Major Article

Effect of Fall 2020 K-12 instruction types on COVID-19 cases, hospital admissions, and deaths in Illinois counties

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Background: One of the most difficult public policy decisions associated with the COVID-19 pandemic has been about how to offer K-12 instruction. We sought to determine whether differences in instruction types at the beginning of the 2020-2021 school year were related to differences in COVID-19 cases, hospitalizations, and deaths in Illinois counties during the first 3 weeks of the school year.

Methods: We divided Illinois counties into 3 groups based on the instruction type used for a majority of K-12 students at the start of the school year: in-person, hybrid, or online-only. We used synthetic control analysis to match counties between the 3 groups.

Results: Both majority hybrid and majority online-only counties had significantly fewer new cases than majority in-person counties. There were no significant differences in new cases between majority hybrid counties and majority online-only counties or in new hospital admissions or deaths between any of the 3 county groups.

Conclusions: This paper adds to the growing scientific consensus that at least some forms of in-person K-12 instruction have not contributed significantly to the spread of the pandemic. However, our results suggest that there may be an important difference between fully in-person instruction and hybrid instruction.

BACKGROUND

One of the most difficult public policy decisions associated with the COVID-19 pandemic has been the decision about how to offer K-12 instruction. During the first wave of the pandemic in March 2020, most states ordered all public schools to close. Most of the remaining states recommended that all public schools should close, and those recommendations were followed by almost all school districts. Only in Montana and Wyoming did a significant number of public schools not close and switch to entirely online learning.[1]

By the time that schools were preparing to resume instruction in August 2020, the situation had changed. The number of new cases had stabilized in most parts of the country and public health experts had a better understanding of the virus. Only two states required schools to provide only online instruction at the start of the 2020-

2021 school year, while four states required schools to provide at least some in-person instruction. The remaining 44 states left decisions about how to provide K-12 instruction to individual counties, cities, districts, or schools.[2]

An important question, of course, was whether students could return to classrooms in a way that was safe for students, teachers, other school employees, and their families. In July 2020, the Centers for Disease Control and Prevention[3] recommended that schools be reopened in Fall 2020, based on its conclusions that COVID-19 posed low risks to children and that children were not likely to be major contributors to the spread of the virus. However, the CDC's recommendations were issued after President Trump and Education Secretary DeVos had stated that schools should be reopened and had threatened to withhold federal funding from districts that did not reopen, which led some people to question the basis for the CDC's recommendations.[4]

Because almost all states closed their public schools and moved to entirely online instruction at about the same time in March 2020, it has been difficult to determine how effective those closings were in limiting the initial spread of the pandemic. Some researchers have attempted to estimate the effect of those early closings on the spread

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of the pandemic by comparing changes in the spread within states or counties before and after the closings occurred.[5-8] However, because so many other social distancing restrictions were being imposed at the same time, it is difficult to disentangle the effect of those early closings from the effects of those other measures. Other researchers have attempted to estimate the effect of those early closings based on differences across counties in the timing of the closings.[9] That approach is also challenging, because so many other factors were changing so quickly during the first few months of the pandemic, such as other social distancing measures, testing capacity, and knowledge about the virus.

During the 2020-2021 school year, there has been much greater variation in K-12 instruction types, not only across states, but also across school districts and schools within states. However, it is still difficult to determine the effects of different instruction types on the spread of the pandemic for 2 reasons. First, it is difficult to find accurate data for the instruction type being used by each district or school at any point in time. Second, districts and schools have changed their instruction types frequently as community metrics have changed and knowledge about the virus has increased. Two working papers have attempted to estimate the effect of in-person schooling during Fall 2020 on the spread of the pandemic using community data. Goldhaber et al.[10] used data from monthly surveys of school districts in Michigan and Washington in Fall 2020. Harris, Ziedan, and Hassig[11] used data from Burbio and MCH Strategic Data on instruction types at the start of the 2020-2021 school year in selected school districts nationally. Two CDC-sponsored studies have attempted to estimate the effect of in-person schooling during Fall 2020 on the spread of the pandemic using individual data. Hobbs et al.[12] used individual data for 397 children in Mississippi who took COVID-19 tests between September 1, 2020 and November 5, 2020 to assess whether various factors, including in-person school or child-care attendance, were associated with a positive test result. Falk et al.[13] used data from 17 K-12 schools in rural Wisconsin to assess likely transmission locations for students and staff with confirmed COVID-19 cases during 13 weeks of in-person instruction.

