# School Opening Associated with Significantly Lower Test-Adjusted COVID-19 Case Rates in Children — United States, August to December 2021

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**ABSTRACT**

Objective: To estimate the relationship between school openings and transmission of SARS-COV-2 among children, while accounting for potential confounders including community case rates, mitigations in schools, and rates of testing among schoolchildren.

Design: Cross-sectional analysis of all U.S. school districts in the Fall of 2021, from three weeks prior until 12 weeks after school opening.

Setting: Observational study of U.S. school districts with K-12 in-person attendance. Data are aggregated to the county-level.

Participants: All 3104 U.S. counties were eligible for the study. Of these, 2592 counties met the criteria for complete data on school opening dates, case rates, vaccination rates and demographic information.

Interventions: Weeks prior to, or following school openings; community case rates, mitigation measures, testing rates and demographic characteristics.

Main Outcome Measures: Per-capita rates of pediatric cases of Covid-19.

Results: School openings were associated with a rise in cases among children relative to adults, with a peak of 39.3 [37.7,40.9] additional cases per 100,000 per week. However, children were tested at higher rates when schools were in session. After adjusting for testing rates, case rates among children were significantly lower after schools reopened by 4.7 cases per 100,000 compared with rates over summer break. After three weeks of in-person schooling, cases were lower by 10.6 [3.9,17.6] cases per 100,000 compared with when schools were closed.

Conclusions: The results reconcile the apparent contradiction between prior studies from the U.S. versus other countries. The seeming positive correlation between schools and transmission rates is explained by higher rates of testing schoolchildren. The results are inconsistent with a causal effect of in-person schools on increased case rates and raise the question of whether pandemic-era school closures may have been counter-productive.

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**Key Messages**

**What is already known on this topic:**

There is conflicting evidence regarding the effect of schools on transmission of Covid-19 among children. Many prior studies are subject to both selection bias and confounding due to lack of data on testing in schools and infection rates in the community.

**What this study adds:**

This study uses both spatial and temporal variation in school openings, exploiting the fact that schools across the U.S. open at different dates after the summer break. It uses new data to show that children are disproportionately tested for Covid-19 when schools are in session, which will cause an over-estimate of the effect of schools on case rates.

**How this study might affect research, practice or policy**

Once testing rates are accounted for, school openings are associated with lower rates of Covid-19 among children, suggesting that pandemic-era school closures may have been unnecessary and even counter-productive.

## I INTRODUCTION

The effect of in-person school on SARS-CoV-2 transmission and COVID-19 case rates in the United States has been heavily debated, although establishing causal effects is fraught with challenges.

Estimating whether schools contribute to transmission requires confronting at least three statistical obstacles. First, different areas closed schools at different times, at least partly in response to community case rates [1]. This makes it difficult to disentangle the causal effects of school closures on rates of transmission. Second, schools may have opened at times that coincided with community waves, thus creating a spurious impression that the former caused the latter. Third, measured case rates depend heavily on the extent of testing, but the availability and take-up of tests varied across age groups, regions, and time. Testing was also found to correlate with political attitudes, which may have driven other pandemic responses [2].

We address these challenges using three novel approaches. First, rather than relying purely on spatial variation across areas that opened or closed schools, we focus on the Fall of 2021 when schools in all 50 U.S. states opened for regular in-person learning after the summer. This allows us to exploit both spatial and temporal variation in the opening of schools, as opening dates did not depend on case rates but rather on long-standing school calendars. For example, schools in the South typically open many weeks before schools in the Northeast, which provides exogenous variation in the timing of school openings.

Second, we employ restricted data from the Centers for Disease Control (CDC) to directly control for community case rates, which alleviates confounding. Specifically, we estimate rates of infections in children controlling for rates in adults, to examine whether school openings were associated with disproportionately greater case rates in children. Therefore, even if school opening coincided with a local wave of cases, this will be accounted for by our measure of community transmission.

Third, although systematic nationwide data on testing by age group do not exist, some states and local governments do provide this information. We obtained data from four jurisdictions on age-stratified Covid-19 testing rates and demonstrate a sharp increase in the rates of testing school-aged children when schools reopened. This is likely to have been an important confounder in previous studies of the relationship between schools and case rates [3,4,5,6]. We use these data to adjust our estimates of the effect of school openings on transmission.

Past research provides some evidence that schools did not cause increased cases, based on studies from Australia [7,8], Germany [9,10], Ireland [11], Japan [12], Brazil [13], the Nordic countries [14,15,16] and in meta-analyses [17,18].

The U.S. provides an excellent setting to examine this question, as most school policies are set at either the state or local level, thus providing at least 50 jurisdictions across which to compare interventions and outcomes. By contrast, in many other countries, school opening decisions during the pandemic were made at the national level.

Within the U.S., most prior studies suggest that schools may have contributed to increased transmission [3,4,5,6], which contrasts with the international evidence discussed above, although other U.S. studies find no clear relationship [19,20]. All these prior studies examine the 2020-21 school year, comparing areas with closed versus open schools. However, the decision to close schools was endogenous, occurring in conjunction with other pandemic related interventions and driven by community case rates as well as political attitudes. Indeed, as Bravata et al [3] note, "[C]omparing COVID-19 cases between reopened and non-reopened schools…is likely to lead to biased results." Additionally, most prior studies do not separate out pediatric and adult cases. Finally, none of these studies considers that testing rates can be an important confounder. If children are tested for Covid-19 at higher rates when schools are in session, this will cause an over-estimate of the association between schools and case rates.

## II METHODS

We examined school districts across the United States that opened in the Fall of 2021, following the summer break. Our study period was August 1 to December 15, 2021, which we chose for two reasons. Primarily, it was the first time during the Covid-19 pandemic that schools across the country opened according to their regular schedule, which had been disrupted during the 2020-21 school year. Had we examined the 2020-21 school year instead, as done by all prior U.S. studies described above, the results would have been confounded by certain states or districts choosing to close in response to case rates, especially as the CDC discouraged opening schools during periods of high transmission [1]. We end the study period on December 15, because the Winter of 2021-22 had very high cases due to the Omicron wave. This caused a shortage of testing in some areas [21] —which would have understated case counts—and further disrupted schools in January 2022.

### Data and Sample

We study K-12 school districts in the U.S. We obtain county-level data on Covid-19 cases from the Restricted Case Dataset provided by the Centers for Disease Control (CDC). We obtain dates of school opening from the data provider MCH, which has been used in similar studies in the past [22,23]. Of the 3104 counties in the United States, we obtained complete data from 2592 counties, which contain over 86% of the U.S. population.

The Supplementary File contains additional details on data sources and sample construction.

**Statistical Analysis**

We estimate linear regressions of pediatric Covid-19 cases per capita in each county and week, on adult cases per capita in the same county and week. We include a large set of control variables to account for cross-sectional heterogeneity; further details are in the Supplementary File.

We exploit the temporal variation in school opening dates across the United States by including fixed-effects for each week prior to, or following, school opening. In each county we define Week 0 as the week of school opening, with Week -1 the week prior and so on. The data range from three weeks prior to school opening until twelve weeks following it, for a total of 16 weeks in each county.

These estimated school-week fixed-effects represent our main result as they measure pediatric infections per capita in the corresponding school-week, holding constant all other covariates, including adult infections, demographic characteristics, vaccination rates, and other potentially unobserved factors that are constant within each state. We normalize to zero the fixed-effect for three weeks prior to opening. Therefore, all coefficients should be interpreted as the increase in pediatric case rates relative to adult case rates, for the corresponding school-week relative to three weeks prior to the start of school.

The Supplementary File contains more details on the empirical specification.

**Testing**

An important potential confounder is that rates of testing children may be correlated with school opening. Policies such as "Test-to-stay" required automatic testing of children in a classroom with a known case of Covid-19; guidelines required a minimum of two tests per child [24]. Additionally, some families may have voluntarily tested their school-age children, even without such requirements. Both these factors would have caused children to be tested at higher rates, relative to adults, once schools reopened after the summer vacation. This higher rate of testing would have likely mechanically increased reported cases even if schools were not the source of exposures.

There is no source that provides data on age-stratified testing for the entire country. We obtained data from four jurisdictions: the states of New York, Florida and Georgia, and the city of Chicago. All of these report testing rates and confirmed cases based on laboratory reports, separately for various age categories. The Supplementary File provides data definitions, sources, and the full list of jurisdictions that were searched. We use these data to examine whether testing rates rose in children after schools opened, and then adjust the regression estimates to account for the different rates of testing when schools reopened.

