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REVIEW

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The economic impact of school closures during the 2015 flood in Richland County, South Carolina

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Abstract

Research on the societal costs of disaster-related US school closures has focused, and due to COVID-19 will likely continue to focus, on pandemics, with very limited research on closures from natural hazards. This is surprising given that school closures occur frequently to protect children, teachers, and staff pre-event as well as post-disaster to convert facilities into emergency shelters, etc. This study investigates the secondary effects from post-flooding, temporary school closures after the catastrophic 2015 flash flood in Richland County, South Carolina. Lost productivity from school closures was quantified using the Human Capital Method. Out of the 208 completed surveys, 75% of households had children that missed school. Post-stratifying survey results on race produced an average of $437 in lost productivity due to school closures and an overall $2175 in lost productivity due to flood-related impacts in general. Expressed in FEMA benefit-cost analysis terms, our study shows that schools have a standard value of $215 per household and per day for the unweighted sample ($180 for the race-weighted sample). Furthermore, households' disutility for a late start is almost as great as their disutility for a school closure. These exploratory findings suggest that unplanned school closures should be minimized, and community characteristics carefully considered to avoid unintended socioeconomic consequences.

KEYWORDS

flood, human capital method, indirect costs, school closure, socioeconomic impact

INTRODUCTION

When an extreme event such as a severe thunderstorm, hurricane, flood, or earthquake is impending or has occurred, schools are temporarily closed for a variety of reasons such as avoidance of injuries/fatalities, structural damage, inaccessible roads, power outages, lack of potable water (Heflin et al., 2014), and more. Furthermore, school busses are commonly diverted for evacuation logistics and school facilities closed and converted into emergency shelters, staging or distribution sites, command centers, volunteer housing quarters, and more (FEMA, 2010, 2020b). Temporary school closures not only adversely affect students in terms of academic attainment (Coombe et al., 2015) and mental health (SAMHSA, 2018) but have much broader consequences: caretakers are unable to go to work (Hoffman & Miller, 2020), families lose income, food-insecure children skip meals (Wilson, 2020), students with disabilities are cut off from support systems, child abuse incidents rise (Thomas et al., 2020), and more.

The scale and duration of school closures due to the ongoing COVID-19 pandemic ignited national discussions on the trade-offs between economic, developmental, and educational demands on one hand and school closures as a public health intervention to curb viral transmission on the other (American Association of Pediatrics, 2021; Betz, 2020; Levinson et al., 2020; NASEM, 2020) as temporary school closures starkly revealed longstanding, systemic racial and socioeconomic injustices inherent in the US educational system (NASEM, 2020). Such a nuanced discussion is still missing regarding the economic, societal, and educational impacts of unplanned school closures in the realm of non-pandemic emergencies and long-term disaster recovery. Albeit rarely as long and widespread as during the COVID-19 pandemic, unplanned, temporary school closures, that is, closures not pre-identified in the school calendar with or without prior notice of several hours or days such as closures for common emergencies such as winter weather, heat, and hurricanes are frequent. In 2018, Hurricane Florence forced some schools in North and South Carolina to close for more than 3 weeks—some of which never reopened (Baez, 2019; Bowers, 2018). Between 2011 and 2013, about 21,000 temporary, unplanned school closures of one day or longer occurred within the United States with nearly 95% of those closures due to natural hazards (K. K. Wong et al., 2014).

Before COVID-19, few schools or school districts had operating procedures in place that ensured educational continuity such as policies for partial district opening, utilization of alternate facilities, access to distance education including learning devices and internet, temporary transfers to other schools, use of external services (e.g., food, water, sanitation), or a combination thereof (Zheteyeva et al., 2017). These procedures used to emerge on an ad-hoc basis and were put in place only after experiencing a major catastrophe (e.g., 2017 Hurricane Maria/Puerto Rico, 2017 flooding/Houston, 2005 Hurricane Katrina/LA, and MS, etc.).

Research shows that schools are key community resources during "normal" times and even more so after a disaster (Pfefferbaum et al., 2015). A quick return to regular school operations post-disaster signals a degree of normalcy, a return to pre-disaster conditions with parents being able to work knowing their children are safe at school (Ronan & Johnston, 2005). More empirical evidence is needed, particularly for non-pandemic scenarios, to make the case for keeping schools open, modifying emergency preparedness and response procedures, and possibly classifying schools as essential infrastructure and community lifeline. Unfortunately, limited research exists in a non-pandemic context, largely because of the lack of data, that examines and quantifies the secondary, cascading effects beyond academic attainment when children suddenly must stay home from school for days, weeks, or months. Using five wildfire and one tropical storm case studies, Poujaud (2019), for example, found that schools and school districts with a higher percentage of low-income and vulnerable populations experience longer school closures.

This study is among few that investigate the secondary effects from post-disaster temporary school closures including lost productivity. The objective is to offer exploratory evidence that shows the socioeconomic reach of school closure impacts in the context of a local disaster. More broadly, the goal is to encourage the development of more agile school operating procedures as well as county-level emergency management guidance that maximize school days safely and limit the number of school closures. Establishing such policies will provide common ground rules for school officials who have to manage the backlash from parents as well as for emergency managers who will no longer need to rely on guesstimates or experience when deciding when to release school facilities for normal operations. Such guidance is needed given that our case study of the 2015 flash flood in South Carolina, as detailed in the following, suggests that school closures can trigger cascading economic impacts far exceeding the direct damage inflicted by the disaster itself. We surmise that our past emergency management practices for non-pandemic events may have overemphasized public safety benefits without due consideration of the burden and cascading effects on children, parents, and caregivers, particularly when the event and/or disaster recovery lasted longer than a few days.