We sought to determine whether differences in K-12 instruction types at the beginning of the 2020-2021 school year in Illinois school districts were related to differences in COVID-19 cases, hospitalizations, and deaths in Illinois counties during the 3-week period from August 24, 2020 to September 13, 2020.

MATERIAL AND METHODS

Data

For data on instruction types, we started with a dashboard on the Illinois State Board of Education (ISBE) website with the results of the ISBE's July 2020 survey of the 852 school districts in Illinois about their plans for instruction to start the school year.[14] However, we observed that some dashboard data did not accurately reflect instruction types used by districts at the start of the 2020-2021 school year. Therefore, we updated the ISBE dashboard data for the 200 largest districts in Illinois and, to the extent they were not included among the 200 largest districts, for the largest district in each county, by searching district websites and news sources. We coded the districts based on the instruction type that they were using at the beginning of the school year. When a district had different instruction types for different grades, we coded the district with the least restrictive instruction type being used (in-person is the least restrictive type, then hybrid, then online-only).

Because COVID-19 case and death data are not available at the school district level, all of our analyses are at the county level. We first divided the counties into 3 groups: counties where a majority of the students attended districts with primarily in-person instruction, counties where a majority of the students attended districts with primarily hybrid instruction, and counties where a majority of the students attended districts with only online instruction. We excluded Cook County, because it is such an outlier among Illinois counties in so many respects that it was not possible to match it closely with other Illinois counties on the predictor variables that we used, and we excluded 6 counties with relatively large numbers of college students (Champaign, Coles, DeKalb, Jackson, McDonough, and McLean Counties), because the resumption of college classes contributed to case spikes in many college towns. Of the 95 remaining counties, 41 were majority in-person counties, 32 were majority hybrid counties, and 17 were majority online-only counties; 5 counties did not have a majority of students in any of the 3 categories.

We obtained daily COVID-19 case and death data for each county from the New York Times.[15] We obtained data on weekly confirmed and suspected COVID-19 hospital admissions from the U.S. Department of Health and Human Services.[16] The hospital admissions data did not include counties of residence for the admitted patients so we used the counties in which the hospitals are located, which is not ideal because some people may have to travel to a neighboring county for hospital access. Also, the hospital admissions data were updated only weekly, reflecting admissions from Friday to Thursday, unlike the case and death data, which were updated daily.

Finally, we obtained county-level data on the demographic covariates in our models from various U.S. Census Bureau[17,18] and U.S. Department of Agriculture[19−22] datasets. All of the covariates were measured in 2018. Table 1 shows descriptive statistics for the variables included in our analyses.

Methods

Many Illinois schools started 1 or 2 weeks later than usual in 2020, with most schools starting sometime between August 24 and September 2. Therefore, we used August 24 as the treatment date in our analyses. Although a few schools started earlier than August 24, it usually takes at least a few days for COVID-19 cases to be detected and reported. Therefore, we would not expect school reopenings to have noticeably affected reported COVID-19 case numbers until at least August 24; we would not expect school reopenings to have noticeably affected reported COVID-19 hospitalization or death numbers until at least a few more days after August 24.

We first used linear regressions to identify the demographic variables that were significant predictors of new COVID-19 cases or deaths in Illinois counties, using data from August 3, 2020 through September 13, 2020. We considered 23 different demographic variables in those regressions and ultimately selected 10 predictor variables. In addition to those 10 predictor variables, which are listed in Table 1, the other variables that we considered but that were not significant predictors were percent of population who are Asian, percent of population who are black, percent of population with less than a high school education, percent of population who are over age 17, percent of population who are over age 64, percent of population who are over age 74, percent of population who are over age 84, population, land area, population density, unemployment rate, metro code, and rural-urban code.