### Mitigations in Schools

Another potential confounder may have been variation in public health interventions to mitigate transmission, that may also have been correlated with school opening dates. Some prior studies suggest that such interventions may reduce transmission rates in schools [25,26,27]. To account for this, we control for school mask mandates in the statistical analysis. We are not aware of any data source with information on other interventions, such as ventilation improvements, cohorting, daily screening or smaller class sizes. However, mask mandates should be a good proxy for other public health interventions, as areas which mandated masks in schools also tended to introduce other interventions [22].

## III RESULTS

**Figure 1** presents aggregate results for the entire country. The figure plots school-week fixed effects, and the associated 95% confidence interval, normalizing the value for three weeks prior to opening to zero. **Figure 1** suggests that case rates rise in the period surrounding the opening of school, peak in the second week after school opening, but then decline steadily in successive weeks. At the peak, there are an average of 39.3 [37.7,40.9] additional cases per 100,000 children, compared to the rate three weeks prior to school opening.

**Figure 2** stratifies the aggregate result for each of the four Census regions in the United States. The national pattern is replicated in all four regions of the country, with cases rising around the start of school, peaking around week 2, and then generally declining.

**Figure 3** stratifies the aggregate data from Figure 1 by whether school districts implemented mask mandates. It shows that case rates decline after the first two weeks of school in both groups of counties with no discernible relationship between case rates and school mask requirements.

**Figures A1 to A4** in the Supplementary File contain various robustness exercises. These include using the ratio of pediatric to adult cases as the dependent variable, and further stratifying the country into the nine Census divisions. The pattern of results shown thus far is repeated in these additional tests.

**Figure 4** presents data on cases and testing for the four jurisdictions for which we obtained age-stratified testing data. The dashed black line in each sub-plot corresponds to the median week of school opening in each jurisdiction. This ranges from week 31 (August 2) in Georgia to week 36 (September 6) in New York.

**Figure 4** suggests: (i) reported pediatric cases, relative to the total population, closely track the relative rates of pediatric testing and (ii) rates of pediatric testing, relative to the total population, were generally flat in the weeks leading up to school opening, but then rose considerably after schools opened. Together, these two facts suggest that, following school opening, the clear increase in reported cases in children relative to adults may have been mechanically driven by increased testing rates. **Figure 4** also reports that the correlation between rates of testing and cases in children, relative to the total population, is over 90% in all four jurisdictions.

**Table 1** illustrates the pattern of increased testing cases in children following school opening. For each jurisdiction we calculate the average fraction in children of both tests and cases, separately for 6-week periods prior to and following the start of school. The proportion of tests done in children rises by an average of 10% (from 12 to 22%) between these periods, and the proportion of cases rises by 8% (15 to 23%).

**Figure 5** incorporates the temporal variation in testing rates, to adjust for reported cases of Covid-19 in school-aged children. The blue and red curves plot week fixed-effects from regressions with and without controlling for age-stratified testing rates, respectively. Both curves have similar shapes, but the blue curve is considerably lower, with a peak in week 1 of just 19 additional cases per 100,000 children, as opposed to a peak of 35 in the red curve. The blue curve also stabilizes at a level that is not just below that of the red curve, but also significantly below zero ($p$<0.01 for all coefficients except week 12).

We calculate that, once rates of testing are properly adjusted for, case rates among schoolchildren are lower, by 10.65 [3.9, 17.6] cases per 100,000 students, after three weeks of school, than they were prior to schools opening. When comparing all weeks that schools were open, we calculate that rates were lower by 4.7 cases per 100,000 ($p$<0.01) than in the summer before schools opened.

Regardless of controlling for testing rates, we do observe a brief rise in pediatric cases around the start of school (**Figures 1,2,3,5**). The Supplementary File discusses possible reasons for this pattern.

## IV DISCUSSION

Our study shows that school openings coincided with an initial rise in recorded pediatric cases of Covid-19, relative to adult cases in the community. However, once testing rates are adjusted for, COVID-19 case rates among children were significantly lower after around three weeks of schools being in session than during the summer break.

Our findings of zero or even inverse correlation of school opening with COVID-19 transmission among children are consistent with multiple international studies [7,8,9,10,11,12,13,14,15,16]. However, they are inconsistent with studies from the United States which thus far have not been able to adjust for testing rates [3,4,5,6].

Overall, our results do not support the hypothesis that in-person schooling is responsible for driving infections among children. In all specifications, case rates decline quickly once schools have been open for more than two weeks. We also show that mask mandates do not affect the results, which is consistent with randomized studies on masking [28], and some prior observational studies [22,29].

Our findings raise the question of whether school closures in the United States may in fact have been counterproductive for controlling SARS-CoV-2 spread. This could have been answered by a randomized controlled trial of school closures, as was suggested in Norway [30].

We acknowledge some limitations of our study. First, this study is observational and cannot definitively rule out a link between school openings and increased cases. Nevertheless, a strong causal link is unlikely, given that we account for both spatial and temporal effects, as well for confounders such as testing and non-pharmaceutical interventions.

Second, our results depend on reported cases and rates of testing, both of which are subject to error. For example, our data on testing are based on laboratory tests, and there are no reliable data on home testing rates. Moreover, jurisdictions vary in data reporting practices and definitions of school-age children.

Third, while our analysis of age-stratified testing rates is novel, and addresses an important confounder in past studies, it uses data from just four jurisdictions. Further research is necessary to confirm or refute this finding.

Finally, the data only permit us to examine children aged 0-19, not all of whom are in the K-12 school system, though we note that testing was encouraged or required in daycares and college as well [31,32].

Our study has several strengths and novel features. First, it is the largest observational study to date of the relationship between schools and pediatric Covid-19 cases, encompassing over 86% of the United States population. Second, by exploiting both temporal and spatial variation in school opening dates, it avoids the problem of selection bias in studies that rely only on a spatial comparison of areas that kept schools open or closed.

Third, this is the first study to incorporate age-stratified data on testing, which is likely to be a major confounder in prior studies. We show that rates of testing are strongly correlated with the dates of school opening, suggesting that studies which ignore this variable may over-estimate the effect of schools on case rates.

## Conclusion

School reopening is significantly negatively associated with pediatric COVID-19 case rates compared with community rates once testing was adjusted for. These findings raise questions about whether school closures during the COVID-19 pandemic had any effect on curbing SARS-CoV-2 transmission or may even have been counterproductive for disease mitigation.

Contributors

AC and TH conceptualized the study. AC collected the data, performed the empirical analysis and wrote the first draft. AC and TH jointly conducted the literature review and approved the final manuscript for submission.

Data sharing

The county case data were obtained from the CDC's Restricted Case Dataset and may not be publicly shared. All other data sources are publicly available. Publicly available data, and all codes, are available at https://github.com/ambarishchandra/school-openings

