# The Effect of COVID-19 Restrictions During the Delta Wave

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**Abstract**

The rapid spread of the Delta variant of COVID-19 and the variation in the reinstatement of COVID restrictions offer insight into the effect of these restrictions on the spread of COVID. Specifically, I explore whether states with strict mask mandates[2] experienced lower case rates than states without strict mask mandates, even when controlling for individual states' populations and vaccination rates over time. I find that there is a significant negative relationship between having a strict mask mandate during the Delta wave and case rates during the Delta wave.

**Keywords:** COVID-19, restrictions, mask mandate

**JEL Codes:** I12, I18, P16

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[2] I define "strict mask mandates" as mask mandates that require mask indoors in all public places, both public and private.

# 1 Introduction

It has become common to hear different news outlets, politicians, and Twitter-trained epidemiologists proclaim that "State X has more COVID cases than state Y! Clearly, state X must be doing something wrong!" While this may in fact be true, a more careful analysis is necessary to avoid making spurious claims. Most previous analyses of COVID-19 related restrictions and their effect on case rates use data from early to mid-2020 and thus cannot offer much insight into case trends in 2021 due to the high rates of vaccination across the U.S. In this paper, I analyze trends in COVID-19 cases from February to November 2021 on both the state and county levels, controlling for vaccination rates. I find that, prior to the Delta wave, most areas were experiencing relatively similar vaccination-adjusted case rates. Once the Delta variant became the predominant strain of COVID-19 in the U.S., several states reinstated universal mask mandates while several other states moved in the opposite direction by imposing bans on mask mandates. I find that during the Delta wave, areas with strict mask mandates saw significantly lower case rates than would be expected based on these states' own populations and vaccination rates.

Section 2 discusses the the sources and limitations of my data. Section 3 discusses my empirical methodology. Section 4 is an analysis of the data. Section 5 concludes.

# 2 Data

## 2.1 Data Sources

Most of the data for this paper originally came from the U.S. Census Bureau or the U.S. Centers for Disease Control and Prevention (CDC). However, I used secondary sources for COVID data and for demographic data due to the data being pre-formatted and relatively easy to use. COVID case data on the county level is from the New York Times' publicly available database on GitHub. [1] Population data for both states and counties is from the U.S. Census Bureau. [2] State and county level demographic data is originally from the U.S. Census Bureau, but the county-level data was compiled by the CORGIS data project and is publicly available on GitHub.[3] [3] State-level vaccination data is from Our World in Data, which compiles data from many sources, including the CDC and state health agencies.[4] County-level vaccination data

[3]Only the 50 U.S. states and the District of Columbia were included in the final dataset. Incomplete data on U.S. territories prevented me from including them in my analysis.

came directly from the CDC.[4][5] Mask usage data on the county level is from The New York Times, based on roughly 250,000 interviews conducted by Dynata from July 2 to July 14, 2020 and is publicly available on GitHub.[6]

### 2.2 Data Limitations

There are several clear limitations to my data. First, the case data only accounts for positive tests, thus undercounting of COVID cases in particular regions cannot be measured. However, it may be the case that states/counties with more relaxed COVID restrictions also tend to have lower COVID testing rates. If this is the case, my results are likely a lower bound on the true difference in case rates between states with more and less restrictions. Second, my data on mask usage is based on survey results from summer 2020, thus I have to make the assumption that mask usage in 2020 is strongly correlated with mask usage in 2021. While this assumption may not hold perfectly, I will show that analyzing case trends based on mask usage generates interesting results.

## 3 Empirical Methodology

I use the following model to generate predicted case rates for each state:

$$\hat{casesper1000}_{it} = \hat{\beta}_0 + \hat{\beta}_1 \%vaccinated_{it} + \hat{\beta}_2 state_i + \hat{\beta}_3 date_t$$

Then, I use the following model to generate a standard difference-in-differences estimator:

$$casesper1000_{it} - \hat{casesper1000}_{it} = \hat{\delta}_0 + \hat{\delta}_1 highrestriction_i + \hat{\delta}_2 delta + \hat{\delta}_3 highrestriction * delta$$

Where the variables are defined as follows:

$casesper1000_{it}$ = cumulative COVID cases per 1000 residents of state i at time t

$\%vaccinated_{it}$ = the percentage of state i's population that is fully vaccinated at time t

$state_i$ = a variable that generates state-level fixed effects

$date_t$ = takes the value 1 on February 1, 2021, 2 on February 2, 2021, and so on.[5]

[4]Some counties did not have recorded vaccination data, so these counties were dropped from the dataset.

[5]In the final model, quadratic and cubic time trends are added to account for nonlinear trends in case rates.

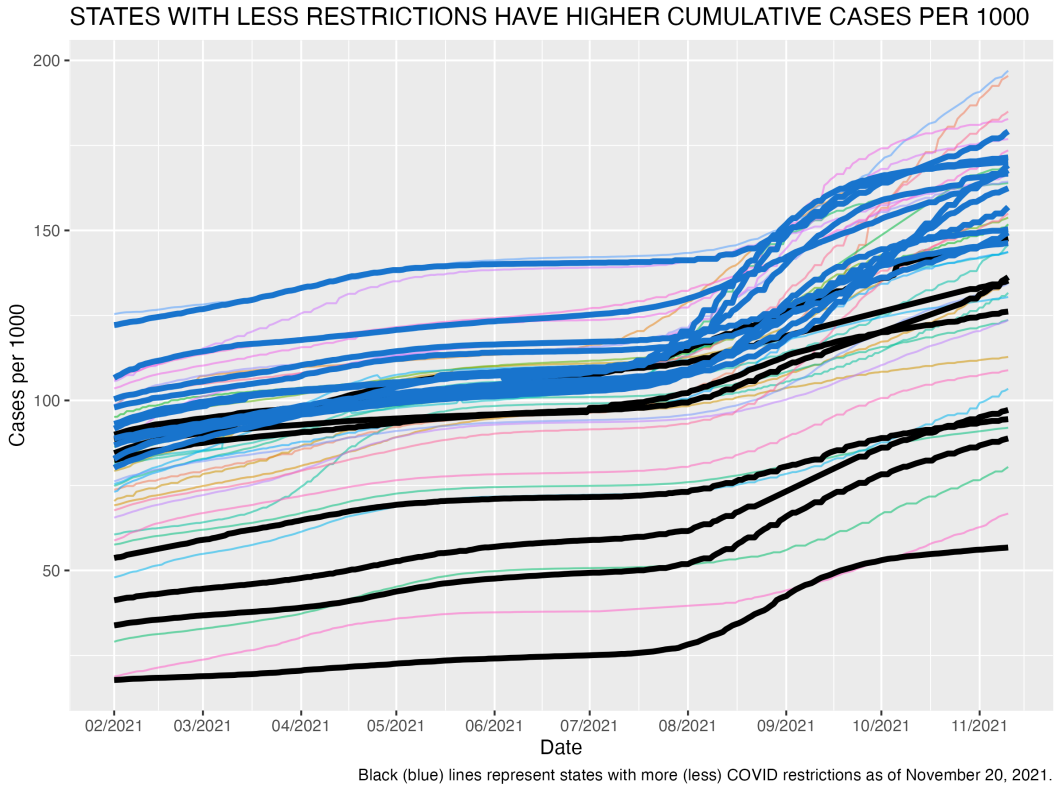
$highrestriction_i$ = takes the value 1 if state i has a universal mask mandate, 0 otherwise [6]