For our main analyses, we used the synthetic control method to match counties from each group with counties from each other group on the predictor variables, including a pretreatment value of the outcome variable averaged over the 7 days prior to August 24, 2020. Synthetic control analysis constructs a synthetic control unit for each treated unit by finding a weighted combination of control units that matches the treated unit as closely as possible on the pretreatment averages of the predictor variables. An advantage to synthetic control analysis is that a weighted combination of control units can often provide a better match for a treated unit than any individual control

Table 1
Descriptive statistics for variables included in analyses

Variable	Majority in-person counties (n = 41)		Majority hybrid counties (n = 32)		Majority online-only counties (n = 17)	
	Mean	SD	Mean	SD	Mean	SD
Outcome variables (post-treatment average from August 24 to September 13):						
New confirmed or probable COVID-19 cases per 100,000 people	20.8	12.8	18.3	8.8	14.9	5.5
New confirmed or suspected COVID-19 hospital admissions per 100,000 people	1.2	2.6	2.6	2.7	3.1	2.4
New confirmed or probable COVID-19 deaths per 100,000 people	0.22	0.34	0.34	0.49	0.22	0.25
Lagged outcome variables included as predictors (pre-treatment average from August 3 to August 23):						
New confirmed or probable COVID-19 cases per 100,000 people	15.3	9.2	14.5	9.3	15.0	5.9
New confirmed or suspected COVID-19 hospital admissions per 100,000 people	0.5	1.2	6.1	20.3	2.4	2.0
New confirmed or probable COVID-19 deaths per 100,000 people	0.24	0.49	0.23	0.32	0.13	0.23
Other predictor variables:						
% of population who are Hispanic	1.7	1.0	4.7	4.8	9.2	8.0
% of population who are Native American	0.21	0.09	0.27	0.12	0.27	0.09
% of population with high school education or less	47.9	4.6	47.2	6.1	40.6	7.5
Median age	42.8	2.1	40.8	2.1	38.7	2.9
Death rate	11.8	1.5	11.2	1.9	9.3	2.5
Median household income (000s)	54.4	7.8	53.2	8.9	68.5	17.2
Poverty rate	11.9	3.2	14.1	4.3	10.4	4.3
Urban influence code	5.7	2.8	4.9	3.3	2.7	2.2
Domestic migration rate	−4.2	5.7	−7.6	7.1	−4.6	5.3
International migration rate	0.21	0.28	0.71	1.02	0.89	1.04

unit or even than an average of 2 or more control units. However, unlike with our nearest neighbor matching that we describe below, we were not able to adjust in our synthetic control analysis for any remaining bias due to differences in predictor variable averages between the treated units and their synthetic control units.

We used 3 other methods as robustness checks for our synthetic control results. For all of these analyses, we compared a 3-week post-treatment period from August 24 to September 13, with a 3-week pretreatment period from August 3 to August 23. First, we used nearest neighbor matching to match counties from each group with the 3 nearest counties from each other group within a caliper of 5; counties that did not have 3 neighbors in the other group within a caliper of 5 were excluded from the analysis. We used a bias adjustment in our nearest neighbor matching analyses, which adjusts the difference in the outcome variable values between matched units to account for differences in the values of their predictor variables, and we used heteroscedasticity robust standard errors. Second, we used difference-in-differences to compare the post-treatment versus pretreatment outcome variable difference for each county group with that same difference for each other county group. In the difference-in-differences analyses, we adjusted for differences in predictor variable values and again used heteroscedasticity robust standard errors. Third, we used 2-stage propensity score regressions to compare each county group with each other group. In the first stage, we estimated the likelihood of each county being in the more restrictive county group in the comparison using a logistic regression; in these regressions, we used a slightly different set of 11 demographic predictor variables that were significant predictors of instruction types at the start of the school year, including the pretreatment cases and deaths values. In the second stage, we estimated the effect of being in the more restrictive group on the post-treatment outcome variable value, controlling for the estimated propensity score and the original 11 predictor variables, including the pretreatment outcome variable value.