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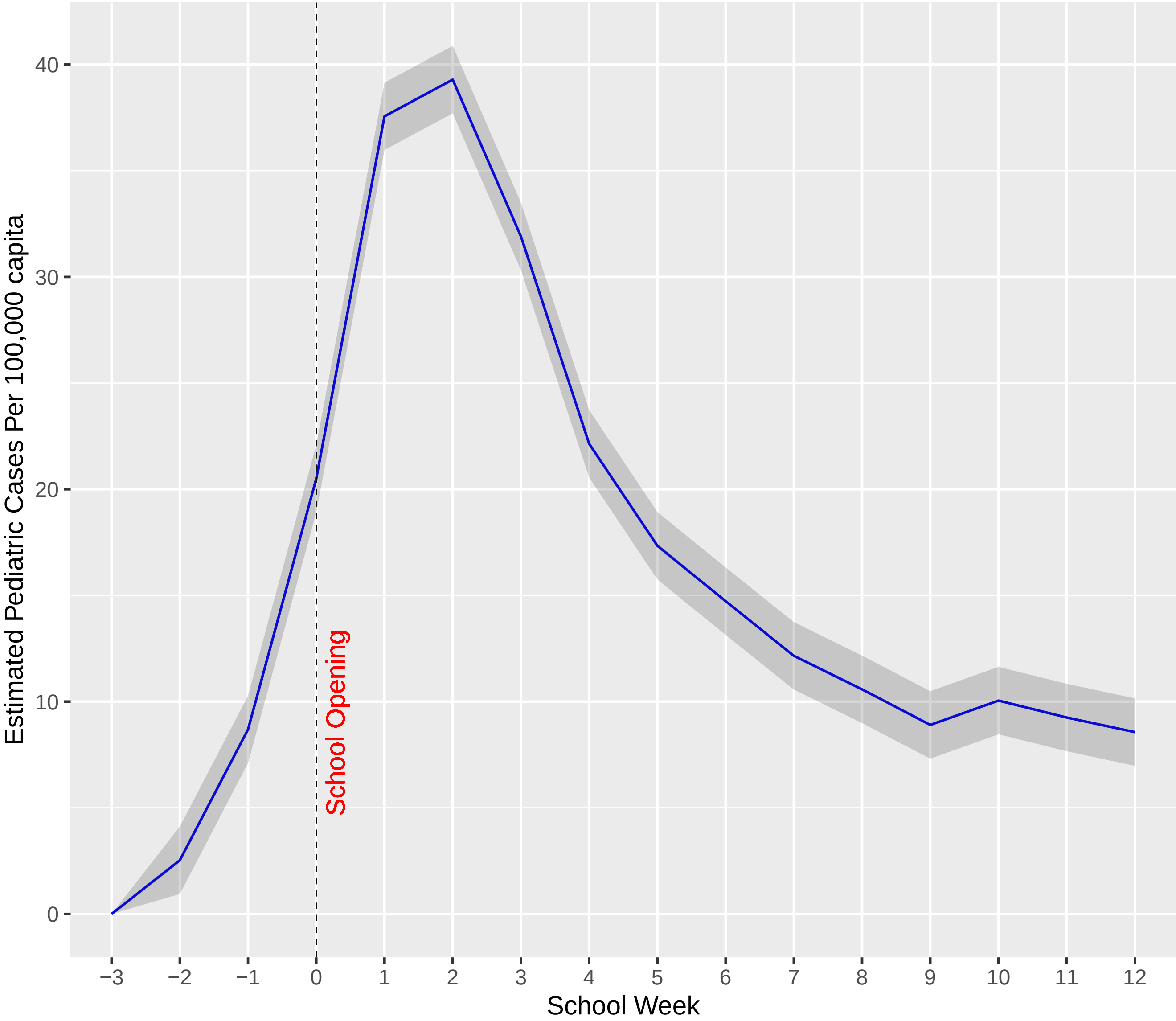
**TABLE 1: Fraction of Cases and Tests in Children, Academic Year 2021-22**

| | Average over Weeks: | | | |
|---|---|---|---|---|
| | -6 to -1 | | 2 to 7 | |
| Fraction in children of: | Tests | Cases | Tests | Cases |
| Chicago | 0.10 | 0.14 | 0.27 | 0.21 |
| New York | 0.14 | 0.17 | 0.21 | 0.23 |
| Georgia | 0.07 | 0.08 | 0.17 | 0.19 |
| Florida | 0.17 | 0.20 | 0.24 | 0.30 |
| Average | 0.12 | 0.15 | 0.22 | 0.23 |

Notes: Values are based on closest possible approximations to school-aged children as a fraction of population totals. Chicago: 0—17; NY: 5—19; GA: 5—17; FL 0—19.

Figure 1: Pediatric cases per capita ages 0−19, from 3 weeks prior to 12 weeks post−academic year start, 2021−22




Note: The graph plots estimated fixed−effects for each school−week from a regression of weekly per−capita pediatric cases of Covid−19. Control variables included: adult cases in the corresponding county and week, pediatric vaccination rates, county−level demographic variables. See text for additional details.

Figure 2: Pediatric case rates per capita ages 0−19, from 3 weeks prior to 12 weeks post−academic year start, 2021−22, stratified by Census Region

