



Unequal Opportunity Spreaders: Higher COVID-19 Deaths with Later School Closure in the U.S.

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Abstract

Mixed evidence on the relationship between school closure and COVID-19 prevalence could reflect focus on large-scale levels of geography, limited ability to address endogeneity, and demographic variation. Using county-level CDC COVID-19 data through June 15, 2020, two matching strategies address potential heterogeneity: nearest geographic neighbor and propensity scores. Within nearest neighboring pairs in different states with different school closure timing, each additional day from a county's first case until state-ordered school closure is related to 1.5%-2.4% higher cumulative COVID-19 deaths per capita (1,227-1,972 deaths for a county with median population and deaths/capita). Results are consistent using propensity score matching, COVID-19 data from two alternative sources, and additional sensitivity analyses. School closure is more strongly related to COVID-19 deaths in counties with a high concentration of Black or poor residents, suggesting schools play an unequal role in transmission and earlier school closure is related to fewer lives lost in disadvantaged counties.

Keywords: COVID-19; school closure; health; race; poverty

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INTRODUCTION

Beginning in February 2020, K-12 schools across the United States began closing in an attempt to curb the spread of COVID-19. By March 25, every school district in the country had ended in-person instruction (Decker, Peele, and Riser-Kositsky 2020). However, evidence is mixed on the extent to which K-12 school closure slows the spread of coronavirus outbreaks (Viner et al. 2020; Zhang et al. 2020). Influenza transmission is lower when schools are closed for the summer or holidays (Chao et al. 2010; Chowell et al. 2011; Earn et al. 2012; Huang et al. 2014; Litvinova et al. 2019; Wu et al. 2010) and school closures substantially reduce the number of social contacts among both students and workers (Cauchemez et al. 2008; Huang et al. 2014; Jackson et al. 2011). Reviews find early school closures can slow influenza transmission when infection rates are higher among children than adults (Jackson et al. 2014a, 2014b).

However, unlike most previous influenza and novel virus outbreaks such as H1N1 (Cauchemez et al. 2009; Chao et al. 2010), COVID-19 causes higher symptomatic infection rates at older ages (Nogrady 2020; Rasmussen and Thompson 2020; Wu et al. 2020; Zhang et al. 2020) and transmission rates from young children are relatively low (Park et al. 2020). K-12 school closures may therefore be weakly related or unrelated to the spread of COVID-19. School closure has high costs for children's development and mental health, as well as for parents and communities (Coibion, Gorodnichenko, and Weber 2020; OECD 2020; Orben, Tomova, and Blakemore 2020; UNESCO 2020). If school closures do little to prevent the spread of COVID-19, other public health measures that do not inhibit children's development may be a better approach to control the pandemic.

In addition to age, COVID-19 has unequal implications by race, ethnicity, and poverty. Black and Hispanic Americans are more likely to contract COVID-19 and experience severe

symptoms than White Americans (Alcendor 2020; The Centers for Disease Control and Prevention 2020a; Zelner et al. 2020). Low-income individuals and communities also face higher risk of severe illness from COVID-19 (Koma et al. 2020; Wiemers et al. 2020), due in part to lower economic ability to practice social distancing (Jay et al. 2020). The relationship between school closure and COVID-19 spread may differ by race, ethnicity, or poverty due to segregation and unequal health risks and resources (Carratala and Maxwell 2020; de Brey et al. 2019; Egede 2006; Phelan and Link 2015; Phelan, Link, and Tehranifar 2010; Williams 2012; Williams et al. 2019a). Because school closures are a universal intervention, they may be especially effective at curbing the spread of COVID-19 in Black, Hispanic, and low-income communities.

Country-level analyses of the relationship between school closure and COVID-19 incidence or mortality yield mixed results (Banholzer et al. 2020; Flaxman et al. 2020; Liu et al. 2020), but state-level analyses within the U.S. suggest school closure is related to lower COVID-19 mortality (Auger et al. 2020; Rauscher 2020). The different results could reflect the different geographic level of analysis. COVID-19 is transmitted interpersonally and smaller-scale analyses may provide a better estimate of the relationship between transmission and non-pharmaceutical interventions (NPIs) such as school closure. Existing work has limited ability to address potential endogeneity in the relationship: national or state political leadership, for example, could influence both NPI implementation and COVID-19 prevalence or mortality.

It remains unclear whether or to what extent school closure timing is related to COVID-19 spread or whether the relationship differs by race, ethnicity, or poverty. To help weigh the economic and social costs against the health benefits of closing schools (Cauchemez et al. 2009) during an outbreak with higher infection rates at older ages, this study:

- 1) Estimates the relationship between state K-12 school closure timing and COVID-19 deaths and cases within matched county pairs in different states and with different school closure timing. County pairs are identified using two matching strategies: nearest geographic neighbor and propensity score matching.
- 2) Estimates whether the relationship between state K-12 school closure timing and county COVID-19 deaths vary by county poverty, race, and ethnicity.

Results suggest later school closure is related to higher COVID-19 deaths per capita and that the relationship varies by poverty and race/ethnicity. Closing schools later is related to higher COVID-19 deaths in counties with high concentrations of poor and Black residents. Results have implications for our understanding of the economic and social costs of school closures.

BACKGROUND

Schools and Public Health

Education became a stronger determinant of individual and social life in the U.S. throughout the 20th and 21st centuries (Fischer and Hout 2006). Institutionalization and expansion of formal education has shaped culture, the workplace, religion, economy, and family, among other aspects of life (Baker 2014; Fischer and Hout 2006). Educational expansion has incorporated a greater portion of the population for longer periods, which has independent effects on other social institutions. Institutional theories of education suggest schools are an independent force in society, instilling cultural, organizational, and economic changes through ideas (e.g., about efficiency, appropriateness) and socialization (e.g., national identity, civic duty; Baker 1999, 2009, 2014; Cremin 1951, 1961; Meyer et al. 1979; Meyer, Ramirez, and Soysal 1992; Meyer and Rubinson 1975; Ramirez and Boli 1987).

This institutional perspective makes clear the potentially important role of schools in public health efforts to control an infectious outbreak. However, while previous work emphasizes the importance of education through culture and ideas, schools also play a role through in-person social gatherings. For example, in addition to developing and disseminating knowledge, schools also develop social networks (Small 2009). Weeden and Cornwell (2020) illustrate the “small world” network at a medium-sized university in the U.S. Using simulations, the authors found that most students are connected to one another through multiple transmission paths. Complex systems of social ties may cause schools to be particularly efficient spreaders of infectious disease.

K-12 schools similarly create social networks, with children, teachers, and staff interacting in classes, cafeterias, buses, and playgrounds. K-12 students and employees typically reside at home and travel daily to school, connecting school and family networks. By reducing in-person interactions and overlap of social networks, school closure could reduce opportunities for COVID-19 transmission. Alternatively, families could substitute other social gatherings for school (e.g., church school, play dates, or informal shared family childcare). When schools close, families may engage in alternative social activities, yielding a null or positive relationship between school closure and COVID-19 transmission. For example, household networks may expand during school closures to include older family members for childcare, which could theoretically increase symptomatic COVID-19 infections and deaths, due to higher susceptibility at older ages (Wu et al. 2020; Zhang et al. 2020).

Existing evidence about the relationship between school closure and COVID-19 transmission is mixed (Auger et al. 2020; Banholzer et al. 2020; Flaxman et al. 2020; Haug et al. 2020; Liu et al. 2020). The mixed results could reflect different geographic levels of analysis.

For example, national-level analyses may be more likely to find a weak relationship because COVID-19 is transmitted locally through person-to-person interactions (Banholzer et al. 2020; Flaxman et al. 2020). However, a comparison of thousands of NPIs in 226 countries finds that school closure is strongly related to transmission (Haug et al. 2020). The mixed results could also reflect limited ability to address potential endogeneity in the relationship between school closure and COVID-19 transmission. Unobserved characteristics such as political leadership could influence both school closure timing and COVID-19 prevalence or mortality. County-level analyses that apply matching strategies to address potential endogeneity contribute to existing evidence about the relationship between transmission and school closure at a finer level than state or national analyses.

Schools and Inequality

Horace Mann – a 19th century Massachusetts politician and champion of the common school – called education “the great equalizer of the conditions of men” (1849:59). However, this ideal role of education is far from reality. A common argument is that education could increase equality if children enjoyed equal access to education. Research examining labor market outcomes often finds greater equality of opportunity among those with higher levels of education (particularly, a college degree; Bernardi and Ballarino 2016; Breen and Jonsson 2007; Hout 1988; Torche 2011). However, when accounting for selection, recent work finds that higher education does not increase equality of opportunity (Fiel 2019; Zhou 2019). Even 19th century compulsory schooling laws did not increase equality of opportunity in the labor market (Rauscher 2016). This evidence raises questions about whether or in which contexts education increases equality.

Similar questions arise about the relationship between education and health (Cutler and Lleras-Muney 2008). Education is significantly related to multiple health outcomes for both

adults and children (Abuya et al. 2012; Currie and Moretti 2003; Goldman and Smith 2011; Gunes 2015; Hahn and Truman 2015; Ross and Mirowsky 1999). However, those who are more likely to attain higher levels of education may also be healthier for a variety of other reasons, including social background, behavior, or neighborhood exposure to pollution. Evidence is mixed when accounting for selection into education. Extended compulsory schooling laws reduced mortality rates and improved health (Arendt 2005; Lleras-Muney 2005; Oreopoulos 2007) and greater access to college increased women's educational attainment and health of their children at birth (Currie and Moretti 2003). However, several rigorous studies that use natural experiments to account for unequal selection into education find no effect of education on health (Clark and Royer 2013; Dursun, Cesur, and Mocan 2018; Malamud, Mitrut, and Pop-Eleches 2018).

Mixed evidence of the relationship between education and health could partly reflect the focus on individual-level outcomes. Education has spillover effects, with social benefits beyond the individuals who gain more education. For example, educational expansion may spur state or national economic growth and occupational upgrading (Lutz, Cuaresma, and Sanderson 2008; Rauscher 2015). Similarly, education may have effects on population or public health, beyond its individual-level effects (Benjamin-Chung et al. 2018; Berniell, de la Mata, and Valdes 2013). For example, schools may play a role in transmission of infectious disease. Because schools gather students from diverse families and backgrounds in one place, schools could allow infectious diseases such as COVID-19 to spread more quickly.

Inequality and Health

Because of systemic race and income inequality, school closure could affect COVID-19 deaths differently across groups. The fundamental cause argument explains how social inequality produces health inequality. This theory suggests that those in economically and racially

advantaged positions have greater access to flexible resources, which they use to maintain better health compared to those with fewer resources (Phelan and Link 2015; Phelan et al. 2010).

Unequal resource distribution means that health inequality by race and income persists through multiple pathways (see e.g., Chetty et al. 2016), and cannot be ameliorated by individual interventions. The fundamental causes of racism and income inequality manifest in the unequal distribution and experiences of COVID-19.

Low-income, Black, and Hispanic Americans experience higher rates of COVID-19 infection than White and high-SES Americans (Centers for Disease Control and Prevention 2020a; Centers for Medicare and Medicaid Services 2020; Raine et al. 2020; Zelner et al. 2020). According to the Centers for Disease Control and Prevention (2020a), Black Americans contract COVID-19 at 1.4 times the rate of Whites, while Hispanic or Latino individuals contract the virus at 1.7 times the rate of Whites. Evidence also suggests that low-income people are much more likely than wealthier people to contract COVID-19. Data from the Centers for Medicare and Medicaid Services (CMS) show that people on Medicare who are poor enough to qualify for Medicaid are four times more likely to test positive for the coronavirus or be hospitalized from it than their high-income peers (CMS 2020). Barriers to physical distancing might explain higher infection rates among poor, Black, and Hispanic individuals. These groups are more likely to be essential workers and live in more densely-populated or crowded areas which puts them at higher risk for exposure to the virus (Arasteh 2020; Chen and Krieger 2020; Jay et al. 2020; Rogers et al. 2020).

In addition to being more likely to contract the virus, Black and Hispanic individuals are also more likely to experience severe symptoms or death (CDC 2020a). There are several explanations for this which stem from systemic and long-standing inequalities in employment

opportunities and conditions, living conditions, health, and discrimination (Alcendor 2020; CDC 2020a; Williams 2012; Williams et al. 2019a; Williams et al. 2019b). First, Black Americans have a higher incidence of chronic disease (e.g., obesity, hypertension, diabetes, asthma) than White Americans which makes them more susceptible to severe COVID-19 infections (Carratala and Maxwell 2020; Wiemers et al. 2020; Williams 2012). Second, Black and Hispanic Americans are more likely to be un- or under-insured, have less access to health care, and receive worse medical treatment, all of which likely make recovery from COVID-19 more difficult (Alsan, Garrick, and Graziani 2019; Bor, Cohen, and Galea 2017; Carratala and Maxwell 2020; Egede 2006).

Because school closures are a universal intervention and poor, Black, and Hispanic Americans are most affected by COVID-19, we expect school closures to be more strongly associated with COVID-19 deaths in counties with high percentages of poor, Black, or Hispanic residents. As argued by the theory of fundamental causes, health inequalities are likely to persist when interventions focus on individual risk factors because those with more resources use them to leverage new opportunities (Phelan et al. 2010). In contrast, an intervention that is not resource-dependent (such as closing schools) should yield universal benefits, because it has the ability to reduce mortality rates regardless of individual resources. Further, current data suggest that poor, Black, and Hispanic individuals are at greater risk of contracting and dying from COVID-19, and that low-income neighborhoods and majority-nonwhite neighborhoods have a higher incidence of COVID-19 deaths. If school closures are an effective intervention to reduce COVID-19 mortality, we expect this to benefit areas that have been hit harder by the virus: areas with high concentrations of low-income, Black, or Hispanic residents.

Alternatively, since low-income Americans and Black and Hispanic individuals are more likely to be exposed to the coronavirus from other sources (such as employment and neighborhood factors), school closures could be more weakly related to COVID-19 for these groups. Following from fundamental cause theory, because it does not address the root cause of racial or income inequality, school closure may have similar implications regardless of demographics and may not be sufficient to reduce racial disparities in health outcomes.

Zajacova and Lawrence (2018) emphasize the importance of social context for understanding the relationship between education and health and leveraging it to improve population health and reduce health disparities. Using a finer level of geography than previous research and examining variation by county poverty and race/ethnicity, this paper quantifies the relationship between school closure timing and county-level COVID-19 deaths to provide more information when considering the high social costs of school closures (Coibion et al. 2020). At the same time, this paper provides a new analysis of the institutional theory of education (Baker 2014) by examining the relationship between schools and public health during a pandemic.

DATA AND METHODS

Using daily cumulative data on COVID-19 deaths and cases by county from the Centers for Disease Control through June 15, 2020, this study examines dates after the first case in each county through the end of the academic year. June 15 includes dates through the end or within a few weeks of the end of the academic year in most states. June 15 also predates the publicized interventions into CDC data by the Trump administration, which began in July when they transferred COVID-19 data collection responsibility from the CDC to the Department of Health and Human Services (Stolberg 2020). COVID-19 prevalence measures are similar using county-

level data from the CDC, *The New York Times* (NYT), and Johns Hopkins University (JHU).