RESULTS

Main Synthetic Control Analyses

We conducted 3 synthetic control analyses each for cases, hospital admissions, and deaths: an analysis that compared majority in-person counties with majority hybrid counties, an analysis that compared majority hybrid counties with majority online-only counties, and an analysis that compared majority in-person counties with majority online-only counties. Table 2 shows the results of those 9 analyses. Table 2 shows the estimated effect of being in the more restrictive group on the number of new cases, hospital admissions, or deaths per 100,000 people; negative numbers indicate that the more restrictive instruction type resulted in fewer cases, admissions, or deaths.

Table 2 shows that majority hybrid counties had significantly fewer new cases (averaged over the last seven days) from August 28 to September 8 than their synthetic control groups of majority in-person counties. Similarly, it shows that majority online-only counties generally had significantly fewer new cases from August 24 to September 8 than their synthetic control groups of majority in-person counties. However, there were no significant differences in new cases for majority online-only counties as compared with majority hybrid counties. And there were no significant differences in new hospital admissions or new deaths in any of the comparisons.

Robustness checks

Table 3 summarizes the results of the additional analyses that we conducted to estimate the effects of the different county groups on average new cases during the 3-week post-treatment period from August 24 to September 13, as compared with the 3-week pretreatment period from August 3 to August 23; we also conducted additional analyses for hospital admissions and deaths, but those results were never statistically significant, so we do not present them. The synthetic control estimates in Table 3 differ from the estimates for September 13 in Table 2, because the estimates in Table 2 are one-week averages while the estimates in Table 3 are 3-week averages. In the synthetic control estimates in Table 3, having a majority of students in hybrid districts resulted in 8.51 fewer new daily cases per 100,000 people over the post-treatment period than having a majority of students in primarily in-person districts, which represents a 32 percent reduction. The other methods all produced smaller estimates of that effect, with the estimates ranging from 1.69 to 6.65 fewer new daily cases per 100,000 people for the majority hybrid counties. Having a majority of students in online-only districts resulted in 0.89

Table 2
Main synthetic control analyses of effect of K-12 instruction types on new daily COVID-19 cases, hospital admissions, and deaths in Illinois counties

| | Majority in-person (n = 41) vs majority hybrid (n = 32) | | | Majority hybrid (n = 32) vs majority online-only (n = 17) | | | Majority in-person (n = 41) vs majority online-only (n = 17) | | |
| | Estimated effect of having 50% or more of county students in hybrid districts (as compared with having 50% or more in in-person districts) on 7-day average per 100,000 people for: | | | Estimated effect of having 50% or more of county students in online-only districts (as compared with having 50% or more in hybrid districts) on 7-day average per 100,000 people for: | | | Estimated effect of having 50% or more of county students in online-only districts (as compared with having 50% or more in in-person districts) on 7-day average per 100,000 people for: | | |
Day	Cases	Admits	Deaths	Cases	Admits	Deaths	Cases	Admits	Deaths
8/24	−3.0		−0.13	−2.0		0.05	−9.8†		−0.10
8/25	−3.0		−0.05	−2.4		0.002	−9.9‡		−0.23+
8/26	−5.3		−0.28‡	−1.5		0.12	−10.2‡		−0.23
8/27	−5.0	0.28	−0.19	−0.3	−0.38	0.11	−8.5	0.64	−0.13
8/28	−6.4‡		−0.13	−0.7		0.05	−9.1		−0.17
8/29	−8.4†		−0.10	−0.7		0.05	−10.2		−0.15
8/30	−9.4*		−0.06	−1.6		0.06	−10.3‡		−0.09
8/31	−6.3†		−0.002	−2.0		0.06	−7.3		−0.05
9/1	−6.9†		−0.22	−0.7		0.09	−6.7		−0.01
9/2	−12.2*		−0.11	−0.4		0.01	−13.1‡		−0.11
9/3	−10.2*	1.06	−0.04	−1.1	0.42	−0.03	−11.6†	1.99	−0.11
9/4	−14.2*		0.002	−1.0		−0.06	−15.9‡		−0.07
9/5	−15.2*		0.04	−1.3		−0.04	−18.1‡		−0.03
9/6	−14.6†		0.06	−0.5		−0.07	−18.9‡		−0.06
9/7	−14.5†		0.06	0.05		−0.07	−18.0‡		−0.08
9/8	−13.6†		0.18	−1.6		−0.08	−17.5‡		−0.09
9/9	−7.9		0.28	−0.4		−0.07	−11.2		−0.11
9/10	−8.3	1.22	0.28	−0.5	0.27	−0.004	−13.0	2.35	−0.11
9/11	−4.6		0.25	−0.3		0.08	−10.3		−0.07
9/12	−2.2		0.23	−0.7		0.07	−7.3		−0.07
9/13	−1.6		0.22	−1.8		0.06	−8.1		−0.07
9/14	−2.2		0.21	−1.8		0.03	−9.0		−0.07
9/15	−2.4		0.21	−1.0		0.04	−8.6		0.03
9/16	−1.0		0.12	−2.3		0.03	−8.7		−0.07
9/17	−0.5	1.94	−0.04	−1.3	0.05	−0.01	−7.5	3.07	−0.13
9/18	0.3		−0.28	−0.3		−0.05	−6.5		−0.34
9/19	1.6		−0.33	1.3		0.04	−5.8		−0.28
9/20	2.1		−0.31	1.8		0.07	−5.0		−0.27