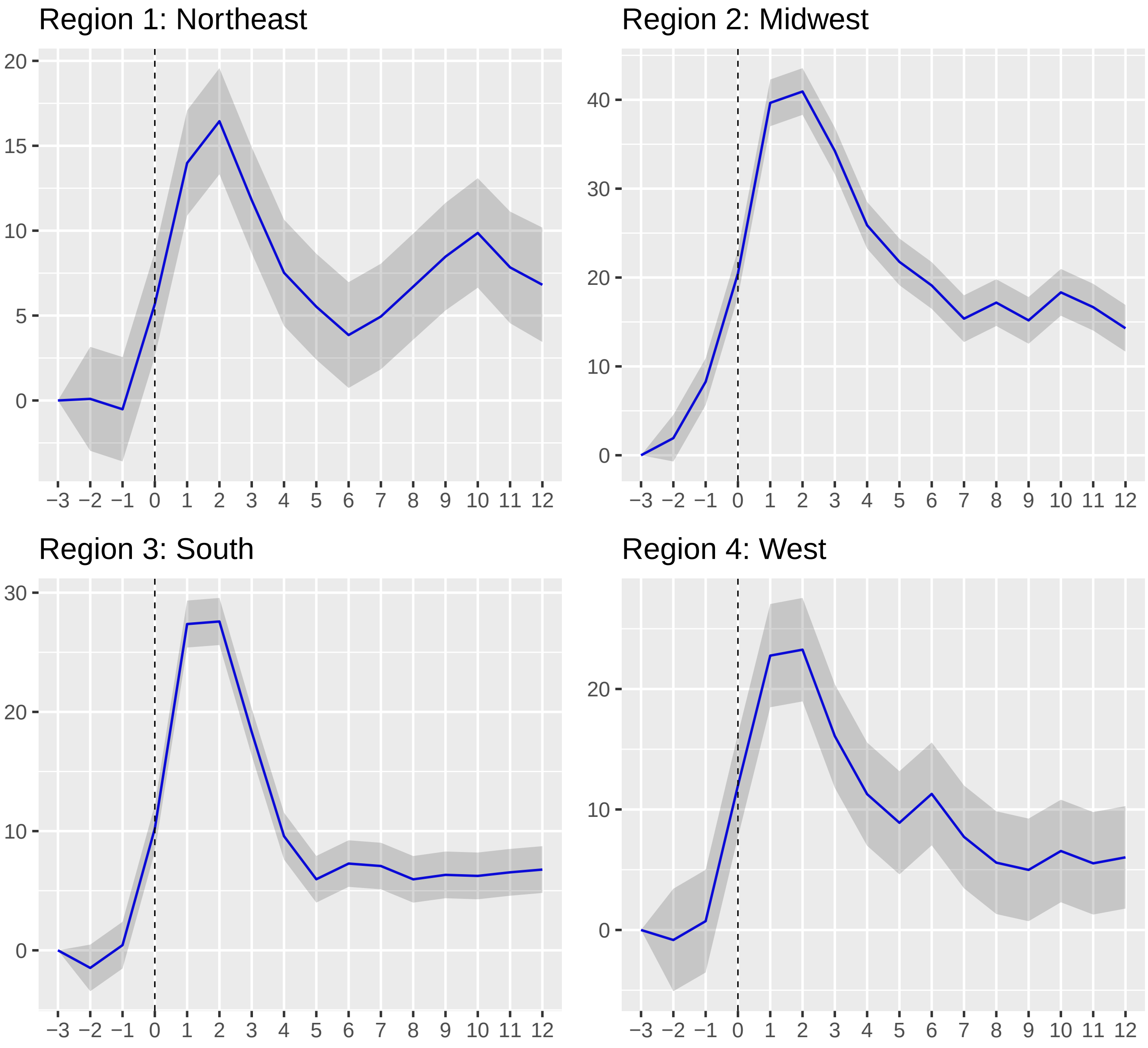
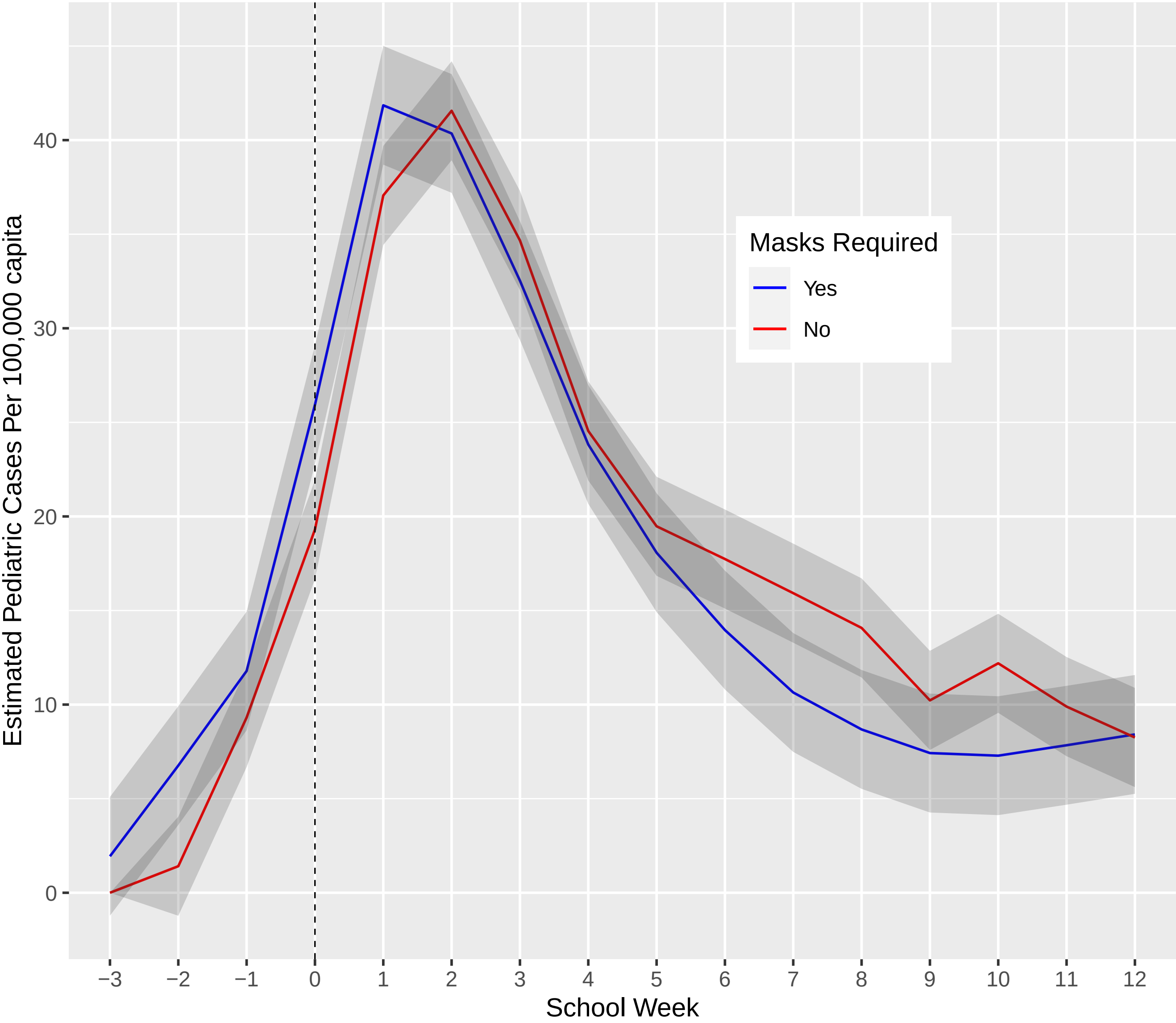
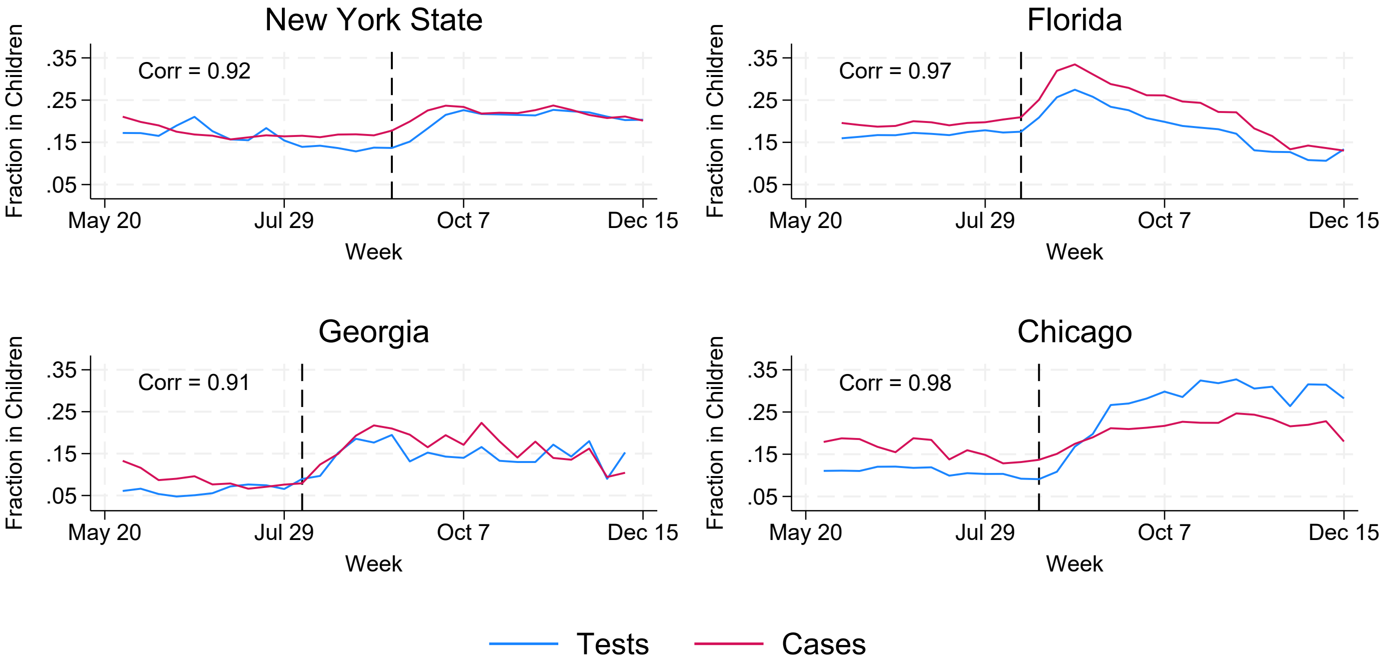


Figure 3: Pediatric case rates per capita ages 0−19, from 3 weeks prior to 12 weeks post−academic year start 2021−22, by county mask mandate status.



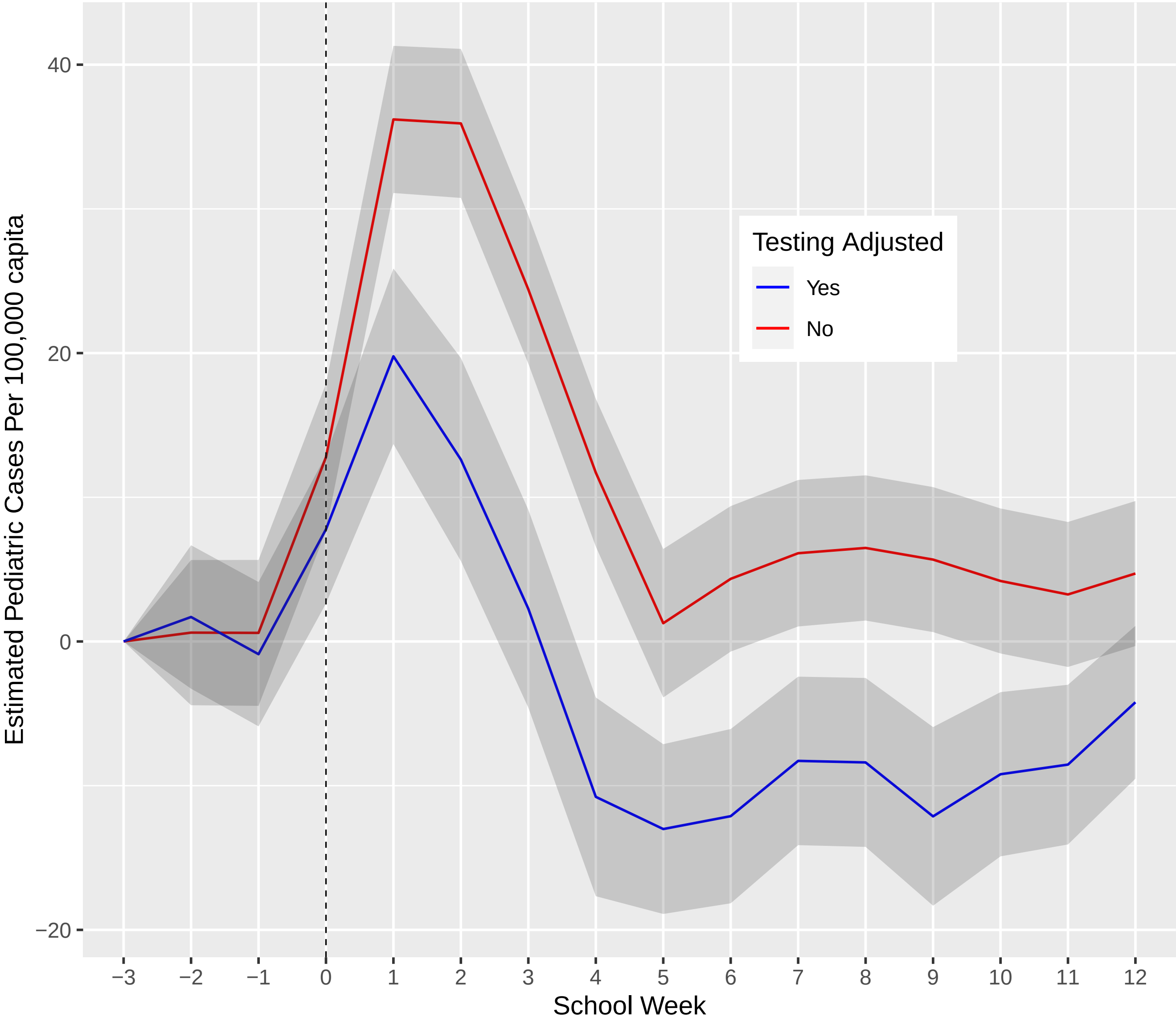

Note: The graph plots estimated fixed−effects for each school−week from a regression of weekly per−capita pediatric cases of Covid−19. Control variables included: adult cases in the corresponding county and week, pediatric vaccination rates, county−level demographic variables. See text for additional details.