Mean values of deaths and cases per capita from NYT and JHU differ by less than 2% from CDC measures (see Table A1) and are highly correlated with CDC measures (0.995 or higher). Results are similar using NYT or JHU data (see Appendix Tables A12-A15).

Key Measures

COVID-19 prevalence is measured as the logged number of deaths (and cases) per 100,000 residents. Time to school closure is the number of days from the first case in each county until schools were closed based on state-ordered school closure dates from *EdWeek* (2020a). All states closed schools within 11 days after President Trump declared a national state of emergency on March 13. Variation in prevalence rates on March 13 (0-56.3 cases per 100,000 residents; 0-1.4 deaths per 100,000 residents) allows examination of the relationship between COVID-19 spread and school closure timing. Appendix Table A1 provides information about each measure used in the analyses.

Analytic Approach

State school closure decisions could partly reflect state COVID-19 prevalence, potentially biasing state estimates. State closures are not based on prevalence in each specific county and school closure timing is therefore less likely related to prevalence and more exogenous at the county level. (Correlations between state school closure date and COVID-19 cases and deaths per capita (log) on the date of school closure are 0.30 and -0.28 at the state level and 0.16 and -0.01 at the county level, respectively.)

Two matching strategies are used to address additional heterogeneity between counties: nearest geographic neighbor matching and propensity score matching. Matching is conducted using observed characteristics and unobserved characteristics may still differ after matching. These two strategies are complementary and results should be consistent using both approaches.

First, National Weather Service geocode data for county centroid location is used to identify nearest neighboring county pairs in different states and the distance between those county pairs. Counties in close geographic proximity to each other have similar potential COVID-19 exposure and similar economic and demographic contexts. However, state school closure timing is more likely exogenous with respect to county COVID-19 prevalence among nearby counties in different states. Appendix Table A2 Panel A compares variation among all counties compared to within county pairs less than 100 miles apart in different states. Variation within pairs is lower on all measures than in the unmatched sample (by 37%-138%, depending on the measure). Mean differences between paired counties are less 0.1 standard deviations on all measures.

Second, propensity score matching is used to identify county pairs with similar characteristics by school closure timing (Abadie et al. 2004; Rosenbaum and Rubin 1985). Specifically, we use `psmatch2` (Leuven and Sianesi 2003) to identify the five nearest-neighbor matches between counties above and below the median of seven days from the first case in the county until states closed schools.

We estimate propensity scores using multiple county- and state-level measures (see Table A2 Panel B). Table A2 Panel B and Figure A1 show evidence of balance on observed characteristics between treatment and control counties within matched pairs (using `pstest`, Leuven and Sianesi 2003). The balance tests in Table A2 Panel B compare mean values, standardized percentage bias (difference in means divided by square root of the variance; Rosenbaum and Rubin 1985), and variance ratios (ratio of variance of residuals in treatment and control groups for each variable regressed on the propensity score; Rubin 2001). Tests of overall balance and for each variable are within the ranges recommended by Rubin (2001).

Using the propensity score from `psmatch2`, we use two approaches to estimate the relationship between late school closure and COVID-19 deaths: 1) we create strata (deciles) of propensity score and estimate the relationship within each strata (Long and Kurlaender 2009); 2) we use the nearest neighbor match for each county with late school closure and estimate the relationship within county pairs. We limit the propensity score analyses to those in the range of common support on the propensity score (excluding 405 counties with propensity score > 0.9628).

Statistical Analyses

As with other matching approaches, the geographic and propensity score matching techniques do not address unobserved variation, but they adjust for observed heterogeneity and allow us to compare counties with similar observed characteristics other than school closure timing (Dehejia and Wahba 1999; Morgan 2001). We use the matched counties in regressions with fixed effects for county pair or propensity score strata to estimate the relationship between the continuous measure of school closure timing and COVID-19 deaths within similar counties.

Equation 1 predicts log cumulative deaths per capita in county (i) in pair (j) as of June 15, 2020 with time to school closure and county pair fixed effects. Within pairs of matched counties, $\exp(\beta_1)$ estimates the percent increase in deaths for each additional day from a county's first case until the state closed schools. Standard errors are adjusted for county pair clustering.

$$\ln(\text{COVID19 Deaths}/100\text{k})_{ij} = \alpha + \beta_1 \text{Time to School Closure}_{ij} + \beta_k X_{ij} + \text{Pair}_j + \varepsilon_{ij} \quad (1)$$

We estimate the relationship separately within geographic pairs and propensity score pairs. We use a similar approach to estimate the relationship within propensity score strata (j), adjusting standard errors for clustering within strata. When using geographic pairs, models are fit with and without the following controls (X_i) to address potential confounding: county-level population (log), population density (log), percent Black, percent Hispanic, percent Asian, percent urban, median income (log), poverty rate (from U.S. Census Bureau), percent of

residents who frequently wear a mask in public, percent who always wear a mask, percent who rarely/never wear a mask (from *New York Times* survey, July 2020); state-level number of public schools (log), public school enrollment (log), school closure date (from *EdWeek* 2020a); median age, percent group quarters residence (from IPUMS; Ruggles et al. 2020), number of long-term care facilities with COVID-19 cases at the end of May (from Kaiser Family Foundation; mean value assigned to seven non-reporting states). States implemented other physical distancing measures in addition to school closure. Controls therefore include dates of state: stay-at-home order, non-essential business closure, and restaurant closure (coded as last observed date for states without each policy; from Raifman et al. 2020; results are similar using stay-home dates from *Wall Street Journal* and *Aljazeera* as of April 21). In the propensity score analyses, we fit models with and without controlling for propensity score and controls from the geographic analyses not used to create the propensity score (X_i).

Heterogeneity by Poverty, Race, and Ethnicity

Based on U.S. Census Bureau data, we create indicators for whether counties are above the median values of percent poverty (14.1%), Black (2.0%), Hispanic (3.3%), American Indian (0.4%), Asian (0.5%), and white (85.8%) residents. We also create indicators for whether counties are above 70th percentile of poverty rate (17.3%) to distinguish counties with concentrated poverty. Equation 2 is similar to Equation 1, predicting log cumulative deaths per capita in county (i) in pair (j) with time to school closure and county pair fixed effects, but adds an interaction term between time to school closure and the indicator for high poverty rate (or high proportion of residents by race/ethnicity). Within pairs of matched counties, $\exp(\beta_1)$ estimates the percent increase in deaths for each additional day from a county's first case until the state closed schools in low-poverty counties. $\exp(\beta_3)$ estimates the additional percent increase in deaths for each day until school closure in high-poverty counties and tests whether

the relationship between school closure timing and COVID-19 deaths differs by county poverty rate. Standard errors are adjusted for county pair clustering.

$$\ln(\text{COVID19 Deaths}/100\text{k})_{ij} = \alpha + \beta_1 \text{Time to School Closure}_{ij} + \beta_2 \text{High Poverty}_{ij} + \beta_3 \text{Time to School Closure}_{ij} * \text{High Poverty}_{ij} + \beta_k X_{ij} + \text{Pair}_j + \varepsilon_{ij} \quad (2)$$

As in the main analyses, we estimate the relationship separately within geographic pairs, propensity score pairs, and propensity score strata (standard errors adjusted for strata clustering). We fit models with and without the same controls (X_i) in the main analyses.

Sensitivity Analyses

Geographic matched pair estimates shown (in Figure 2) are limited to county pairs less than 100 miles and less than 40 miles apart, but other distance thresholds yield consistent results. Counties can be matched multiple times, resulting in multiple observations per county (mean is 2 observations; range 1-10 in geographic pairs). Results are consistent when weighted by the inverse of the number of observations for each county (i.e. weighting each county to represent one observation) or when adjusting standard errors for county rather than pair clustering.

Estimates within county pairs could be biased if states closed schools based on the number of cases in all of its counties or if cases were evenly distributed throughout states and states closed schools based on state prevalence. Estimates could be downwardly biased if counties or districts closed schools at dates other than the state-mandated closure date. Because of potential bias, estimates are associational and interpreted using associational language throughout the paper. However, Oster (2019) bounds are used to identify the degree of selection on unobservables required to explain the estimates (i.e. required to make coefficients zero).

We replicate analyses using COVID-19 data from *The New York Times* and from Johns Hopkins University (Johns Hopkins University 2020; New York Times 2020). We use alternative measures of the dependent variable, including number deaths or cases (log)

unadjusted for population size, when excluding the 7 states that recommended rather than ordered schools closed, when excluding the 5 counties in New York City (see Appendix Tables A1-A3), and when including counties with zero deaths (by adding one death per one hundred thousand residents), which are excluded when log-transforming deaths per capita.

We repeat the propensity score analyses when matching on additional variables: % Black, median income (log), and state median age and restaurant closure date. Overall balance statistics did not meet recommended levels when including these measures, so the main analyses control for them in regressions rather than in propensity score calculation. Propensity score analyses are unweighted, but results are consistent when weighting by the frequency a county is matched divided by five (to normalize weights across the five potential matched counties).

States implemented several other physical distancing measures during the COVID-19 pandemic. Controls include dates of these measures, but it is difficult to isolate the role of school closures alone. A step in this direction is to limit analyses to county pairs with the same dates of other non-pharmaceutical interventions.

COVID-19 prevalence and its relationship to school closure could change over time. Sensitivity analyses predict daily cumulative county COVID-19 deaths per capita with daily observations from the first case in each county. These analyses add date and county fixed effects in Equation 1 to account for stable differences between counties and national changes over time. Models are fit with and without controlling for a 1-day lagged measure of deaths per capita.

We predict COVID-19 deaths and deaths due to all causes separately by race/ethnicity. However, the distribution of deaths by race/ethnicity are suppressed by the CDC in many counties due to small numbers to protect privacy and data are only available for approximately 400 counties. Significant differences (Paternoster et al. 1998) between β_1 coefficients in

Equation 1 predicting Black and Hispanic deaths compared to those predicting white deaths would indicate that the relationship between school closure timing and death rates differs by race or ethnicity. Due to the small number of counties with mortality data by race/ethnicity, this approach is provided as a sensitivity check.

RESULTS

Figure 1 compares cumulative state COVID-19 deaths per capita over time by timing of school closure, restaurant closure, business closure, and stay-home orders. States that closed schools late have substantially higher deaths per capita than states that closed schools early. In contrast, there is little difference in deaths per capita by stay-home order or business closure timing. Restaurant closure timing is related to differences in deaths per capita. Based on these preliminary analyses, we use dates of these non-pharmaceutical interventions (in addition to other measures) as controls or to match counties in statistical analyses.

Table 1 shows estimates using geographic nearest-neighbor county pairs in different states with variation in school closure timing. Within nearby county pairs, one additional day before school closure is related to 1.5%-2.4% higher county COVID-19 deaths per capita (an additional 1,227-1,972 deaths for a county with median deaths per capita and median population). Figure 2 shows estimates limited to counties less than 100 miles apart, less than 40 miles apart, and with and without controls, which include county- and state-level characteristics. Results are consistent when predicting COVID-19 cases and when limited to counties at other maximum distances.

Table 2 shows estimates when matching counties based on propensity score, with similar observed characteristics but with different school closure timing. Within the same propensity

score strata, one additional day before school closure is related to 1.2%-1.6% higher county COVID-19 deaths per capita (an additional 980-1,310 deaths for a county with median deaths per capita and median population). Within propensity score pairs, there is no relationship between school closure timing and deaths when not including controls, but the estimate is similar to other analyses when including controls: an additional day before school closure is related to 1.7% higher county COVID-19 deaths per capita (an additional 1,392 deaths for a county with median deaths per capita and median population). Propensity score models predicting COVID-19 cases add further support for a relationship to school closure timing.

Table 3 shows results examining variation in COVID-19 deaths by county poverty, race, and ethnicity. Coefficients for the interaction between school closure timing and high proportions of poor or Black residents suggest variation by poverty and race, but not by ethnicity. For example, Models 5 and 6 in Panel A (within geographic county pairs) suggest minimal relationship between school closure and COVID-19 deaths in counties below median percent Black residents. However, in counties with a high proportion of Black residents, an additional day before school closure is related to 1.9%-2.3% higher county COVID-19 deaths per capita. Propensity score analyses similarly find a significantly stronger relationship between school closure and deaths in counties with a high concentration of Black residents (marginal estimates illustrated in Figure 3). Poverty interaction terms are not statistically significant within geographic pairs. However, propensity score analyses suggest school closure is more strongly related to COVID-19 deaths in high poverty counties (above the 70th percentile of poverty rate). Specifically, each additional day before school closure is related to approximately 1% higher COVID-19 deaths in low-poverty counties, but this relationship is significantly higher (1%-3%) in high poverty counties. Interaction terms are not significant for counties above the median

poverty rate, suggesting the relationship emerges in counties with high poverty rates. Interaction terms are also not significant for counties with a high proportion of Hispanic residents. Thus, results indicate variation in the relationship between COVID-19 deaths and school closure by poverty and race, but not by ethnicity.

Sensitivity Analyses

Sensitivity analyses find consistent results when predicting the number of deaths or cases (log) unadjusted for population size, when excluding the 7 states that recommended rather than ordered schools closed, or when excluding the 5 counties in New York City (see Appendix Tables A3-A5).

Results are also consistent when including counties with zero deaths, which are excluded when log-transforming deaths per capita. Table A6 shows results when assigning a value of one death per 100,000 residents to counties before the first death occurred to include all matched counties.

On the whole, results shown in Tables A7-A9 are consistent when limited to county pairs with the same dates of restaurant closure, stay-home order, or business closure. The main analyses control for the timing of other physical distancing measures and these sensitivity analyses add further confidence that school closure is independently related to COVID-19 spread. However, small samples sizes among propensity score pair analyses (Table A9) indicate the limitations of this approach.

As a robustness check, Table A10 shows results examining the relationship between COVID-19 prevalence as of December 15, 2020 and state Fall 2020 school opening policies (from *EdWeek* 2020b). Compared to counties in states that began Fall 2020 K-12 schooling in-person, those in states that began at least partially closed had 20%-53% lower cumulative COVID-19 deaths as of December 15, 2020.

Table A11 shows results from models predicting daily cumulative county COVID-19 deaths per capita with date and county fixed effects, weighted by the inverse of the number of observations for each county to prevent counties where the first case emerged earlier from driving results. Controlling for lagged COVID-19 deaths, results suggest each additional day before school closure is related to 0.1% faster daily growth in COVID-19 deaths.

Tables A12-A15 show results when using COVID-19 data from the *New York Times* and Johns Hopkins University. Results are consistent with the main analyses. We repeat propensity score analyses when matching on four additional variables: % Black, median income (log), and state median age and restaurant closure date. Results are similar to the main analyses (shown in Appendix Tables A16-A17). The main analyses control rather than match on those measures to achieve the recommended balance levels (Rubin 2001).

