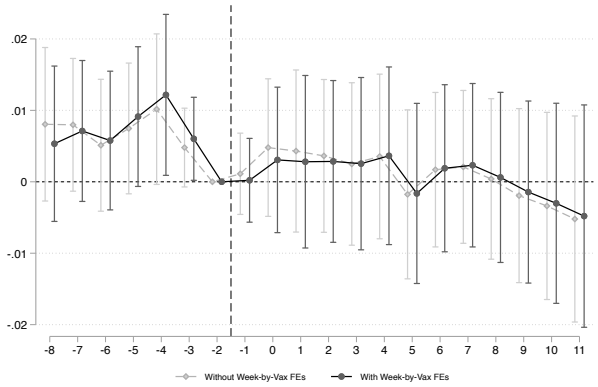
Figure 4: Event Studies with Economic Outcomes



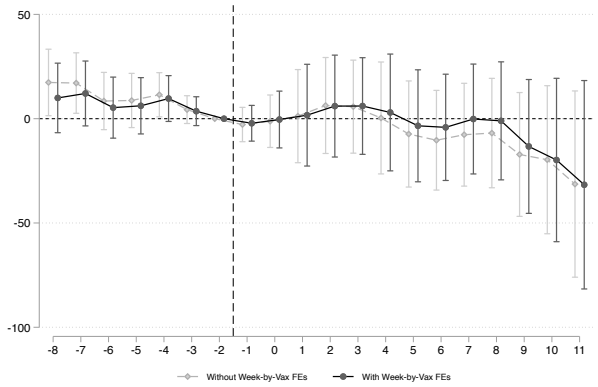
Note: These figures show the results of event studies that include county and week fixed effects, week-by-region fixed effects, and week-by-baseline vaccination rate fixed effects. The line shows the effect of the mandate relative to college counties without mandates. We include 95% confidence intervals. Panels are labeled by the outcome measure.

Figure 5: Placebo Test: 2020 Outcomes for Colleges That Opened In Person

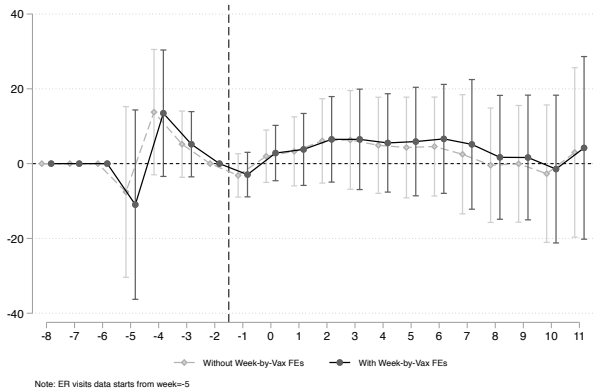
(a) Positivity Rate



(b) Cases

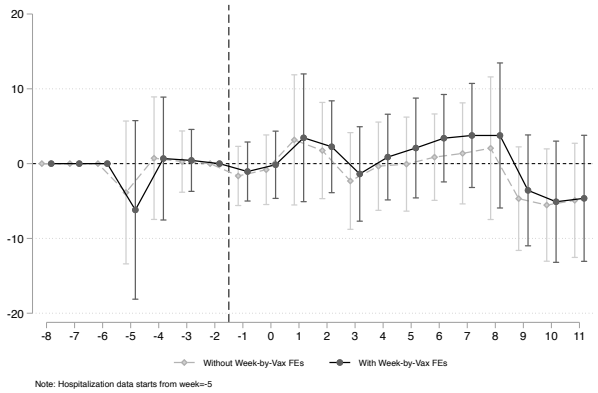


(c) ER Visits



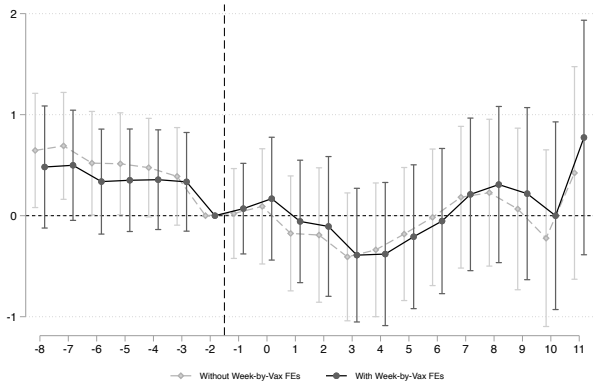
Note: ER visits data starts from week=-5