Figure 4: Reported Pediatric PCR Positive Tests and Pediatric Testing for four jurisdictions




Notes: The graph plots the share of reported tests and cases in children, as a proportion of the total in the population. Dashed vertical lines denote the median week of school opening in each jurisdiction. Children are defined according to the following age groups: NYS: 5-19; FL: 0-19; GA: 5-17; Chicago: 0-17.

Figure 5: Pediatric cases per capita, ages 0−19, adjusted for testing: Four jurisdictions.




Note: The graph plots estimated fixed−effects for each school−week from a regression of weekly per−capita pediatric cases of Covid−19. Control variables included: adult cases in the corresponding county and week, pediatric vaccination rates, county−level demographic variables. See text for additional details.

# School Opening Associated with Significantly Lower Test-Adjusted COVID-19 Case Rates in Children —United States, August to December 2021: Supplementary File

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This document contains supplementary material that extends some of the results in the main paper. Section 1 provides more details on data sources. Section 2 discusses the main regression specification used in the paper, as well as an alternative, and shows that the results using the alternative are very similar to those presented in the main paper. Section 3 contains tables with the regression results that correspond to the figures shown in the main paper. Section 4 expands on the Discussion section in the paper with some more details regarding the rise in cases around the start of school.

## 1 Additional Details on Data Sources and Sample Construction

All regressions in the paper include the following control variables: median age, race, population density, Social Vulnerability Index, the percent uninsured, the percent in poverty, and the rate of pediatric vaccinations in the county as of October 1, 2021. We add state-level fixed-effects to account for correlations across counties within a state, which would arise from state-level mandates or public health recommendations for schools. In various sensitivity analysis tests, we control for whether school districts required masks, as well as rates of testing among school-aged children in the relevant jurisdiction.

As discussed in the main paper, data on case rates by age group were obtained from the CDC's Restricted Case dataset. School opening dates were obtained from the data provider MCH. We also use data provided by MCH on districts that required mask wearing in schools. This analysis uses a smaller sample of 1832 counties, which were the only ones with unambiguous information on whether masks were mandated in schools. More information is available in [22].

County level demographic data and school district to county mappings were obtained from the U.S. Census Bureau. Pediatric vaccination rates were obtained from the U.S. Department of Health and Human Services.

An additional control variable is the Social Vulnerability Index, which is a composite based on certain county-level demographic characteristics, and has been used before in similar studies [22,23]. We obtained this variable from the CDC.

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As the CDC data on age-stratified cases are at the county level, we map school districts to counties and keep counties where at least one school district provides information on the date that schools reopened following the summer. If multiple districts report dates that are not in alignment, we assign the median opening date to all districts in the county.

## 1.1 Data Sources for Age-Stratified Testing

This subsection describes the exercise for collecting age-stratified testing data, and reports data sources and definitions for the age-stratified testing data that we were successful in obtaining.

As discussed in the paper, there is no nationwide source for age-stratified testing data. Some states, counties and cities make aggregate data on testing available, but for our purposes it is necessary for these data to be stratified by age; very few governments provide this level of detail.

We searched the Covid-19 dashboards and other data sources for a selection of jurisdictions in order to identify such data at the local level. We specifically identified 12 states, 5 counties and 6 cities that were likely candidates for making such data available. The criteria for searching these jurisidictions included (i) large populations (ii) open data initiatives and (iii) our prior awareness of the likelihood of detailed data availability, based on news reports and other sources. Table 1 presents the 23 jurisdictions that we investigated, along with the dates that we accessed their Covid-19 dashboards or data repositories.

Although many of these jurisdictions do provide aggregate data on testing, at either weekly or monthly frequencies, we only identified five that stratified these data by age, which is a requirement for our analysis. These five jurisdictions are identified with check marks in Table 1. Of these, we did not use data from New York City in order to avoid duplication, as these data are included in the weekly data releases for New York State. Our final sample consiists of three states—New York, Florida and Georgia—and the city of Chicago. All of these jurisdictions report testing rates and confirmed cases based on laboratory reports, separately for various age categories.

Different jurisdictions report age-stratified testing rates according to different criteria and age groups. We constructed the closest possible approximation to the population of school aged children. These are as follows: New York—ages 5 to 19; Georgia—ages 5 to 17; Chicago: ages 0 to 17; Florida—ages 0 to 19.

Note that, as the Covid-19 pandemic has waned, many states and cities have terminated data collection initiatives. Moreover, in some cases, data that were earlier available for public access are now archived and not easily available. Our data collection sources were accurate as of the dates noted in Table 1, but we do not claim that these data sources will remain available in the future.

Data sources and definitions for these four jurisdictions are as follows:

1. New York: NYS Department of Health reports testing and positive cases based on PCR and Antigen (until April 2022) tests based on data from hospital and clinical laboratories across the state.
   `health.data.ny.gov/Health/New-York-State-Statewide-COVID-19-Testing-By-Age-G/h8ay-wryy`
2. Florida: New case definition is based on the number of people for whom the department received PCR or antigen laboratory results. A positive case requires either of the following: Detection of SARS-CoV-2 RNA using molecular amplification test (e.g., polymerase chain reaction [PCR]); or detection of SARS-CoV-2 by genomic sequencing.
   `ww11.doh.state.fl.us/comm/_partners/covid19_report_archive/covid19-data`
3. Georgia:Confirmed COVID-19 cases reported to the Georgia Department of Public Health (DPH), defined as an individual with a positive molecular (PCR) test.

Table 1: Searches for Age-Stratified Testing Data, selected jurisdictions

| | Data Available | Date Searched/Accessed |
|---|---|---|
| STATES: | | |
| California | | |
| Massachusetts | | March 14, 2023 |
| New York | ✓ | March 14, 2023 |
| Florida | ✓ | March 14, 2023 |
| Texas | | March 14, 2023 |
| Washington | | April 6, 2023 |
| Maryland | | April 6, 2023 |
| Georgia | ✓ | April 6, 2023 |
| Pennsylvania | | April 6, 2023 |
| Ohio | | April 21, 2023 |
| Illinois | | April 21, 2023 |
| Colorado | | April 21, 2023 |
| COUNTIES: | | |
| Cook (IL) | | May 3, 2023 |
| Los Angeles (CA) | | May 3, 2023 |
| Orange (CA) | | May 8, 2023 |
| Harris (TX) | | May 8, 2023 |
| San Diego (CA) | | May 8, 2023 |
| CITIES: | | |
| New York | ✓ | May 3, 2023 |
| Los Angeles | | May 3, 2023 |
| Chicago | ✓ | May 3, 2023 |
| Philadelphia | | May 3, 2023 |
| Miami | | May 8, 2023 |
| Houston | | May 8, 2023 |

Notes: For each jurisdiction, Covid-19 dashboards or other available sources were searched for age-stratified data on laboratory testing.

dph.georgia.gov/school-aged-covid-19-surveillance-data

4. Chicago: Testing rates are based on Molecular (PCR) and antigen tests received through electronic lab reporting. Only Chicago residents are included based on the home address as provided by the medical provider.

   data.cityofchicago.org/Health-Human-Services/COVID-19-Daily-Testing-By-Test/gkdw-2tgv

## 2 Regression Specifications and Additional Robustness Exercises

The main regression presented in the paper is as follows:

$$\text{childrate}_{ct} = \beta_0 + \beta_1 \text{adultrate}_{ct} + \boldsymbol{\gamma} \boldsymbol{X}_c + \theta_s + \delta_t + \varepsilon_{ct} \quad (1)$$

Here, $c$ denotes counties, $t$ denotes weeks and $s$ denotes the state corresponding to each county. *childrate* and *adultrate* measure pediatric and adult cases per-capita in the corresponding county and week; **X** refers to all other covariates in the county that do not vary over the sample period, such as age, race, density and the pediatric vaccination rate. State fixed-effects are represented by $\theta$ and the school-week fixed-effects by $\delta$.