Going forward, there is an urgent need to apply and adapt the COVID-19 lessons and planning efforts to non-pandemic emergencies to increase community resilience and reduce the uneven burden of disasters. In the absence of federal guidance as well as solid continuity of operations practices for schools (and funding to implement it), there is a risk that pre-COVID standard operating procedures return such as closing entire districts when only one school is impacted and most other schools within the district could feasibly operate (K. K. Wong et al., 2014) or the alignment of closure policies between school districts and other facilities such as daycares, colleges, and private schools.

THE STANDARD VALUE OF SCHOOLS

Direct damage, the effects directly caused by the hazard such as injuries, fatalities, or destruction of property, tends to be the leading measure of the destructiveness of an event. The instant destruction laid bare by a tornado, earthquake, or hurricane is easily observed and measured—though not always documented or reported comprehensively (Gall et al., 2009; Meyer et al., 2013). The indirect or secondary effects, however, are complex, widespread, long-ranging, and uniquely dependent on the characteristics of local economies and demographics, requiring economic modeling (e.g., input-output models) and/or surveys to capture and understand local dynamics and conditions (Hallegatte, 2015). As a result, indirect damage figures from natural disasters are either rough estimates based on a multiple of direct damage (Hallegatte et al., 2007) or singular case studies, mostly of large-scale catastrophic events. Independent of the approach, quantifying indirect damage revolves around assessing the adverse effects of the disaster on production of goods and services, expressed in loss of gross domestic product, lost productivity, and so forth (Rose, 2009). For example, several papers quantify impacts of wildfires or floods on housing markets (Atreya & Ferreira, 2015; Bin et al., 2008; Bin & Landry, 2010; Mueller et al., 2009), reduction in agricultural yields (Auffhammer, 2018; Schauberger et al., 2017), or worker productivity (Henriet et al., 2012; Hsiang, 2010; Orlov et al., 2019).

What has been overlooked, and what this paper focuses on, is lost work hours due to school closures that may accompany natural disasters. Not only are the costs associated with temporary school closures omitted from loss or impact assessments as schools do not per se produce any goods or services, but the costs or investments needed to keep schools operating—with redundant systems such as backup generators, hardened facilities resistant to high winds and flooding, reliable heating and A/C systems, air and water filtering systems, and more—are also not accounted for adequately on the front end of hazard mitigation planning. At present, the value of schools to a community is narrowly defined in non-disaster contexts and based largely on student achievement and test scores (Frey & Verhagen, 2021; Peek, 2008), public spending (Barrow & Rouse, 2004), or effects on local home values (Bogart & Cromwell, 2000).

Unlike other public services identified as critical infrastructure (e.g., water, power, police, fire, EMS, and hospitals), there is no "worth" measure of schools—for example, no standard value as defined by the Federal Emergency Management Agency (FEMA). Standard values, pre-determined amounts of the value of a service, are a common metric used in benefit cost analysis (BCA), which is a decision-making tool to weigh the societal and economic benefits (avoided losses) associated with a proposed hazard mitigation project versus the project costs (Ganderton, 2005). For example, the standard value for loss of service of roads/bridges is $34.72 per vehicle per hour and the loss of water services is $114 per capita per day (FEMA, 2020a). Standard values exist for other critical infrastructure such as police, fire, EMS, and hospitals. These values vary locally depending on population served, distance traveled, number of officers, and so forth (FEMA, 2009). These standard values are the de facto benefit communities attribute to public services as they apply for federal hazard mitigation grant dollars. As long as a proposed mitigation project costs less to implement than the benefits (avoided losses) it promises to accrue, FEMA considers the project worth funding with up to 75% in federal mitigation dollars—assuming the project complies with additional program requirements (FEMA, 2015). Thus, standard values are an important metric in accounting for and justifying infrastructure expenditures, including schools, that make communities safer and more resilient to natural hazards. Without a standard value for schools based on, for example, the student population served, student population on free and reduced-priced meals, number of teachers, learning loss as well as productivity loss of working-caregiver households how are communities to determine or justify, let alone implement, mitigation projects that increase the resilience of schools?

By definition there is a difference between cost—the expense of producing or delivering a service or good—and value, the "worth" expressed in money or goods (Raucher, 2005). In the context presented here, the calculated cost of school closures represents a lower bound of the benefit of schools remaining open (Aubuchon & Morley, 2013) and a possible pathway to a standard value for schools.

ECONOMIC EFFECTS OF TEMPORARY, UNSCHEDULED SCHOOL DISMISSALS

According to K. K. Wong et al. (2014), schools nationwide closed nearly 21,000 times between August 2011 and June 2013—95% of the time due to weather/disaster-related causes. Other closure reasons identified by K. K. Wong et al. (2014) were the temporary loss of utilities, school violence, health concerns, teacher strikes, death of staff or students, environmental problems, and more. Dismissing school early or closing schools for a day or more is standard procedure in the face of an imminent threat such as a winter storm or hurricane, or after an event that inflicted major, widespread damage across a community. Pre-event, schools close as a precautionary measure to keep staff and students safe and to allot time to secure the facility itself. After an incident, closures are generally the result of damage to school facilities impeding continued operations or because roads are impassable, making school bus drop-offs and pickups infeasible (Peek, 2008). To a lesser extent temporary closures arise from the need for short-term shelters to house displaced residents (Ronan & Johnston, 2005). In rare instances, state-owned school busses are diverted for disaster evacuations, thereby interrupting school access, and forcing schools to close since children without access to personal transportation would not be able to attend. Depending on the scale and magnitude of the event, school districts may opt to close all schools within a district including those undamaged and accessible to maintain educational uniformity and avoid disadvantaging students enrolled in damaged or inaccessible schools. K. K. Wong et al. (2014) found that on average, district-wide closures occur for 70 percent of weather/disaster-related school dismissals.