(d) Hospitalizations



Note: Hospitalization data starts from week=-5

(e) Deaths



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

Table 1: Summary Statistics

	Mandate	**No Mandate**	**Difference**	
Population	532,620	194,434	338,186	(61,756)
Population Density	1852	314.8	1,537	(389.4)
% White	77.062	82.144	-5.082	(1.316)
Median Household Income	66,560	54,628	11,932	(1,298)
% Bachelor's Degree	33.945	26.611	7.334	(0.838)
Baseline Vaccination Rate	0.537	0.412	0.125	(0.010)
New England	0.148	0.020	0.128	(0.024)
New Jersey/New York	0.190	0.020	0.170	(0.027)
Mid-Atlantic	0.249	0.102	0.147	(0.032)
Southeast	0.093	0.285	-0.192	(0.031)
Midwest	0.156	0.353	-0.197	(0.035)
Southwest	0.013	0.138	-0.126	(0.020)
Mountain Plains	0.017	0.054	-0.037	(0.015)
West	0.135	0.028	0.107	(0.024)
Number of Four-Year Colleges	2.633	1.274	1.359	(0.174)
% of Colleges w/ Mandate	0.814	0.000	0.814	(0.017)
% of Colleges Remote in 2020	0.401	0.254	0.147	(0.034)
Number of College Students	18,908	8,233	10,675	(1,945)
% of Students w/ Mandate	0.822	0.000	0.822	(0.019)
% of Students Remote in 2020	0.439	0.258	0.181	(0.036)
Observations	237	354	591	

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.

Table 2: Cumulative and Average Results for Health Outcomes

	Cases per 100k (1)	**Positivity Rate (2)**	**% Doctor Visits (3)**	**ER Visits per 100k (4)**	**% ER Visits (5)**	**Hosp. per 100k (6)**	**Deaths per 100k (7)**	**Vax Rate (8)**
Panel A. Main Specification								
Effect	-629***	-0.011***	-0.134**	-169**	-0.021***	-3.656	-7.30***	-0.023
	(133)	(0.004)	(0.056)	(78.595)	(0.005)	(22.691)	(2.430)	(0.017)
Observations	11814	11672	11514	11291	11266	11291	11814	11814
Panel B. Controlling for time-varying vaccination rate								
Effect	-619***	-0.011***	-0.131**	-168**	-0.021***	-2.593	-7.28***	-
	(133)	(0.004)	(0.056)	(78.421)	(0.005)	(22.661)	(2.430)	-
Observations	11814	11672	11514	11291	11266	11291	11814	11814
Mean	3444	0.099	1.125	1915	0.167	361.2	42.3	0.549
Estimate Type	Cumulative	Average	Average	Cumulative	Average	Cumulative	Cumulative	Cumulative

Note: The table shows 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. All values per 100k are sums of the event study estimates in Figure 3 from -1 through 11. All percentage values are averages of these coefficients. The main specification in Panel A includes county, week, week-by-region, and week-by-baseline vaccination rate fixed effects. Panel B additionally controls for the time-varying, weekly vaccination rate in the county. All standard errors are clustered at the county level. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 3: Cumulative and Average Results for Economic Outcomes

	Rest. Visits (1)	**Cons. Spend. (2)**	**GPS Retail & Rec. (3)**	**GPS Grocery (4)**	**GPS Parks (5)**	**GPS Transit (6)**	**GPS Work (7)**	**GPS Residential (8)**	**GPS Away from Home (9)**
Panel A. Main Specification									
Effect	756.615	0.018	0.005	0.004	0.033	0.025**	-0.003	-0.001	0.001
	(637.931)	(0.011)	(0.006)	(0.005)	(0.041)	(0.012)	(0.002)	(0.001)	(0.001)
Observations	11314	8450	10701	10170	5487	7376	11094	10795	10795
Panel B. Controlling for time-varying vaccination rate									
Effect	724.765	0.018	0.005	0.004	0.033	0.025**	-0.003	-0.001	0.001
	(631.946)	(0.011)	(0.006)	(0.005)	(0.041)	(0.012)	(0.002)	(0.001)	(0.001)
Observations	11314	8450	10701	10170	5487	7376	11094	10795	10795
Estimate Type	Cumulative	Average	Average	Average	Average	Average	Average	Average	Average

Note: The table shows cumulative effects of vaccine mandates on economic outcomes during the first 11 weeks of the semester. The baseline specification includes the county, week, week-by-region, and week-by-baseline vaccination rate fixed effects. The Vax Rate specification controls for contemporary vaccination rates. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 4: Cumulative Estimates from Robustness Checks