A concern in interpreting results is that school closure timing may be endogenous. Unobserved characteristics could influence both school closure and COVID-19 deaths. Using Oster (2019) bounds, estimates for school closure timing predicting deaths per capita remain positive when assuming potential selection on unobservables is 13% higher than selection on observables within county pairs less than 100 miles apart ($\delta = 1.13$) and over seven times selection on observables within pairs less than 40 miles apart ($\delta = 7.22$). Within propensity score strata, estimates remain positive when assuming selection on unobservables is nearly eight times selection on observables within strata ($\delta = 7.97$). Bounds are calculated by assigning a maximum r-squared value of 1.3*estimated r-squared (the value at which 90% of randomized estimates survive; Oster 2019). Bounds are appropriate for coefficients that decrease when adding controls and therefore are not calculated for estimates based on propensity score pairs.

CONCLUSION

Although children do not appear to be the primary spreaders of COVID-19 (Lee and Raszka 2020; Park et al. 2020), earlier school closure is related to lower deaths and cases per capita in U.S. counties. Previous inconsistent evidence on the relationship between school closure and COVID-19 prevalence could reflect a focus on large-scale levels of geography, limited ability to address endogeneity, and variation by poverty, race, or ethnicity. We build on previous work by examining county-level data and applying two matching strategies to address potential heterogeneity: nearest geographic neighbor and propensity score matching. Within nearest neighboring county pairs in different states with different school closure timing, each additional day from a county's first case until state-ordered school closure is related to 1.5%-2.4% higher cumulative county COVID-19 deaths per capita. Propensity score analyses suggest that one additional day before school closure is related to 1.2%-1.7% higher county COVID-19 deaths per capita. For a hypothetical county with median population and deaths per capita, this amounts to 980-1,972 deaths for each day before school closure.

We find that school closure is more strongly related to COVID-19 deaths in counties with a high concentration of Black or poor residents. Schools may therefore be unequal opportunity spreaders, playing an unequal role in transmission. The stronger relationship could reflect unequal school resources (if schools in advantaged counties can leverage resources to prevent spread during in-person schooling; Baker et al. 2018; Sosina and Weathers 2019), unequal family or individual socioeconomic resources, and higher risk of COVID-19 exposure and severe symptoms due to economic and social inequality and preexisting health conditions (Alcendor

2020; Centers for Disease Control and Prevention 2020b; Williams 2012; Wiemers et al. 2020; Williams et al. 2019; Zelner et al. 2020).

School closure creates a larger burden for families – especially those with few resources, but it is a relatively universal intervention which does not require family resources to access or adopt. The universal nature of school closure may account for its stronger link to COVID-19 deaths among Black and low-income Americans (Phelan and Link 2015; Phelan et al. 2010). Results do not differ in counties with high concentrations of Hispanic residents, which could reflect the lower rate of preexisting health conditions related to severe COVID-19 symptoms (Wiemers et al. 2020) and the Hispanic health paradox, which yields better health than expected for both individuals and communities (Hummer et al. 2007; Markides and Coreil 1986; Shaw et al. 2013).

School closure has social, economic, psychological, and cognitive costs for individuals and societies (Coibion et al. 2020), with potentially long-term implications, which is why states rarely close schools. In the context of the first wave of COVID-19, however, results suggest school closure is related to lower death rates. Estimates are robust to multiple sensitivity analyses and remain positive when assuming potential selection on unobservables is larger than selection on observables – in some analyses over 7 times larger (Oster 2019). The costs are high, but in the absence of a robust test and trace containment strategy, earlier school closure was related to lower COVID-19 deaths during the first outbreak in the U.S.

Although other physical distancing policies are not the focus of this study, descriptive results echo existing work (Friedson et al. 2020; Lin and Meissner 2020), which provides mixed evidence for a relationship between COVID-19 spread and stay-at-home orders and non-essential business closures. This may be because those measures were generally implemented later than

school closures. Restaurant closure shows some relationship with COVID-19 deaths. Future research could directly examine restaurant closure compared to other physical distancing measures.

An important limitation of this study is that it cannot establish a causal relationship. Two county matching strategies are used to reduce the possibility that unobserved heterogeneity could account for the results. However, matching is necessarily based on observed characteristics. Similar results using both geographic and propensity score matching strategies reduce the possibility that random variation or selection explain the findings, but additional research is required to establish a causal relationship.

Evidence from the above analyses supports institutional theories of education, which suggest schools are an independent force in society (Baker 2009, 2014). While work in this area has focused on the importance of education in shaping culture and the economy, results of this study add to evidence that schools can also play a role in public health through in-person social gatherings (Weeden and Cornwell 2020). The role of schools likely differs by the specific disease examined, but results suggest public health implications of schools can spillover and extend beyond those who enter schools to include other community members (Berniell et al. 2013; Benjamin-Chung et al. 2018), including older individuals.

Furthermore, this study contributes to our understanding of the relationship between education and inequality. Recent work finds that education does not increase equality of opportunity in the labor market (Fiel 2019; Rauscher 2016; Zhou 2019) and has no effect on health (Clark and Royer 2013; Dursun et al. 2018; Malamud et al. 2018). However, the majority of studies focus on individual-level outcomes, omitting important spillover effects and social benefits of education. Results of this study add to evidence of the link between education and

population or public health (Benjamin-Chung et al. 2018; Berniell et al. 2013). Results suggest schools may play a role in transmission of infectious diseases. In the case of COVID-19, schools are more strongly related to death rates in counties with a high proportion of Black or low-income residents. This evidence is consistent with a recent finding that school closure is unrelated to COVID-19 prevalence in areas with low infection rates, but may help reduce spread in areas with high infection rates (Harris et al. 2021). Our results suggest school closure may be related to lower COVID-19 deaths in disadvantaged areas. Balancing the unequal learning opportunities created by closing schools (Aucejo et al. 2020; Bacher-Hicks et al. 2021; Chetty et al. 2020; Kuhfeld et al. 2020; Lancker and Parolin 2020) with the potential for lower mortality among disadvantaged populations poses an ethical challenge.

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Tables

Table 1. Predicted County COVID-19 Deaths/Cases per 100,000 Residents within Geographic County Pairs

Panel A: County Pairs <100 Miles Apart

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log) Baseline	+ Controls	Cases/100k (log) Baseline	+ Controls
Days from First Case until School Closure	0.018**	0.015*	0.022**	0.016**
	(0.005)	(0.006)	(0.002)	(0.002)
Constant	2.817**	1,670.333**	5.608**	361.738
	(0.019)	(482.489)	(0.018)	(220.399)
Observations	1,452	1,452	3,322	3,320
Number of County Pairs	726	726	1,661	1,660
R-squared	0.710	0.768	0.774	0.820
County Pair Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Panel B: County Pairs <40 Miles Apart

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log) Baseline	+ Controls	Cases/100k (log) Baseline	+ Controls
Days from First Case until School Closure	0.024**	0.024*	0.017**	0.011**
	(0.008)	(0.012)	(0.002)	(0.003)
Constant	2.944**	2,332.964**	5.677**	589.500
	(0.032)	(843.829)	(0.022)	(405.333)
Observations	492	492	1,040	1,040
Number of County Pairs	246	246	520	520
R-squared	0.775	0.842	0.832	0.868
County Pair Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Predicted CDC COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to county pairs in different states with unequal school closure timing. Even numbered models include controls for county population (log), population density (log), percent Black, percent Hispanic, percent Asian, percent urban, median income (log), poverty rate (from U.S. Census Bureau), percent of residents who frequently wear a mask in public, percent who always wear a mask, percent who rarely/never wear a mask (from *New York Times* survey, July 2020); state number of public schools (log), public school enrollment (log), school closure date (from *EdWeek*); median age, percent group quarters residence (from IPUMS), number of long-term care facilities with COVID-19 cases at the end of May (from Kaiser Family Foundation; mean value assigned to seven non-reporting states), stay-at-home order, non-essential business closure, and restaurant closure (coded as last observed date for states without each policy; from Raifman et al. 2020; similar results using stay-home dates from *Wall Street Journal* and *Aljazeera* as of April 21).

Robust standard errors adjusted for county pair clustering in parentheses.

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

Table 2. Predicted County COVID-19 Deaths/Cases per 100,000 Residents within Counties Matched Based on Propensity Scores

Panel A: Propensity Score Strata

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log)	Deaths/100k (log)	Cases/100k (log)	Cases/100k (log)
	Baseline	+ Controls	Baseline	+ Controls
Days from First Case until School Closure	0.016*	0.012*	0.019**	0.013*
	(0.006)	(0.004)	(0.006)	(0.005)
Constant	2.548**	75.627	5.865**	-108.024*
	(0.041)	(48.831)	(0.042)	(42.790)
Observations	1,446	1,446	1,446	1,446
Number of Strata	10	10	10	10
R-squared	0.046	0.164	0.025	0.211
County Strata Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Panel B: Propensity Score Pairs

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log)	Deaths/100k (log)	Cases/100k (log)	Cases/100k (log)
	Baseline	+ Controls	Baseline	+ Controls
Days from First Case until School Closure	0.000	0.017**	0.016**	0.017**
	(0.004)	(0.005)	(0.004)	(0.005)
Constant	2.468**	31.294	5.855**	-146.624
	(0.035)	(95.456)	(0.034)	(107.435)
Observations	1,226	1,226	1,226	1,226
Number of County Pairs	613	613	613	613
R-squared	0.479	0.580	0.493	0.610
County Pair Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Predicted CDC COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to counties within range of propensity score support. Even numbered models include controls for county propensity score, percent Black, median income (log), state median age, and date of restaurant closure (coded as last observed date for states without; from Raifman et al. 2020).

Robust standard errors adjusted for county strata (Panel A) or county pair (Panel B) clustering in parentheses.

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

Table 3. Predicted County COVID-19 Deaths per 100,000 Residents by County Poverty and Race/Ethnicity
 Panel A: Geographic County Pairs <100 Miles Apart

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Deaths/100k (log)							
Days from First Case until School Closure	0.016** (0.006)	0.016* (0.008)	0.015** (0.005)	0.013+ (0.008)	0.001 (0.009)	0.003 (0.010)	0.018* (0.008)	0.017* (0.008)
High Poverty (>median)	0.400** (0.093)	0.121 (0.106)						
High Poverty (>70 th percentile)			0.399** (0.110)	0.106 (0.133)				
High Pov x Days to School Closure	0.006 (0.008)	-0.002 (0.009)	0.009 (0.008)	0.003 (0.008)				
High Black (>median)					0.142 (0.149)	-0.013 (0.150)		
High Black x Days to School Closure					0.023* (0.010)	0.019+ (0.010)		
High Hispanic (>median)							-0.123 (0.113)	-0.197 (0.123)
High Hispanic x Days to School Closure							0.002 (0.009)	-0.005 (0.010)
Constant	2.611** (0.055)	1,635.548** (483.258)	2.681** (0.044)	1,655.274** (484.560)	2.697** (0.125)	1,706.476** (485.127)	2.884** (0.077)	1,578.232** (479.596)
Observations	1,452	1,452	1,452	1,452	1,452	1,452	1,452	1,452
Number of County Pairs	726	726	726	726	726	726	726	726
R-squared	0.717	0.768	0.716	0.768	0.713	0.769	0.711	0.769
County Pair Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
Controls		Y		Y		Y		Y

Predicted CDC COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to county pairs in different states with unequal school closure timing. Even numbered models include controls for county population (log), population density (log), percent Black, percent Hispanic, percent Asian, percent urban, median income (log), poverty rate (from U.S. Census Bureau), percent of residents who frequently wear a mask in public, percent who always wear a mask, percent who rarely/never wear a mask (from *New York Times* survey, July 2020); state number of public schools (log), public school enrollment (log), school closure date (from *EdWeek*); median age, percent group quarters residence (from IPUMS), number of long-term care facilities with COVID-19 cases at the end of May (from Kaiser Family Foundation; mean value assigned to seven non-reporting states), stay-at-home order, non-essential business closure, and restaurant closure (coded as last observed date for states without each policy; from Raifman et al. 2020; similar results using stay-home dates from *Wall Street Journal* and *Aljazeera* as of April 21). Robust standard errors adjusted for county pair clustering in parentheses. ** p<0.01, * p<0.05, + p<0.1

Panel B: Propensity Score Strata

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Deaths/100k (log)							
Days from First Case until School Closure	0.011 (0.006)	0.010 (0.006)	0.010 (0.006)	0.009+ (0.005)	0.006 (0.005)	0.004 (0.003)	0.022* (0.007)	0.014** (0.004)
High Poverty (>median)	0.296* (0.120)	-0.209* (0.088)						
High Poverty (>70 th percentile)			0.662** (0.110)	0.217* (0.093)				
High Pov x Days to School Closure	0.011 (0.010)	0.005 (0.009)	0.019* (0.006)	0.009+ (0.004)				
High Black (>median)					0.544** (0.039)	0.124* (0.054)		
High Black x Days to School Closure					0.019** (0.004)	0.020** (0.004)		
High Hispanic (>median)							-0.108 (0.084)	-0.035 (0.071)
High Hispanic x Days to School Closure							-0.012+ (0.006)	-0.004 (0.005)
Constant	2.396** (0.068)	77.579 (51.423)	2.326** (0.049)	74.156 (50.367)	2.219** (0.029)	77.417 (51.607)	2.606** (0.079)	75.960 (48.971)
Observations	1,446	1,446	1,446	1,446	1,446	1,446	1,446	1,446
Number of Strata	10	10	10	10	10	10	10	10
R-squared	0.057	0.169	0.093	0.166	0.079	0.169	0.049	0.164
County Pair Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
Controls		Y		Y		Y		Y

Predicted CDC COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to counties within range of propensity score support. Even numbered models include controls for county propensity score, percent Black, median income (log), state median age, and date of restaurant closure (coded as last observed date for states without; from Raifman et al. 2020).

Robust standard errors adjusted for county strata clustering in parentheses.

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

Panel C: Propensity Score Pairs

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Deaths/100k (log)							
Days from First Case until School Closure	-0.008 (0.007)	0.013+ (0.007)	-0.008 (0.006)	0.011+ (0.006)	-0.013* (0.006)	0.005 (0.006)	0.007 (0.007)	0.018* (0.007)
High Poverty (>median)	0.500** (0.135)	-0.275+ (0.165)						
High Poverty (>70 th percentile)			0.866** (0.143)	0.110 (0.173)				
High Pov x Days to School Closure	0.018 (0.012)	0.007 (0.011)	0.030* (0.013)	0.018 (0.012)				
High Black (>median)					0.483** (0.131)	-0.069 (0.141)		
High Black x Days to School Closure					0.024* (0.012)	0.027* (0.011)		
High Hispanic (>median)							-0.321* (0.132)	-0.079 (0.124)
High Hispanic x Days to School Closure							-0.012 (0.011)	-0.001 (0.010)
Constant	2.206** (0.074)	43.612 (96.109)	2.171** (0.056)	42.305 (94.787)	2.177** (0.080)	29.096 (94.686)	2.633** (0.079)	28.301 (97.109)
Observations	1,226	1,226	1,226	1,226	1,226	1,226	1,226	1,226
Number of County Pairs	613	613	613	613	613	613	613	613
R-squared	0.493	0.585	0.517	0.582	0.491	0.589	0.485	0.580
County Pair Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
Controls		Y		Y		Y		Y

Predicted CDC COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to counties within range of propensity score support. Even numbered models include controls for county propensity score, percent Black, median income (log), state median age, and date of restaurant closure (coded as last observed date for states without; from Raifman et al. 2020).