An alternative specification is:

$$(\frac{\text{childrate}}{\text{adultrate}})_{ct} = \beta_0 + \boldsymbol{\gamma X}_c + \theta_s + \delta_t + \varepsilon_{ct} \tag{2}$$

The specification in (2) models the *ratio* of pediatric to adult case rates, as opposed to the specification in (1) which models the level of per-capita pediatric cases, controlling for per-capita adult cases. The second specification models pediatric infections as a constant proportion of adult infections, and so is less flexible than our more general specification but is perhaps more intuitive and provides a useful robustness check. The two regression models should produce similar results if case rates in children are generally proportional to those in adults.

The figures in this supplementary file present results using specification (2), and these are similar to the figures in the main paper, which use specification (1).

Figure A.1 shows the result using the specification in (2), for the full sample of 2592 counties. The results are very similar to those in Figure 1 in the main paper, showing that the ratio of pediatric to adult cases per-capita peaks in the first week after school opening, and then declines in successive weeks.

Figure A.2 uses the specification in (2) to stratify the aggregate result by Census region, corresponding to Figure 2 in the main paper. Once again the pattern of results is similar, showing that the same trend is reproduced in each of the four regions of the country.

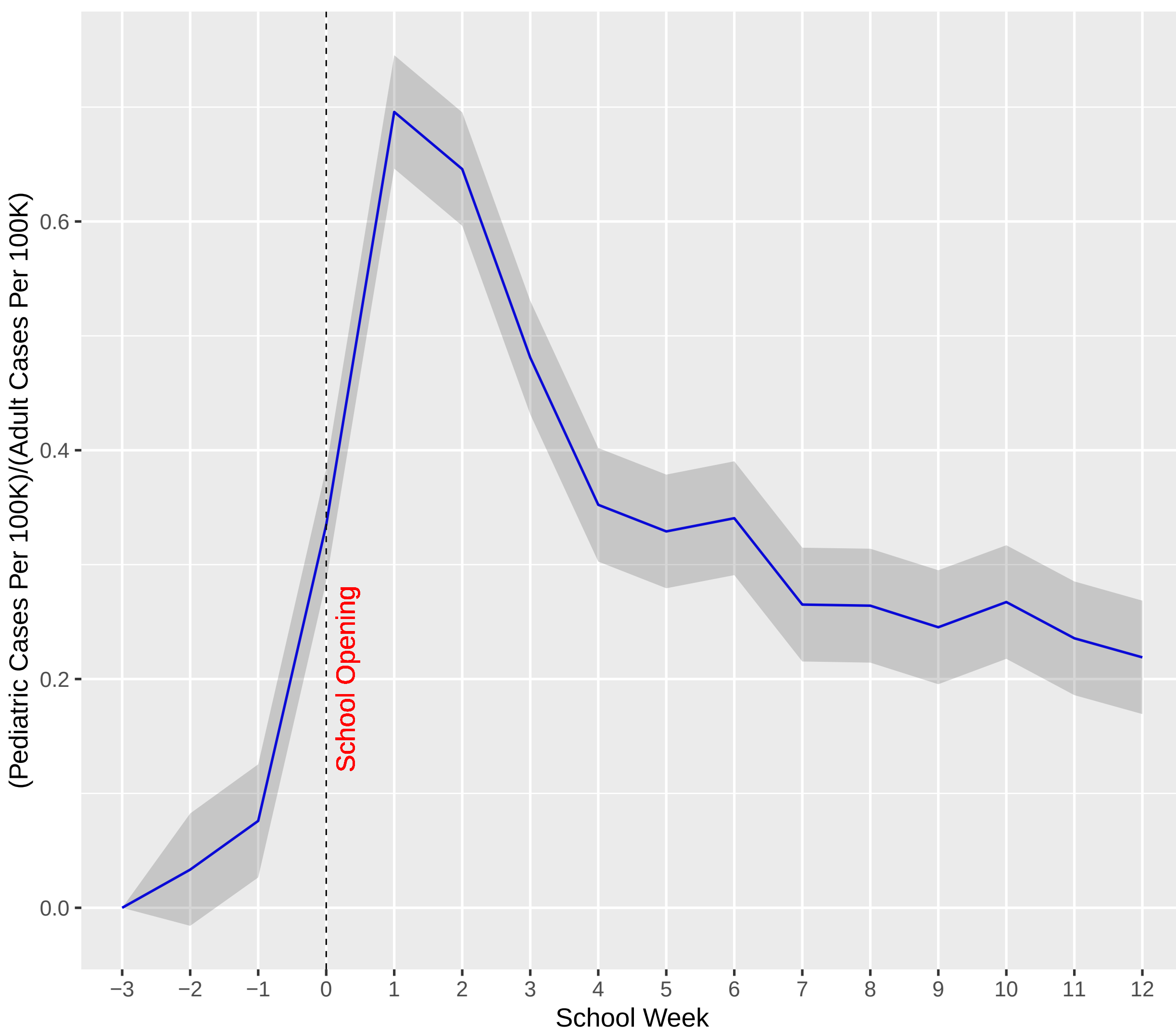
Figure A.3 corresponds to Figure 5 in the paper. It shows that the ratio of pediatric to adult cases per-capita is significantly affected by adjusting for rates of testing school-aged children. Once testing is taken into account, this ratio is lower, after three weeks of school, than prior to the start of school.

Figure A.4 once again employs specification (1), and extends the result shown in Figures 1 and 2 in the main paper by further stratifying the country into the nine Census divisions. Of note, dividing the data so finely results in noisier estimates, with relatively wide confidence intervals. Nevertheless, the same general pattern seen so far is repeated in almost all Census divisions—relative case rates in children appear to peak in the second week of school, and then tend to decline. One exception is the Northeast; here too, relative case rates in children start to drop after the second week of school, but they appear to climb again after week 8. Note however, that Northeast also has the lowest average case rates among all the divisions, and the widest confidence intervals. Except for the coefficient on week 11 in the Northeast, none of the other week coefficients are statistically significantly different from the estimate for week 2.

# 3 Regression Coefficients

Tables 2 and 3 present the full set of estimated coefficients for the regressions corresponding to Figures 1, 2, 3 and 5 in the main paper.

Figure A.1: Ratio of Pediatric to adult cases per capita, from 3 weeks prior to 12 weeks post−academic year start, 2021−22




Note: The graph plots estimated fixed−effects for each school−week from a regression of the ratio of weekly pediatric to adult cases per−capita of Covid−19. Control variables included: adult cases in the corresponding county and week, pediatric vaccination rates, county−level demographic variables. See text for additional details.

Figure A.2: Ratio of Pediatric to Adult cases per capita, from 3 weeks prior to 12 weeks weeks post−academic year start, 2021−22, stratified by Census Region