	Cases	**ER Visits**	**Hosp.**	**Deaths**	**Vax Rate**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
Panel A. Main Specification					
Effect	-629.339***	-169.282**	-3.656	-7.298***	-0.023
	(132.949)	(78.595)	(22.691)	(2.430)	(0.017)
Obs.	11814	11291	11291	11814	11814
Panel B. Weighted by County Population					
Effect	-819.652***	-188.323***	-48.546***	-10.033***	0.014
	(145.289)	(66.690)	(16.074)	(2.046)	(0.022)
Obs.	11814	11291	11291	11814	11814
Panel C. Weighted by % Students					
Effect	-902.642***	-229.206	-49.903	-11.719**	-0.014
	(186.472)	(176.726)	(47.419)	(5.206)	(0.026)
Obs.	11814	11291	11291	11814	11814
Panel D. Remote-by-Week FEs					
Effect	-615.755***	-161.914**	-2.543	-7.214***	-0.023
	(131.251)	(78.106)	(22.611)	(2.431)	(0.017)
Obs.	11814	11291	11291	11814	11814
Panel E. Drop Negative Values					
Effect	-631.937***	-169.282**	-3.656	-7.351***	-0.023
	(133.215)	(78.595)	(22.691)	(2.397)	(0.017)
Obs.	11756	11291	11291	11731	11814
Panel E. Drop Partially Treated					
Effect	-662.313***	-177.163*	-3.894	-7.426**	-0.045**
	(160.260)	(90.197)	(29.201)	(3.063)	(0.020)
Obs.	10012	9494	9494	10012	10012

Note: The table shows cumulative effects from the robustness checks described in Section 4.4. All regressions include county and week fixed effects, week-by-region fixed effects, and week-by-baseline vaccination rate fixed effects. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 5: Difference in Differences Estimates by Week of Semester Start

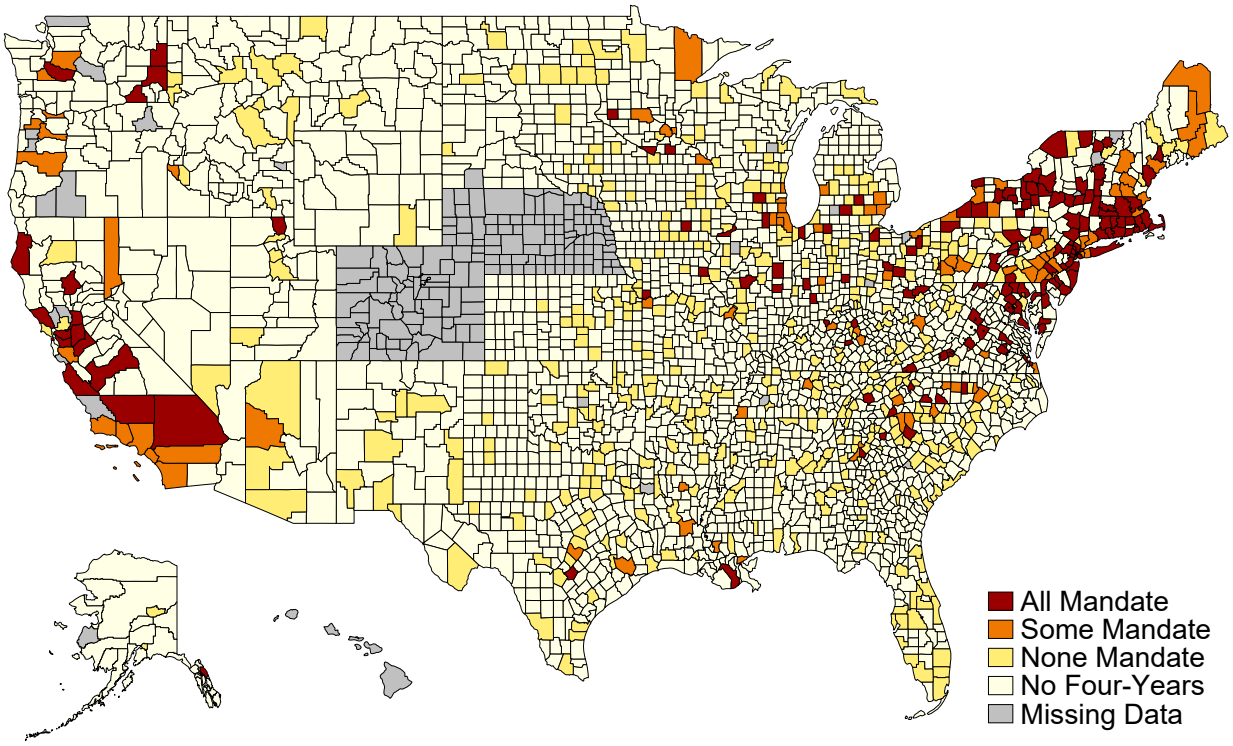
	Main (1)	**Weeks 33-35** (2)	**Week 33** (3)	**Week 34** (4)	**Week 35** (5)	**Weighted Avg.** (6)
Panel A. Cases						
Effect	-629.339***	-676.609***	-529.971	-541.642***	-672.035***	-562.543***
	(132.949)	(136.934)	(360.392)	(177.688)	(232.786)	(130.417)
Obs.	11814	11178	2440	5960	2740	11180
Panel B. COVID-19 ER Visits						
Effect	-169.282**	-230.225***	-414.488*	-166.601**	-119.078	-206.730***
	(78.595)	(74.619)	(225.560)	(82.894)	(139.405)	(71.579)
Obs.	11291	10730	2280	5799	2613	10732
Panel C. Hospitalizations						
Effect	-3.656	-19.511	-68.070	-19.355	33.055	-16.824
	(22.691)	(20.587)	(58.802)	(22.703)	(51.571)	(20.887)
Obs.	11291	10730	2280	5799	2613	10732
Panel D. Deaths						
Effect	-7.298***	-7.998***	-14.950*	-4.568	-5.388	-6.981***
	(2.430)	(2.503)	(8.486)	(2.923)	(4.357)	(2.548)
Obs.	11814	11178	2440	5960	2740	11180
Panel E. Vaccination Rate						
Effect	-0.023	-0.019	-0.027	0.027	-0.099***	-0.017
	(0.017)	(0.018)	(0.049)	(0.023)	(0.035)	(0.018)
Obs.	11814	11178	2440	5960	2740	11180