Robust standard errors adjusted for county pair clustering in parentheses.

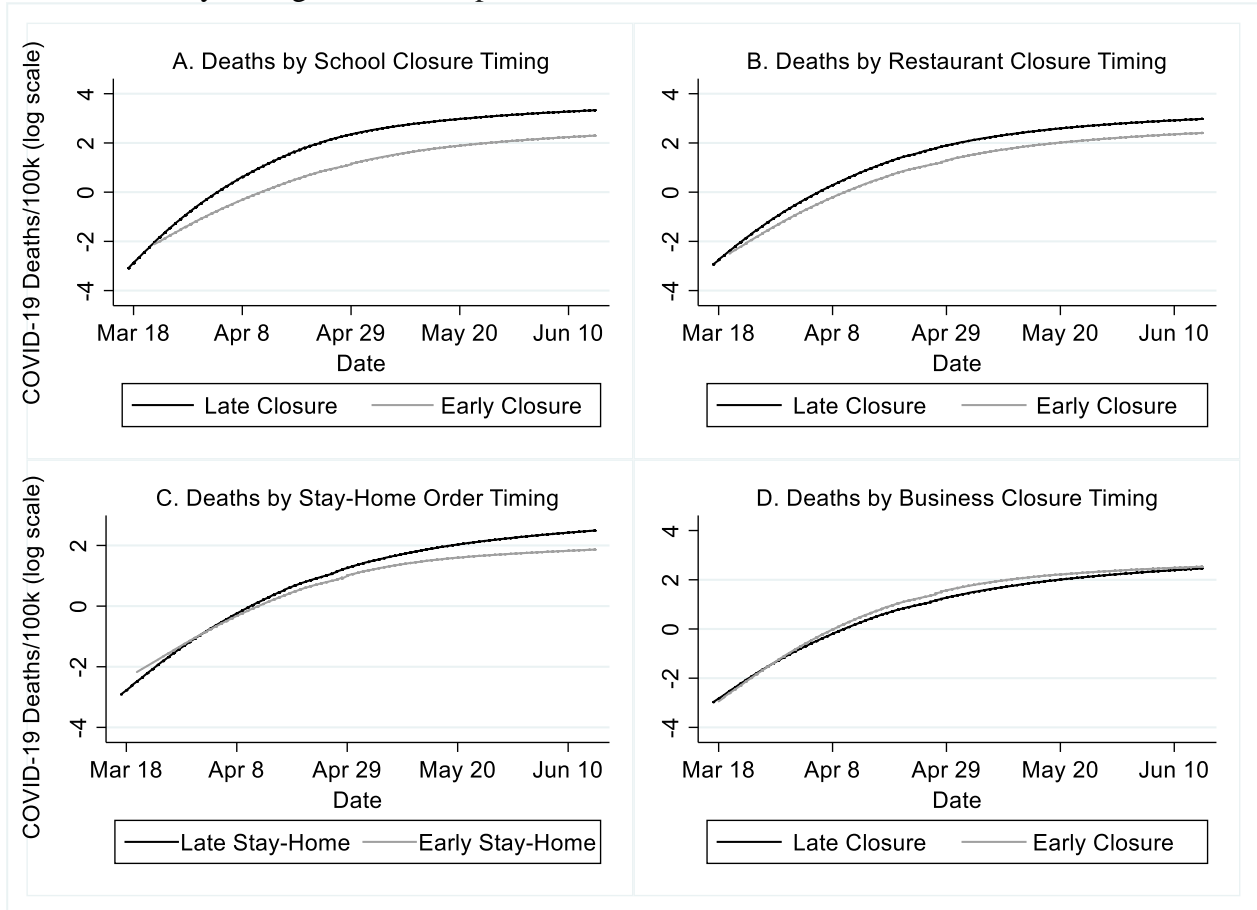
** p<0.01, * p<0.05, + p<0.1

In Panels A-C, counties with high poverty, Black, or Hispanic concentration are above the median value among all counties (U.S. Census Bureau 2010, 2018).

Models 3 & 4 examine counties above the 70th percentile for poverty rate.

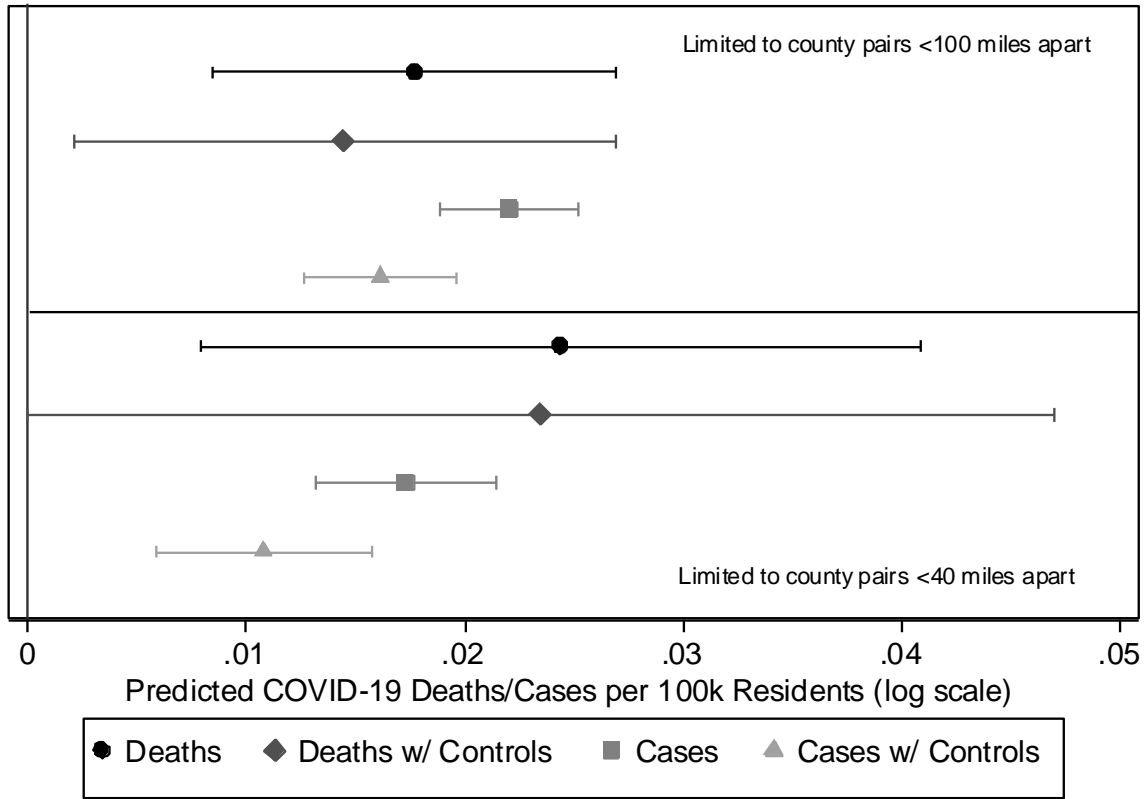
Figures

Figure 1. Lowess graphs of (log) daily cumulative state COVID-19 deaths per 100,000 residents over time by timing of state non-pharmaceutical interventions.



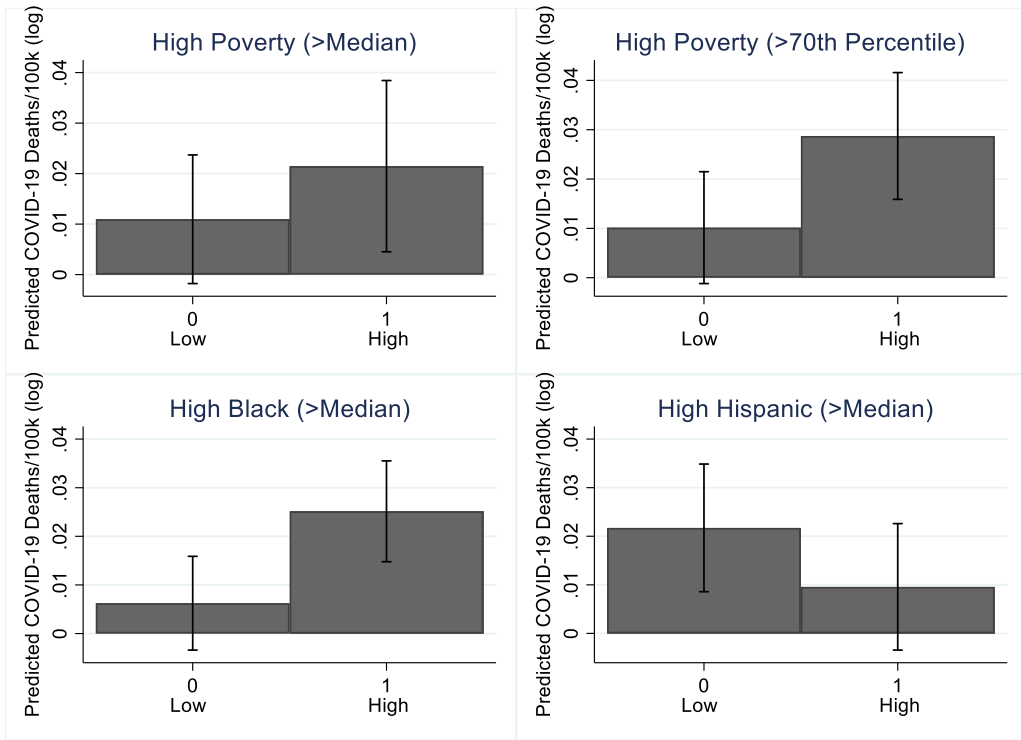
Late Closure includes states in the top tercile of days from 100 cases until each measure. Early Closure includes states in the bottom tercile of days from 100 cases until each measure. Panel A: Late School Closure - on or after the day a state reached 100 cases. Early School Closure - 5 or more days before reaching 100 cases. Panel B: Late Restaurant Closure - 2 or more days after reaching 100 cases. Early Restaurant Closure - 4 or more days before reaching 100 cases. Panel C: Late Stay-Home Order - 16 or more days after reaching 100 cases. Early Stay-Home Order - less than 7 days after reaching 100 cases. Alternative stay-home order dates from *Wall Street Journal* and *Aljazeera* show consistent results. Panel D: Late Business Closure - 13 or more days after reaching 100 cases. Early Business Closure - less than 5 days after reaching 100 cases. Quadratic graphs with confidence intervals indicate significant differences in Panels A & B and overlap in Panels C & D.

Figure 2. Predicted COVID-19 Deaths and Cases per 100,000 Residents within Geographic County Pairs



Estimates based on models in Table 1. Within nearest neighboring county pairs in different states with different school closure timing, each additional day from a county's first case until state-ordered school closure is related to 1.5%-2.4% higher cumulative county COVID-19 deaths per capita as of June 15, 2020 (an additional 1,227-1,972 deaths for a county with median deaths per capita and median population). Estimates are β_1 coefficients from Table 1 with 95% confidence intervals (standard errors adjusted for county pair clustering). Analyses are limited to counties <100 miles or <40 miles apart (alternative distance thresholds yield consistent results).

Figure 3: Predicted COVID-19 Deaths per 100,000 Residents within Propensity Score Strata



Marginal estimates at sample mean values based on odd-numbered models in Table 3, Panel B. Within propensity score strata, the relationship between school closure timing and predicted county COVID-19 deaths per 100,000 residents is higher in counties with high poverty rate and high proportion Black residents.

Online Appendix

Figure A1: Standardized Bias Before and After Propensity Score Matching

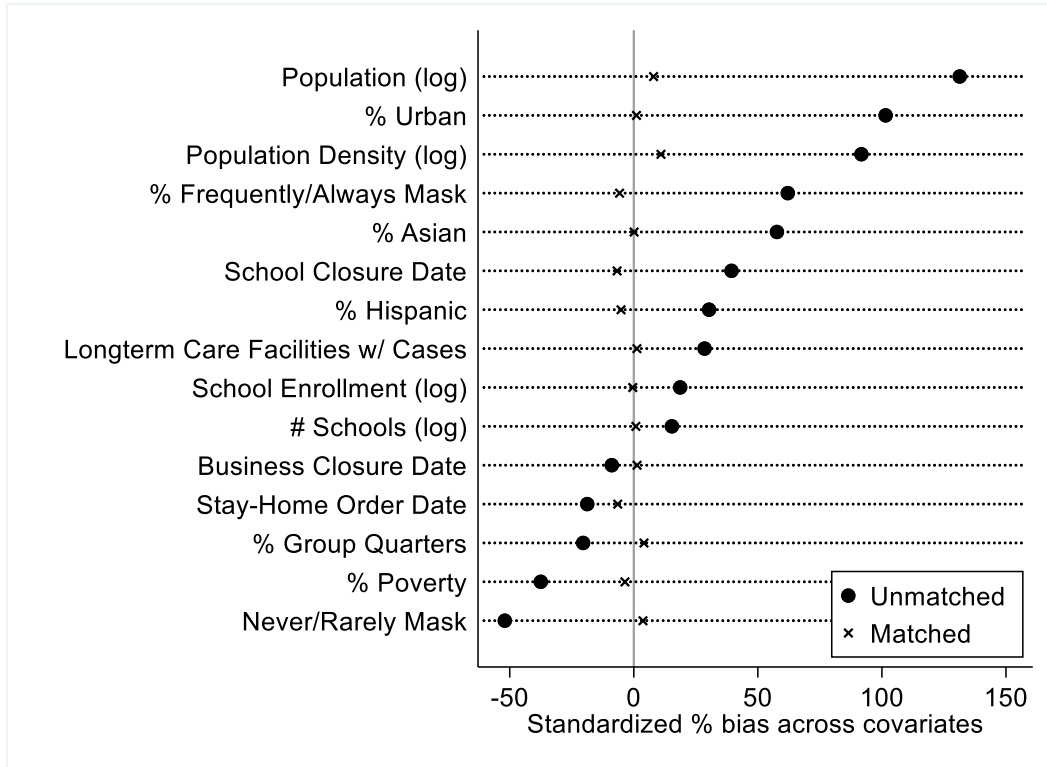


Figure A1 shows standardized percent bias (difference in means divided by square root of the variance) on observed characteristics between treatment and control counties before and after matching (pctest, Leuven and Sianesi 2003).