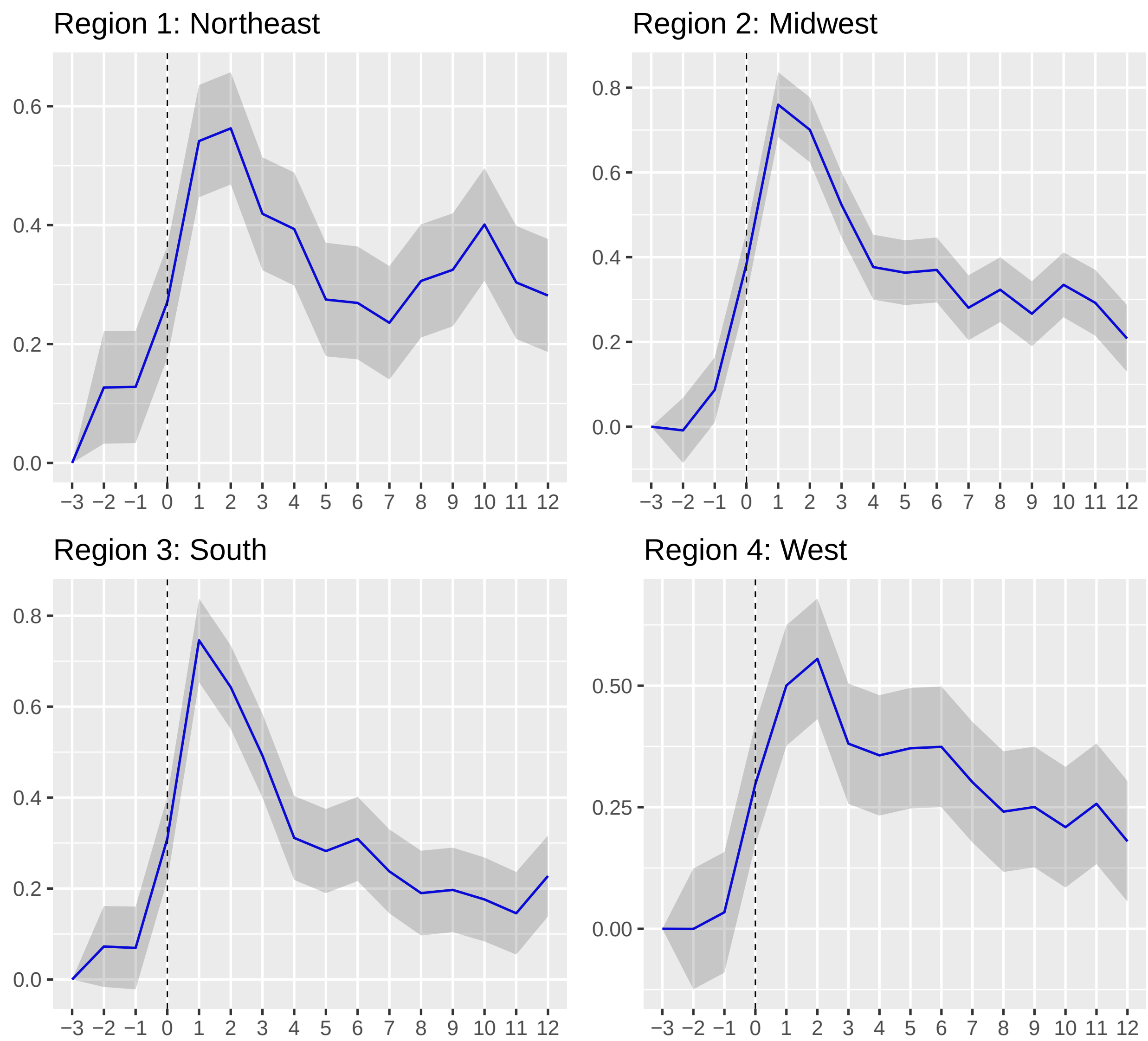
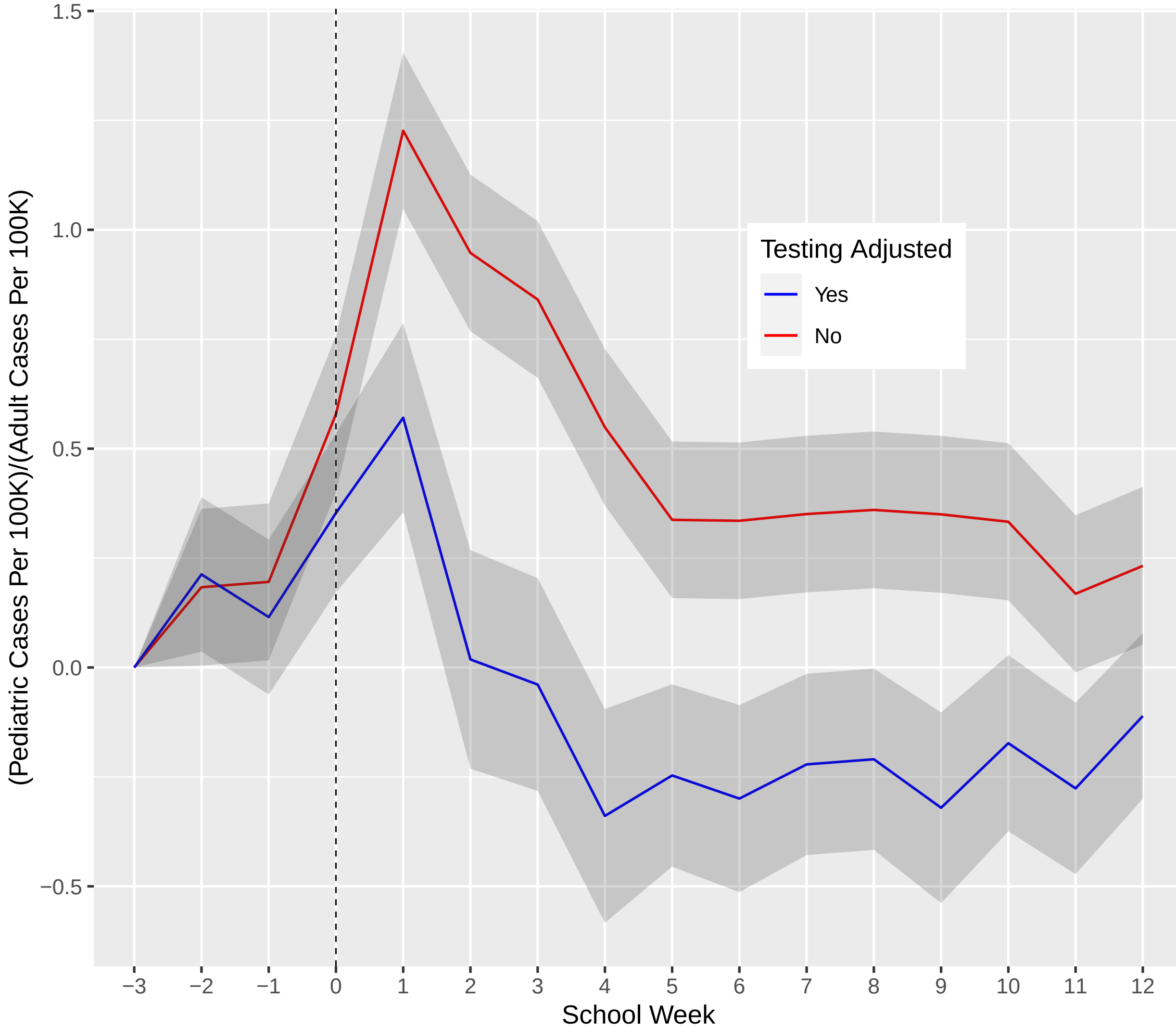


Figure A.3: Ratio of Pediatric to adult cases per capita, adjusted for testing: Four jurisdictions.




Note: The graph plots estimated fixed−effects for each school−week from a regression of weekly per−capita pediatric cases of Covid−19. Control variables included: adult cases in the corresponding county and week, pediatric vaccination rates, county−level demographic variables. See text for additional details.