Note: The table shows cumulative effects by the week of semester start as described in Section 4.4. All regressions include county and week fixed effects, week-by-region fixed effects, and week-by-baseline vaccination rate fixed effects. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Online Appendix

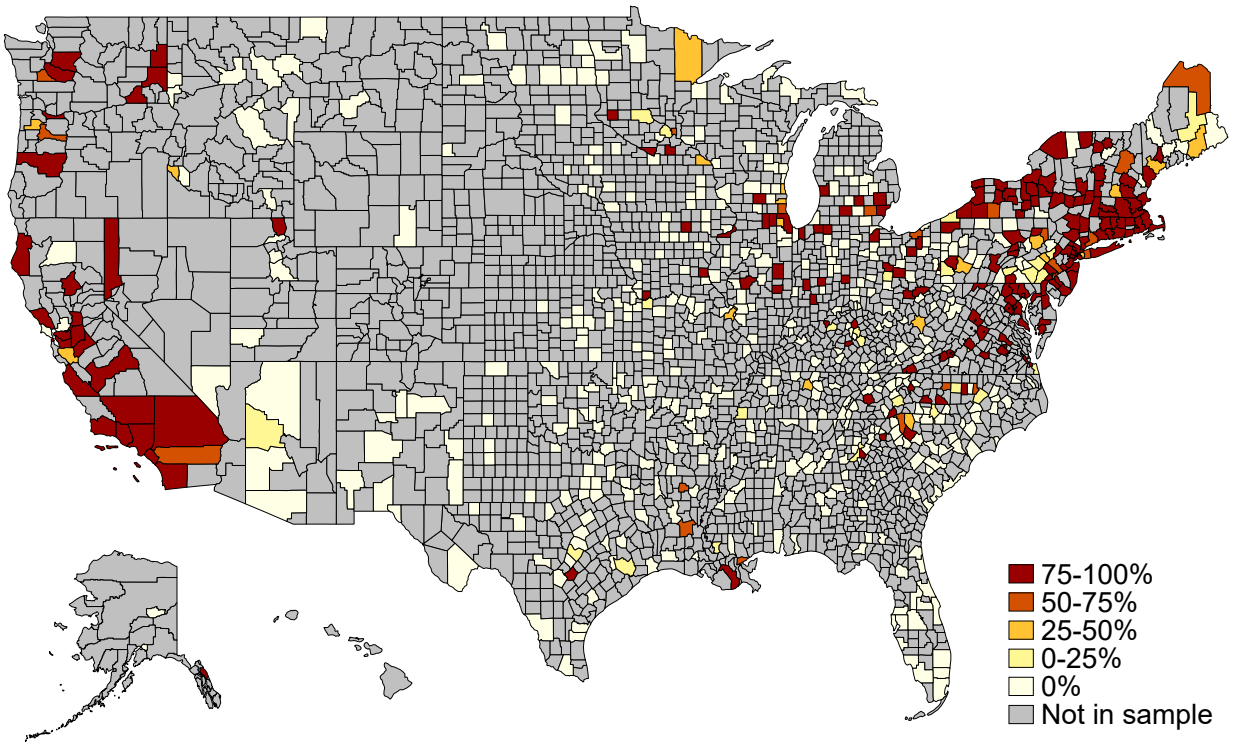
A Additional Figures & Tables

Figure A.1: Map of College Vaccine Mandates



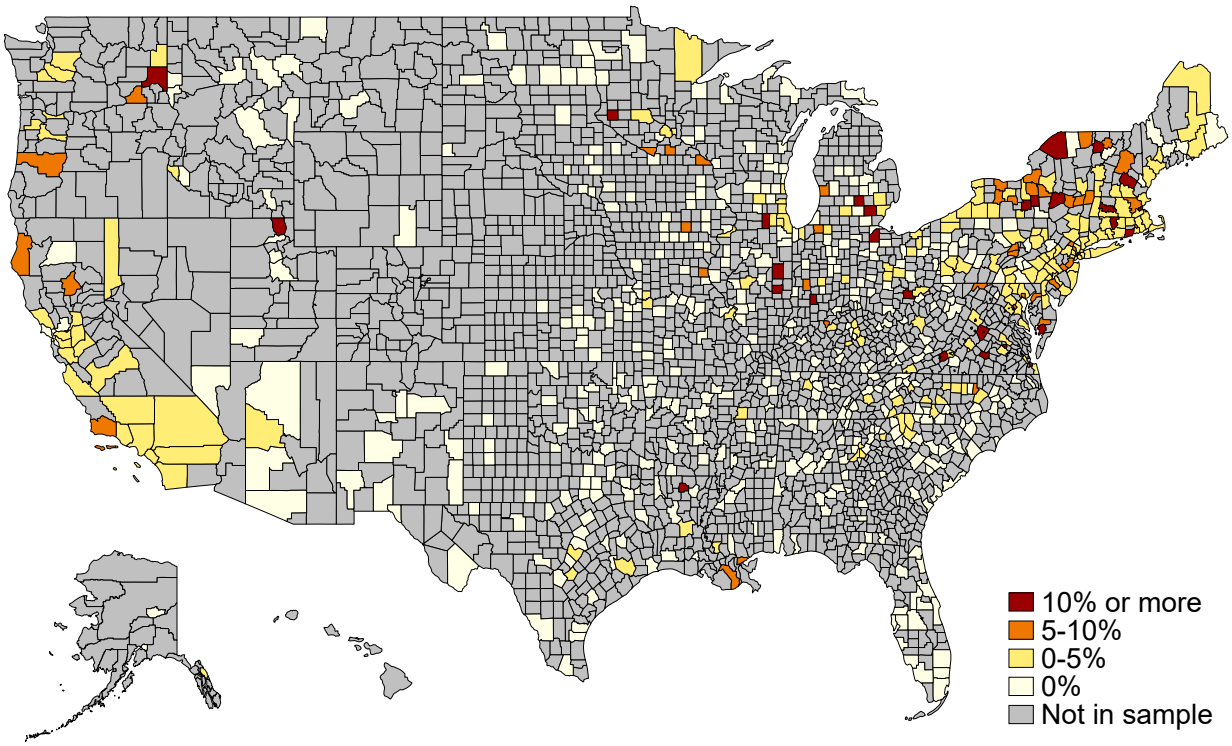
Note: This county-level map shows whether the county has a four-year college in the sample, and whether any of these colleges had a vaccine mandate. Counties with incomplete or inconsistent vaccination data are excluded. In the analysis, states that have no counties with vaccine mandates are excluded as well.