Figure A2: Propensity Score Distribution by Treatment

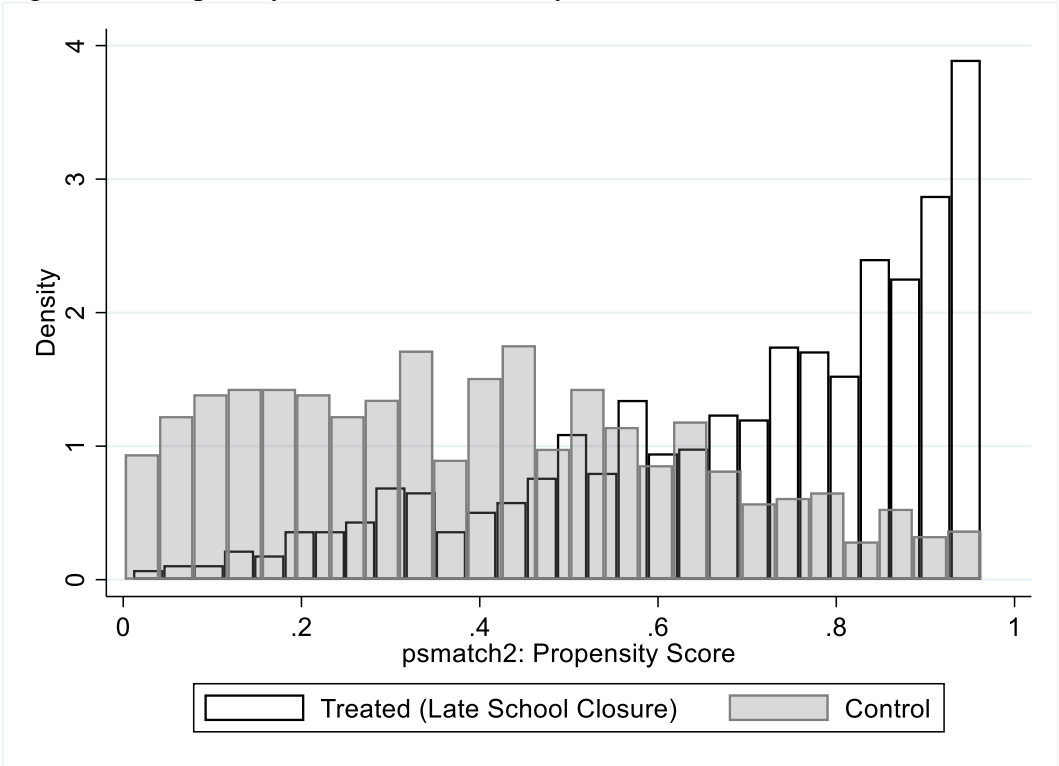


Figure A2 shows the distribution of propensity score values among the treatment and control counties using psmatch2 (Leuven and Sianesi 2003).

Table A1: Descriptive Statistics and Data Sources

Variable	Mean	Std. Dev.	Source
Deaths/100k	15.59	31.97	CDC June 15, 2020
Cases/100k	414.42	705.18	CDC June 15, 2020
NY Times Deaths/100k	15.43	30.70	NY Times June 15, 2020
NY Times Cases/100k	415.52	703.62	NY Times June 15, 2020
JHU Deaths/100k	15.77	31.95	JHU June 15, 2020
JHU Cases/100k	414.52	710.59	JHU June 15, 2020
Days from First Case until School Closure	-10.89	17.08	EdWeek May 15, 2020
Population	109142.20	340363.70	US Census Bureau 2019
Population Density	271.02	1763.26	US Census Bureau 2010
% Urban	41.66	30.56	US Census Bureau 2010
Median Income	52940.72	14028.31	US Census Bureau 2018
% Poverty	15.20	6.18	US Census Bureau 2018
% Black	9.24	14.68	US Census Bureau 2010
% Hispanic	8.29	13.09	US Census Bureau 2010
% Asian	1.17	2.42	US Census Bureau 2010
% American Indian	1.88	7.17	US Census Bureau 2010
% White	78.09	19.70	US Census Bureau 2010
% Always Wear Mask	51.29	15.03	NY Times July 2-14, 2020
% Frequently Wear Mask	20.65	6.26	NY Times July 2-14, 2020
% Never/Rarely Wear Mask	15.98	9.43	NY Times July 2-14, 2020
State Measures			
Public School Enrollment	1455332.00	1488474.00	EdWeek 2016-17
Number of Public Schools	2707.83	2359.21	EdWeek 2016-17
% Group Quarters Residence	0.03	0.00	IPUMS, ACS 2019
Median Age	37.89	1.79	IPUMS, ACS 2019
No. Long-term Care Facilities w/ Cases	236.53	171.76	KFF May 28, 2020
School Closure Date	17-Mar	2.57	EdWeek May 15, 2020
Stay-Home Order Date	6-Apr	26.27	Raifman et al. 2020
Restaurant Closure Date	21-Mar	13.16	Raifman et al. 2020
Business Closure Date	16-Apr	35.76	Raifman et al. 2020
N Counties	3,003		

Note: County COVID-19 deaths and cases are cumulative values as of June 15, 2020, excluding 139 counties with zero cases.

Table A2: Sample Comparisons Before and After Matching
 Panel A: Variation in Observed Characteristics Before and After Geographic Matching

Variable	Coefficient of Variation			Std Deviation			Mean Pair Difference (sd units)
	All	Within Pairs	% Reduction	All	Within Pairs	% Reduction	
No. Long-term Care Facilities w/ Cases	72.62	45.57	-37.24	171.76	87.70	-48.94	0.06
School Enrollment (log)	6.87	3.06	-55.55	0.95	0.41	-56.17	0.08
No. of Public Schools (log)	9.67	4.62	-52.27	0.74	0.35	-53.17	0.09
Population (log)	13.62	5.01	-63.19	1.41	0.52	-63.59	0.01
Population Density (log)	41.76	16.69	-60.03	1.64	0.46	-71.82	0.00
School Closure Date	0.01	0.01	-48.18	2.57	1.33	-48.17	0.05
Stay-Home Order Date	0.12	0.04	-67.48	26.27	8.55	-67.45	0.01
Restaurant Closure Date	0.06	0.02	-67.44	13.16	4.29	-67.41	0.02
Business Closure Date	0.16	0.07	-57.51	35.76	15.21	-57.48	0.05
Median Income (log)	2.25	0.75	-66.58	0.24	0.08	-66.56	0.07
% Poverty	40.62	13.92	-65.74	6.18	2.14	-65.28	-0.05
% Group Quarters	17.48	8.02	-54.16	0.00	0.00	-52.28	-0.01
% Black	158.94	41.94	-73.61	14.68	3.12	-78.75	-0.06
% Hispanic	157.85	28.87	-81.71	13.09	1.67	-87.25	0.01
% Asian	206.61	36.13	-82.51	2.42	0.39	-83.91	0.07
Median Age	4.72	1.73	-63.28	1.79	0.66	-62.96	-0.04
% Urban	73.36	47.75	-34.92	30.56	13.00	-57.46	0.03
% Always Mask	29.29	8.55	-70.83	15.03	4.02	-73.27	0.02
% Frequently Mask	30.31	12.30	-59.42	6.26	2.46	-60.70	0.04
% Never/Rarely Mask	59.00	19.18	-67.49	9.43	2.86	-69.70	-0.02
Days from First Case until School Closure	-156.84	59.99	-138.25	17.08	8.12	-52.46	-0.02
N Counties/Pairs	3,003	1,822		3,003	1,822		1,822

Table compares measures of variation among all counties to those within geographically matched pairs <100 miles apart. Coefficient of variation is standard deviation divided by mean. Percent reduction columns indicate the percent difference within pairs compared to all counties (% Reduction = 100*[All-Within]/All). Mean pair difference is the mean difference within each pair divided by the pair standard deviation.

Variation is 37%-138% lower within geographic pairs, depending on the measure. Within-pair differences are less than 0.1 standard deviation on each measure.

Panel B: Balance on Observed Characteristics Before and After Propensity Score Matching

Variable	Unmatch/ Matched	Mean		% Bias	%	t-test of Equal		Variance Ratio
		Treated	Control		Reduction Bias	Mean Values t	p> t	
No. Long-term Care Facilities w/ Cases	U	277.34	229.47	28.50		5.78	0.00	1.11
	M	251.58	249.51	1.20	95.70	0.25	0.81	0.80*
School Enrollment (log)	U	13.97	13.81	18.70		3.72	0.00	1.42*
	M	13.87	13.87	-0.40	97.60	-0.09	0.93	0.96
Number of Public Schools (log)	U	7.73	7.63	15.40		3.02	0.00	1.66*
	M	7.65	7.65	0.80	94.80	0.16	0.88	0.92
Population (log)	U	11.48	10.08	131.40		25.13	0.00	1.33*
	M	10.82	10.73	7.90	94.00	2.02	0.04	0.85
Population Density (log)	U	4.99	3.81	91.70		18.03	0.00	1.01
	M	4.37	4.23	10.90	88.10	2.58	0.01	0.91
School Closure Date	U	17-Mar	16-Mar	39.40	0.00	7.84	0.00	1.52*
	M	17-Mar	17-Mar	-6.80	82.80	-1.27	0.21	0.79*
Stay-Home Order Date	U	1-Apr	5-Apr	-18.80		-4.01	0.00	0.57*
	M	3-Apr	4-Apr	-6.50	65.40	-1.32	0.19	0.86
Business Closure Date	U	13-Apr	16-Apr	-8.90		-1.83	0.07	0.90
	M	14-Apr	14-Apr	1.30	85.50	0.26	0.79	0.97
% Poverty	U	14.29	16.60	-37.50		-7.71	0.00	0.84
	M	15.36	15.58	-3.60	90.40	-0.76	0.45	1.30*
% Group Quarters	U	0.03	0.03	-20.40		-4.03	0.00	1.58*
	M	0.03	0.03	4.10	80.10	0.78	0.43	0.87
% Hispanic	U	9.78	6.24	30.30		6.00	0.00	1.42*
	M	7.54	8.14	-5.20	83.00	-1.05	0.29	0.95
% Asian	U	2.02	0.62	57.70		10.51	0.00	6.56**
	M	0.96	0.96	0.10	99.80	0.04	0.97	0.56*
% Urban	U	59.95	33.30	101.50		20.55	0.00	0.66*
	M	48.05	47.78	1.00	99.00	0.23	0.82	0.92

% Frequently/ Always Mask	U	77.56	70.58	62.10		12.68	0.00	0.83
	M	74.16	74.81	-5.80	90.70	-1.18	0.24	1.02
% Never/Rarely Mask	U	12.28	16.51	-52.00		-10.74	0.00	0.74*
	M	14.46	14.16	3.70	93.00	0.74	0.46	0.95
	Pseudo	LR Test	Mean	Median	Rubin's		% Variables	
Samples	R ²	p> χ^2	Bias	Bias	B	R	Concern	Bad
Unmatched	0.362	0	47.6	37.5	155.8*	3.00*	60	7
Matched	0.009	0.193	4	3.7	22	1.23	27	0

Table shows balance tests between treatment and control counties before and after matching (pctest, Leuven and Sianesi 2003). U indicates Unmatched sample. M indicates Matched sample after psmatch2 (Leuven and Sianesi 2003). Standardized percent bias is the difference in treatment and control means divided by square root of the variance (Rosenbaum and Rubin 1985). Percent bias reduction indicates the percent decrease in the absolute value of the standardized bias after matching. T-test columns test of equal means in the two samples before and after matching. Variance ratio is the ratio of the variance of the residuals orthogonal to the propensity score for treatment and control groups (residuals in treatment and control groups for each variable regressed on the propensity score; Rubin 2001). Asterisk indicates variables of concern, with variance ratio <0.8 or >1.25.

Overall measures of imbalance in the unmatched and matched samples are reported at the bottom of the table.

Pseudo R-squared is reported from a probit estimate of the propensity score on all variables. LR test provides the p-value from likelihood-ratio test of joint significance of all regressors. Mean and median bias are measures of the absolute value of standardized bias in the samples. Rubin's B is the absolute standardized difference of the mean propensity score in treated and control groups. Rubin's R is the ratio of treated to control variances of propensity score. Percent of variables of concern (variance ratio 0.5-0.8 or 1.25-2) or bad (<.5 or >2) (Rubin 2001). Rubin (2001) recommends $B < 25$ and $0.5 < R < 2$ in matched samples to consider treatment and control groups balanced.

Variables used to generate propensity score: county-level population (log), population density (log), percent Hispanic, percent Asian, percent urban, median income, poverty rate (from U.S. Census Bureau), percent of residents who frequent/always wear a mask in public, percent who rarely/never wear a mask in public (from *New York Times* survey, July 2020); state-level number of public schools (log), public school enrollment (log), school closure date (from *EdWeek*); state stay-home order date, business closure date (from Raifman et al. 2020); state percent group quarters residence (from IPUMS), and state number of long-term care facilities with COVID-19 cases at the end of May (from Kaiser Family Foundation; mean value assigned to seven non-reporting states). We repeat propensity score analyses when matching on four additional variables: % Black, median income (log), and state median age and restaurant closure date. Results are similar to the main analyses (shown in Appendix Tables A14-A15). The main analyses control rather than match on those measures to achieve the recommended balance levels (Rubin 2001).

Table A3. Predicted Number of County COVID-19 Deaths/Cases
 Panel A: Geographic County Pairs <100 Miles Apart

VARIABLES	(1)	(2)	(3)	(4)
	Deaths (log)		Cases (log)	
	Baseline	+ Controls	Baseline	+ Controls
Days from First Case until School Closure	0.083**	0.015*	0.055**	0.016**
	(0.007)	(0.006)	(0.002)	(0.002)
Constant	2.638**	1,658.820**	4.817**	350.225
	(0.027)	(482.489)	(0.026)	(220.399)
Observations	1,452	1,452	3,322	3,320
Number of County Pairs	726	726	1,661	1,661
R-squared	0.810	0.904	0.829	0.939
County Strata Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Predicted CDC COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to county pairs in different states with unequal school closure timing. Even numbered models include controls for county population (log), population density (log), percent Black, percent Hispanic, percent Asian, percent urban, median income (log), poverty rate (from U.S. Census Bureau), percent of residents who frequently wear a mask in public, percent who always wear a mask, percent who rarely/never wear a mask (from *New York Times* survey, July 2020); state number of public schools (log), public school enrollment (log), school closure date (from *EdWeek*); median age, percent group quarters residence (from IPUMS), number of long-term care facilities with COVID-19 cases at the end of May (from Kaiser Family Foundation; mean value assigned to seven non-reporting states), stay-at-home order, non-essential business closure, and restaurant closure (coded as last observed date for states without each policy; from Raifman et al. 2020; similar results using stay-home dates from *Wall Street Journal* and *Aljazeera* as of April 21).

Robust standard errors adjusted for county pair clustering in parentheses.

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

Panel B: Propensity Score Strata

VARIABLES	(1)	(2)	(3)	(4)
	Deaths (log)		Cases (log)	
	Baseline	+ Controls	Baseline	+ Controls
Days from First Case until School Closure	0.447*	0.361**	4.107	1.677
	(0.158)	(0.094)	(4.471)	(4.334)
Constant	26.160**	1,443.872	578.506**	-93,295.043+
	(1.138)	(1,724.811)	(32.220)	(41,711.512)
Observations	1,446	1,446	1,446	1,446
Number of Strata	10	10	10	10
R-squared	0.027	0.157	0.011	0.078
County Strata Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Panel C: Propensity Score Pairs

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log)		Cases/100k (log)	
	Baseline	+ Controls	Baseline	+ Controls
Days from First Case until School Closure	0.211+	0.475**	0.007	3.788
	(0.126)	(0.163)	(3.315)	(4.229)
Constant	25.545**	-1,018.535	567.872**	-89,527.017
	(1.022)	(2,946.604)	(26.957)	(75,539.140)
Observations	1,226	1,226	1,226	1,226
Number of County Pairs	613	613	613	613
R-squared	0.498	0.584	0.498	0.546
County Pair Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Predicted CDC COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to counties within range of propensity score support. Even numbered models include controls for county propensity score, percent Black, median income (log), state median age, and date of restaurant closure (coded as last observed date for states without; from Raifman et al. 2020).