$delta$ = takes the value 1 during the Delta wave, 0 otherwise[7]

# 4 Analysis

First, we should take an exploratory look at the raw data. Figure 1 plots cumulative cases per 1000 people by state. For ease of interpretation, I have highlighted states with relatively high restrictions (ie. universal mask mandates) in black and several states with relatively low restrictions in blue. Note that the states with low restrictions generally have higher cases per 1000 people than states with high restrictions.

**Figure 1**

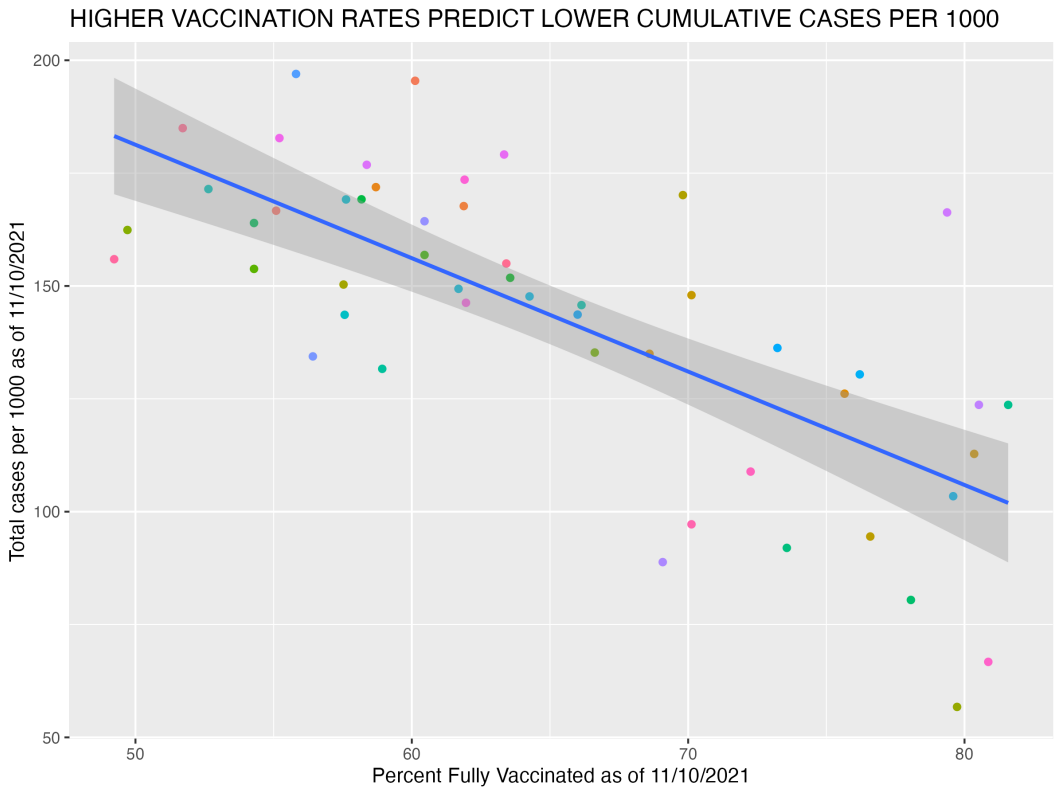



[6]Data on mask mandates is from the AARP and is available at https://www.aarp.org/health/healthy-living/info-2020/states-mask-mandates-coronavirus.html

[7]I define the "Delta wave" as beginning on August 3, 2021, which is approximately 1 week after the CDC announced new mask wearing guidelines that encouraged mask wearing in areas of high or substantial transmission of COVID.

However, it would be problematic to not include the effect of vaccination rates on case rates in each state. As shown in Figure 2, where each point represents a state and the data is taken at one point in time (November 10, 2021), there is a negative correlation between vaccination rates and case rates. This correlation is significant, as I show in Table 1.[8]