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



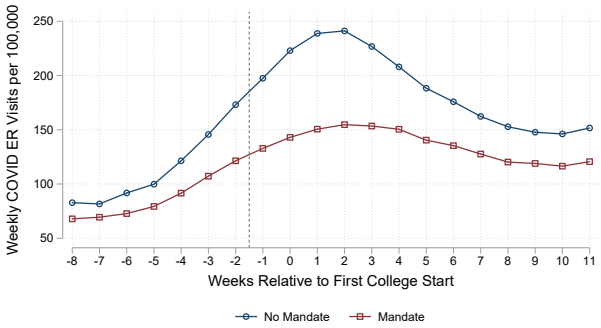
Note: This county-level map shows the proportion of four-year students covered by a mandate in each county. Counties that do not have four-year colleges and counties with incomplete or inconsistent vaccine data are excluded. In analysis, we also exclude the states that have no colleges with mandates.

Figure A.3: Mandate-Covered Students as Share of Total Population

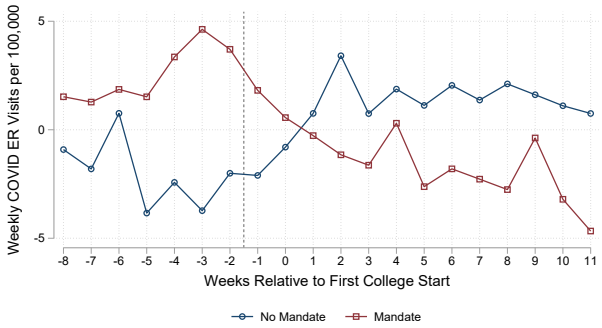


Note: This county-level map shows the four-year students covered by a mandate as a fraction of population in each county. Counties that do not have four-year colleges and counties with incomplete or inconsistent vaccine data are excluded. In analysis, we also exclude the states that have no colleges with mandates.