Robust standard errors adjusted for county strata (Panel B) or county pair (Panel C) clustering in parentheses.

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

Table A4. Predicted County COVID-19 Deaths/Cases per 100,000 Residents – Excluding States that Recommended Rather than Ordered School Closure

Panel A: Geographic County Pairs <100 Miles Apart

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log)	Cases/100k (log)	Baseline	+ Controls
Days from First Case until School Closure	0.022**	0.014*	0.025**	0.019**
	(0.005)	(0.007)	(0.002)	(0.002)
Constant	2.968**	1,794.793**	5.729**	868.567**
	(0.021)	(551.747)	(0.021)	(304.450)
Observations	1,196	1,196	2,464	2,464
Number of County Pairs	598	598	1,232	1,232
R-squared	0.714	0.769	0.779	0.826
County Pair Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Predicted CDC COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to county pairs in different states with unequal school closure timing. Even numbered models include controls for county population (log), population density (log), percent Black, percent Hispanic, percent Asian, percent urban, median income (log), poverty rate (from U.S. Census Bureau), percent of residents who frequently wear a mask in public, percent who always wear a mask, percent who rarely/never wear a mask (from *New York Times* survey, July 2020); state number of public schools (log), public school enrollment (log), school closure date (from *EdWeek*); median age, percent group quarters residence (from IPUMS), number of long-term care facilities with COVID-19 cases at the end of May (from Kaiser Family Foundation); mean value assigned to seven non-reporting states), stay-at-home order, non-essential business closure, and restaurant closure (coded as last observed date for states without each policy; from Raifman et al. 2020; similar results using stay-home dates from *Wall Street Journal* and *Aljazeera* as of April 21).

Robust standard errors adjusted for county pair clustering in parentheses.

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

Panel B: Propensity Score Strata

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log) Baseline	+ Controls	Cases/100k (log) Baseline	+ Controls
Days from First Case until School Closure	0.019*	0.014*	0.020*	0.013+
	(0.007)	(0.005)	(0.006)	(0.006)
Constant	2.624**	119.043	5.902**	2.488
	(0.048)	(113.096)	(0.046)	(87.353)
Observations	1,289	1,289	1,289	1,289
Number of Strata	10	10	10	10
R-squared	0.041	0.158	0.026	0.217
County Strata Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Panel C: Propensity Score Pairs

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log) Baseline	+ Controls	Cases/100k (log) Baseline	+ Controls
Days from First Case until School Closure	0.009+	0.025**	0.018**	0.020**
	(0.005)	(0.006)	(0.005)	(0.006)
Constant	2.575**	-66.628	5.908**	-25.836
	(0.040)	(197.291)	(0.040)	(172.762)
Observations	982	982	982	982
Number of County Pairs	491	491	491	491
R-squared	0.472	0.576	0.492	0.610
County Pair Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Predicted CDC COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to counties within range of propensity score support. Even numbered models include controls for county propensity score, percent Black, median income (log), state median age, and date of restaurant closure (coded as last observed date for states without; from Raifman et al. 2020).

Robust standard errors adjusted for county strata (Panel B) or county pair (Panel C) clustering in parentheses.

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

Table A5. Predicted County COVID-19 Deaths/Cases per 100,000 Residents – Excluding Five New York City Counties

Panel A: Geographic County Pairs <100 Miles Apart

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log)		Cases/100k (log)	
	Baseline	+ Controls	Baseline	+ Controls
Days from First Case until School Closure	0.018**	0.014*	0.022**	0.016**
	(0.005)	(0.006)	(0.002)	(0.002)
Constant	2.788**	1,652.652**	5.597**	364.564+
	(0.020)	(482.922)	(0.018)	(221.324)
Observations	1,434	1,434	3,304	3,302
Number of County Pairs	717	717	1,652	1,651
R-squared	0.694	0.756	0.770	0.817
County Pair Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Predicted CDC COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to county pairs in different states with unequal school closure timing. Even numbered models include controls for county population (log), population density (log), percent Black, percent Hispanic, percent Asian, percent urban, median income (log), poverty rate (from U.S. Census Bureau), percent of residents who frequently wear a mask in public, percent who always wear a mask, percent who rarely/never wear a mask (from *New York Times* survey, July 2020); state number of public schools (log), public school enrollment (log), school closure date (from *EdWeek*); median age, percent group quarters residence (from IPUMS), number of long-term care facilities with COVID-19 cases at the end of May (from Kaiser Family Foundation); mean value assigned to seven non-reporting states), stay-at-home order, non-essential business closure, and restaurant closure (coded as last observed date for states without each policy; from Raifman et al. 2020; similar results using stay-home dates from *Wall Street Journal* and *Aljazeera* as of April 21).

Robust standard errors adjusted for county pair clustering in parentheses.

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

Panel B: Propensity Score Strata

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log) Baseline	+ Controls	Cases/100k (log) Baseline	+ Controls
Days from First Case until School Closure	0.016*	0.012*	0.019**	0.013*
	(0.006)	(0.004)	(0.006)	(0.005)
Constant	2.548**	75.627	5.865**	-108.024*
	(0.041)	(48.831)	(0.042)	(42.790)
Observations	1,446	1,446	1,446	1,446
Number of Strata	10	10	10	10
R-squared	0.046	0.164	0.025	0.211
County Strata Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Panel C: Propensity Score Pairs

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log) Baseline	+ Controls	Cases/100k (log) Baseline	+ Controls
Days from First Case until School Closure	0.000	0.017**	0.016**	0.017**
	(0.004)	(0.005)	(0.004)	(0.005)
Constant	2.468**	31.294	5.855**	-146.624
	(0.035)	(95.456)	(0.034)	(107.435)
Observations	1,226	1,226	1,226	1,226
Number of County Pairs	613	613	613	613
R-squared	0.479	0.580	0.493	0.610
County Pair Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Predicted CDC COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to counties within range of propensity score support. Even numbered models include controls for county propensity score, percent Black, median income (log), state median age, and date of restaurant closure (coded as last observed date for states without; from Raifman et al. 2020).

Robust standard errors adjusted for county strata (Panel B) or county pair (Panel C) clustering in parentheses.

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

Table A6. Predicted County COVID-19 Deaths per 100,000 Residents – Including Counties with Zero Deaths

Panel A: Geographic County Pairs <100 Miles Apart

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log)			
	<100 miles apart		<40 miles apart	
	Baseline	+ Controls	Baseline	+ Controls
Days from First Case until School Closure	0.142**	0.067**	0.138**	0.064**
	(0.010)	(0.011)	(0.018)	(0.019)
Constant	-1.299**	2,065.196	-1.033**	-3,718.767
	(0.107)	(1,331.280)	(0.190)	(2,792.891)
Observations	3,322	3,320	1,040	1,040
Number of County Pairs	1,661	1,660	520	520
R-squared	0.693	0.732	0.706	0.767
County Pair Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Predicted CDC COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to county pairs in different states with unequal school closure timing. Even numbered models include controls for county population (log), population density (log), percent Black, percent Hispanic, percent Asian, percent urban, median income (log), poverty rate (from U.S. Census Bureau), percent of residents who frequently wear a mask in public, percent who always wear a mask, percent who rarely/never wear a mask (from *New York Times* survey, July 2020); state number of public schools (log), public school enrollment (log), school closure date (from *EdWeek*); median age, percent group quarters residence (from IPUMS), number of long-term care facilities with COVID-19 cases at the end of May (from Kaiser Family Foundation; mean value assigned to seven non-reporting states), stay-at-home order, non-essential business closure, and restaurant closure (coded as last observed date for states without each policy; from Raifman et al. 2020; similar results using stay-home dates from *Wall Street Journal* and *Aljazeera* as of April 21).

Robust standard errors adjusted for county pair clustering in parentheses.

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

Panel B: Propensity Score Strata

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log) Baseline	+ Controls	Cases/100k (log) Baseline	+ Controls
Days from First Case until School Closure	0.140**	0.104**	0.028**	0.022**
	(0.017)	(0.014)	(0.003)	(0.002)
Constant	-1.367**	219.678+	5.604**	-129.580**
	(0.189)	(107.125)	(0.033)	(19.932)
Observations	2,961	2,961	2,961	2,961
Number of Strata	10	10	10	10
R-squared	0.267	0.351	0.152	0.319
County Strata Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Panel C: Propensity Score Pairs

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log) Baseline	+ Controls	Cases/100k (log) Baseline	+ Controls
Days from First Case until School Closure	0.211**	0.083**	0.029**	0.024**
	(0.007)	(0.011)	(0.001)	(0.002)
Constant	-0.584**	-1,773.249	5.591**	-481.739+
	(0.082)	(1,485.557)	(0.016)	(275.263)
Observations	2,686	2,686	2,686	2,686
Number of County Pairs	1,343	1,343	1,343	1,343
R-squared	0.598	0.680	0.579	0.647
County Pair Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Predicted CDC COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to counties within range of propensity score support. Even numbered models include controls for county propensity score, percent Black, median income (log), state median age, and date of restaurant closure (coded as last observed date for states without; from Raifman et al. 2020).

Robust standard errors adjusted for county strata (Panel B) or county pair (Panel C) clustering in parentheses.

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

Table A7. Predicted County COVID-19 Deaths/Cases per 100,000 Residents within Geographic County Pairs – Limited to County Pairs with the Same Date of Other Non-Pharmaceutical Interventions

Panel A: County Pairs with the Same Restaurant Closure Date

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log)		Cases/100k (log)	
	<100 miles apart	<40 miles apart	<100 miles apart	<40 miles apart
Days from First Case until School Closure	0.037**	0.061**	0.036**	0.030**
	(0.010)	(0.022)	(0.004)	(0.006)
Constant	3.295**	3.343**	5.944**	6.030**
	(0.021)	(0.004)	(0.036)	(0.054)
Observations	238	96	508	214
Number of County Pairs	119	48	254	107
R-squared	0.754	0.864	0.822	0.846

Panel B: County Pairs with the Same Non-Essential Business Closure Date

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log)		Cases/100k (log)	
	<100 miles apart	<40 miles apart	<100 miles apart	<40 miles apart
Days from First Case until School Closure	-0.026	0.086+	0.015**	0.030**
	(0.020)	(0.042)	(0.004)	(0.004)
Constant	2.170**	2.378**	5.195**	5.300**
	(0.116)	(0.171)	(0.065)	(0.035)
Observations	100	26	360	94
Number of County Pairs	50	13	180	47
R-squared	0.551	0.401	0.705	0.822

Panel C: County Pairs with the Same Stay-at-Home Order Date

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log)		Cases/100k (log)	
	<100 miles apart	<40 miles apart	<100 miles apart	<40 miles apart
Days from First Case until School Closure	0.002	0.023	0.020**	0.019**
	(0.010)	(0.016)	(0.003)	(0.004)
Constant	2.425**	2.816**	5.646**	5.840**
	(0.064)	(0.133)	(0.043)	(0.050)
Observations	274	82	660	166
Number of County Pairs	137	41	330	83
R-squared	0.659	0.663	0.755	0.790

Panel D: County Pairs with the Same Stay-at-Home Order Date from Alternate Source

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log)		Cases/100k (log)	
	<100 miles apart	<40 miles apart	<100 miles apart	<40 miles apart

Days from First Case until School Closure	0.012 (0.009)	0.021* (0.009)	0.016** (0.004)	0.019** (0.004)
Constant	2.794** (0.060)	2.954** (0.071)	5.833** (0.053)	6.111** (0.049)
Observations	238	102	468	154
Number of County Pairs	119	51	234	77
R-squared	0.671	0.763	0.791	0.843

Predicted CDC COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to county pairs in different states with unequal school closure timing and with the same date of state: A) restaurant closure, B) non-essential business closure, C) stay-at-home order based on Raifman et al. 2020; and D) stay-at-home order based on *Wall Street Journal* and *Aljazeera* as of 4/21/20.

Robust standard errors adjusted for county pair clustering in parentheses.

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

Table A8. Predicted County COVID-19 Deaths/Cases per 100,000 Residents within County Propensity Score Strata – Including Fixed Effects for Dates of Other Non-Pharmaceutical Interventions

Panel A: Propensity Score Strata and Restaurant Closure Date Fixed Effects

VARIABLES	(1) Deaths/100k (log)	(2) Cases/100k (log)
Days from Date of First Case until School Closure	0.015* (0.005)	0.019* (0.006)
Constant	2.424** (0.226)	5.445** (0.126)
Observations	1,446	1,446
Number of Strata	10	10
R-squared	0.131	0.143

Panel B: Propensity Score Strata and Non-Essential Business Closure Date Fixed Effects

VARIABLES	(1) Deaths/100k (log)	(2) Cases/100k (log)
Days from Date of First Case until School Closure	0.013* (0.005)	0.016* (0.005)
Constant	2.264** (0.312)	5.329** (0.257)
Observations	1,446	1,446
Number of Strata	10	10
R-squared	0.144	0.152

Panel C: Propensity Score Strata and Stay-at-Home Order Date Fixed Effects

VARIABLES	(1) Deaths/100k (log)	(2) Cases/100k (log)
Days from Date of First Case until School Closure	0.011* (0.005)	0.015* (0.005)
Constant	1.458** (0.445)	5.258** (0.602)
Observations	1,446	1,446
Number of Strata	10	10
R-squared	0.146	0.153

Panel D: Propensity Score Strata and Stay-at-Home Order Date from Alternate Source Fixed Effects

VARIABLES	(1) Deaths/100k (log)	(2) Cases/100k (log)
Days from Date of First Case until School Closure	0.012* (0.005)	0.017* (0.005)
Constant	1.462** (0.446)	5.256** (0.611)

Observations	1,446	1,446
Number of Strata	10	10
R-squared	0.151	0.170

Predicted CDC COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to counties within range of propensity score support and with the same date of state: A) restaurant closure, B) non-essential business closure, C) stay-at-home order based on Raifman et al. 2020; and D) stay-at-home order based on *Wall Street Journal* and *Aljazeera* as of 4/21/20.

Robust standard errors adjusted for county strata clustering in parentheses.