Despite these frequent and common practices to suspend school operations temporarily pre- and/or post-disaster, there is very little research on the economic costs of school closures, which may partially explain the lack of a standard value. A study initiated by the Mississippi State Department of Health and conducted by the Centers for Disease Control in the Harrison County School District with regard to a 4-day school closure (2012 Hurricane Isaac) revealed the following (Zheteyeva et al., 2017): 55% of surveyed households lost income due to missing work, 18% of households with children on free or reduced meals experienced challenges in providing food at home, and nearly 26% of households incurred additional child care expenses (median: $150). These figures are higher than previously conducted research, which exclusively focused on closures as pandemic risk management strategy (Kavanagh et al., 2012; Nishiura et al., 2014).

These economic impact studies are limited the 2009/2010 H1N1 context and the product of data collected through an ad-hoc established, short-lived national surveillance systems during the H1N1 outbreak in the United States—the Influenza-like Illness (ILI)-related school dismissal monitoring system developed in conjunction by the Centers for Disease Control and Prevention (CDC) and the US Department of Education (Kann et al., 2017). The limited number of studies on illness-related closures indicate that parents perceive unplanned school closures of short duration as minor problems with many families being able to make accommodations by means of nonworking family members providing child care or the ability to take time off work without severe repercussions such as job loss and pay cuts (Epson et al., 2015). For example, during influenza-related school closures in southeastern Kentucky in 2008, about 40% of households could provide alternative care through a homemaker or nonworking adult in the household. On the other hand, nearly 30% of households missed work and about 16% of households lost pay. Furthermore, 43% of students enrolled in school meal programs relied on food at home and 10% of meal-dependent households indicated difficulties feeding their children (Timperio et al., 2009). Similarly, a telephone survey conducted in 39 states in 2009 revealed that 20% of households missed work, 10% lost pay, 11% incurred additional child care costs, 2% of households felt at risk of losing their job, and 19% of households had children enrolled in school meal programs (Steelfisher et al., 2010). Observational research on the economic impacts of prolonged school closure is even sparser and limited to simulated epidemics and hypothetical behaviors. For example, based on data collected on school closures during the 2009 H1N1 pandemic in Western Australia, Effler et al. (2010) found that a substantially higher number of households (about 50%) anticipate adverse economic impacts for 12-day school dismissal scenarios with increasingly higher numbers for longer closure periods.

Despite the potentially greater economic impacts of school dismissals when caused by natural hazards, there is agreement that school closures pose more significant challenges for households of lower-income, single-adult households as well as ethnic and racial minorities. Thus, school closures "raise serious ethical concerns, many of which have been largely overlooked" and "have the potential to create serious adverse consequences, which will disproportionately affect vulnerable populations" (Berkman, 2008, p. 372).

STUDY AREA

Between October 1 and 5 of 2015, a stalled front offshore combined with the remnants of Hurricane Joaquin and a strong upper-level low-pressure system formed a climatological setup (so-called atmospheric river) that produced record-breaking precipitation levels and flooding throughout the state of South Carolina, with many areas receiving 2 inches of rain per hour and more than 20 inches in total (NWS, 2016, Figure 1). Urbanized areas such as the City of Columbia (the State's capital) in Richland County and the City of Charleston were particularly hard hit due to the prevalence of impervious surfaces and high run-off generating flash flooding along with major riverine flooding. A total of 50 dams failed, more than 500 roads/bridges were closed and more than 1500 water rescues occurred statewide (SCEMD, 2016). Reservoirs such as Lake Murray had to release excess water during and shortly after the event, causing extensive backwater flooding.

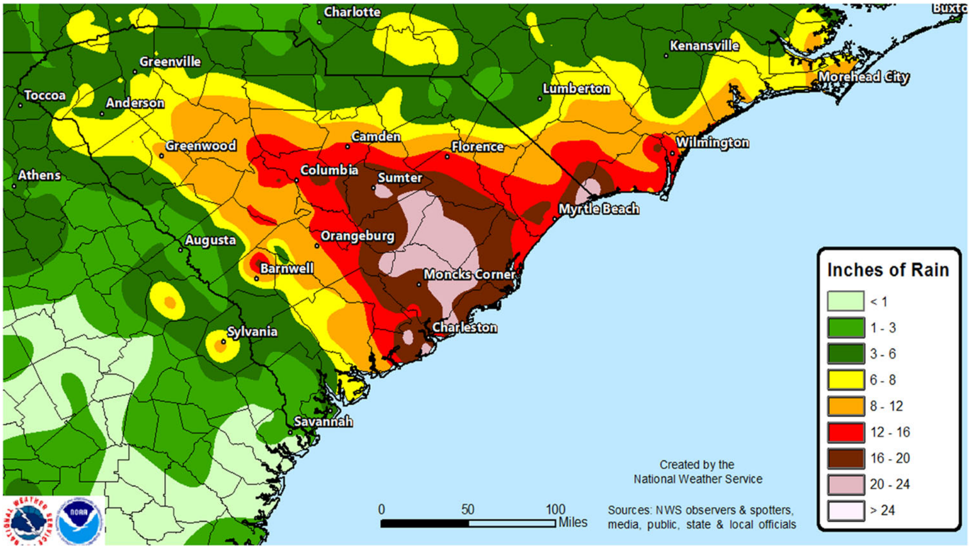

FIGURE 1 Total rainfall from October 2nd through 6th, 2015 across South Carolina and parts of Georgia and North Carolina

The flood event caused an estimated $2.2 billion in direct damage and 25 deaths (NCEI, 2021). The Presidential Disaster Declaration (DR-4241) issued for the event encompassed more than $90 million in individual assistance for 28,138 applicants as well as more than $90 million in public assistance (FEMA, 2017). Flood damage across the state was widespread: out of the state's 46 counties, half (23) received both individual and public assistance, 12 counties received public assistance, and Greenville County received individual assistance. Only ten counties did not receive any federal recovery funding.