Figure A.4: Pediatric case rates per capita ages 0−19, 9 Census Divisions

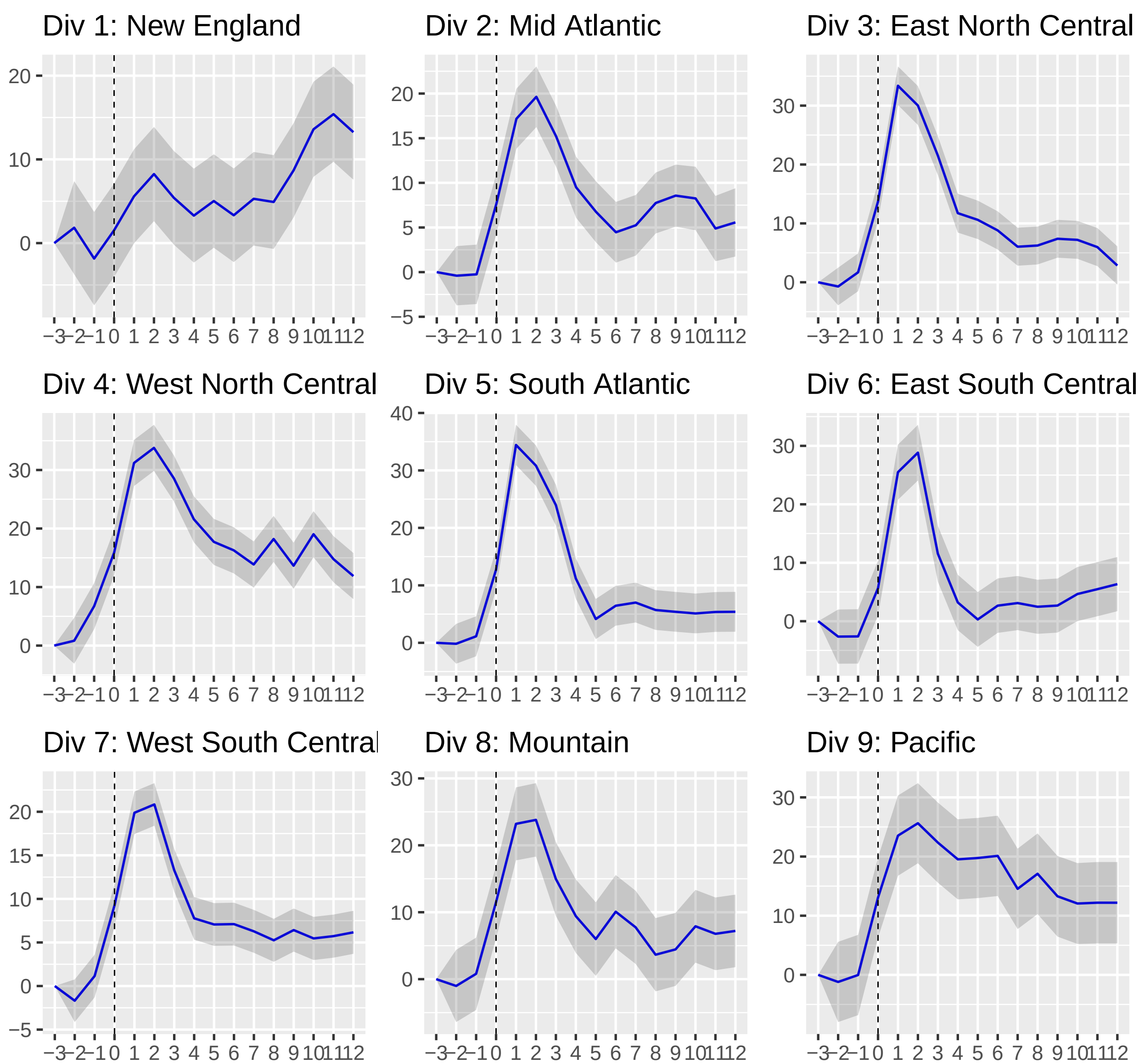


Table 2: Regression of Per-Capita Pediatric Cases

| | Full Sample | Northeast | Midwest | South | West |
|---|---|---|---|---|---|
| Adult Cases per 100K | 0.483 | 1.068 | 0.376 | 1.214 | 0.839 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Percent Uninsured | -0.550 | -0.619 | -1.416 | 0.032 | -1.264 |
| | (0.000) | (0.014) | (0.000) | (0.657) | (0.000) |
| Percent in Poverty | 0.421 | 0.532 | 0.456 | 0.375 | 0.637 |
| | (0.000) | (0.006) | (0.000) | (0.000) | (0.000) |
| Population Density | -0.004 | -0.001 | -0.016 | 0.000 | -0.008 |
| | (0.000) | (0.051) | (0.000) | (0.600) | (0.003) |
| Social Vulnerability Index | 7.052 | -0.765 | 12.269 | -6.728 | 1.844 |
| | (0.000) | (0.802) | (0.000) | (0.000) | (0.506) |
| Percent Non-Hispanic White | 10.924 | -15.424 | 4.982 | -3.588 | -8.792 |
| | (0.000) | (0.001) | (0.178) | (0.014) | (0.059) |
| Median Age | 0.293 | 0.957 | 0.405 | 0.418 | 0.584 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Pediatric Vaccination Rate | -4.826 | 9.447 | -5.422 | -4.883 | 9.414 |
| | (0.002) | (0.004) | (0.084) | (0.059) | (0.000) |
| schoolweek=1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | (.) | (.) | (.) | (.) | (.) |
| schoolweek=2 | 2.527 | 0.095 | 1.928 | -1.478 | -0.832 |
| | (0.002) | (0.951) | (0.150) | (0.139) | (0.702) |
| schoolweek=3 | 8.691 | -0.519 | 8.272 | 0.433 | 0.732 |
| | (0.000) | (0.741) | (0.000) | (0.665) | (0.737) |
| schoolweek=4 | 20.500 | 5.673 | 20.451 | 10.218 | 11.981 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| schoolweek=5 | 37.563 | 13.984 | 39.655 | 27.369 | 22.769 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| schoolweek=6 | 39.293 | 16.446 | 40.931 | 27.584 | 23.263 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| schoolweek=7 | 31.907 | 11.799 | 34.247 | 18.315 | 16.093 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| schoolweek=8 | 22.142 | 7.523 | 25.879 | 9.577 | 11.272 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| schoolweek=9 | 17.341 | 5.523 | 21.761 | 5.961 | 8.894 |
| | (0.000) | (0.001) | (0.000) | (0.000) | (0.000) |
| schoolweek=10 | 14.730 | 3.852 | 19.103 | 7.276 | 11.292 |
| | (0.000) | (0.015) | (0.000) | (0.000) | (0.000) |
| schoolweek=11 | 12.155 | 4.944 | 15.368 | 7.071 | 7.724 |
| | (0.000) | (0.002) | (0.000) | (0.000) | (0.000) |
| schoolweek=12 | 10.577 | 6.703 | 17.177 | 5.954 | 5.585 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.010) |
| schoolweek=13 | 8.902 | 8.470 | 15.177 | 6.329 | 4.985 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.022) |
| schoolweek=14 | 10.047 | 9.865 | 18.330 | 6.241 | 6.553 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.003) |
| schoolweek=15 | 9.250 | 7.838 | 16.665 | 6.542 | 5.531 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.011) |
| schoolweek=16 | 8.562 | 6.813 | 14.286 | 6.774 | 6.028 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.005) |
| Constant | -24.989 | -38.723 | -0.887 | -25.956 | 13.616 |
| | (0.000) | (0.000) | (0.852) | (0.000) | (0.026) |
| $R^2$ | 0.562 | 0.699 | 0.543 | 0.768 | 0.487 |
| Obs | 41472 | 3296 | 15872 | 16768 | 5536 |

Notes: Regression results correspond to those presented in Figures 1 and 2 in the text. p-values reported in parentheses. All regressions include state fixed-effects.

# 4 Discussion: Rise in cases around school reopening

As documented in the paper, and shown in Figures 1, 2, 3 and 5, there is a brief rise in reported case rates among children, relative to those of adults, even after controlling for age-stratified testing rates.

One explanation for the fleeting rise in case rates around the start of school may be increased home

Table 3: Regression of Per-Capita Pediatric Cases

| | | Adjusted for Testing | |
|---|---|---|---|
| | Mask Mandates | No | Yes |
| Adult Cases per 100K | 0.457 | 1.128 | 1.085 |
| | (0.000) | (0.000) | (0.000) |
| Percent Uninsured | -0.475 | 0.120 | 0.103 |
| | (0.000) | (0.581) | (0.632) |
| Percent in Poverty | 0.475 | 0.652 | 0.634 |
| | (0.000) | (0.000) | (0.000) |
| Population Density | -0.003 | -0.006 | -0.006 |
| | (0.000) | (0.039) | (0.029) |
| Social Vulnerability Index | 7.472 | -12.611 | -11.841 |
| | (0.000) | (0.001) | (0.001) |
| Percent Non-Hispanic White | 12.257 | -9.839 | -8.913 |
| | (0.000) | (0.051) | (0.073) |
| Median Age | 0.279 | 0.710 | 0.681 |
| | (0.000) | (0.000) | (0.000) |
| Pediatric Vaccination Rate | -3.341 | 10.340 | 9.382 |
| | (0.097) | (0.161) | (0.198) |
| Pediatric Frac. Tests | | | 244.965 |
| | | | (0.000) |
| Constant | -28.378 | -30.952 | -65.552 |
| | (0.000) | (0.000) | (0.000) |
| $R^2$ | 0.546 | 0.668 | 0.677 |
| Obs | 29312 | 3344 | 3344 |

Notes: Regression results correspond to those presented in Figures 3 and 5 in the text. p-values reported in parentheses. All regressions include fixed-effects for state and school-week. Estimated school-week fixed-effects, and associated 95% confidence intervals, are presented in Figures 3 and 5 of the text.

testing of schoolchildren, for which no reliable data are available. Many districts encouraged families to test students prior to school start. This may have set off a snowball effect of detection of cases, which would have further increased home testing rates. If children who tested positive at home were then disproportionately likely to be selected for confirmation from laboratory testing, this would have caused even laboratory results to exhibit higher positivity rates, which may explain the small spike in the period around school opening.

An alternative explanation for the increased case rates around school openings is the following: the start of term coincides with the end of summer vacations. These often involve travel, summer camps and routines for children that are different from when they are in school. It may not be surprising that case rates increase around the time of school reopening, as families return from travel and children join new networks. Once schools have been in session for two or more weeks, the regular routine and structure implies that children are less likely to be exposed to members of networks different from their own, which may explain the decline in case rates over time.