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

Table A9. Predicted County COVID-19 Deaths/Cases per 100,000 Residents within Counties Matched Based on Propensity Scores – Limited to Pairs with the Same Date of Other Non-Pharmaceutical Interventions

Panel A: Propensity Score Pairs with the Same Restaurant Closure Date

VARIABLES	(1) Deaths/100k (log)	(2) Cases/100k (log)
Days from Date of First Case until School Closure	0.016 (0.010)	0.029+ (0.015)
Constant	2.549** (0.082)	5.885** (0.122)
Observations	116	116
Number of County Pairs	58	58
R-squared	0.565	0.540

Panel B: County Pairs with the Same Non-Essential Business Closure Date

VARIABLES	(1) Deaths/100k (log)	(2) Cases/100k (log)
Days from Date of First Case until School Closure	-0.001 (0.013)	-0.016+ (0.009)
Constant	2.543** (0.114)	5.799** (0.082)
Observations	114	114
Number of County Pairs	57	57
R-squared	0.350	0.484

Panel C: County Pairs with the Same Stay-at-Home Order Date

VARIABLES	(1) Deaths/100k (log)	(2) Cases/100k (log)
Days from Date of First Case until School Closure	-0.014 (0.018)	0.007 (0.022)
Constant	2.527** (0.163)	5.858** (0.202)
Observations	78	78
Number of County Pairs	39	39
R-squared	0.462	0.288

Panel D: County Pairs with the Same Stay-at-Home Order Date from Alternate Source

VARIABLES	(1) Deaths/100k (log)	(2) Cases/100k (log)
Days from Date of First Case until School Closure	-0.010 (0.014)	0.031+ (0.017)
Constant	2.538** (0.127)	6.292** (0.151)
Observations	68	68

Number of County Pairs	34	34
R-squared	0.529	0.407

Predicted CDC COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to counties within range of propensity score support and with the same date of state: A) restaurant closure, B) non-essential business closure, C) stay-at-home order based on Raifman et al. 2020; and D) stay-at-home order based on *Wall Street Journal* and *Aljazeera* as of 4/21/20.

Robust standard errors adjusted for county pair clustering in parentheses.

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

Table A10. Predicted County COVID-19 Deaths/Cases per 100,000 Residents by Fall 2020 State School Opening Policies

Panel A: Geographic County Pairs <100 Miles Apart

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log)		Cases/100k (log)	
	Baseline	+ Controls	Baseline	+ Controls
Fall Start At Least Partially Closed	-0.211** (0.050)	-0.199** (0.054)	-0.062** (0.023)	-0.087** (0.027)
Constant	4.350** (0.008)	-225.836 (194.444)	8.533** (0.004)	413.229** (77.116)
Observations	3,322	3,318	3,516	3,512
Number of County Pairs	1,661	1,659	1,758	1,756
R-squared	0.666	0.703	0.810	0.861
County Pair Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Predicted CDC COVID-19 data by county as of December 15, 2020 using *EdWeek* school closure data. Limited to county pairs in different states with unequal school closure timing. Even numbered models include controls for county population (log), population density (log), percent Black, percent Hispanic, percent Asian, percent urban, median income (log), poverty rate (from U.S. Census Bureau), percent of residents who frequently wear a mask in public, percent who always wear a mask, percent who rarely/never wear a mask (from *New York Times* survey, July 2020); state number of public schools (log), public school enrollment (log), school closure date (from *EdWeek*); median age, percent group quarters residence (from IPUMS), number of long-term care facilities with COVID-19 cases at the end of May (from Kaiser Family Foundation; mean value assigned to seven non-reporting states), stay-at-home order, non-essential business closure, and restaurant closure (coded as last observed date for states without each policy; from Raifman et al. 2020; similar results using stay-home dates from *Wall Street Journal* and *Aljazeera* as of April 21).

Robust standard errors adjusted for county pair clustering in parentheses.

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

Panel B: Propensity Score Strata

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log)		Cases/100k (log)	
	Baseline	+ Controls	Baseline	+ Controls
Fall Start At Least Partially Closed	-0.383** (0.084)	-0.490** (0.104)	0.006 (0.073)	-0.101 (0.070)
Constant	2.498** (0.014)	71.827 (51.145)	5.725** (0.012)	-116.397* (44.309)
Observations	1,446	1,446	1,446	1,446
Number of Strata	10	10	10	10
R-squared	0.051	0.181	0.006	0.205
County Strata Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Panel C: Propensity Score Pairs

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log)		Cases/100k (log)	
	Baseline	+ Controls	Baseline	+ Controls
Fall Start At Least Partially Closed	-0.438** (0.120)	-0.534** (0.115)	-0.075 (0.111)	-0.118 (0.101)
Constant	2.542** (0.021)	37.288 (94.399)	5.739** (0.020)	-159.856 (105.815)
Observations	1,226	1,226	1,226	1,226
Number of County Pairs	613	613	613	613
R-squared	0.490	0.588	0.481	0.602
County Pair Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Predicted CDC COVID-19 data by county as of December 15, 2020 using *EdWeek* school closure data. Limited to counties within range of propensity score support. Even numbered models include controls for county propensity score, percent Black, median income (log), state median age, and date of restaurant closure (coded as last observed date for states without; from Raifman et al. 2020).

Robust standard errors adjusted for county strata (Panel B) or county pair (Panel C) clustering in parentheses.

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

Table A11. Predicted Daily Cumulative County COVID-19 Deaths per 100,000 Residents within County Pairs <100 miles apart

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log)		Deaths/100k (log)	
	Baseline	+ Controls	Baseline	+ Controls
Days from First Case until School Closure	0.014**	0.026**	0.001**	0.001*
	(0.005)	(0.006)	(0.000)	(0.000)
Lag Deaths/100k (log) Day t-1 (1-day lag)			0.968**	0.966**
			(0.001)	(0.001)
Constant	2.130**	1,590.131**	0.101**	54.777**
	(0.019)	(425.222)	(0.003)	(18.369)
Observations	123,106	123,106	121,056	121,056
Number of County Pairs	1,325	1,325	1,325	1,325
R-squared	0.782	0.795	0.993	0.993
County Pair and Date Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Predicted CDC COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to county pairs in different states with unequal school closure timing. Even numbered models include controls for county population (log), population density (log), percent Black, percent Hispanic, percent Asian, percent urban, median income (log), poverty rate (from U.S. Census Bureau), percent of residents who frequently wear a mask in public, percent who always wear a mask, percent who rarely/never wear a mask (from *New York Times* survey, July 2020); state number of public schools (log), public school enrollment (log), school closure date (from *EdWeek*); median age, percent group quarters residence (from IPUMS), number of long-term care facilities with COVID-19 cases at the end of May (from Kaiser Family Foundation; mean value assigned to seven non-reporting states), stay-at-home order, non-essential business closure, and restaurant closure (coded as last observed date for states without each policy; from Raifman et al. 2020; similar results using stay-home dates from *Wall Street Journal* and *Aljazeera* as of April 21).

Robust standard errors adjusted for county pair clustering in parentheses.

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

Comparable analyses are not applicable for propensity score analyses because counties are matched on one date.

Table A12. Predicted County COVID-19 Deaths/Cases per 100,000 Residents – New York Times COVID-19 Data
 Panel A: Geographic County Pairs <100 Miles Apart

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log)	Cases/100k (log)	Baseline	+ Controls
Days from First Case until School Closure	0.016**	0.013*	0.022**	0.016**
	(0.005)	(0.006)	(0.002)	(0.002)
Constant	2.811**	1,419.728**	5.608**	376.345+
	(0.020)	(457.576)	(0.018)	(223.149)
Observations	1,422	1,422	3,304	3,302
Number of County Pairs	711	711	1,652	1,651
R-squared	0.700	0.763	0.767	0.816
County Pair Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Predicted New York Times COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data.

Limited to county pairs in different states with unequal school closure timing. Even numbered models include controls for county population (log), population density (log), percent Black, percent Hispanic, percent Asian, percent urban, median income (log), poverty rate (from U.S. Census Bureau), percent of residents who frequently wear a mask in public, percent who always wear a mask, percent who rarely/never wear a mask (from *New York Times* survey, July 2020); state number of public schools (log), public school enrollment (log), school closure date (from *EdWeek*); median age, percent group quarters residence (from IPUMS), number of long-term care facilities with COVID-19 cases at the end of May (from Kaiser Family Foundation; mean value assigned to seven non-reporting states), stay-at-home order, non-essential business closure, and restaurant closure (coded as last observed date for states without each policy; from Raifman et al. 2020; similar results using stay-home dates from *Wall Street Journal* and *Aljazeera* as of April 21).

Robust standard errors adjusted for county pair clustering in parentheses.

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

Panel B: Propensity Score Strata

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log) Baseline	+ Controls	Cases/100k (log) Baseline	+ Controls
Days from First Case until School Closure	0.015*	0.011*	0.019*	0.013*
	(0.005)	(0.004)	(0.006)	(0.005)
Constant	2.562**	94.508+	5.875**	-96.171+
	(0.039)	(50.766)	(0.043)	(43.338)
Observations	1,433	1,433	1,446	1,446
Number of Strata	10	10	10	10
R-squared	0.044	0.161	0.023	0.204
County Strata Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Panel C: Propensity Score Pairs

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log) Baseline	+ Controls	Cases/100k (log) Baseline	+ Controls
Days from First Case until School Closure	-0.001	0.016**	0.015**	0.017**
	(0.004)	(0.006)	(0.004)	(0.005)
Constant	2.480**	64.530	5.867**	-130.508
	(0.037)	(95.120)	(0.034)	(108.446)
Observations	1,202	1,202	1,226	1,226
Number of County Pairs	601	601	613	613
R-squared	0.475	0.575	0.487	0.601
County Pair Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Predicted CDC COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to counties within range of propensity score support. Even numbered models include controls for county propensity score, percent Black, median income (log), state median age, and date of restaurant closure (coded as last observed date for states without; from Raifman et al. 2020).

Robust standard errors adjusted for county strata (Panel B) or county pair (Panel C) clustering in parentheses.

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

Table A13. Predicted County COVID-19 Deaths/Cases per 100,000 Residents – Johns Hopkins University COVID-19 Data

Panel A: Geographic County Pairs <100 Miles Apart

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log)		Cases/100k (log)	
	Baseline	+ Controls	Baseline	+ Controls
Days from First Case until School Closure	0.018**	0.014*	0.022**	0.016**
	(0.005)	(0.006)	(0.002)	(0.002)
Constant	2.835**	1,614.226**	5.610**	359.920
	(0.020)	(458.514)	(0.018)	(226.730)
Observations	1,458	1,458	3,306	3,304
Number of County Pairs	729	729	1,653	1,652
R-squared	0.712	0.771	0.775	0.822
County Pair Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Predicted Johns Hopkins University COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to county pairs in different states with unequal school closure timing. Even numbered models include controls for county population (log), population density (log), percent Black, percent Hispanic, percent Asian, percent urban, median income (log), poverty rate (from U.S. Census Bureau), percent of residents who frequently wear a mask in public, percent who always wear a mask, percent who rarely/never wear a mask (from *New York Times* survey, July 2020); state number of public schools (log), public school enrollment (log), school closure date (from *EdWeek*); median age, percent group quarters residence (from IPUMS), number of long-term care facilities with COVID-19 cases at the end of May (from Kaiser Family Foundation; mean value assigned to seven non-reporting states), stay-at-home order, non-essential business closure, and restaurant closure (coded as last observed date for states without each policy; from Raifman et al. 2020; similar results using stay-home dates from *Wall Street Journal* and *Aljazeera* as of April 21).

Robust standard errors adjusted for county pair clustering in parentheses.

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

Panel B: Propensity Score Strata

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log) Baseline	+ Controls	Cases/100k (log) Baseline	+ Controls
Days from First Case until School Closure	0.016*	0.012*	0.020**	0.013*
	(0.006)	(0.004)	(0.006)	(0.005)
Constant	2.571**	92.130+	5.872**	-111.154*
	(0.040)	(48.537)	(0.042)	(41.914)
Observations	1,427	1,427	1,442	1,442
Number of Strata	10	10	10	10
R-squared	0.043	0.160	0.026	0.209
County Strata Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Panel C: Propensity Score Pairs

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log) Baseline	+ Controls	Cases/100k (log) Baseline	+ Controls
Days from First Case until School Closure	0.002	0.017**	0.017**	0.017**
	(0.004)	(0.006)	(0.004)	(0.005)
Constant	2.500**	65.688	5.866**	-147.339
	(0.036)	(94.599)	(0.034)	(108.268)
Observations	1,196	1,196	1,220	1,220
Number of County Pairs	598	598	610	610
R-squared	0.483	0.582	0.493	0.607
County Pair Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Predicted CDC COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to counties within range of propensity score support. Even numbered models include controls for county propensity score, percent Black, median income (log), state median age, and date of restaurant closure (coded as last observed date for states without; from Raifman et al. 2020).

Robust standard errors adjusted for county strata (Panel B) or county pair (Panel C) clustering in parentheses.

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

Table A14. Predicted County COVID-19 Deaths per 100,000 Residents by County Poverty and Race/Ethnicity – New York Times COVID-19 Data

Panel A: Geographic County Pairs <100 Miles Apart

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Deaths/100k (log)							
Days from First Case until School Closure	0.014*	0.014+	0.013*	0.011	0.003	0.003	0.018*	0.016+
	(0.006)	(0.008)	(0.006)	(0.007)	(0.009)	(0.010)	(0.008)	(0.008)
High Poverty (>median)	0.433**	0.204+						
	(0.095)	(0.108)						
High Poverty (>70 th percentile)			0.376**	0.087				
			(0.112)	(0.135)				
High Pov x Days to School Closure	0.006	-0.002	0.010	0.004				
	(0.009)	(0.009)	(0.009)	(0.009)				
High Black (>median)					0.131	0.004		
					(0.143)	(0.144)		
High Black x Days to School Closure					0.019+	0.015		
					(0.010)	(0.010)		
High Hispanic (>median)							-0.135	-0.221+
							(0.110)	(0.122)
High Hispanic x Days to School Closure							-0.001	-0.007
							(0.009)	(0.010)
Constant	2.587**	1,361.539**	2.683**	1,407.816**	2.702**	1,447.365**	2.889**	1,322.009**
	(0.056)	(455.618)	(0.046)	(459.349)	(0.120)	(459.582)	(0.075)	(457.044)
Observations	1,422	1,422	1,422	1,422	1,422	1,422	1,422	1,422
Number of County Pairs	711	711	711	711	711	711	711	711
R-squared	0.708	0.764	0.705	0.763	0.701	0.764	0.701	0.764
County Pair Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
Controls		Y		Y		Y		Y

Predicted New York Times COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to county pairs in different states with unequal school closure timing. Even numbered models include controls for county population (log), population density (log), percent Black, percent Hispanic, percent Asian, percent urban, median income (log), poverty rate (from U.S. Census Bureau), percent of residents who frequently wear a mask in public, percent who always wear a mask, percent who rarely/never wear a mask (from *New York Times* survey, July 2020); state number of public schools (log), public school enrollment (log), school closure date (from *EdWeek*); median age, percent group quarters residence (from IPUMS), number of long-term care facilities with COVID-19 cases at the end of May (from Kaiser Family Foundation; mean value assigned to seven non-reporting states), stay-at-home order, non-essential

business closure, and restaurant closure (coded as last observed date for states without each policy; from Raifman et al. 2020; similar results using stay-home dates from *Wall Street Journal* and *Aljazeera* as of April 21). Robust standard errors adjusted for county pair clustering in parentheses. ** p<0.01, * p<0.05, + p<0.1

Panel B: Propensity Score Strata

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Deaths/100k (log)							
Days from First Case until School Closure	0.010 (0.007)	0.009 (0.006)	0.009 (0.006)	0.008 (0.005)	0.006 (0.005)	0.004 (0.003)	0.021** (0.006)	0.014** (0.004)
High Poverty (>median)	0.302* (0.120)	-0.187+ (0.090)						
High Poverty (>70 th percentile)			0.649** (0.109)	0.205+ (0.100)				
High Pov x Days to School Closure	0.011 (0.011)	0.005 (0.009)	0.019* (0.006)	0.010* (0.004)				
High Black (>median)					0.532** (0.040)	0.120* (0.053)		
High Black x Days to School Closure					0.017** (0.004)	0.018** (0.004)		
High Hispanic (>median)							-0.108 (0.083)	-0.038 (0.070)
High Hispanic x Days to School Closure							-0.013* (0.005)	-0.005 (0.005)
Constant	2.407** (0.067)	95.606 (52.761)	2.343** (0.047)	93.086 (52.684)	2.237** (0.028)	96.039 (53.185)	2.621** (0.077)	95.053+ (51.017)
Observations	1,433	1,433	1,433	1,433	1,433	1,433	1,433	1,433
Number of Strata	10	10	10	10	10	10	10	10
R-squared	0.055	0.165	0.088	0.163	0.076	0.165	0.047	0.161
County Pair Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
Controls		Y		Y		Y		Y

Predicted New York Times COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to counties within range of propensity score support. Even numbered models include controls for county propensity score, percent Black, median income (log), state median age, and date of restaurant closure (coded as last observed date for states without; from Raifman et al. 2020).

