The Incidence and Magnitude of the Health Costs of In-person Schooling during the COVID-19 Pandemic*

by Casey B. Mulligan

March 2021

Abstract

The health costs of in-person schooling during the pandemic, if any, fall primarily on the families of students, largely due to the fact that students significantly outnumber teachers. Data from North Carolina, Wisconsin, Australia, England, and Israel covering almost 80 million person-days in school help assess the magnitude of the fatality risks of in-person schooling (with mitigation protocols), accounting for the age and living arrangements of students and teachers. The risks of in-person schooling to teachers are comparable to the risks of commuting by automobile. Valued at a VSL of $10 million, the average daily fatality cost ranges from $0.01 for an unvaccinated young teacher living alone to as much as $29 for an elderly and unvaccinated teacher living with an elderly and unvaccinated spouse. COVID-19 risk avoidance may also be more amenable to Bayesian updating and selective protection than automobile fatalities are. The results suggest that economic behaviors can sometimes invert epidemiological patterns when it comes to the spread of infectious diseases in human populations.

*I appreciate financial support from the University of Chicago's Initiative on Enabling Choice and Competition in Healthcare, the research assistance of Alex Kahn, and clarifications from Professors Kanecia Zimmerman and Daniel Benjamin.

I. Introduction

The spread of COVID-19 in the United States has prompted extraordinary, although often untested, steps by individuals and institutions to limit infections. One of the longest-duration avoidance strategies has been the closing of public-school buildings even to uninfected students and teachers. Some have worried that this part of "the cure is worse than the disease." The purpose of this paper is to assess the incidence and magnitude of the health benefits (if any) of remote-learning or, conversely, the health costs of in-person schooling.

This paper first addresses incidence questions, because their answers require the least information. There is little debate as to the pupil-teacher ratio, the age profile of fatality risks of COVID infections, or the distribution of age and living arrangements among teachers and parents of students. Although these demographic data by themselves are not enough to assess the magnitude of the risk of in-person teaching, they say a lot as to how the risk would be distributed across families. Sections II and III show that, in relative terms, the fatalities among the adults in student families from school-acquired COVID-19 would far outnumber those among teachers and spouses.

I assume that infection rates cannot be negative for students and teachers engaged in elearning or whatever else is their next-best alternative during school hours to in-person schooling. This assumption allows for the estimation of an upper bound on the effect of in-person schooling on infections and thereby fatalities. The rate that infections are acquired at K-12 school is estimated in Section IV from a study of all open schools in England (Ismail, et al. 2020), a study of Wisconsin schools (Falk, et al. 2021) and a study of North Carolina schools (Zimmerman, et al. 2021). COVID-19 prevalence in the surrounding communities varies by two orders of magnitude across the studies, with the propensity to acquire the infection in school varying nearly proportionally. Because no outbreak severe enough to close schools occurred during the three studies, I supplement them with Israeli data where a COVID outbreak did occur in a school (Stein-Zamir, et al. 2020).

The infection-rate findings in combination with the incidence findings suggest that the upper bound for fatality risks from in-person schooling varies by age and living arrangements. As long as community prevalence is in the range that occurred during fall 2020 in the various U.S. states, these risks are similar to the fatality risks of commuting by automobile (Section V). For each 22 million students and teachers schooling in-person for a five-day week, the expected number of fatalities among teachers and spouses is one or less. Note that 22 million people distanced six feet apart could form a line that stretches from South Africa across two continents to northeastern Siberia and back to South Africa.

Even holding constant infection rates in the surrounding community, in-school COVID transmission rates vary across schools and evolve over time. In-person schooling therefore has an option value in that it begins to reveal situation-specific in-school transmission rates. Situations with intolerably high transmission rates can be terminated with a return to remote learning. In contrast, remote learning by itself does not reveal which schools will have acceptably low transmission rates.

An Appendix reviews a study of New South Wales, Australia estimating in-school "attack rates": the number of infections among in-school close contacts of infectious persons who were present in school. Arguably the estimated attack rates are in line with the other three studies. The results suggest that infections are rarely acquired in school due to a combination of low attack rates and school successes at keeping community members out of the school while they are infectious.

II. Incidence Arithmetic

Private health costs (or, possibly, benefits) of in-person schooling accrue to teachers, students, and each of their families.[1] A bit of arithmetic shows how the share of the total health costs accruing to students and their families can be estimated with fewer data and assumptions than is required to estimate the overall level of health costs. Conceptually, I distinguish fatality costs from nonfatal health costs of COVID-19 such as chronic conditions or injuries. The

[1] I exclude non-teaching staff from those who would be present with students during in person schooling. This assumption could be modified by broadening "teachers" to include "teachers and in-person staff" and adjusting the teacher-population statistics accordingly.

fatality costs of each group are decomposed into the product of the number of cases the group acquires at school and the group's average infection fatality rate. The nonfatal heath costs can similarly be decomposed into a number of infections and an infection nonfatal-injury rate. For family members who are not present at school their cases acquired "at school" are the product of cases acquired by the student (or teacher) in their household times the household transmission rate for COVID-19. Individuals who share a household with multiple students or a teacher and student are counted multiple times, once for each household member they have present at school.[2] As is appropriate for assessing private costs of in-person schooling, this paper does not estimate infection risk for the broader community of these households. Broader-community effects would be necessary for social welfare calculations.

Assume for the moment that (i) the adults involved have the same (nonzero) fatalities per infection regardless of whether associated with student or teacher (ii) in-school infections per teacher are no greater than in-school infections per student, and (iii) each household has exactly two adults. The inequality (1) is a sufficient condition for student-family fatalities from COVID acquired in school to exceed those for teacher-family fatalities.

$$\left(2\frac{students}{teachers}-1\right)HHT+\frac{students}{teachers}\frac{IFR_{student}}{IFR_{adult}}>1 \tag{1}$$

where HHT is the rate that COVID infections are transmitted from one household member to another, which is assumed to be the same for student and teacher families. IFR denotes the average number of fatalities per COVID infection, which would be replaced by the injury rate for the purposes of deriving an inequality for nonfatal injuries. Note that the number of infections acquired in school is absent from (1). That number affects the overall level of fatalities among teacher and student families, but not the comparison of the two. The inequality (1) requires only the relative infection fatality rate and, especially, the student-teacher ratio.

The RHS of (1) represents the fatalities of teachers, as distinct from their spouses. The HHT term on the LHS represents family members of students (before the minus sign) and of teachers (after the minus sign). The two is present because all of the adults in a two-adult

[2] This overstates the individual's risk because acquiring infection from one family member may prevent being infected by a second family member. However, given the low in-school infection rates, the overstatement is miniscule.

student household are outside the school but only one of the adults in a two-adult teacher household are outside the school. The second term on the LHS is the ratio of student fatalities to teacher fatalities. Either of the two LHS terms exceeding one would be sufficient to satisfy all of (1).