## Figure 2



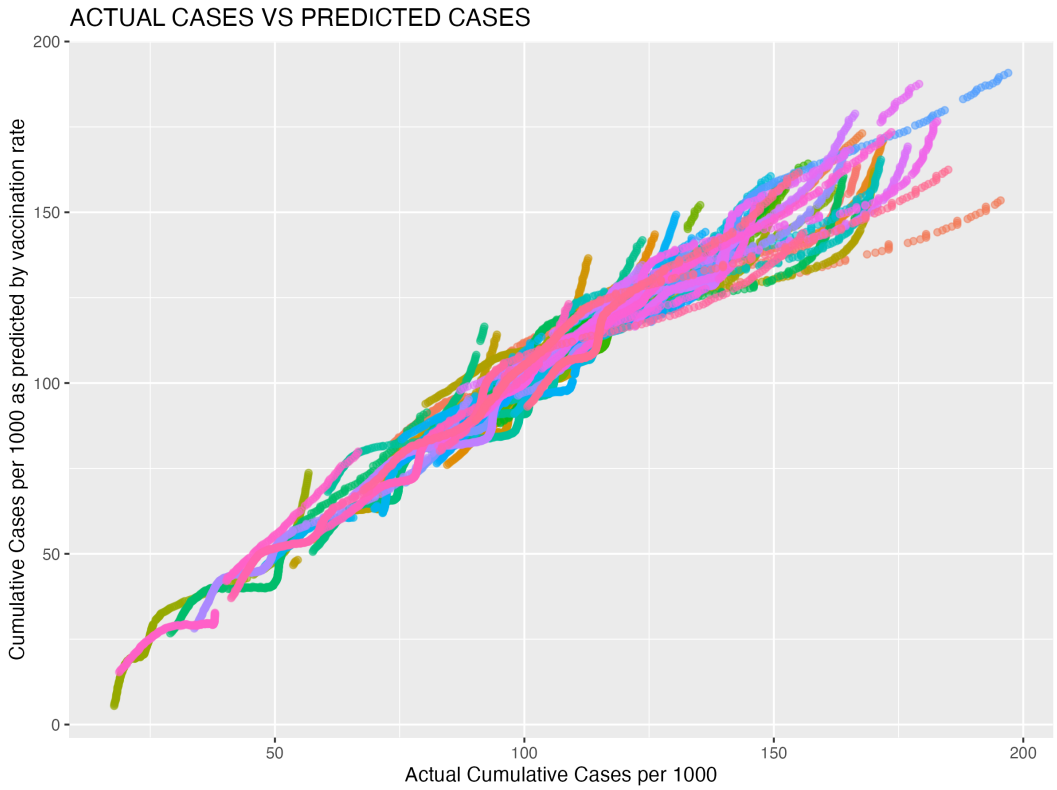

Thus, I used the following model to control for the effects of vaccination rates on case rates over time:

$$\hat{cases per 1000}_{it} = \hat{\beta}_0 + \hat{\beta}_1 \%vaccinated_{it} + \hat{\beta}_2 state_i + \hat{\beta}_3 date + \hat{\beta}_4 date^2 + \hat{\beta}_5 date^3$$

[8] All Tables are printed in Section 7: Tables

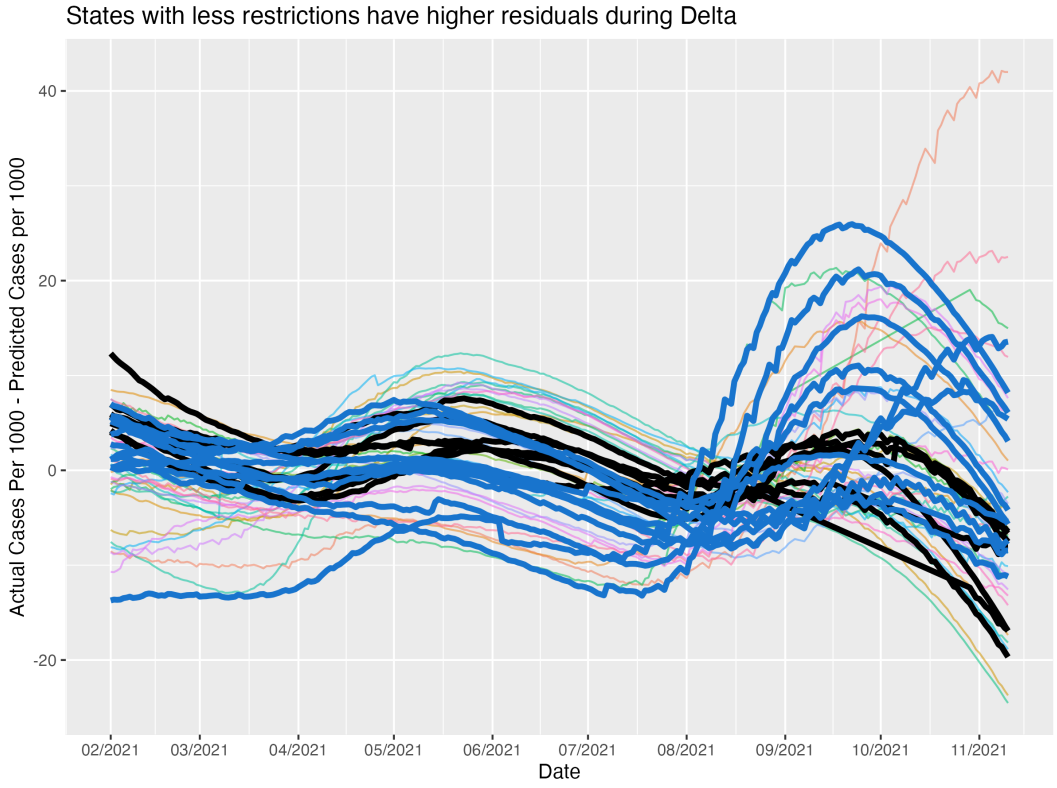
Once I ran the model that generates the predicted cumulative cases per 1000 people in each state, I plotted the actual cases per 1000 against the cases per 1000 as predicted by vaccination rates. As shown in Figure 3, where each state's case rates are a different color, there is a very strong correlation between the actual case rates and the predicted case rates. In other words, vaccination rates are a strong predictor of case rates. Note, however, that vaccines do not perfectly predict case rates - there is variation in the model's residuals, and I will be exploiting this variation to show that states with high restrictions have significantly less cases during the Delta wave than predicted by these states' own vaccination rates.