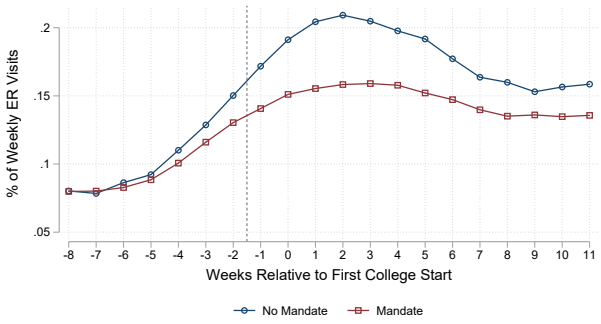
Figure A.4: Additional Health Outcome Measures, Raw and Residualized



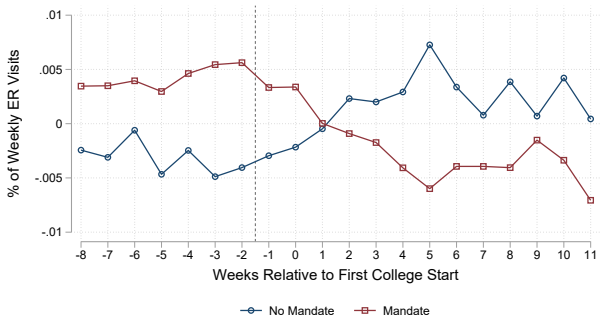
(a) ER Visits



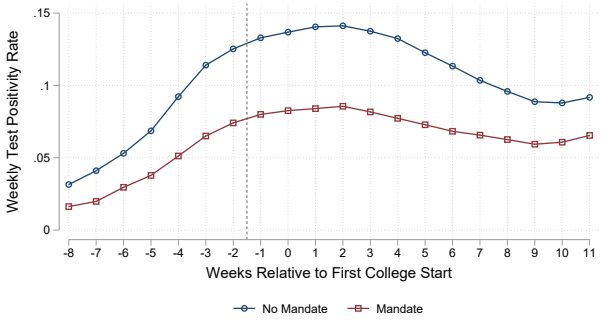
(b) ER Visits Residuals



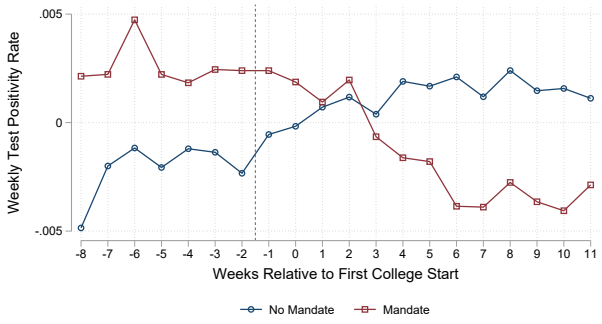
(c) % ER Visits COVID



(d) % ER Visits COVID Residuals



(e) Positivity Rate

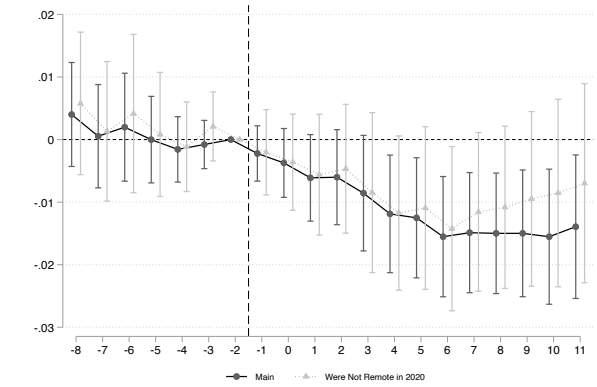


(f) Positivity Rate Residuals

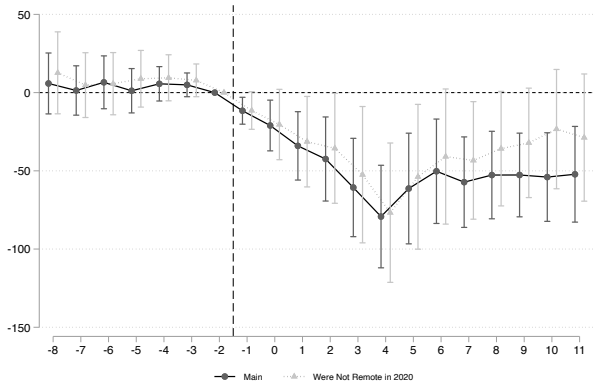
Note: These figures show raw COVID-19 outcome measures at the county level and the residuals from a regression of the COVID-19 outcome measures on county and week fixed effects, week-by-region fixed effects, and week-by-baseline vax rate fixed effects. The levels for college counties with (without) a mandate are given by the square (circular) markers. Subfigures (a) and (b) show the raw and residualized number of COVID-Related ER visits. Subfigures (c) and (d) show the raw and residualized weekly share of ER visits related to COVID. Subfigures (e) and (f) show the raw and residualized weekly COVID Test Positivity Rate.