With many students per teacher, likely student families bear most of the health costs of in-person schooling. Take a student-teacher ratio of 15. Any HHT greater than 1/29 is, according to (1), sufficient to conclude that in-person schooling would generate more fatalities for student families than teacher families. If the number of adults in the household sometimes differs from two, then the HHT coefficient becomes $A_{student}\frac{students}{teachers} - A_{teacher} + 1$, where A indicates the average number of adults in each type of household. As shown in the next section, empirical values for the A's are not enough different from two to significantly modify the 1/29 cutoff for HHT.

III. Demographic data used in this paper

For calibrating the inequality (1) and extensions of it, I draw on four sources. The most important is the pupil-teacher ratio of 15.4 from National Center for Education Statistics (2020). Second is the distribution of ages and living arrangements for teachers, students, and their families, which I take from the January through March 2020 Current Population Surveys (CPS) as provided by IPUMS.[3] Students are identified as any child age 6-15 plus any person aged 16-24 who reports full-time high-school enrollment. Teachers are identified as any person with a job during the survey week and occupation code for teachers of preschool, kindergarten, elementary, middle, or high school.[4] Third, I use Grijalva et al.'s (2020) estimates of the household transmission rate of COVID infections. They estimate that, conditional on having an infection in the household, 59 percent of household members aged 18-49 were infected on average (including asymptomatic cases as infections). They estimate 43 percent for ages 50 and older. Fourth, I take age-specific case fatality rates, for unvaccinated persons, from Yang et al

[3] The CPS is conducted on the week including the 12th of the month. In 2020, the week of March 12 was the week before most schools closed during the pandemic.
[4] By these definitions, the national total of CPS students per CPS teacher is only 9.9, in part because not all persons indicated as teachers in the CPS are in the classroom every day. The total CPS students by this definition is 51.6 million, as compared to 56.4 million elementary and secondary school students reported by NCES.

(2021).[5] The mean and median case fatality rates are 0.79 percent and 0.12 percent for the adults in teacher families, respectively. For the adults in student families, the corresponding rates are 0.59 percent and 0.12 percent.

The first column of Table 1 shows the results using only the demographic data and the accounting framework associated with the inequality (1). The table is built on the assumption that students and teachers are present in-person in the normal 15.4 ratio and with family age and living distributions as before the pandemic. In this case, 88 percent of the fatalities from infections acquired in school or from an immediate family member who was in school would occur in the families of the students. Students living with two adults aged 45-64 would experience many of the 88 percent because that living arrangement is common and the adults have above-average fatality risk. Only 12 percent of the fatalities would be teachers or spouses. If non-fatal injury risks are proportional to fatalities, then the distribution shown in the first column is also a distribution of the non-fatal COVID-19 injuries originating in schools.

[5] A number of studies show lower rates (Madewell, et al. 2020), which would imply less fatality cost than estimated in this paper. Almost all estimates exceed the 1/29 critical value cited above.

Table 1. The Distribution of Fatalities from School-Acquired COVID

Occupation and living arrangement	Distribution	Annual nat'l fatalities, by transmission data: NC scaled to VT community	NC scaled to US community	Wood Co. WI
Families of students	*88.1%*	*86*	*727*	*1561*
Only one parent/guardian				
Ages 25-44	2.0%	2	16	35
Ages 45-64	6.1%	6	51	108
Living with two adults				
Both aged 25-44	8.9%	9	74	158
Both aged 45-64	28.1%	28	232	498
Ages 25-44, 45-64	13.2%	13	109	234
Ages 25-44, 65-74	5.3%	5	44	94
Remaining 22 categories	24.5%	24	202	433
Teachers and spouses	*11.9%*	*12*	*98*	*211*
Living alone				
Less than age 25	0.0%	0	0	0
Ages 25-44	0.2%	0	2	4
Ages 45-64	1.1%	1	9	20
Ages 65-74	0.7%	1	6	12
Living with one adult, same age bracket				
Ages 25-44	0.7%	1	6	12
Ages 45-64	4.0%	4	33	71
Ages 65-74	1.8%	2	15	32
Living with one adult in next-older bracket				
Ages 25-44	0.3%	0	2	5
Ages 45-64	0.8%	1	6	14
categories	2.3%	2	19	41
Families of students & teachers				
Acquired at school, or from family who acquired at school	**100.0%**	**98**	**826**	**1,772**
All other COVID fatalities		**43,599**	**42,872**	**41,925**
Addendum: Auto fatalities (students and teachers only) if all commuted by car, 10 miles each way		*1,251*	*1,251*	*1,251*

IV. School Transmission Data

IV.A. The Frequency of In-school Transmission

Additional data, discussed further below, is required to obtain estimates of the expected number of fatalities such as those shown in the final three columns of Table 1. Estimating the level of fatality risks from in-person schooling requires estimates of the number of cases acquired in school and the number of cases acquired by remote learners during school hours, or at least estimates of the difference between the two. As a bounding exercise, I assume that zero cases are acquired by remote learners during school hours and then return to this assumption at the end of the paper.

Although this paper does not have original infection data, it does assemble published data from five distinct settings and puts their findings in common metrics. The metrics are selected for comparability with familiar risks and with metrics used in the literature on compensating differences. Sometimes computation of the common metrics requires supplementing the published data with additional schooling data from the same setting of the published study.[6] I found five published studies on school-acquired cases, one from each of Australia, England, North Carolina, Wood County Wisconsin, and an Israeli school that experienced an outbreak.[7] The Australian study examines only the (rare) classrooms where a student or staff entered the class with an infection during the study period, which provides an "attack rate" rather than a rate of infection that accounts for the fact that on some days none of a person's contacts at school would be infected. The similarities and differences between attack and infection rates are discussed further in the Appendix to this paper.

Ismail et al (2020) looked at the entire country of England between June 1 and July 17, 2020, which is the summer half term as England "reopened after the first national lockdown." For comparability with the other studies, I use their results for primary and secondary schools and supplement with attendance data from U.K. Department for Education and prevalence data

[6] For example, one study reports only median attendance rather than mean attendance.
[7] The English study (Ismail, et al. 2020) refers to all in-school transmission as "outbreak." This paper refers to an outbreak as a large number of transmissions in a single school during a short time period.

from Our World in Data. The vast majority of schools were open at some point during this time and the majority of staff appear to be present. However, summer-term attendance was not mandatory and therefore student attendance overall was only about one-sixth of what it would be later in the fall and less in secondary schools (Ismail, et al. 2020, U.K. Office of Statistics Regulation 2020). Overall, 32 million staff days present and 43 million student days present in about 20,000 schools were covered by the study.