## Figure 3



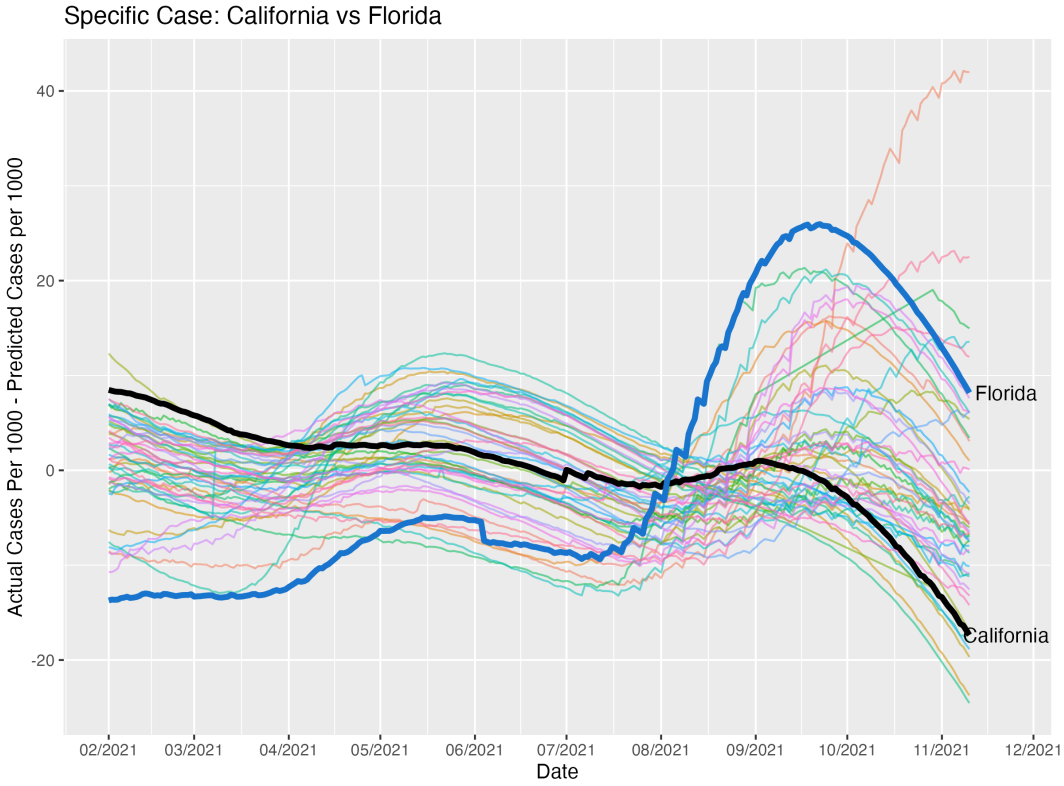
To more clearly show the between-state differences in the variation in case rates that is explained by variation in vaccination rates, I plotted the residuals (variation in cases per 1000 over time not explained by variation in vaccination rates) for each state in Figure 4. The states highlighted in blue have very few COVID restrictions while the states highlighted in black have strict mask mandates. Figure 4 shows that, on average, it appears that states with strict mask mandates have less cases per 1000 than states with less restrictions, even after accounting for variation in vaccination rates between states over time.

## Figure 4



Although Figure 4 tells an interesting story, it may be useful to zoom in and take a look at two specific states that have frequently been used as examples of how to handle COVID restrictions: California and Florida. As shown in Figure 5, Florida has significantly more cases during the Delta wave that cannot be explained by vaccination rates when compared to California. Thus, it must not be the case that, for instance, Florida experienced higher case rates than California because of differences in vaccination rates between the two states.

## Figure 5

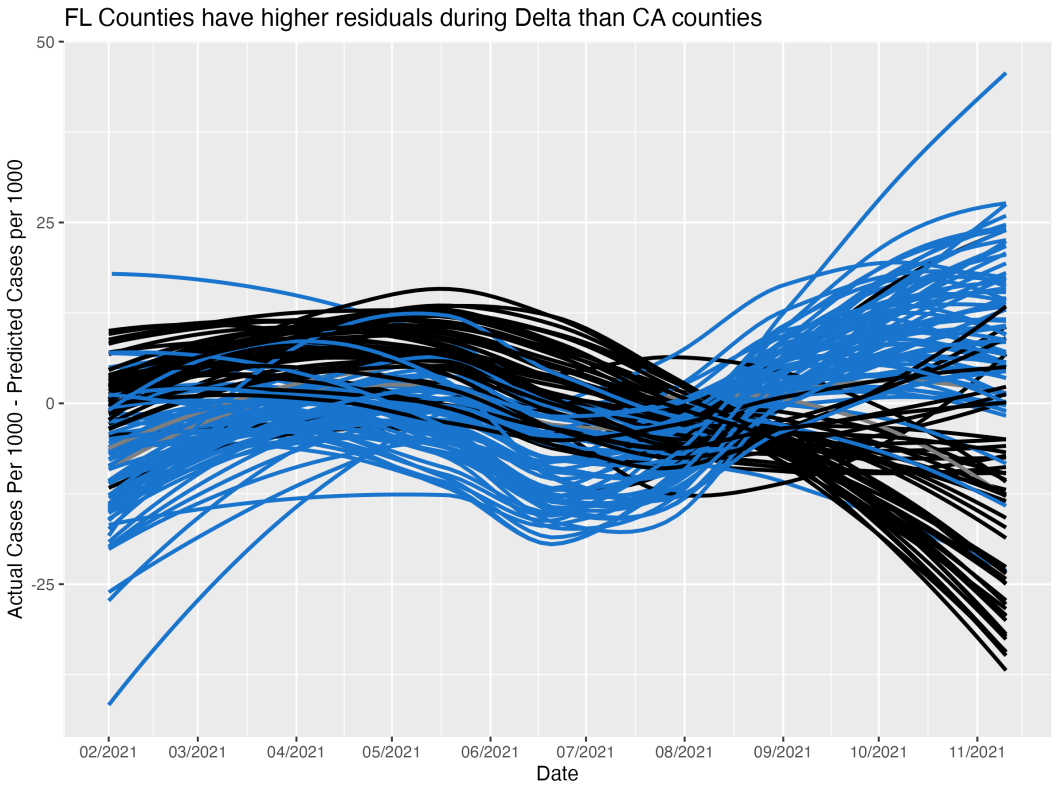



However, Florida and California are vastly different states, so I decided to perform the same type of analysis I performed on the state level (control for vaccination rates and serial correlation, plot the residuals) on the county level for both California and Florida. The model I used is below:

$$\hat{cases per 1000}_{it} = \hat{\beta}_0 + \hat{\beta}_1 \%vaccinated_{it} + \hat{\beta}_2 county_i + \hat{\beta}_3 date + \hat{\beta}_4 date^2 + \hat{\beta}_5 date^3$$