Figure A.5: 2021 Event Studies on Colleges That Opened In Person in 2020

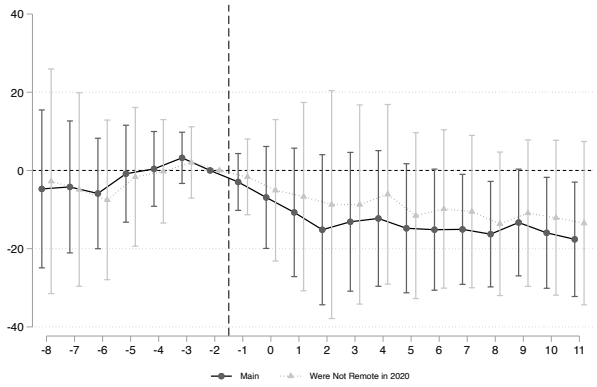
(a) Positivity Rate



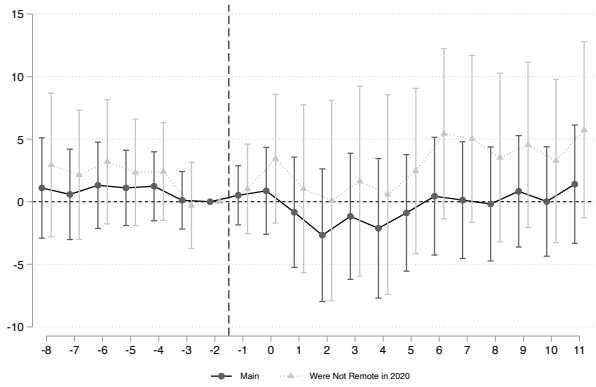
(b) Cases



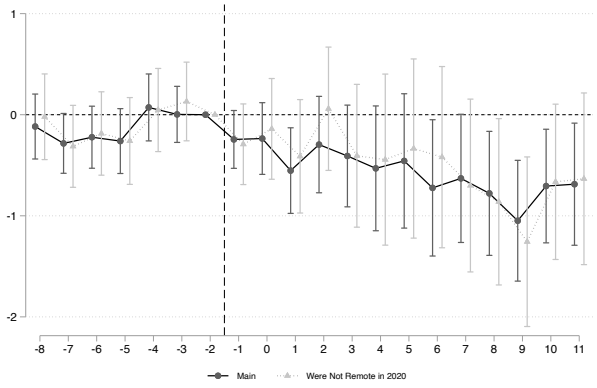
(c) ER Visits



(d) Hospitalizations



(e) Deaths



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

Table A.1: Event Study Estimates

	Cases (1)	**Positivity (2)**	**Doctor Visits (3)**	**ER Visits (4)**	**% ER Visits (5)**	**Hosp. (6)**	**Deaths (7)**	**Vax Rate (8)**
Pre: 8	5.849	0.004	-0.090	-4.722	-0.005	1.100	-0.117	-0.003*
	(9.912)	(0.004)	(0.057)	(10.277)	(0.006)	(2.040)	(0.164)	(0.002)
Pre: 7	1.356	0.001	-0.100*	-4.214	-0.004	0.586	-0.284*	-0.003**
	(8.032)	(0.004)	(0.051)	(8.588)	(0.005)	(1.838)	(0.151)	(0.001)
Pre: 6	6.577	0.002	-0.102**	-5.885	-0.006	1.316	-0.223	-0.002**
	(8.603)	(0.004)	(0.046)	(7.190)	(0.004)	(1.753)	(0.156)	(0.001)
Pre: 5	1.188	-0.000	-0.085**	-0.835	-0.003	1.107	-0.261	-0.001**
	(7.217)	(0.004)	(0.042)	(6.312)	(0.004)	(1.529)	(0.163)	(0.001)
Pre: 4	5.616	-0.002	-0.050	0.394	-0.003	1.237	0.072	-0.001
	(5.594)	(0.003)	(0.037)	(4.866)	(0.003)	(1.402)	(0.169)	(0.001)
Pre: 3	4.961	-0.001	-0.008	3.220	0.001	0.119	0.003	-0.000
	(3.865)	(0.002)	(0.027)	(3.334)	(0.003)	(1.169)	(0.141)	(0.000)
Post: 0	-21.033**	-0.004	-0.069	-6.904	-0.007*	0.872	-0.236	-0.000
	(8.254)	(0.003)	(0.050)	(6.636)	(0.004)	(1.766)	(0.181)	(0.000)
Post: 1	-34.048***	-0.006*	-0.140**	-10.722	-0.014***	-0.837	-0.553**	-0.001
	(11.123)	(0.004)	(0.062)	(8.361)	(0.005)	(2.245)	(0.216)	(0.001)
Post: 2	-42.438***	-0.006	-0.127	-15.163	-0.020***	-2.676	-0.295	-0.001
	(13.684)	(0.004)	(0.082)	(9.767)	(0.005)	(2.698)	(0.243)	(0.001)
Post: 3	-60.657***	-0.009*	-0.117	-13.127	-0.022***	-1.167	-0.408	-0.002*
	(16.003)	(0.005)	(0.091)	(9.033)	(0.006)	(2.565)	(0.256)	(0.001)
Post: 4	-79.222***	-0.012**	-0.188**	-12.275	-0.027***	-2.123	-0.531*	-0.003*
	(16.689)	(0.005)	(0.091)	(8.829)	(0.009)	(2.838)	(0.314)	(0.002)
Post: 5	-61.310***	-0.013**	-0.170*	-14.785*	-0.034**	-0.888	-0.457	-0.003*
	(18.012)	(0.005)	(0.087)	(8.400)	(0.013)	(2.370)	(0.338)	(0.002)
Post: 6	-50.273***	-0.016***	-0.124	-15.143*	-0.027***	0.443	-0.724**	-0.002
	(16.990)	(0.005)	(0.081)	(7.879)	(0.009)	(2.396)	(0.343)	(0.002)