"Extensive social distancing and infection control measures were implemented with strict limitations on the number of staff and children in each bubble." (Ismail, et al. 2020, p. 352). 96 staff and 8 student cases were identified by Public Health England (PHE) as potentially acquired in primary and secondary schools, although the study did not always verify that the person acquired the case was ever in close contact with the primary case.[8] That is about 721,000 person-days per infection. Reweighting the student and staff infection rate to reflect the 15.4 teacher-pupil ratio that is normal during the academic year, that is 2.8 million person-days per infection as shown in the first row of Table 2. New cases were low in England during that time; rescaling to the per capita new infections in the U.S. during its fall 2020 term yields about 127,000 person days per school-acquired infection.

Note that all of the data in this subsection refers to COVID-19 infections rather than COVID-19 deaths, which are two orders of magnitude less common. The probabilities and rates being measured in Tables 2 and following are very small and therefore not measured with high precision. 2,800,991 person days per infection (the inverse of a daily infection rate) can hardly be distinguished from 2,000,000, let alone from 2,800,992.

[8] The study acknowledges that persons in the same school sometimes interact outside of school. The study also notes that only one teacher in England died from COVID during this period, which was acquired from a spouse who acquired it in the community. Regarding the information available for monitoring transmission, the authors note that "PHE has legal permission … to process patient confidential information for national surveillance of communicable diseases and as such, individual patient consent is not required."

Table 2. Person days at school per school-acquired infection: Four sources

		Person-days per infection	
Setting	Person-days	Measured	Adj. to U.S. positivity Sep 1 - Nov 29
England: entire nation Jun 1 - Jul 17	75,022,754	2,800,991	127,318
NC: 11 school districts Aug 15 - Oct 23	2,291,675	71,615	67,817
WI: 17 schools Aug 31 - Nov 29	221,163	31,595	98,772
Addendum: Australian attack-rate study	N/A	N/A	160,868

Note: The adjustment to U.S. is a ratio of CDC-published positivity rates for the corresponding location and time period. The exception is England, where the ratio of new cases per capita is used. See also Appendix I on attack rates.

About half of the North Carolina's school districts participated in some capacity in the study by Zimmerman et al (2021). The participants were somewhat larger school districts with somewhat less in-person instruction than average. Many of the participating districts did not offer any in-person instruction and therefore did not provide any data for using in my paper. The authors explain how "districts were required to have universal masking for all ≥5 years of age (except the adapted curriculum, during meals, and when sufficiently distanced outside), implement 6-foot distancing, and wash hands … as well as perform daily symptom monitoring and temperature checks" adding that "case adjudication of within-school transmission was performed via contact tracing by the local health department." None of those offering in-person instruction had to terminate the instruction during the study period, due to outbreak or any other factor.

The study shows 90,338 in-person students and staff in the eleven districts providing in-school data over the 9 weeks of the study, which makes for a maximum of 4 million person days. The study notes that somewhat more than 3,000 persons quarantined at home at some point during the study, which I take to be 31,000 person-days out of the potential. Because many students were on hybrid schedules, I assume that half of the potential in-person days were spent off campus on scheduled remote learning, putting my estimate of in-person days at about 2.3 million. With 32 cases acquired in school from August 15 through October 23, 2020, the inverse of the infection rate is about 72,000 person days. According to the COVID-testing data from the

U.S. Department of Health and Human Services (2021), the state of North Carolina's positivity rate during its study was slightly less than the nationwide average rate during the full fall term. The final column of Table 2 therefore shows an inverse rate of about 68,000 when adjusted to U.S. positivity rates.

The Wood County, Wisconsin study (Falk, et al. 2021) involved about 5,600 students and staff attending schooling in person for at least part of the week. In-person elementary students attended every day. Middle and high school students attended half of days on average across the nine such schools in the study. Mask wearing was required, students were organized in classroom cohorts of size 11 to 20, all classes and lunch periods were held indoors, and close contacts of positive were quarantined. I assume that quarantine days are the same percentage of the calendar as in North Carolina, except rescaled for the higher positivity rate in Wood County.

The study lasted thirteen weeks (August 31 to November 29) during which time typically seven holidays/teacher-workshop occurred, putting total time in person at about 220,000 person days. Seven cases were acquired in school during that time, putting the inverse infection rate at about 32,000 person days. The average positivity rate in Wood County at that time exceeded even that of the highest U.S. state (Montana) and was triple the U.S. average. The final column therefore shows an adjusted inverse infection rate of about 99,000 person days.

Table 2 reveals that surrounding-community COVID prevalence varies almost two orders of magnitude across studies. Although uniformly low by standards discussed further in the next section, the measured rates of school-acquired infection vary across the studies in close proportion to the surrounding-community prevalence. This is why the final column of Table 2 varies much less than the second column. Ismail et al's (2020) study of England is large enough to investigate the proportionality hypothesis across regions within their own study, which is confirmed in their Figure 3A.

Infected students were quarantined, but arguably England, WI and NC were "lucky" in that in-person school was not terminated during the study period due to an outbreak. I therefore consider a hypothetical "high-risk" scenario in which Wood County (with its high community prevalence) had an outbreak, whose probability and intensity we measure from Israel as the number of infections in the Israeli school that had the outbreak divided by the nationwide number of student-days of in-person schooling that occurred between the opening of Israel schools to the reclosing upon outbreak (Stein-Zamir, et al. 2020). This approach likely exaggerates the probability and intensity of an outbreak in U.S. schools because (i) Israel was selected because it had an outbreak, (ii) all but two of the cases in the Israeli school are assumed to come from the outbreak rather than the broader community, and (iii) the outbreak school was not requiring masks and other mitigation methods commonly used in schools.[9]

Estimating separate infection rates for students and staff is difficult because of the small numbers of transmissions in the North Carolina and Wisconsin studies. For what it is worth, the Wisconsin study found zero cases that staff acquired in school. Of the 32 cases of in-school transmission found in the North Carolina study, none were student to staff. Most of the cases found in English study were among staff, but the staff-pupil ratio was particularly high during the time of the study (summer break).

With all of these studies, there is a concern that cases are underestimated. However, under the weak assumption that true cumulative COVID-19 infections cannot exceed the population, cases generally are not undercounted by more than a factor of ten.[10] Furthermore, Section V below multiplies cases per capita by fatalities per case, which means that any proportional case measurement error that is common to the two sources will cancel for the purposes of assessing fatalities per capita. Appendix I's attack rate estimates are also interesting in this regard because the attack rate is a ratio of cases to cases. Even if Section V's fatality-rate estimates were multiplied by ten because of suspected undercounts, the rates would still be in the range of familiar risks.

None of the studies directly report person-days present in person, which is the denominator for my transmission rates. As described above I have estimated based on bits of information provided in the published articles together with supplemental information I found online. My point estimates of person-days per school-acquired infection (and thereby the estimates of person-years per school-acquired fatality that follow) can be understood as over- or under-estimates in the same proportion that I over- or under-estimated in-person attendance, respectively.