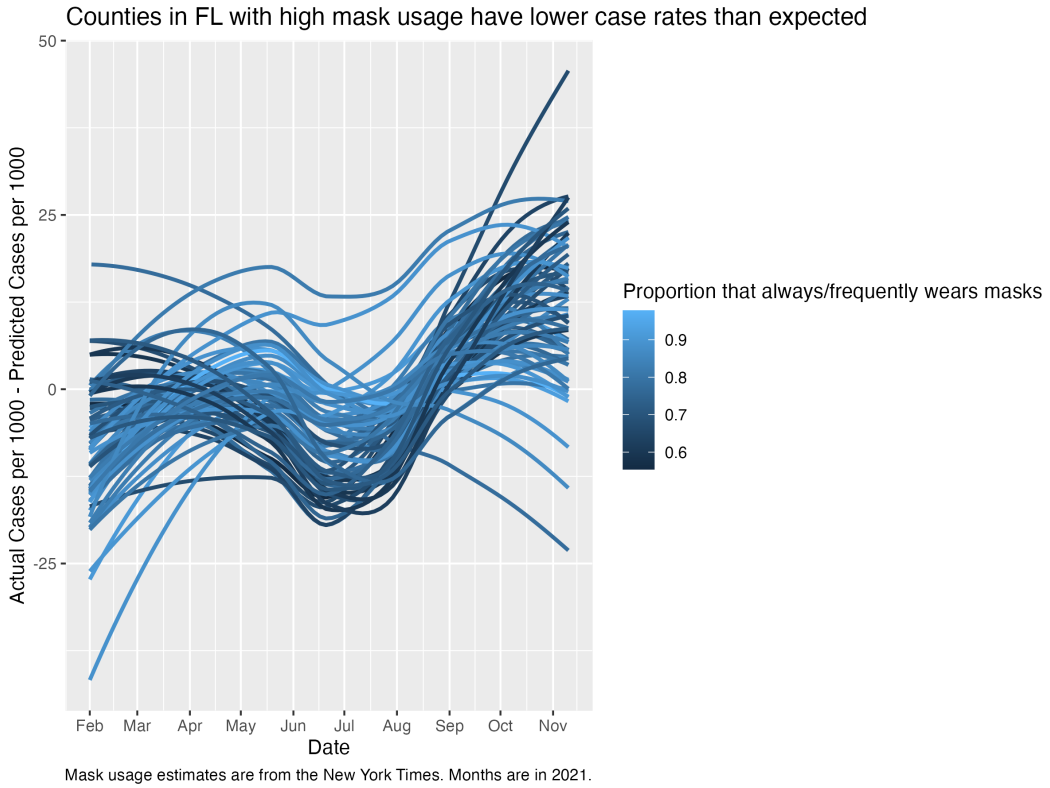
Figure 6 is very similar to Figure 4, but plots the variation in case rates that cannot be explained by vaccination rates for each county in California and each county in Florida rather than for entire states. Florida's counties are represented by blue lines and California's counties are represented by black lines. Given the significant variation in population demographics between the counties in these two large states, it is striking that nearly every county in Florida saw higher case rates than expected during the Delta wave and nearly every county in California saw lower case rates than expected.

## Figure 6



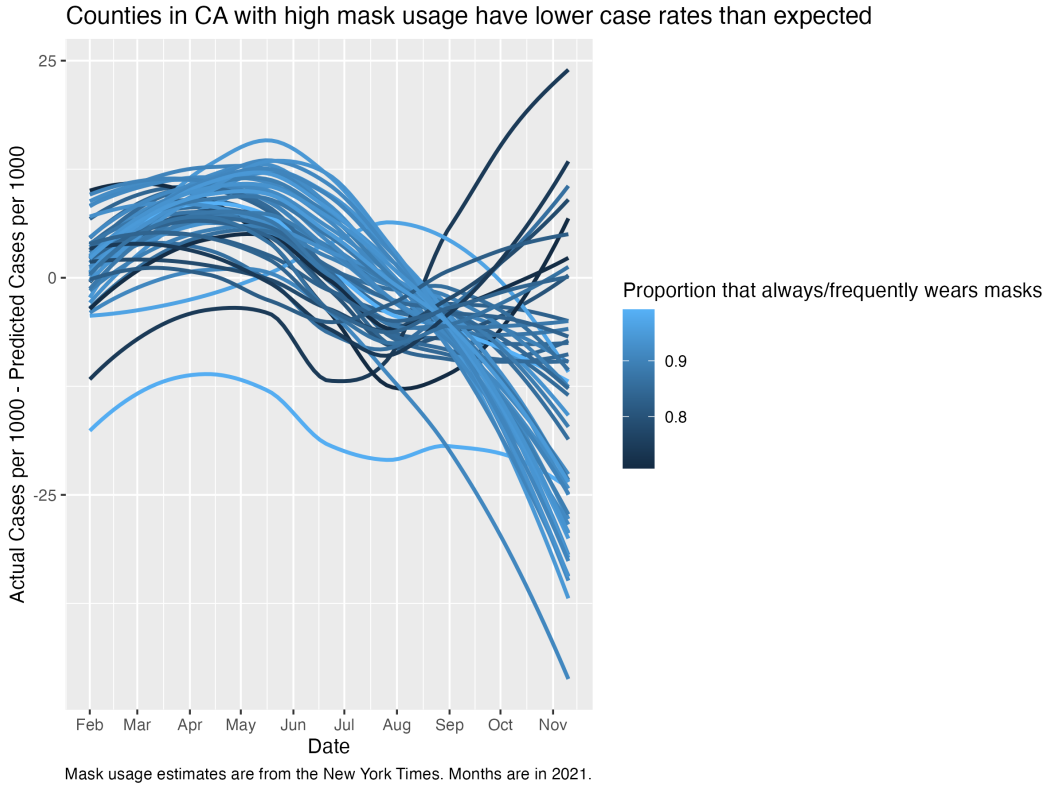
Finally, I used data from summer 2020 on mask usage to plot the residuals for all counties in California and in Florida by mask usage. Clearly, it is a significant extrapolation to assume that mask usage in summer 2020 is correlated with mask usage in 2021, but as I show below, the data produces some interesting results. Figure 7 plots the residuals for each county in Florida, where higher proportions of people that always or frequently wear masks in public are denoted by lighter colored lines. Figure 8 does the same, but for all counties in California. As Figure 7 shows, almost all counties in Florida experienced higher than expected case rates during the Delta wave, regardless of mask usage. The counties with lower rates of mask usage (darker lines) experienced the highest case rates, and the only counties that experienced lower than expected case rates had relatively high mask usage rates (lighter lines).