Post: 7	-57.243***	-0.015***	-0.129	-15.065**	-0.024***	0.130	-0.630*	-0.002
	(14.728)	(0.005)	(0.079)	(7.163)	(0.006)	(2.373)	(0.323)	(0.002)
Post: 8	-52.691***	-0.015***	-0.170***	-16.287**	-0.027***	-0.176	-0.778**	-0.002
	(14.242)	(0.005)	(0.062)	(6.866)	(0.006)	(2.321)	(0.312)	(0.002)
Post: 9	-52.656***	-0.015***	-0.190***	-13.311*	-0.021***	0.833	-1.049***	-0.004
	(13.619)	(0.005)	(0.063)	(6.948)	(0.006)	(2.266)	(0.304)	(0.002)
Post: 10	-53.983***	-0.016***	-0.183***	-15.946**	-0.027***	0.017	-0.706**	-0.002
	(14.417)	(0.005)	(0.066)	(7.219)	(0.006)	(2.226)	(0.286)	(0.003)
Post: 11	-52.197***	-0.014**	-0.140*	-17.610**	-0.027***	1.404	-0.687**	-0.001
	(15.577)	(0.006)	(0.075)	(7.443)	(0.007)	(2.405)	(0.308)	(0.003)
Constant	203.030***	0.089***	1.033***	143.053***	0.141***	27.424***	2.063***	0.522***
	(9.628)	(0.003)	(0.062)	(8.117)	(0.004)	(2.148)	(0.155)	(0.001)
Obs.	11,814	11,672	11,514	11,291	11,266	11,291	11,814	11,814
R^2	0.743	0.799	0.735	0.865	0.816	0.728	0.567	0.992

Note: This table shows the event study estimates that correspond to those shown in Figure 3. The rows are labeled by the number of weeks pre- or post-semester start. The estimates are relative to non-mandate college counties. All regressions include county and week fixed effects, week-by-region fixed effects, and week-by-baseline vaccination rate fixed effects. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table A.2: Distribution of Effects with One State Left Out

Outcome	**max**	**p75**	**p50**	**p25**	**min**
Cases	-546.991	-602.789	-624.013	-635.871	-699.85
	(130.284)	(133.902)	(133.095)	(133.972)	(133.866)
Hospitalizations	3.017	-2.053	-2.855	-4.071	-22.207
	(23.402)	(23.295)	(22.775)	(23.168)	(20.979)
ER Visits	-128.4	-160.569	-167.858	-173.447	-194.066
	(73.882)	(79.602)	(78.638)	(79.522)	(80.167)
Deaths	-6.224	-7.026	-7.276	-7.594	-8.307
	(2.48)	(2.466)	(2.458)	(2.515)	(2.489)
Vaccination Rate	-.011	-.021	-.023	-.025	-.035
	(.017)	(.017)	(.017)	(.018)	(.017)

Note: The table shows percentiles from the distribution of estimated effects using our main specification but leaving out one state from the analysis at a time. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$