The North Carolina and Wisconsin studies measured community-acquired cases among their students and staff as well as school-acquired. Table 3 shows the corresponding (inverse) daily infection rates for the student and teacher populations regardless of whether acquired in

[9] The study notes two index cases that came into the school from the community (Stein-Zamir, et al. 2020).
[10] At the time of my writing, cumulative U.S. cases were nine percent of the population, with new cases added at a rate of about 50,000 per day.

school. For this purpose, weekend days are added to the person-days numerator from Table 2 and community-acquired cases added to the denominator. The final column rescales the results to the U.S. average positivity rate. The person days shown in Table 3 are about one twentieth those shown in Table 2 because the NC and WI studies found that the daily rate of acquiring a COVID-19 infection in school is, for students and staff, about one twentieth of the rate of acquiring an infection from any source.[11]

Table 3. Person days per infection, including those acquired outside school

	Person days per infection	
Setting	Measured	Adj. to U.S. positivity Sep 1 - Nov 29
NC: 11 school districts Aug 15 - Oct 23	3,986	3,774
WI: 17 schools Aug 31 - Nov 29	1,621	5,068
Oster/CovidSchoolDashboard Aug 31 - Nov 22		
Students	N/A	7,368
Staff	N/A	3,387
Combined at 15.4 student-teacher ratio	N/A	6,876
CDC prevalence data reweighted based on age of:		
Students		5,641
Teachers		2,734
Combined at 15.4 student-teacher ratio		5,298

Note: Weekend days are counted in the numerator.

Emily Oster (2020a, 2020b) has led a "COVID-19 School Response Dashboard" project gathering attendance and prevalence data from participating schools in almost every U.S. state. The prevalence measures are only for school students and staff but do not distinguish infections acquired in school from those acquired at home or in the community. Table 3 therefore provides the appropriate comparison. Both Oster find about 7,000 person days per infection (i.e., a daily infection rate of about 1/7000). The Wisconsin study finds a higher infection rate in a high-positivity area, which corresponds to a rescaled daily infection rate of about 1/5000. The rate in the NC study (Zimmerman, et al. 2021) is about 1/4000.

[11] For the purposes of Table 3, the daily rate includes weekends.

The CDC provides national case counts by age group, with the population-weighted sum across age groups yielding the national case counts. The CDC data can be reweighted to reflect the age of students, or the age of teachers, rather than the nation as a whole. The final rows of Table 3 show the results applied to the period September 1 through November 29, 2020.[12] The CDC data suggest about 5,000 person days per infection among persons of student or teacher age, as compared to about 7,000 in Oster's sample of actual students. One interpretation of the discrepancy between the two methods is that Oster's sample of schools is not quite representative (in the direction of fewer cases) of all schools or of the NC and WI schools.

IV.B. Fatality Benchmarks

For comparison purposes, this paper also shows fatalities risks in more familiar occupational and consumer contexts. The comparison of familiar risks with COVID-19 risks serves two purposes. One is to provide context given that a pandemic is a new experience for many people. Second, the comparisons show whether or not the COVID-19 risks are in the range of risks that have been priced in labor and consumer markets (Viscusi 1992, Viscusi and Aldy 2003).

Table 4 fatality risks for selected activities, sorted by fatality risk. The highest risks shown in the table are occupational fatalities from the *National Census of Fatal Occupational Injuries* published by the U.S. Bureau of Labor Statistics (2020a, 2020b). BLS measures the risks per year engaged in the occupation. Farming has about 4,000 person years per fatal injury on the job. Driving occupations – both truck drivers and sales workers – also average about 4,000. Aircraft pilots and flight engineers are more lethal by comparison: only 1,600 person-years per fatality.[13]

[12] The CDC age distribution of cases, which it calculates cumulatively for most of the pandemic, is rescaled to match new national daily infections during fall 2020. Age-specific daily infection rates for the fall are found by dividing age-specific daily infections by the national population in that age group. The results shown in Table 3 are inverse weighted averages of the age-specific daily infection rates.

[13] Because this paper focuses on primary and secondary schools, in which face-to-face student learning normally occurs 180 days per year, when necessary, I use a factor of 180 to convert between person years and person days.

Table 4. Person years of selected activities per fatality in that activity
circa 2019

Activity (sorted more fatal to less)	Person-years	Person-days
Aircraft pilots and flight engineers	1,618	
Driver/sales workers and truck drivers	3,731	
Farming	4,310	
Construction	10,309	
All jobs	28,571	
Commuting to work by car		
25 miles each way	19,578	3.5 million
10 miles each way	48,944	8.8 million
Commuting to work by train		
25 miles each way	258,398	46.5 million

Note: Commuting days converted to years using 180 days per year.

On the consumer side, driving is a familiar fatality risk. Many adults, teachers included, commute to work daily by car. The U.S. Department of Transportation (2017, 2020) measures automobile fatalities per mile traveled, which I convert to daily risks by selecting various commuting lengths.[14] The purpose here is not to estimate the modes or numbers of miles that teachers and students commute but rather to provide information on risks familiar to adults generally. Commuting 10 miles each way, there are almost 49,000 person years of commuting for each automobile fatality.

All of these activities also involve prevention and treatment costs to reduce fatalities. Vehicles are built with seatbelts and engineering features to help protect passengers. Drivers and the legal system limit speeds, drunk driving etc. Many auto injuries are not fatal because of medical resources spent to help the victim survive. Pandemic risks also have these qualitative features, including personal protective equipment and various hospitalization treatments. Unlike COVID-19, many familiar work-place accidents are neither infectious nor contagious, although automobile accidents often do involve third parties who are on foot or in another vehicle.

[14] Both driver and passenger(s) count in the numerator for automobile fatalities. Table 1 uses recent automobile fatality risks, which are less than half of what they were in the 1980s and before. See also Savage (2013).

The distinction between accident and fatality is relevant for decision making, especially because the fatalities are comparatively rare. A new traffic pattern can, in principle, be monitored for accidents and modified before a fatality occurs.[15] With COVID-19, the infections are about 100 times more common than fatalities and the former can be monitored in a new schooling situation and adjusted before a fatality occurs.

Cases per fatality are expected to be greater in schools than all-adult workplaces due to the fact that most of the people in school are children. In other words, schools would have a Bayesian advantage (from the perspective of preventing fatalities) over all-adult workplaces even if children were equally likely to transmit infections because cases among the children serve as a warning to the adults without the fatality risks of cases among adults. The Israeli outbreak was discovered in this way. Moreover, student is by far the most common occupation, which means that schools can learn from each other faster than, say, a law office could learn from the results at a meat-packing factory. Although pandemics are not new, the learning rate is relevant because COVID-19 is far newer than automobiles or farm equipment.

Table 5 quantifies some of the Bayesian eliminate of fatality risks by analogizing motor-vehicle accidents to COVID infections, which is a way of reconciling infections (Tables 2 and 3) with fatalities (Table 4). COVID "accidents" per fatality are least in the general population because it has a higher infection fatality rate due to its older age. The lowest of the three IFRs, and therefore the most COVID accidents per fatality, is in the school population limited to exclude the elderly. The elderly could be excluded by excusing students and teacher who live with elderly people.