## Figure 7



As Figure 8 shows, most of the counties in California experienced lower than expected case rates during the Delta wave. However, the difference in case rates based on mask usage in California is striking. The only counties in California that experienced higher than expected case rates during the Delta wave were counties with relatively low mask usage (darker lines). Additionally, the only counties in California that experienced lower than expected case rates during the Delta wave were those with relatively high mask usage (lighter lines).

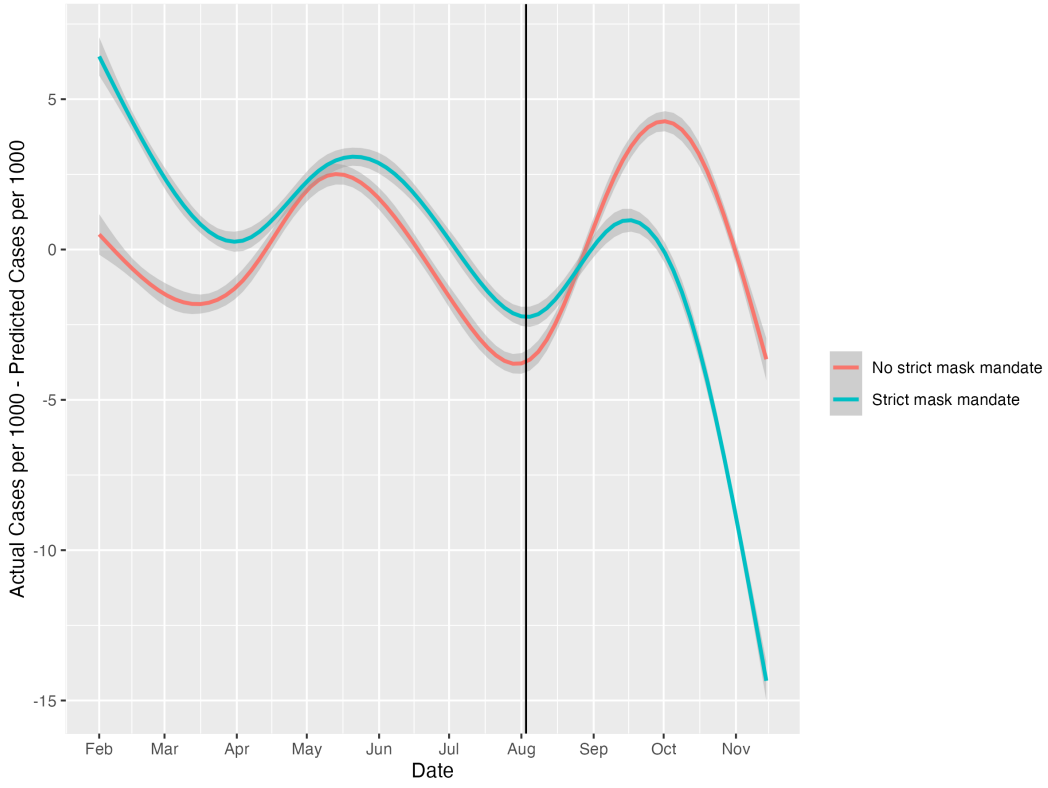
## Figure 8




Although the previous analysis is compelling even without estimating a specific model, I ran difference-in-differences models on both the state level and the county level (for counties in Florida and California). Table 2 shows the results for the state-level model. There is a significant negative correlation between case rates in states with high restrictions during the Delta wave and case rates in states without high restrictions during the Delta wave. Note that, in this analysis, I included all states without high restrictions rather than just the few states highlighted in blue in some of the previous figures.

In Figure 9a, I used loess smoothing to show the difference between actual and predicted cases in high and low restriction states. States with strict mask mandates in place during the Delta wave had a lower peak in case rates and also experienced faster declines in case rates in Fall 2021.