*$P < .01$.
†$P < .05$.
‡$P < .10$.

fewer new daily cases per 100,000 people over the post-treatment period than having a majority of students in hybrid districts in the synthetic control estimates. The other methods all produced somewhat larger estimates of that effect, but none of the estimates was nearly statistically significant. Having a majority of students in online-only districts resulted in 10.13 fewer new daily cases per 100,000 people over the post-treatment period than having a majority of students in primarily in-person districts in the synthetic control estimates, which represents a 41% reduction although the effect was not quite statistically significant. The other methods all produced smaller estimates of that effect, with the estimates ranging from 5.50 to 6.21 fewer new daily cases per 100,000 people for the majority online-only counties.

DISCUSSION

For the comparison of cases in majority in-person counties and majority hybrid counties, the effect in Table 2 followed a U-shaped pattern, with no effect at the beginning of the period, a statistically significant negative effect in the middle of the period, and no effect at the end of the period. This U-shaped effect was not unexpected. It is not surprising that the difference between in-person and hybrid instruction did not begin to affect the number of reported cases for several days. It is also not surprising that, after several days, majority hybrid counties had significantly fewer reported cases than their synthetic control units of majority in-person counties, because in-person instruction generally involves having almost all students at school at the same time, while hybrid instruction usually means having less than half of students at school at a time. Finally, it is not surprising that the effect disappeared toward the end of the period, because many in-person districts that experienced school or community outbreaks changed quickly to hybrid or online-only instruction and some hybrid districts with favorable community metrics changed to in-person instruction. So, there was a significant amount of crossover between treated and control counties by the end of the period. The comparison of cases in majority in-person counties and majority online-only counties also showed a U-shaped effect pattern, although even on the first day of the period, majority online-only counties already had significantly fewer reported cases than their synthetic control units of majority in-person counties.

It was also not surprising that there was not a significant effect on hospital admissions or deaths in any of the comparisons. The population of students, teachers, and other employees at K-12 schools are generally not in the high-risk groups for severe complications from the virus as some populations are, such as nursing facility residents. Although there are undoubtedly some students, teachers, and other school employees who are in high-risk groups or who have immediate family members in those groups, many of those people likely chose not to participate in in-person classes in in-person or hybrid districts.