[15] According to the National Safety Council (2020), 345 motor-vehicle crashes occurred for every fatality in those crashes.

Table 5. Reported Accidents per Fatality

Motor vehicles, 2019	345
COVID, general population	56
COVID, school population	196
COVID, school population w/o elderly family	285

Note: A confirmed COVID case is considered a "reported accident" for the purposes of this table.

Sources: National Safety Council (2020), Johns Hopkins, Current Population Surveys Jan - Mar 2020, Yang et al (2021).

V. Private Fatality Risks Accounting for Age and Living Arrangements

Table 6 combines the results in Tables 1 and 2 to show fatality risks for unvaccinated teachers and their unvaccinated spouses. The units are person-years per fatality rather than person-days per infection because fatalities are a small fraction of infections. The rows of the table are age and living-arrangement cells, ranging from the most common (couples aged 25-44) to the least common (elderly teacher living alone). The percentages in the second column sum to 100 percent. The third column shows the expected number of fatalities that result for the household's adults if the teacher brings home an infection from school. For teachers living without any other adult, it simply the infection fatality rate (IFR) for persons their age.[16] For teachers living with another adult, the third column takes the household transmission rate times the IFR corresponding to the age of the spouse/partner and adds the IFR for the teacher. The remaining four columns show (inverse) fatality rates for various in-school COVID transmission scenarios.

[16] Children living with teachers are ignored in these calculations because their fatality rates are so close to zero.

Table 6. In-person School Years Per COVID Fatality, by Teacher Age and Living Arrangement

Age & living arrangement	Percentage of teachers	Total fatalities as % of primary infections	Person-years per fatality NC scaled to VT community	NC scaled to US community	Wood Co. WI	WI + Outbreak
Living alone						
Less than age 25	4%	0.01%	32,658,629	3,876,152	1,805,822	1,364,956
Ages 25-44	15%	0.12%	2,736,568	324,795	151,315	114,374
Ages 45-64	10%	0.94%	338,064	40,124	18,693	14,129
Ages 65-74	1%	4.87%	65,183	7,736	3,604	2,724
Living with one adult, same age bracket						
Ages 25-44	31%	0.18%	1,721,112	204,273	95,167	71,933
Ages 45-64	25%	1.34%	236,408	28,059	13,072	9,881
Ages 65-74	2%	6.96%	45,583	5,410	2,520	1,905
Living with one adult in next-older bracket						
Ages 25-44	4%	0.52%	610,735	72,486	33,770	25,525
Ages 45-64	2%	3.03%	104,659	12,422	5,787	4,374
Remaining 21 categories	6%	3.20%	99,202	11,774	5,485	4,146

Note: Columns are low, medium, high, and outbreak transmission scenarios. Total fatalities include fatalities of spouse/living partner, using a secondary infection rate includes asymptomatic cases. "WI + Outbreak" assumes a Poisson outbreak probability that was unrealized in the NC, WI, or England studies but having parameters measured in Israel. Teachers, students, and family members are assumed to be unvaccinated.

Table 6's first scenario is the safest scenario in which the transmission rate found in the North Carolina study is rescaled to Vermont, which is the state with the lowest positivity rate in fall 2020. In this scenario, the number of in-person teacher years per fatality among teachers and spouses ranges from about 46,000 for an elderly teacher living with another elderly person to 33 million for a young teacher living without any other adult. For all ages and living arrangements, the first scenario is safer than any of the familiar occupational and automobile risks shown in Table 4 except for the dual-elderly couple where the COVID and automobile risks are about the same. The second scenario is the "middle" estimate that takes the NC study with a (slight) rescaling to average U.S. positivity rates.[17] Unless an elderly person is involved, this scenario shows fatality risks that are also less than any of the familiar occupational risks shown in Table 4 as well as commuting 25 miles each way.

The two relatively dangerous scenarios are derived from the Woods County, Wisconsin study without any adjustment to U.S. positivity rates. The county's positivity rate during the study was more than triple the U.S. average and exceeded the rate in any single U.S. state. The unadjusted infection rate in Wood County schools was the highest of the three studies (recall Table 2). The final scenario adds the unrealized possibility of an outbreak in a school that is extensive enough to close the school. Still, even for the elderly teacher with an elderly spouse, the annualized risk is about 1/2000 or similar to an aircraft pilot. On a daily basis, the risk is similar to driving in a car (alone) for 500 miles.

Table 7 shows the results for the adults living with students. It is arranged as Table 6, with rows showing ages and living arrangements and columns showing transmission scenarios. Fatality risks would be lower (more person years per fatality) in both tables – especially Table 7 – to the extent that Grijalva et al. (2020) overestimate the household transmission rate, as suggested by the studies reviewed in Madewell et al. (2020).

Table 1's final three columns show the expected national number of fatalities due to school-acquired COVID that would occur in the families of students and teachers with full in-person schooling. The totals are the product of the corresponding fatality rates shown in Table 6 or 7 and the aggregate number of person-days in school during a normal school year. Although student families have somewhat lower fatality rates than teacher families, student families have

[17] Recall from Table 2 that, adjusted for positivity rates, the in-school transmission rate in NC was somewhat greater than both England and WI. In this sense, building the "middle" scenario on NC is somewhat conservative.

more total fatalities because student families are more numerous. The national total COVID fatalities are not zero, but still less than automobile fatalities except in the highest-positivity scenario.

The bottom of Table 1 also shows how a year of COVID fatalities experienced by students, teachers, and their families are composed between school-acquired versus acquired outside school.[18] The total of the two is 43,697, which I obtain by reweighting the 459,480 occurring nationally between February 1, 2020 and January 31, 2021 to reflect the number and age distribution of teacher and teacher families as opposed to the national age distribution. The school-acquired total is from the rows above.

[18] As noted previously, a student infection occurring at school that taken home and transmitted to a parent counts as "school acquired."

Table 7. In-person School Years Per COVID Fatality, by Student Age and Living Arrangement

Age & living arrangement	Percentage of students	Total fatalities as % of primary infections	Person-years per fatality: NC scaled to VT community	NC scaled to US community	Wood Co. WI	WI + Outbreak
Only one parent/guardian						
Ages 25-44	16%	0.07%	4,638,251	550,500	256,467	193,854
Ages 45-64	8%	0.40%	786,195	93,311	43,472	32,859
Living with two adults						
Both aged 25-44	35%	0.14%	2,319,125	275,250	128,233	96,927
Both aged 45-64	19%	0.81%	393,097	46,656	21,736	16,429
Ages 25-44, 45-64	15%	0.47%	672,247	79,787	37,171	28,096
Ages 25-44, 65-74	1%	2.16%	146,791	17,422	8,117	6,135
Remaining 22 categories	5%	2.41%	131,490	15,606	7,271	5,496

Note: Columns are low, medium, high, and outbreak transmission scenarios. Total fatalities include fatalities of parents and guardians, using a secondary infection rate includes asymptomatic cases. "WI + Outbreak" assumes a Poisson outbreak probability that was unrealized in WI but having parameters measured in Israel. Teachers, students, and family members are assumed to be unvaccinated.