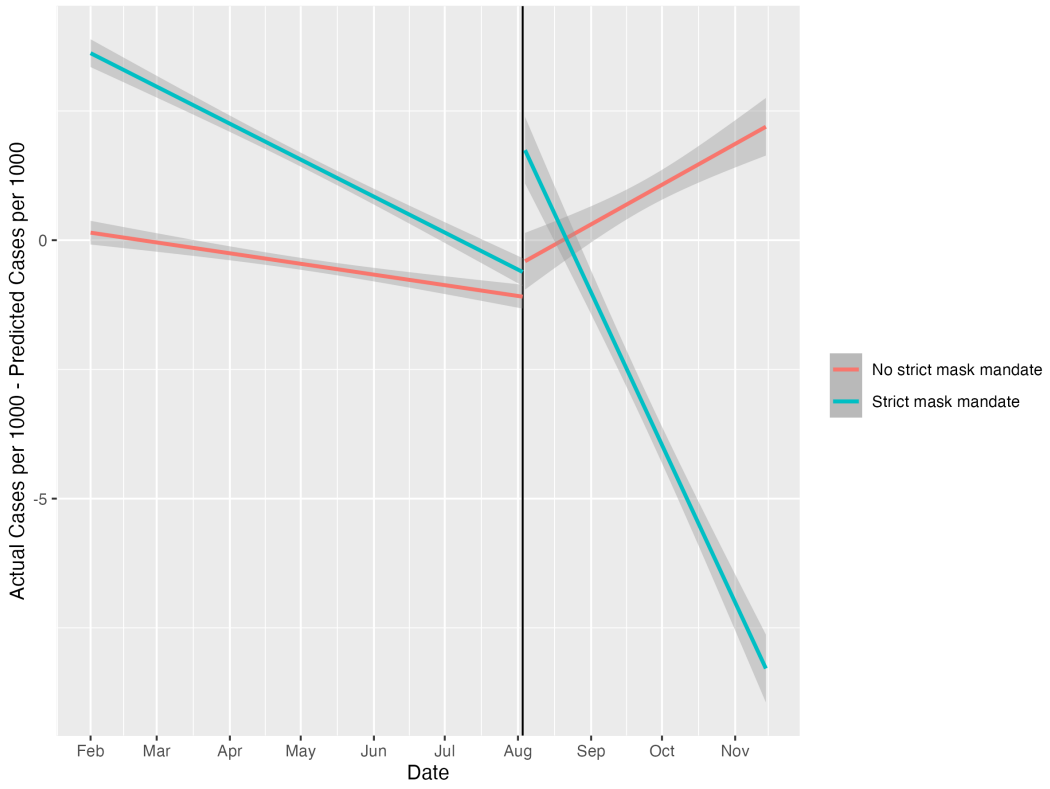
**Figure 9a**




In Figure 9b, I used the same data but rather than using loess smoothing, I regressed the residual case rates on the date variable[9], allowing for a change in the linear trend on August 3, 2021, to show the linear trends in states with and without strict mask mandates, both before and during the Delta wave. It appears that the parallel trends assumption does not hold perfectly, thus the difference-in-differences estimator reported in Table 2 is likely an overestimate of the effect of strict mask mandates on case rates during the Delta wave. However, the fact remains that states with strict mask mandates experienced lower than expected case rates (as predicted by vaccination rates over time) while states without strict mask mandates experienced higher than expected case rates.

[9]The model is: $casesper1000_{it} - \hat{casesper1000}_{it} = \gamma_0 + \gamma_1 date + \gamma_2 delta$, where delta equals one after August 3, 2021.

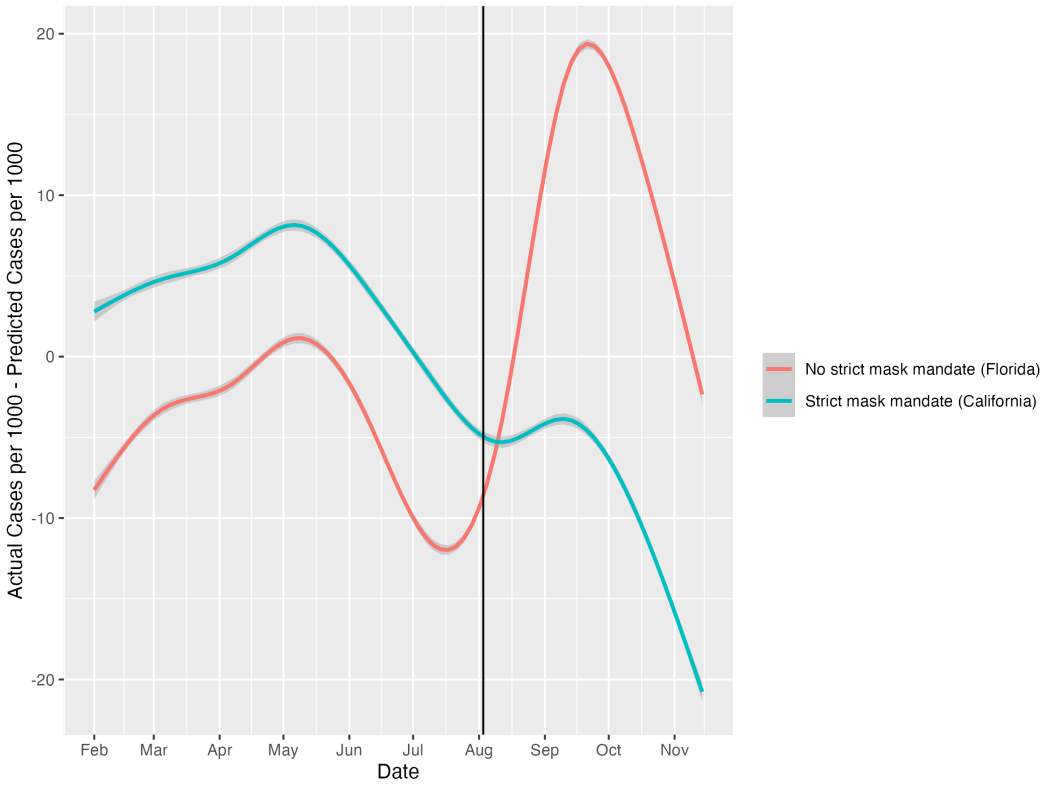
## Figure 9b




If we perform the same analysis as above but with the counties in California and in Florida, the difference-in-differences estimator is shown in Table 3. The difference-in-differences estimator is significantly negative, implying that California's strict mask mandate may have caused California to have lower case rates than expected during the Delta wave.