Table 3
Additional analyses of effect of K-12 instruction types on new daily COVID-19 cases in Illinois counties

Analysis method	Majority in-person (n = 41) vs. majority hybrid (n = 32)	Majority hybrid (n = 32) vs. majority online-only (n = 17)	Majority in-person (n = 41) vs. majority online-only (n = 17)
	Estimated effect of having 50% or more of county students in hybrid districts (as compared with having 50% or more in in-person districts) on average new daily cases per 100,000 people from August 24 to September 13	Estimated effect of having 50% or more of county students in online-only districts (as compared with having 50% or more in hybrid districts) on average new daily cases per 100,000 people from August 24 to September 13	Estimated effect of having 50% or more of county students in online-only districts (as compared with having 50% or more in in-person districts) on average new daily cases per 100,000 people from August 24 to September 13
Synthetic control	−8.51[†]	−0.89	−10.13
Nearest neighbor matching	−6.65[*,‡]	−3.58[§]	−6.21[¶]
Difference-in-differences	−1.69	−3.96	−5.65[†]
Propensity score regression	−5.35	−2.06	−5.50

[*] $P < .05$.
[†] $P < .10$.
[‡] Two majority in-person counties and six majority hybrid counties were excluded from the analysis because they did not have 3 matches in the other group within the caliper of 5.
[§] Four majority hybrid counties were excluded from the analysis because they did not have 3 matches in the other group within the caliper of 5.
[¶] Twenty-eight majority in-person counties and five majority online-only counties were excluded from the analysis because they did not have 3 matches in the other group within the caliper of 5.

The most unexpected result was that there was not a significant effect on reported cases in the comparison of majority hybrid counties and majority online-only counties in any of our analyses. That result suggests that hybrid instruction did not contribute significantly to the spread of the pandemic. As noted above, hybrid instruction generally involves having fewer than half of the students in each class attend school at a time, which may allow the students and teachers to maintain an adequate distance to prevent significant transmission of the virus. Of course, screening and contact tracing likely also contributed, by keeping potentially infected people out of the classrooms and quickly controlling any outbreaks that did occur through quarantines.

This study had some important limitations. We were able to consider only a 3-week period because there was a significant amount of crossover among the 3 county groups by the end of that period as districts changed instruction types to respond to community conditions. For a similar reason, we were able to consider only the period at the start of the school year, when COVID-19 case rates were relatively low in Illinois compared to some other periods during the 2020-2021 school year; districts changed instruction types so frequently after the first couple of weeks of the school year that it would be difficult to find a period with stable instruction types across districts later in Fall 2020. We were not able to consider differences by grade level; a few districts had different instruction types for different grades, but there was not enough variation across grade levels within districts to estimate the effects of those differences. Although we attempted to verify and correct the data on the ISBE dashboard for the 200 largest districts in Illinois and the largest district in each county, our data on school district instruction types at the start of the school year likely still had some inaccuracies, which may have affected our results. As we discussed above, the hospital admissions data that we used were not ideal, because they were available only weekly and reflected the location of the hospital rather than the residence of the patient. Finally, we cannot explain why majority in-person counties had more cases per capita than majority in-person and majority hybrid counties; in-person schooling did not necessarily result in more transmission among students, because resuming in-person schooling also enabled more adults to return to workplaces (including schools) and other activities, which may have contributed to the higher case numbers.

CONCLUSION

This paper adds to the growing scientific consensus that at least some forms of in-person K-12 instruction have not contributed significantly to the spread of the pandemic, including all four of the studies using data from Fall 2020 that we cited above.[10−13] There is still uncertainty, however, about the specific circumstances under which in-person K-12 instruction can safely be conducted. The CDC has continued to recommend that decisions about instruction types should depend on the level of transmission in the community[23] and 2 of those 4 prior studies suggested that in-person schooling may contribute more to the spread of the pandemic in communities with higher baseline levels.[10,11] Under the CDC's recommendations, as of March 2021, only 4% of children in the United States lived in counties with transmission levels low enough for full-time in-person learning.[24] However, many experts believe that the CDC has been too slow to adjust its recommendations and that in-person schooling could safely be conducted more widely, regardless of community metrics.[25] We were not able to control for pre-existing transmission levels in this study, but our results suggest that there may also be an important difference between fully in-person instruction and hybrid instruction. Illinois counties that started the 2020-2021 school year with a majority of students in hybrid districts had 32% fewer new daily cases during the first 3 weeks of the school year than their synthetic control units of counties that started the school year with a majority of students in in-person districts.

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