Table 8 uses a $10 million value of a statistical life (VSL) to convert the unvaccinated-teacher risks in Table 6 into dollars per day; divide by about seven hours per day to obtain hourly compensating differences. The risk being priced here includes the risk of bringing a COVID-19 infection from school to home, where an unvaccinated family member becomes infected and dies, *relative to an alternative with exactly zero infection risk*. The compensating differences range from less than a penny per day for a young teacher living alone in a low-prevalence community to $29 per day for an elderly teacher living with an unvaccinated elderly adult in a high-prevalence community. The compensating differences are less than a dollar a day for the modal teacher category (aged 25-44 living with an unvaccinated adult in that age bracket).

Table 8. Estimated in-person compensating differences
by age and data source

		In-person premium, $/teacher/day			
Age & living arrangement	Percentage of teachers	NC scaled to VT community	NC scaled to US community	Wood Co. WI	WI + Outbreak
Living alone					
Less than age 25	4%	0.00	0.01	0.03	0.04
Ages 25-44	15%	0.02	0.17	0.37	0.49
Ages 45-64	10%	0.16	1.38	2.97	3.93
Ages 65-74	1%	0.85	7.18	15.41	20.39
Living with one adult, same age bracket					
Ages 25-44	31%	0.03	0.27	0.58	0.77
Ages 45-64	25%	0.23	1.98	4.25	5.62
Ages 65-74	2%	1.22	10.27	22.04	29.16
Living with one adult in next-older bracket					
Ages 25-44	4%	0.09	0.77	1.65	2.18
Ages 45-64	2%	0.53	4.47	9.60	12.70
Remaining 21 categories	6%	0.56	4.72	10.13	13.40

Note: these are compensating differences for unvaccinated teachers based on Table 6 and a VSL of $10 million. Columns are low, medium, high, and outbreak transmission scenarios.

VI. Conclusions

This paper assembles data from several different sources, finding that they all fit together. The data include in-school transmission rates from communities and time frames with community prevalence rates that vary by almost two orders of magnitude, age-specific prevalence from the CDC, time-specific and region-specific positivity rates from HHS, and prevalence rates specific to in-person school populations obtained by Oster/COVIDSchoolDashboard.

Students and teachers at in-person school during 2020 were about 20 times more likely to be infected outside school than in school. According to the studies, an important reason that acquiring an infection at school is rare is that fewer than one out of two hundred students and staff *that make close contact at school* (e.g., share a class) with an infectious person tests positive for COVID-19. Within-household transmission rates are far higher. Relative to in-home rates, in-school infection rates are reduced by another order of magnitude because infectious students and staff tend to stay out of school. These two advantages of schools overwhelm their disadvantage, which is that more close contacts are potentially made in school than in the family. This raises the serious question, unanswered in this paper, of whether sending uninfected students and staff home for elearning raises their probability of COVID-19 infection and death, which would be the opposite of what school closings were intended to achieve.[19]

The chance of acquiring COVID-19 in school appears to be proportional to COVID-19 prevalence in the surrounding community. Even in high-prevalence areas by the standards of fall 2020, the expected number of fatalities in a two-adult elderly unvaccinated household is about the same whether one of those adults spent the day driving a car alone or teaching school in person during the COVID-19 pandemic. The fatality risks are orders of magnitude less for teachers of different ages, living arrangements, or community prevalence. Translated into compensating differences relative to exactly zero risk, the fatality risk of in-person teaching ranges from less than a penny per day for a young teacher living alone in a low-prevalence community to $29 per day for an elderly teacher living with an unvaccinated elderly adult in a high-prevalence community. The compensating differences are less than a dollar a day for the

[19] The primary- and secondary-school rates in this paper may be different for college not only because college students are older but because colleges provide both classrooms and living quarters.

modal teacher category (aged 25-44 living with an unvaccinated adult in that age bracket). To put it another way, the fatality risk to self and living partners, which may include an elderly person, for one day taught in-person by the average nonelderly teacher is similar to the risk of driving 16 miles alone in a car. For the modal teacher, the equivalent is five miles. In aggregate, the families of students bear more of the health burden of school-acquired COVID-19 than do teachers and their families.

Under the pandemic conditions that prevailed in the U.S. during 2020, my point estimate is that there are about 38,000 teacher-years (1.4 million teacher-weeks) of in-person schooling for each fatality of a teacher or spouse from an infection that the teacher acquired in school.[20] Because 1.4 million teacher weeks are associated with 21 million student weeks, 22 million people would – without a more targeted approach – have to be removed from in-person schooling for a week to prevent a single teacher fatality. As shown in the Appendix, 22 million people distanced six feet apart could form a line that is almost 29,000 miles long, which is long enough to begin in Cape Town, South Africa, stretch across the continents of Africa and Asia (using Google walking directions) to Magadan in northeastern Siberia, and back to Cape Town by the same route. The risk of fatality from school-acquired COVID-19 is nonzero but, like some more familiar risks, small enough to significantly challenge comprehension.[21]

The low infection rates in schools compared to the wider community or even households may not be a mere quirk of epidemiology. At least since Coase (1937), Buchanan and Tullock (1962) and Alchian and Demsetz (1972), economists have suggested that certain local externalities are alleviated more by voluntary cooperation within firms, clubs, schools, etc., than they are either by government or by a set of individuals that are not part of any voluntary organization.[22] Predating the pandemic, the existence and survival of voluntary organizations

---

[20] The risk would be 35 percent lower if the non-elderly, who are 95 percent of the workforce, did all of the teaching during the pandemic.

[21] For some of the papers on the accuracy of consumer risk assessments, see Kahneman and Tversky (1979), Fischhoff et al. (1981), Viscusi (1985) and Magat, Viscusi and Huber (1988). One emerging theme is that people overestimate small risks when the risks are not part of their consumption specialty or profession, as with nonsmoker over-estimates of smoking risk (Viscusi 1990) or occasional Israeli bus users' overestimates of the frequency of terrorist incidents (Becker and Rubinstein 2004).

[22] Unlike, say, carbon emissions, infectious and contagious diseases are local externalities because the disease is transmitted in geographic proximity. See also Nove (2005) who, observing failures to manage externalities in the public sector, concludes "externalities arise not because of separation of ownership, but because of separation of decision-making units." Mitchell (1912) specifically contrasted households with businesses, observing that "the business enterprise … made possible more elaborate specialization and machinery, more perfect coordination of effort and greater reduction of waste than could be attained by the family." See also Zinberg (2021).

perhaps reveal that they manage local externalities and provide local public goods to members well enough that individuals could justify submitting to the constraints that membership requires. Mandating the closure of schools and businesses idles organizational capital that had passed a market test (Mulligan 2020, Mulligan, Murphy and Topel 2020). From this economic perspective, it is less surprising that schools would be places unlikely to spread COVID-19 from one person to another even though a school normally contains many more people than any one household does.