Richland County and the City of Columbia, South Carolina's capital, experienced some of the most severe damage: 9 fatalities, 30 injuries, and nearly $30 million in direct property damage (CEMHS, 2020). In the Richland I school district, a few facilities experienced extensive damage such as Olympia Learning Center as well as Satchelford, Bradley, and Carver-Lyon elementary schools (Wilks, 2015a).

The City of Columbia (circa 8,100,000 residents within metropolitan statistical area according to 2010 census) saw record-setting rainfall amounts of more than 16 inches. The City of Columbia, which lies at the confluence of two rivers (Saluda River and Broad River) forming the Congaree River, had last experienced catastrophic riverine flooding in the early 1900s. To control floods and generate power, the Saluda (Lake Murray) dam was completed in 1930. Since then, flood stage levels occurred only along a smaller river basin within the city when localized but intense thunderstorms or remnants of tropical systems produced heavy downpours (Cutter et al., 2018). Thus, preparing or responding to catastrophic riverine/flash flooding was uncommon and unfamiliar to most residents and public officials alike.

The National Weather Service, however, had accurately forecast and warned the public days in advance of the event. Nevertheless, no school closures were announced before the weekend of October 3 and 4. Starting on Sunday afternoon (October 4), closures were announced district-wide for the subsequent day. On October 5, a 60-foot embankment breach in the nearly 200-year-old Columbia Canal, a drinking water intake diversion canal from the Congaree River, threatened to shut down water supply to the city. While the city was not de facto cut off from its water supply in subsequent days, the city's residents experienced water disruptions such as pressure loss and water line ruptures along with system-wide boil advisories (375,000 customers) due to excess turbidity (cloudiness) (LeBlanc, 2016). Eight bottled water distribution sites sprung up across the city in subsequent days.

With the disruption in the city's water supply, schools, universities, daycares, and other facilities had no running potable water. Richland 1 school district remained closed for 7 school days from October 5 through October 14 (Wilks, 2015b) (Table 1). From October 15 through 17, Richland 1 schools operated on a 2-h delayed schedule.

TABLE 1 Student population as of 2015/2016 school year and number of schools in Richland County, South Carolina, along with school dismissals due to the October 2015 flooding (Source: SC Department of Education 2016)

School District	Student population	Elementary schools	Middle schools	High schools	Students on meal vouchers	Closure days	Late start days
Richland 1	24,210	31	11	9	74%	7	6
Richland 2	27,484	23	7	6	48%	5	6
Lexington-Richland 5	16,926	12	4	5	37%	3	0

The lengthiness of school closures in Richland 1 school district emanated largely from the inaccessibility of school bus routes and inoperable restrooms due to inadequate water pressure (Wilks, 2015a). Richland 1 Superintendent Craig Witherspoon stated on October 12, 2015: "Schools will use bottled water and portable bathrooms until the city declares the water is safe to drink and sewer lines can handle the volume. We can work through a boil-water advisory" (Wilks, 2015a).

Richland 2 school district was closed for 5 days and reopened October 12 on a 2-h delayed start for the entire week (Cola Daily, 2015) and a 1-h delay in the third week (as did Richland 1) after the flood disasters (including student holidays on October 22 and 23) (Wilks, 2015c). Both districts offered free lunches to any child starting October 8 at designated schools (Ellis, 2015). Lexington-Richland 5 school district was closed for 5 days as well but opened on normal schedule on October 12 (The State, 2015).

METHODS

To gauge the economic impact of school closures in Richland County, we administered an online survey via Survey Monkey and the Survey Monkey phone app. The survey took on average 10 min to complete and was accessible from November 2015 through April 2016. Recruitment occurred via outreach on social media, local news, and targeted emails to parent-teacher organizations, neighborhood groups, and daycares, and participation was incentivized by offering four random drawings to win iPads. This broad and prolonged outreach was necessary since school districts declined to distribute hard-copy surveys to parents. The final sample consisted of 208 responses from adults residing in the Columbia, SC area. Of the 110 respondents who indicated which district their children are enrolled in, approximately half indicated Richland I, a quarter Richland II, 10% in Lexington I, 10% in private school, and the remainder in Lexington II or other.

The survey began with a few broad questions as to if and how the October floods affected the respondent's household including if a child missed school due to a school closure and at what school. Next, respondents indicated for each day starting October 3 (Saturday) over the 2-week period following the floods, how many hours of work he or she missed due to school or daycare closure or late start, workplace closure, road closure, or another reason. Then, respondents answered in a similar layout and fashion how much money he or she spent each day on additional childcare and other children's activities, and for how many hours the respondent left children with friends/family or took children to work. Information on time lost for other household members was solicited as well. Furthermore, respondents provided basic socio-demographic information including average hourly wages or average annual income.

Aside from questions regarding the effects of school closures on households due to the flood event, we also gauged the respondent's attitude towards school closures. To do so, we administered a discrete choice experiment on willingness to pay to avoid a school closure or late start. Respondents had the option to choose if he or she preferred paying a fee to reduce the number of days of school closures and late starts, or to forego a fee and instead experience more school closures and late starts. Fee amounts and number of school closure days/late start days were randomized across respondents using a D-efficient choice experiment designed using NGENE software. Using the data from the discrete choice experiment, willingness to pay to avoid a school closure and a late start were estimated using a multinomial logit model. The utility function was assumed to be linear in price (the "fee"), number of days of school closures avoided, and number of late starts avoided.