Robust standard errors adjusted for county strata clustering in parentheses.

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

Panel C: Propensity Score Pairs

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Deaths/100k (log)							
Days from First Case until School Closure	-0.008 (0.007)	0.013+ (0.008)	-0.011+ (0.006)	0.009 (0.006)	-0.013* (0.006)	0.004 (0.007)	0.007 (0.007)	0.017* (0.008)
High Poverty (>median)	0.497** (0.138)	-0.291+ (0.168)						
High Poverty (>70 th percentile)			0.904** (0.146)	0.139 (0.178)				
High Pov x Days to School Closure	0.016 (0.012)	0.005 (0.011)	0.034** (0.013)	0.021+ (0.012)				
High Black (>median)					0.466** (0.134)	-0.098 (0.144)		
High Black x Days to School Closure					0.022+ (0.012)	0.024* (0.012)		
High Hispanic (>median)							-0.312* (0.136)	-0.059 (0.128)
High Hispanic x Days to School Closure							-0.013 (0.012)	-0.002 (0.011)
Constant	2.221** (0.076)	78.351 (95.549)	2.169** (0.059)	76.811 (94.099)	2.196** (0.083)	63.766 (94.070)	2.640** (0.083)	63.344 (96.148)
Observations	1,202	1,202	1,202	1,202	1,202	1,202	1,202	1,202
Number of County Pairs	601	601	601	601	601	601	601	601
R-squared	0.489	0.580	0.514	0.578	0.485	0.584	0.479	0.576
County Pair Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
Controls		Y		Y		Y		Y

Predicted New York Times COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to counties within range of propensity score support. Even numbered models include controls for county propensity score, percent Black, median income (log), state median age, and date of restaurant closure (coded as last observed date for states without; from Raifman et al. 2020).

Robust standard errors adjusted for county pair clustering in parentheses.

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

In Panels A-C, counties with high poverty, Black, or Hispanic concentration are above the median value among all counties (U.S. Census Bureau 2010, 2018).

Models 3 & 4 examine counties above the 70th percentile for poverty rate.

Table A15. Predicted County COVID-19 Deaths per 100,000 Residents by County Poverty and Race/Ethnicity – Johns Hopkins University COVID-19 Data
 Panel A: Geographic County Pairs <100 Miles Apart

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Deaths/100k (log)							
Days from First Case until School Closure	0.015*	0.014+	0.016**	0.013+	-0.003	-0.001	0.016*	0.016+
	(0.006)	(0.008)	(0.006)	(0.007)	(0.009)	(0.009)	(0.008)	(0.008)
High Poverty (>median)	0.415**	0.166						
	(0.094)	(0.106)						
High Poverty (>70 th percentile)			0.362**	0.066				
			(0.111)	(0.134)				
High Pov x Days to School Closure	0.009	-0.000	0.008	0.002				
	(0.008)	(0.009)	(0.009)	(0.009)				
High Black (>median)					0.282*	0.114		
					(0.142)	(0.142)		
High Black x Days to School Closure					0.027**	0.023*		
					(0.010)	(0.010)		
High Hispanic (>median)							-0.061	-0.132
							(0.114)	(0.119)
High Hispanic x Days to School Closure							0.003	-0.004
							(0.009)	(0.010)
Constant	2.623**	1,578.044**	2.709**	1,608.194**	2.599**	1,649.267**	2.864**	1,549.036**
	(0.055)	(457.117)	(0.045)	(459.268)	(0.119)	(458.252)	(0.076)	(461.314)
Observations	1,458	1,458	1,458	1,458	1,458	1,458	1,458	1,458
Number of County Pairs	729	729	729	729	729	729	729	729
R-squared	0.720	0.772	0.717	0.771	0.716	0.773	0.713	0.772
County Pair Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
Controls		Y		Y		Y		Y

Predicted Johns Hopkins University COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to county pairs in different states with unequal school closure timing. Even numbered models include controls for county population (log), population density (log), percent Black, percent Hispanic, percent Asian, percent urban, median income (log), poverty rate (from U.S. Census Bureau), percent of residents who frequently wear a mask in public, percent who always wear a mask, percent who rarely/never wear a mask (from *New York Times* survey, July 2020); state number of public schools (log), public school enrollment (log), school closure date (from *EdWeek*); median age, percent group quarters residence (from IPUMS), number of long-term care facilities with COVID-19 cases at the end of May (from Kaiser Family Foundation; mean value assigned to seven non-reporting states), stay-at-home order, non-essential

business closure, and restaurant closure (coded as last observed date for states without each policy; from Raifman et al. 2020; similar results using stay-home dates from *Wall Street Journal* and *Aljazeera* as of April 21). Robust standard errors adjusted for county pair clustering in parentheses. ** p<0.01, * p<0.05, + p<0.1

Panel B: Propensity Score Strata

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Deaths/100k (log)							
Days from First Case until School Closure	0.012+	0.010	0.010	0.009+	0.007	0.004	0.021*	0.013**
	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)	(0.003)	(0.007)	(0.004)
High Poverty (>median)	0.250+	-0.235*						
	(0.121)	(0.090)						
High Poverty (>70 th percentile)			0.618**	0.196+				
			(0.112)	(0.102)				
High Pov x Days to School Closure	0.009	0.003	0.017*	0.008				
	(0.010)	(0.009)	(0.006)	(0.004)				
High Black (>median)					0.523**	0.111+		
					(0.043)	(0.049)		
High Black x Days to School Closure					0.018**	0.019**		
					(0.004)	(0.004)		
High Hispanic (>median)							-0.089	-0.031
							(0.083)	(0.068)
High Hispanic x Days to School Closure							-0.011+	-0.003
							(0.006)	(0.005)
Constant	2.442**	94.442+	2.361**	90.370	2.251**	93.223	2.620**	92.327+
	(0.067)	(51.309)	(0.049)	(50.278)	(0.033)	(51.741)	(0.078)	(48.666)
Observations	1,427	1,427	1,427	1,427	1,427	1,427	1,427	1,427
Number of Strata	10	10	10	10	10	10	10	10
R-squared	0.050	0.165	0.084	0.162	0.073	0.165	0.045	0.160
County Pair Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
Controls		Y		Y		Y		Y

Predicted Johns Hopkins University COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to counties within range of propensity score support. Even numbered models include controls for county propensity score, percent Black, median income (log), state median age, and date of restaurant closure (coded as last observed date for states without; from Raifman et al. 2020).

Robust standard errors adjusted for county strata clustering in parentheses.

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

Panel C: Propensity Score Pairs

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Deaths/100k (log)							
Days from First Case until School Closure	-0.004 (0.007)	0.016* (0.007)	-0.007 (0.006)	0.012+ (0.006)	-0.011+ (0.006)	0.005 (0.006)	0.008 (0.007)	0.018* (0.008)
High Poverty (>median)	0.460** (0.135)	-0.332* (0.166)						
High Poverty (>70 th percentile)			0.851** (0.145)	0.105 (0.175)				
High Pov x Days to School Closure	0.014 (0.011)	0.002 (0.011)	0.030* (0.013)	0.017 (0.012)				
High Black (>median)					0.467** (0.133)	-0.091 (0.143)		
High Black x Days to School Closure					0.022+ (0.012)	0.025* (0.011)		
High Hispanic (>median)							-0.293* (0.134)	-0.063 (0.125)
High Hispanic x Days to School Closure							-0.011 (0.011)	-0.001 (0.011)
Constant	2.258** (0.074)	79.286 (94.623)	2.203** (0.058)	75.704 (93.553)	2.216** (0.082)	63.500 (93.208)	2.650** (0.080)	64.075 (95.781)
Observations	1,196	1,196	1,196	1,196	1,196	1,196	1,196	1,196
Number of County Pairs	598	598	598	598	598	598	598	598
R-squared	0.496	0.587	0.520	0.584	0.494	0.591	0.488	0.582
County Pair Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
Controls		Y		Y		Y		Y

Predicted Johns Hopkins University COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to counties within range of propensity score support. Even numbered models include controls for county propensity score, percent Black, median income (log), state median age, and date of restaurant closure (coded as last observed date for states without; from Raifman et al. 2020).

Robust standard errors adjusted for county pair clustering in parentheses.

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

In Panels A-C, counties with high poverty, Black, or Hispanic concentration are above the median value among all counties (U.S. Census Bureau 2010, 2018).

Models 3 & 4 examine counties above the 70th percentile for poverty rate.

Table A16: Predicted County COVID-19 Deaths/Cases per 100,000 Residents – Including Additional Variables to Calculate Propensity Score
Panel A: Propensity Score Strata

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log)	Deaths/100k (log)	Cases/100k (log)	Cases/100k (log)
	Baseline	+ Controls	Baseline	+ Controls
Days from First Case until School Closure	0.011*	0.012*	0.012*	0.012*
	(0.004)	(0.004)	(0.005)	(0.005)
Constant	2.495**	3.739**	5.803**	5.620**
	(0.029)	(0.582)	(0.031)	(0.486)
Observations	1,548	1,548	1,548	1,548
Number of Strata	10	10	10	10
R-squared	0.033	0.036	0.013	0.013
County Strata Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Panel B: Propensity Score Pairs

VARIABLES	(1)	(2)	(3)	(4)
	Deaths/100k (log)	Deaths/100k (log)	Cases/100k (log)	Cases/100k (log)
	Baseline	+ Controls	Baseline	+ Controls
Days from First Case until School Closure	-0.004	0.015**	0.009*	0.012*
	(0.004)	(0.005)	(0.004)	(0.005)
Constant	2.392**	3.078**	5.785**	5.893**
	(0.033)	(0.129)	(0.032)	(0.128)
Observations	1,228	1,228	1,228	1,228
Number of County Pairs	614	614	614	614
R-squared	0.514	0.535	0.500	0.500
County Pair Fixed Effects	Y	Y	Y	Y
Controls		Y		Y

Predicted CDC COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to counties within range of propensity score support. Even numbered models include controls for county propensity score.

Robust standard errors adjusted for county strata (Panel A) or county pair (Panel B) clustering in parentheses.

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

Table A17. Predicted County COVID-19 Deaths per 100,000 Residents by County Poverty and Race/Ethnicity – Including Additional Variables to Calculate Propensity Score
Panel A: Propensity Score Strata

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Deaths/100k (log)							
Days from First Case until School Closure	0.007 (0.005)	0.008 (0.005)	0.007 (0.006)	0.008 (0.006)	0.004 (0.004)	0.005 (0.004)	0.019* (0.007)	0.020* (0.007)
High Poverty (>median)	0.262* (0.092)	0.267* (0.092)						
High Poverty (>70 th percentile)			0.631** (0.148)	0.635** (0.148)				
High Pov x Days to School Closure	0.008 (0.007)	0.009 (0.007)	0.015 (0.010)	0.016 (0.010)				
High Black (>median)					0.571** (0.059)	0.577** (0.057)		
High Black x Days to School Closure					0.018** (0.002)	0.017** (0.002)		
High Hispanic (>median)							-0.166+ (0.074)	-0.159+ (0.074)
High Hispanic x Days to School Closure							-0.015* (0.006)	-0.015* (0.006)
Constant	2.358** (0.053)	3.647** (0.587)	2.288** (0.052)	3.558** (0.634)	2.151** (0.032)	3.600** (0.613)	2.590** (0.069)	3.761** (0.593)
Observations	1,548	1,548	1,548	1,548	1,548	1,548	1,548	1,548
Number of Strata	10	10	10	10	10	10	10	10
R-squared	0.041	0.044	0.078	0.081	0.069	0.073	0.037	0.039
County Pair Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
Controls		Y		Y		Y		Y

Predicted CDC COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to counties within range of propensity score support. Even numbered models include controls for county propensity score.

Robust standard errors adjusted for county strata clustering in parentheses.

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

Counties with high poverty, Black, or Hispanic concentration are above the median value among all counties (U.S. Census Bureau 2010, 2018). Models 3 & 4 examine counties above the 70th percentile for poverty rate.

Panel B: Propensity Score Pairs

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Deaths/100k (log)							
Days from First Case until School Closure	-0.013*	0.002	-0.009	0.007	-0.019**	0.002	0.002	0.021**
	(0.007)	(0.007)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)
High Poverty (>median)	0.467**	0.452**						
	(0.134)	(0.133)						
High Poverty (>70 th percentile)			0.881**	0.874**				
			(0.133)	(0.134)				
High Pov x Days to School Closure	0.019+	0.024*	0.023*	0.027*				
	(0.011)	(0.011)	(0.011)	(0.012)				
High Black (>median)					0.638**	0.758**		
					(0.120)	(0.120)		
High Black x Days to School Closure					0.025*	0.029**		
					(0.010)	(0.010)		
High Hispanic (>median)							-0.067	0.016
							(0.117)	(0.119)
High Hispanic x Days to School Closure							-0.015	-0.013
							(0.009)	(0.010)
Constant	2.141**	2.819**	2.097**	2.719**	2.003**	2.749**	2.427**	3.089**
	(0.076)	(0.151)	(0.052)	(0.137)	(0.074)	(0.132)	(0.070)	(0.135)
Observations	1,228	1,228	1,228	1,228	1,228	1,228	1,228	1,228
Number of County Pairs	614	614	614	614	614	614	614	614
R-squared	0.524	0.544	0.559	0.576	0.535	0.564	0.515	0.537
County Pair Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
Controls		Y		Y		Y		Y

Predicted CDC COVID-19 data by county as of June 15, 2020 using *EdWeek* school closure data. Limited to counties within range of propensity score support. Even numbered models include controls for county propensity score.

Robust standard errors adjusted for county pair clustering in parentheses.

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

Counties with high poverty, Black, or Hispanic concentration are above the median value among all counties (U.S. Census Bureau 2010, 2018). Models 3 & 4 examine counties above the 70th percentile for poverty rate.