.

VII. Appendix: Attack Rates and Infection Rates in School and at Home

The studies utilized in the main text measure school-acquired infection rates, defined as infections acquired in school for each person day that a student or staff is present in school. The denominator includes person days in which none of the students or staff were infected. CDC data show that, for example, only one in 6,000 persons aged 5-17 were infected on the average day during the fall 2020 term.[23] Although infected people may be infectious for multiple days, this shows why the large majority of classes would have no infections present on any given day even if the classes were selected randomly from the general population aged 5-17. Moreover, school protocols such as quarantine based on symptoms or family cases are designed to disproportionately sample in-school attendance from the 5,999 out of 6,000 who were not infected.

A daily attack rate is the ratio of infections acquired in school for each person day that a student or staff has close contact with an infectious person at school.[24] The school-acquired infection and attack rates are related according to:[25]

$$\begin{aligned}(school\ infection\ rate) &= (new\ daily\ infection\ rate\ in\ the\ population) \\ &* (infectious\ days\ per\ infection) \\ &* (fraction\ of\ infectious\ days\ in\ school) \\ &* (close\ contacts\ per\ infected\ per\ day) * (school\ attack\ rate)\end{aligned} \tag{2}$$

The first term on the RHS is outside the school. The second term can be considered a matter of biology. The third term is a function of school policy. If nothing else, even open schools are closed on weekends. That is, a 14-day infectious period translates to at most 10 days infectious

[23] For persons age, say, 30-49, one in 2,700 were infected in a given day.

[24] Infection and attack rates are sometimes defined differently that I define them here. For my purposes, the relevant definition is from the empirical studies of in-school transmission.

[25] This formula infinitesimally exaggerates the infection rate because it assumes that a person could be infected twice in the same day. Algebraically, it approximates $(1-p)p$ with the infection rate p.

in school for each infected student or teacher. School quarantine rules are designed to further reduce the third term toward zero. The fourth term is also a function of school policy, such as the class size, whether students switch classes during the day, and whether large groups use shared facilities during the day.

The daily attack rate may also be a function of school policies such as distancing and mask use. The purpose of this appendix is to examine daily attack rates measured in Australia by Macartney, et al. (2020) and relate them to the infection-rate studies cited in Section IV.A. The study defined a close contact as "as children or staff with face-to-face contact for at least 15 min, or who shared a closed indoor space for at least 40 min (generally the same class or lesson, typically consisting of 20–30 students)" (p. 809). They measured an average of 15.8 close contacts accrued over an average of 3.4 school days for each primary case. Two cases were found among 3,265 close-contact-days, which is a daily attack rate of 0.06 percent. The last four terms of equation (2)'s terms are, in this study, 3.3 percent.

The study occurred in Australia between March 5 and April 9, 2020 when schools were open primarily for the children of essential workers. This place and time are not representative of the U.S. fall 2020 in terms of equation (2)'s first term. However, equation (2)'s first – or third or fourth – term can be calculated from U.S. data instead in order to estimate a school-acquired infection rate for the U.S. under the assumption that the other terms are the same as in the Australian study. Conversely, U.S. values for the third or fourth term could be inferred under the assumption that Australia and the U.S. have the same attack rate.

Table 9 shows how the attack-rate studies can be reconciled with the infection-rate studies. The table's rows are the terms from equation (2), with the second and third term combined into "Row A." The Australia column has no measured infection rate, but the second panel uses the formula E = CD/(AB) by taking row D as the U.S. average for fall 2020 (recall Table 4). Conversely, an inverse attack rate (row C) could be estimated for England, NC, and WI by assuming that they share rows A and B with Australia. The results (not shown in the table) would range from about 1300 contact days for England (similar to Australia) to about 700 contact days for NC.

Table 9. Reconciling attack rates and infection rates

Row	Rate	Units	Published sources: Australia	England	NC	Wisconsin
A	Infectious days in school per student or staff infected and present	Days	3.4	N/A	N/A	N/A
B	Close-contact rate	Contacts per infected	15.8	N/A	N/A	N/A
C	Inverse school attack rate	Contact days per infection	1,633	N/A	N/A	N/A
D	Community population per new daily infection	Person-days per infection	N/A	116,556	5,595	1,695
E = CD/(AB)	Inverse school infection rate	Person-days per infection	N/A	2,800,991	71,615	31,595

Row	Rate	Units	Sources scaled to US avg. community: Australia	England	NC	Wisconsin
A	Infectious days in school per student or staff infected and present	Days	3.4	N/A	N/A	N/A
B	Close-contact rate	Contacts per infected	15.8	N/A	N/A	N/A
C	Inverse school attack rate	Contact days per infection	1,633	N/A	N/A	N/A
D	Community population per new daily infection	Person-days per infection	5,298	5,298	5,298	5,298
E = CD/(AB)	Inverse school infection rate	Person-days per infection	160,868	127,318	67,817	98,772

As noted, for each infectious student or teacher at school, an average of 15.8 close contacts were maintained an average of 3.4 days. At the measured attack rate, that is 30 primary cases for every secondary case whereas at home the ratio is about two primary cases for every secondary. Presumably infectious close contacts last longer at home, perhaps up to 14 days (and also for more hours). This still leaves a residual between attack rates in schools and homes, which might be explained by mitigation protocols used in schools but not homes.[26]

Table 10 shows how I translated the (inverse) frequency of school-acquired infections into a line of students and teachers. My point estimate is that there are about 38,000 teacher-years (1.4 million teacher-weeks) of in-person schooling for each fatality of a teacher or spouse from an infection that the teacher acquired in school. Because 1.4 million teacher weeks are associated with 21 million student weeks, 22 million people would – without a more targeted approach – have to be removed from in-person schooling for a week to prevent a single teacher fatality. 22 million people distanced six feet apart could form a line that is almost 29,000 miles long, which is long enough to begin in Cape Town, South Africa, stretch across the continents of Africa and Asia (using Google walking directions) to Magadan in northeastern Siberia, back to Cape Town by the same route. In terms of New York-Los Angeles round trips, a line of 22 million people would occupy the entire walking route (round trip) five times over.

[26] Larosa, et al.'s (2020)'s study of schools in the Reggio Emilia province of Italy during fall 2020 finds a greater percentage of close contacts to be secondary cases (3.2 percent compared to 0.2 percent for Australia), and more close contacts per primary case (25 compared to 15.8 for Australia). Their findings may suggest somewhat greater transmission in Italian schools than in Italian households; see also Madewell et al. (2020). The duration of close contacts in the Italian case is unclear.