The economic impact derived from the survey data captured lost productivity, not lost wages. The Human Capital Method (HCM) states that under the assumption of perfect competition, marginal revenue product of an employee equals her marginal compensation (Lempel et al., 2009; Sadique et al., 2008; Sander et al., 2009). Arrow et al. (2017, 2012, 2013) propose the concept of "Inclusive Wealth," which captures human capital, natural capital, health improvements, and technological change, as an alternative measure of wealth and sustainability. In this framework, human and natural capital should be considered in addition to man-made capital, as these types of capital are also important for ensuring sustainability and human wellbeing (Duraiappah & Muñoz, 2012; Sato et al., 2018). While we do not measure human capital in terms of educational attainment (Fraumani & Liu, 2019), we do account for lost labor hours as a measure of economic loss.

Therefore, hours of missed work multiplied by the wage rate measures lost productivity. The incidence of this loss may fall on workers (lost wages) or on firms (lower productivity). While missed work hours are translated to lost productivity regardless of a worker being salaried or hourly, lost wages due to missed work likely affect hourly workers more. Future work could explore differential impacts on salaried versus hourly workers.

Past research using HCM multiply average hours lost by average wages. We improve upon these studies by using our household-level data to multiply actual hours of missed work by actual wages. To calculate the value of lost productivity, we used the hourly wage provided by the respondent. If the respondent provided an annual salary but not an hourly wage, we imputed the hourly wage as *annual salary*/ ($8 \times 5 \times 52$). If the respondent provided neither hourly wage nor annual salary, we use the minimum wage of $7.25, which is a lower bound on wages and produces conservative estimates.

Our study sample over-represented households who own rather than rent their residence and individuals who are female, white, and/or highly educated (Table 2). The median income of the sample was $55,000, which is greater than the Richland County median income of $48,674 as reported by the Census Bureau's 2014 American

TABLE 2 Sample characteristics compared to Richland county (Source: U.S. Census Bureau, 2021)

	Richland county	Study sample
Own their residence	60%	84%
Rent their residence	40%	16%
Male	49%	21%
Female	51%	79%
White/Caucasian	47%	87%
Black or African-American	46%	9%
Graduated from high school	46%	2%
Graduated from college	15%	36%
Completed graduate school	9%	47%
Median income	$48,674	$55,000

Community Survey (U.S. Census Bureau, 2021). It is important to note that over 40% of respondents did not answer the demographic questions.

Due to the limited sample size and the large number of respondents who did not answer the demographic questions, it was impossible to construct survey weights such that the survey sample represented Richland County. To overcome this, we generated multiple survey weights by post-stratifying the sample on various demographic variables. In the unweighted sample with no adjustments, we found a mean income of $58,580. Post-stratifying on race generated the lowest survey weight-adjusted mean income of $49,494. Post-stratifying on home ownership, a proxy for income and education, resulted in survey weight-adjusted mean income of $54,302. For transparency and as a robustness check, study results on economic impacts are reported using all three survey weights.

RESULTS

Out of the 149 respondents who answered the relevant question, 75% had children that missed school. Of those, 34% had one child that missed school, 47% had two, and the remaining 19% had three or more. Flood-related school closures affected residents of Richland County in more ways than just children's inability to attend school. For some respondents, the school at which they work was closed (40%) and for others, their place of work closed because it follows the schedule set by a school district (15%). School cancellations affected caused 31.5% of indicating respondents and/or their children to miss other services such as daycare due to closures (Figure 2). Thus, lost productivity due to school closures as quantified in this study encompassed both lost hours of work due to children released from school requiring supervision as well as lost hours due to workplace closures. Workplace closures include both those directly linked to school district schedules as well as those not linked to school district schedules, since respondents did not specify where they worked. Subsequently, lost productivity estimates include all of these elements and any short-hand mentioning of work hours lost due to flooding encompasses school-related as well as nonschool-related workplace closures. Thus, our results are indicative of the overall impacts of

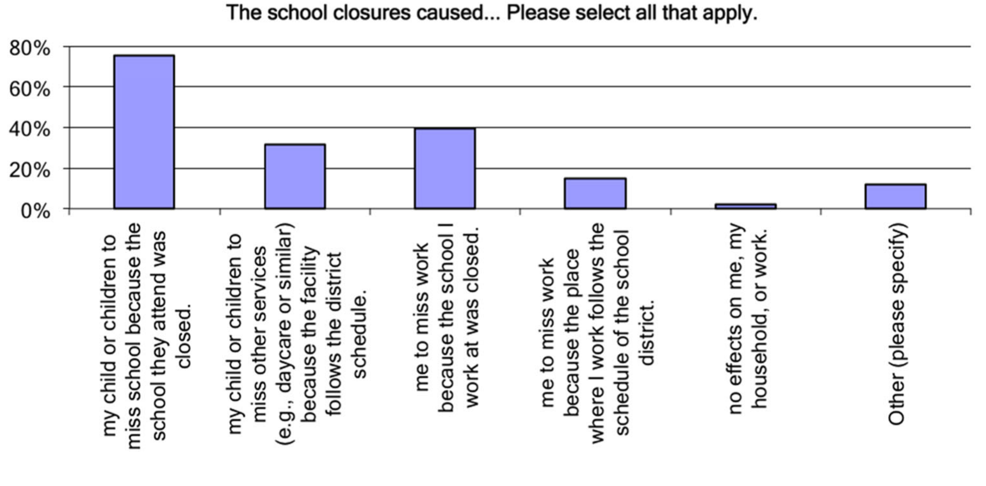

FIGURE 2 Household impacts of school closures due to the 2015 flood in Columbia, SC

TABLE 3 Summary of economic impacts on households affected by school closures due to the 2015 floods in Columbia, SC

		Post-stratified on	
	Unweighted	**Race**	**Home ownership**
Mean Income	$58,580	$49,494	$54,302
Hours of work missed due to…			
School or daycare closure/late start	11.3	13.3	10.9
Workplace closure	10.2	13.7	9.8
Road closure	1.1	2.3	0.9
Other (e.g., flood clean-up)	1.1	1.2	1.0
Hours of work missed (respondent)	23.7	30.5	22.5
Hours of work missed (other household members)	12.3	14.2	11.2
Hours of work missed (household)	36.0	44.7	33.7
Total lost productivity (household)	$1,325	$2,175	$1,482

the flood event on parents with children in school and capture more than just the impacts of school closures alone.