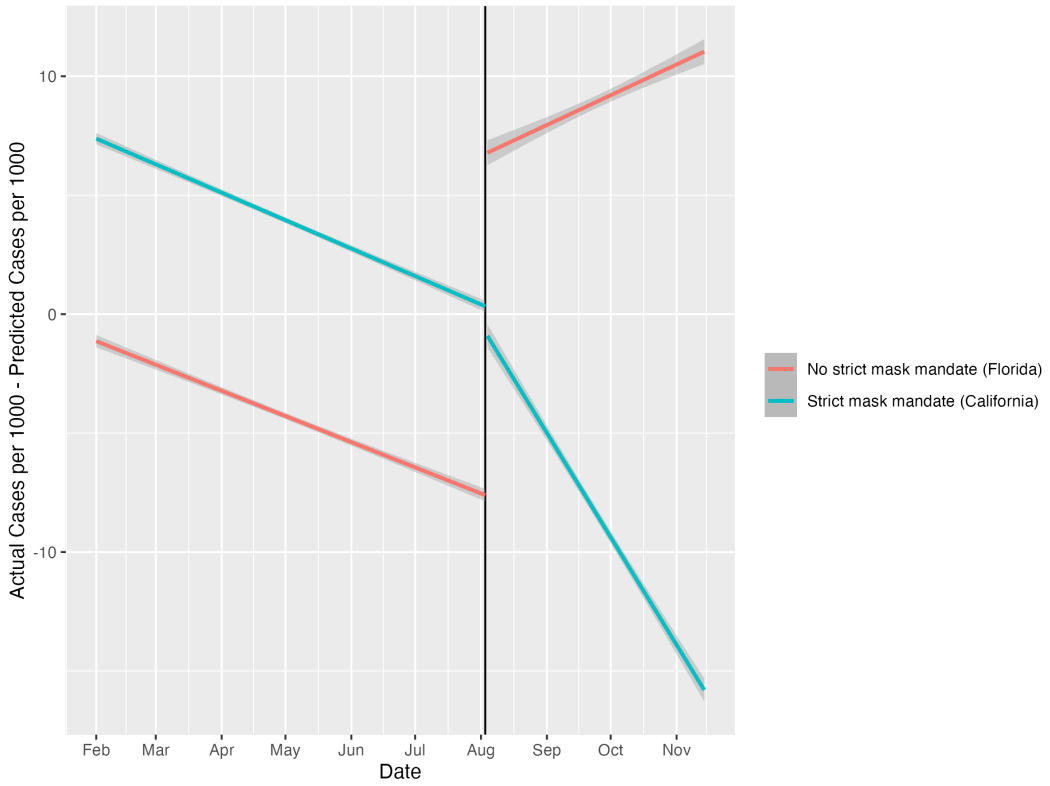
In Figure 10a, I used loess smoothing to show the difference between actual and predicted cases in the counties in California and in Florida. Before the Delta wave hit, the trends appear to be close to parallel. Once the Delta wave hit, Florida clearly experienced much higher case rates than expected based on its own vaccination rates. When comparing Florida's case rates to California's case rates, it is abundantly clear that Florida experienced significantly more cases than expected when compared to California during the Delta wave.

## Figure 10a



In Figure 10b, I used the same data but rather than using loess smoothing, I regressed residual case rates on the date variable to show the linear trends in California and Florida both before and during the Delta wave. I find it striking that when using this linear model, Florida and California had almost perfectly parallel trends in cases not explained by vaccinations or by serial correlation. After the Delta wave hit, Florida experienced a large spike in case rates while California experienced a significant decrease in case rates. Although this linear model cannot fully capture the variation in case rates between all of the counties in Florida and California, it is clear that the states had parallel trends before the Delta wave hit and very different trends after the Delta wave hit. This gives credibility to the supposition that California's strict COVID restrictions caused California to experience lower case rates during the Delta wave when compared to Florida.

## Figure 10b



# 5 Conclusion

States with strict mask mandates experienced lower case rates during the Delta wave, even when controlling for individual states' populations and vaccination rates over time. There is some evidence that, even in states without strict mask mandates, counties with high mask usage experienced higher than expected case rates during the Delta wave. Thus, it appears to be the case that mask mandates were effective in decreasing the rates of transmission of COVID during the Delta wave. However, this association does not hold for each and every state and county, thus there are likely other factors that have significant influences on COVID case rates in different places and times. Future research may include an analysis of the mechanisms by which mask mandates (and other COVID restrictions) affect the behavior of people and why some areas without strict mandates experienced low case rates even during the Delta wave.

# 6 References


[1] *Coronavirus (covid-19) data in the united states, 2021*, 2021. [Online]. Available: https://github.com/nytimes/covid-19-data.

[2] *County population totals: 2010-2019*, Oct. 2021. [Online]. Available: https://www.census.gov/data/datasets/time-series/demo/popest/2010s-counties-total.html#par_textimage_70769902.

[3] R. Whitcomb, J. Min Choi, and B. Guan, *County demographics*. [Online]. Available: https://corgis-edu.github.io/corgis/csv/county_demographics/.

[4] E. Mathieu, H. Ritchie, and E. Ortiz-Ospina, *A global database of covid-19 vaccinations*. 2021. [Online]. Available: https://github.com/owid/covid-19-data/tree/master/public/data.

[5] *Covid-19 vaccinations in the united states, county*. [Online]. Available: https://data.cdc.gov/Vaccinations/COVID-19-Vaccinations-in-the-United-States-County/8xkx-amqh.

[6] *Mask-wearing survey data*, Jul. 2020. [Online]. Available: https://github.com/nytimes/covid-19-data/blob/master/mask-use/README.md.

# 7 Tables

TABLE I: Higher Vaccination rates predict lower cumulative cases per 1000

| | Cases per 1000 |
|---|---|
| (Intercept) | 306.906*** |
| | (22.870) |
| Percent Vaccinated | −2.512*** |
| | (0.347) |
| Num.Obs. | 50 |
| R2 | 0.521 |
| R2 Adj. | 0.511 |
| F | 52.297 |

+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

TABLE II: States with high restrictions experienced lower than expected case rates during the Delta wave

| | Actual Cases - Predicted Cases |
|---|---|
| (Intercept) | −0.452*** |
| | (0.074) |
| highrestrictionsTRUE | 1.976*** |
| | (0.187) |
| deltawaveTRUE | 1.284*** |
| | (0.125) |
| highrestrictionsTRUE × deltawaveTRUE | −6.008*** |
| | (0.327) |
| Num.Obs. | 13 529 |
| R2 | 0.025 |
| R2 Adj. | 0.025 |
| F | 116.407 |

+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

TABLE III: States with high restrictions experienced lower than expected case rates during the Delta wave

| | Actual Cases - Predicted Cases |
|---|---|
| (Intercept) | −4.342*** |
| | (0.078) |
| highrestrictionsTRUE | 8.246*** |
| | (0.119) |
| deltawaveTRUE | 13.096*** |
| | (0.129) |
| highrestrictionsTRUE × deltawaveTRUE | −25.393*** |
| | (0.198) |
| Num.Obs. | 33 702 |
| R2 | 0.337 |
| R2 Adj. | 0.337 |
| F | 5713.417 |

+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001