Table 10. Translating infection frequencies to line length

Pupil-teacher ratio	15.4
Teacher-years to elearning	37,994
Teacher-weeks to elearning	1,367,784
Student-weeks to elearning	21,063,872
Total persons to elearning	22,431,656
Distances in feet	
between persons	6
thickness of a person	1
Distances in miles	
Length of elearning line	27,615
NYC to LA, round trip	5,604
Cape Town to Magadan	28,500
Length of elearning line	
NYC-LA round trips	5
CT-Magadan round trips	1.0

Bibliography

Alchian, Armen A., and Harold Demsetz. "Production, information costs, and economic organization." *The American economic review* 62 (1972): 777–795.

Becker, Gary S., and Yona Rubinstein. "Fear and the response to terrorism: an economic analysis." *University of Chicago mimeo* 93 (2004).

Buchanan James, M., and Gordon Tullock. *The calculus of consent.* Ann Arbor, MI: University of Michigan Press, 1962.

Coase, Ronald. "The theory of the firm." *Economica* 4 (1937): 386–405.

Falk, Amy, Alison Benda, Peter Falk, Sarah Steffen, Zachary Wallace, and Tracy Beth Høeg. "COVID-19 cases and transmission in 17 K–12 schools—Wood County, Wisconsin, August 31–November 29, 2020." *Morbidity and Mortality Weekly Report* 70 (2021): 136.

Fischhoff, Baruch, Paul Slovic, Stephen L. Derby, and Ralph L. Keeney. *Acceptable Risk.* Cambridge: Cambridge University Press, 1981.

Grijalva, Carlos G., et al. "Transmission of SARS-COV-2 infections in households—Tennessee and Wisconsin, April–September 2020." *Morbidity and Mortality Weekly Report* 69 (2020): 1631.

Ismail, Sharif A., Vanessa Saliba, Jamie Lopez Bernal, Mary E. Ramsay, and Shamez N. Ladhani. "SARS-CoV-2 infection and transmission in educational settings: a prospective, cross-sectional analysis of infection clusters and outbreaks in England." *The Lancet Infectious Diseases*, 2020.

Kahneman, Daniel, and Amos Tversky. "An Analysis of Decision under Risk." *Econometrica* 47 (1979): 263–292.

Larosa, Elisabetta, et al. "Secondary transmission of COVID-19 in preschool and school settings in northern Italy after their reopening in September 2020: a population-based study." *Eurosurveillance* 25 (2020): 2001911.

Macartney, Kristine, et al. "Transmission of SARS-CoV-2 in Australian educational settings: a prospective cohort study." *The Lancet Child & Adolescent Health* 4 (2020): 807–816.

Madewell, Zachary J., Yang Yang, Ira M. Longini, M. Elizabeth Halloran, and Natalie E. Dean. "Household Transmission of SARS-CoV-2: A Systematic Review and Meta-analysis." *JAMA network open* 3 (2020): e2031756–e2031756.

Magat, Wesley A., W. Kip Viscusi, and Joel Huber. "Consumer processing of hazard warning information." *Journal of Risk and Uncertainty* 1 (1988): 201–232.

Mitchell, Wesley C. "The backward art of spending money." *The American Economic Review* 2, no. 2 (June 1912): 269–281.

Mulligan, Casey B. "Economic activity and the value of medical innovation during a pandemic." *NBER working paper*, no. 27060 (4 2020).

Mulligan, Casey B., Kevin M. Murphy, and Robert H. Topel. "Some basic economics of COVID-19 policy." *Chicago Booth Review*, 2020.

National Center for Education Statistics. "Table 208.20. Public and private elementary and secondary teachers, enrollment, pupil/teacher ratios, and new teacher hire." *nces.ed.gov.* 2020. https://nces.ed.gov/programs/digest/d19/tables/dt19_208.20.asp.

National Safety Council. "Motor vehicle deaths, injuries, and number of crashes by type of crash, United States, 2019." *injuryfacts.nsc.org.* 2020. https://injuryfacts.nsc.org/motor-vehicle/overview/type-of-crash/.

Nove, Alec. "Socialism and the Soviet Experience." In *The Economics of Feasible Socialism Revisited*, by Alec Nove. London: Harper Collins, 2005.

Oster, Emily. "What Parents Need to Know About School Coronavirus Case Data." *New York Times*, September 28, 2020a.

—. "Schools Aren't Super-Spreaders." *The Atlantic*, October 9, 2020b.

Savage, Ian. "Comparing the fatality risks in United States transportation across modes and over time." *Research in transportation economics* 43 (2013): 9–22.

Stein-Zamir, Chen, et al. "A large COVID-19 outbreak in a high school 10 days after schools' reopening, Israel, May 2020." *Eurosurveillance* 25 (2020): 2001352.

U.K. Office of Statistics Regulation. "Attendance in education and early years settings during the coronavirus (COVID-19) outbreak." *explore-education-statistics.service.gov.uk.* 2020. https://content.explore-education-statistics.service.gov.uk/api/releases/e9fca3d7-4a96-4f9a-49e0-08d84a918dfb/files/56dd5ae6-f8ef-4c9d-c349-08d84a9eaaad.

U.S. Dept. of Transportation, National Highway Traffic Safety Administration. "Quick Facts 2016." *crashstats.nhtsa.dot.gov.* 2017. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812451.

—. "Overview of Motor Vehicle Crashes in 2019." *Traffic Safety Facts*, December 2020.

United States Bureau of Labor Statistics. "National Census of Fatal Occupational Injuries in 2019." December 16, 2020b. https://www.bls.gov/news.release/pdf/cfoi.pdf.

—. "Number and rate of fatal work injuries, by industry sector." December 16, 2020a. https://www.bls.gov/charts/census-of-fatal-occupational-injuries/number-and-rate-of-fatal-work-injuries-by-industry.htm.

United States Department of Health and Human Services. "COVID-19 Diagnostic Laboratory Testing (PCR Testing) Time Series." *healthdata.gov.* 2021. https://healthdata.gov/dataset/COVID-19-Diagnostic-Laboratory-Testing-PCR-Testing/j8mb-icvb.

Viscusi, W. Kip. "A Bayesian perspective on biases in risk perception." *Economics Letters* 17 (1985): 59–62.

Viscusi, W. Kip. "Do smokers underestimate risks?" *Journal of Political Economy* 98 (1990): 1253–1269.

—. *Fatal tradeoffs: Public and private responsibilities for risk.* Oxford University Press, 1992.

Viscusi, W. Kip, and Joseph E. Aldy. "The value of a statistical life: a critical review of market estimates throughout the world." *Journal of risk and uncertainty* 27 (2003): 5–76.

Yang, Wan, et al. "Estimating the infection-fatality risk of SARS-CoV-2 in New York City during the spring 2020 pandemic wave: a model-based analysis." *The Lancet Infectious Diseases* 21 (2021): 203–212.

Zimmerman, Kanecia O., et al. "Incidence and secondary transmission of SARS-CoV-2 infections in schools." *Pediatrics*, 2021.

Zinberg, Joel. "Don't Wait to Reopen Schools." *City Journal*, January 28, 2021.