Using the unweighted sample (over-representing white, highly educated respondents), respondents lost 11.3 h of work due to school or daycare closure in the two weeks following the floods (Table 3). Households spent an average of $17.6 on additional childcare and activities during the two weeks following the floods and either left children with a friend or family member (unpaid) for an average of 2.5 h (7.7% percentage of respondents) and took children to work for an average of 0.3 h.

Respondents additionally reported 10.2 h of lost work due to workplace closure, 1 h due to road closure, and 1 h due to other reasons such as flood cleanup. In total, respondents lost an average of 23.7 h. Additionally, in 63% of households, another household member missed an average of 12.3 h of work due to the floods, for a household total average of 36 h. This translates to an average of $906 in lost productivity for the respondent, $418 for another household member, and a household total of $1324 in lost productivity across all causes of work absenteeism. It is important to note that some respondents (7.7%) stated that they were not affected by the school closures presumably due to the availability of a homemaker or other non-working parents but still reported hours of lost work. We included these numbers in our calculations.

Post-stratifying on race, which made the survey sample most representative of the actual population, produced a mean of 45 h of missed work (13.3 h due to school or daycare closure, 13.7 h due to workplace closure, 2.3 h due to road closure, and 1.3 h for other reasons, plus 14.2 h or work missed by another household member), 30.5 h for the respondent and 14.2 h for another household member (Table 2). This translates to an average of $437 in lost productivity due to school closures and an overall $2175 in lost productivity due to flood-related impacts in general. Given this weighting, households spent an additional $20.3 on average for additional childcare and activities, left children with friends or family for 3.3 h on average, and took children to work for an average of 0.4 h.

Post-stratifying on home ownership produced an average household missed work hours of 33.7 h and lost productivity of $1482 due to floods including $468 directly due to school closures. Using these weights, households spent an additional $14.9 on childcare and activities, left children with friends or family for 1.8 h on average, and took children to work for 0.24 h on average.

In general, hours of missed work due to school closures were lower in the first 3 days of the unfolding flood disaster, which is likely due to the fact that flooding began in the overnight hours from Saturday (October 3rd) to Sunday (October 4th). Considerably more hours of work were missed during the first week following the floods (20–26 h) than the second week (4–6 h). By the second week, Lexington-Richland 5 school district had returned to normal operations and Richland 2 school district operated on a 2-h late start. Only Richland 1 school district remained closed for two additional days during the second week. Again, the majority of hours of missed work were due to school or workplace closure (10–13 h each for the respondent) with only an hour or so on average missed due to road closures or other reasons.

Extrapolating the sample data on households affected by school closures to the entire county produced an estimate of total indirect costs due to the flood event of $1324.54 + $17.60 per household, representing 1.4 weeks of wages and assuming a median income of $48,674 and 50 work weeks per year. Multiplying the number of households in Richland County (144,647 households as of 2010–2014 ACS) by the $1324.54 in indirect costs from lost productivity plus the $17.60 in additional childcare costs/activities resulted in an estimated total indirect loss to households in Richland County of $194 million using equal survey weights. Post-stratifying on home ownership generated an estimate of $216 million, and post-stratifying on race produced an estimate of $317 million. It is important to note that this estimate of indirect costs is very conservative since our survey design and analysis focused on households affected by school closures and did not representatively capture effects on businesses such as manufacturing, service (especially restaurants), and other sectors.

In addition to quantifying economic impacts of school closures, we were interested in households' willingness to pay to avoid school closures—gauging the degree to which schools may be able to acquire additional funds for improved disaster planning and preparedness. We estimated a multinomial logit model using the data from the

TABLE 4 Choice experiment results

	Estimated multinomial coefficients (log odds)	Willingness to pay for a 1-unit change		
		Lower bound	Mean	Upper bound
Fee ($)	–0.0375**			
	(0.015)			
Num. Closures	–0.341**	–$11.90	–$9.10	–$4.94
	(0.156)			
Num. Late Starts	–0.279*	–$10.06	–$7.43	$0.78
	(0.157)			
Observations	291			

Note: Standard errors in parentheses.

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

choice experiment, the results of which are shown in Table 4. We found that households would be willing to pay $9.10 on average ($4.94–$11.90 with 95% confidence) to avoid one additional school closure, and $7.43 on average ($0.78–$10.06 with 95% confidence) to avoid one additional late start. This suggests that households' disutility for a late start is almost as great as their disutility for a school closure.

Lastly, quantifying the economic impact of school closures can be used to value the worth of functioning schools, that is, to generate a standard value for schools as utilized in benefit cost analyses. As discussed above, we estimate the per household lost productivity at $1325 or $2175 (post-stratified by race). In our study, 31% of the sample missed work in the first week following the floods due to school or daycare closures and 47% due to workplace closures. Those numbers are 17% and 11% for the second week. Conditional upon having missed work due to school or daycare closure, households (respondent plus other household member if applicable) missed 37 h of work and 28 respondents (13.5%) reported missing 40 h of work the first week after the floods. The average lost productivity in the full (unweighted) sample due to school closures in the 2 weeks following the floods is $440. For the race-weighted sample, it's very similar at $437. For the 31% of the sample who missed work due to school closures, the average lost productivity was $1164 in the first week and $266 in the second week, for a total of $1430. Post-stratifying on race, these numbers are $980 in the first week, $241 in the second week, for a total of $1221.

To arrive at a standard value, we averaged the per household lost productivity due to school closures divided by the number of days each household missed work due to school closures (as a proxy for the number of days of school closures/delays). Doing so generated a per-household, per-day of school closure/delay value of $214.81 for the unweighted sample and $179.65 for the race-weighted sample. It is important to note that these standard values apply only to households with children in schools that are closed and would be zero for other households.

DISCUSSION

Parents expect schools to close when health or environmental conditions no longer permit safe school operations. In this case study, 62% of respondents thought schools were closed "for the right amount of time," whereas almost 28% thought they were closed for too long. Only 1% of respondents felt schools were closed for too short. The rest were unsure. Despite parents' high approval rate of closing schools, unscheduled school dismissals, independent of the underlying reason, are inconvenient and the economic costs and societal impacts are often overlooked- especially their disproportionate adverse effects on lower income households.

While some households can easily compensate school dismissals through non-working household members or homemakers, families with working guardians or single-guardian households either have to pay for additional childcare (if available) or miss work. Out of the 75% of households with school-aged children in our study, about 41% of them had one or more family member miss work due to closed schools. This percentage is nearly identical to Lempel et al.'s (2009) estimate of 42% but lower than Zheteyeva et al.'s (2017) finding of 55% of parents who missed work due to school closures related to Hurricane Isaac. We concur with Zheteyeva et al. (2017) that school closures triggered by a disaster are likely to cause much greater work absenteeism than epidemics given the direct damage and destruction to (school) facilities, roads, bridges, and other infrastructure, thereby causing much more widespread disruption to local economies, in contrast to pandemics that "only" disrupt (school) operations without impairing properties and infrastructure. The 10% lower absenteeism in this study may be indicative of the more localized impact patterns compared to Hurricane Isaac.

The estimated lost productivity costs in our study are significant, especially for lower-income households. Nevertheless, our estimated impacts are lower than other studies. For example, Sander et al. (2009) estimated an economic impact of $2700 per capita. In their nationwide study, Sander et al. (2009) evaluated the cost-effectiveness of different influenza-mitigating strategies including pre-vaccination and targeting prophylaxis, and closing schools emerged as the costliest option. Reasons for our lower estimates could be that (1) Sander et al. presumed a loss of 2.5 workdays per household (a common standard value used in pandemic research) and 5 workdays for teachers, whereas we found on average a maximum loss of 2 workdays (15.4 h post-stratified by race) per household for school closures of 5+ days; and (2) Sander et al. relied on average national compensation rates where as we utilized effective wage and salary, which are lower in South Carolina compared to the national average.

Unscheduled school closures tend to disproportionately affect lower-income households. Unfortunately, we could not adequately explore this aspect since 40% of respondents did not share their wage and of the 103 respondents who answered the question if their child or children received free or reduced meals at school, only 13 respondents answered affirmatively—although the percentage of eligible children ranges between 40% and 75% across the three school districts in Columbia, SC (Table 1). To overcome this shortcoming, we post-stratified our results given that the unweighted sample over-represented higher-income, white, and more educated households. Post-stratifying on race arguably led to the most representative sample, because it resulted in a weighted-mean income of $49,494, which is much closer to the actual median household income of $48,674 that the unweighted mean sample income of $58,580. Noticeably, post-stratifying on race led to a 25% increase in hours of work missed relative to the unweighted sample (45 vs. 36 h) and a 64% increase in lost productivity ($2175 vs. $1324). This suggests that lower-income and/or minority households are disproportionately affected both in terms of more work hours missed and greater productivity losses (despite lower average income).

School closure impacts on lower-income households and risk of food insecurity were concerns for school districts during the 2015 floods in South Carolina. To alleviate some of the adverse impacts, select schools in Richland County offered free meals to all children even while schools were closed. This was an important measure to counterbalance the disproportionate effects on the high percentage of lower-income households, particularly in the Richland 1 school district. However, not all schools offered free lunches, requiring caregivers to have both time and transportation to shuttle their children to a select number of schools during a 2-h time window (Ellis, 2015). It is unclear if plans for meal replacement existed before the flood disaster. Given the lack of recent natural disasters in the City of Columbia, it is quite likely that such a scenario did not factor into school preparedness planning and that the decision to offer free lunches to all children and the selection of school sites was an ad-hoc process. In the Harrison County school district, which was decimated in 2005 by Hurricane Katrina and suffers from frequent natural disasters, Zheteyeva et al. (2017, p. 8) found that "none of the schools had a plan in place for providing special education, meal replacement, continuing education, communication or childcare during school closure." Instead, school officials were highly concerned about the need for make-up days and modifications to holiday and vacation periods.

Being prepared for school closures goes beyond operational decisions at the school and district level. Plans and procedures must be communicated to parents so they are aware and incorporate those plans into their decision-making. In this case study, 41% of parents had no or only little knowledge how their child's school district is planning or preparing for an emergency situation. About 21% checked the "somewhat" box and 33% of respondents claims to know procedure "quite a bit or more." When asked how confident they are in the ability of their child's school to manage future emergency situations, 41% said slightly or somewhat confident and 59% quite or extremely confident. While we did not probe further or test parental knowledge, we presume that most of this knowledge relates to short-term school dismissals and does not cover plans and procedures for school closures as experienced during the 2015 flood event. For example, school districts did not plan for modified bus routes, additional buses to shorten travel times, or to utilize portable restroom trailers—options which would have allowed schools to reopen much earlier. As our results show, parents would be willing to pay ($9.10 per day) to avoid school closures. Unlike other studies (Gemmetto et al., 2014; Zheteyeva et al., 2017) who proposed expanding the use of late starts, our findings indicate that parents would like to avoid late starts nearly as much as school closures.

STUDY LIMITATIONS

As experienced in a similar study (Epson et al., 2015), the sample size did not permit assessment of other factors that could affect the economic impact of weather/disaster-related temporary school closures such as differences between school districts and school types, child's age, number of children, income, and more. Given the small sample size and the higher participation rate of certain demographics, the post-stratification relied on assumptions (e.g., minimum wage where no wage was provided) that produced conservative estimates and may not have fully removed non-response biases.

The low sample size was due to the inability to directly recruit guardians through the schools their children were enrolled in. Instead, we had to rely on distributed recruitment strategies and online surveys, which are not as accessible to lower-income households. Despite the interest in our topic, none of the school districts in our study cooperated in distributing the survey to parents. One school district agreed to distribute a revised version of our original survey. Unfortunately, the district demanded removal of any identifiers related to demographics (e.g., income levels) or students on meal vouchers, which would have made it impossible to post-stratify the sample. Consequently, we relied on other recruitment tools such as social media, the local television news, and so forth. To achieve a sufficient sample size, we also extended the response time frame from a few weeks to five months, which introduced recall bias.

Given the unrepresentativeness of the sample, the unweighted sample estimates are likely biased and results should be interpreted with caution. We help correct for this using post-stratification by home ownership and race. We report a range of estimates to capture the lower and upper bound. The estimates likely mask heterogeneity across schools, with lost productivity possibly greater in areas with more flood damage. While we lack the data to control for this, it is unlikely to be a major issue because public school closure decisions were made at the district, not the school, level.

The impact of COVID-19 has undoubtedly altered the landscape of unplanned school closures and the ability to work or study remotely. While the technology needed for remote working and learning is now vastly more ubiquitous than when this pre-COVID study was conducted, internet accessibility and reliability as well as the technology needed to work and learn remotely is not available equitably

(NASEM, 2020) nor does it preclude caregivers from staying home with a remote learning student. Although COVID-19 created shifts in the ability to work remotely for some, the impact from the loss of work hours due to unplanned school closures remains the same as before COVID-19 for many families, especially those in lower-income brackets and those in the manufacturing and service industries who cannot work remotely. Furthermore, remote learning or working will require sustained investments in technology. At this point, it is unclear if schools, school districts, employers, or employees will be able to sustain remote learning or working environments. Going forward, a return to pre-COVID school operations—and hence unplanned school closures—seems particularly likely for schools with limited resources unable to maintain remote and/or hybrid learning.

CONCLUSION

As the results from our study show, the indirect costs associated with temporary school closures due to the South Carolina flood in 2015 were substantially higher than the actual direct costs of the event. We estimate that closure-induced lost productivity in Richland County alone amounted to $194 million (using equal survey weights), $216 million (post-stratified on home ownership), and $317 million (post-stratified on race). In terms of a standard value for school, our study estimates a value of $215 per household and per day for the unweighted sample ($180 for the race-weighted sample).

Based on the enormity of academic and socioeconomic costs associated with temporary school closures, a better understanding is critically needed to (1) advance school preparedness planning and move beyond exercises and drills (Burling & Hyle, 1997; Tipler et al., 2018), (2) minimize the utilization of schools and school infrastructure for emergency response purposes outside of public health interventions, and (3) minimize indirect costs associated with an emergency by reducing economic hardship for parents and caregivers. Using intermediate options such as sports stadiums or church facilities to feed and house disaster survivors or evacuate residents should be explored more extensively since their usage creates a lower post-disaster economic footprint compared to schools. It is pertinent for emergency managers to limit the use of school resources and for school officials to return to normal operations as quickly as possible and ensure that "the benefits and burdens of any interventions are distributed equitably" (Berkman, 2008, p. 372).

The lack of empirical research on the socioeconomic effects of school closures is surprising given that school closures are an essential risk management tool both for pandemics (HHS, 2017; WHO, 2017) to increase social distancing and reduce transmission rates (Barrett et al., 2012; Z. S.-Y. Wong et al., 2016), as well as for natural hazards to keep people out of harm's way, off of hazardous roadways, and more. Before COVID-19, most research on the effects of temporary school closures centered on the effects on academic achievement (Frey & Verhagen, 2021; Marcotte & Hemelt, 2008; Meroni & Abbiati, 2016) or closures as pandemic risk management strategy. During the COVID-19 pandemic, and absent federal leadership and more research, it fell upon local school districts to make the ultimate judgement calls on school closings and re-openings (NASEM, 2020). Despite past influenza simulation research showing that "school closures may be beneficial in reducing peak and cumulative attack rates during an influenza pandemic" (Jackson et al., 2014, p. 8), researchers predicted closures "to be most effective if they caused large reductions in contact, if transmissibility was low (e.g., a basic reproduction number <2), and if attack rates were higher in children than in adults" but warned that school closures "should be balanced against the significant social and economic consequences of the intervention" and that "(i)t is difficult to draw conclusions on the effectiveness of school closures from epidemiological data" (2014:1).

While the widespread and prolonged closure of schools during the COVID-19 pandemic will likely provide economists and epidemiologists with sufficient data points to make broad generalizations on the value of schools to society, the failure of the CDC to reinvigorate its H1N1 school dismissal monitoring system (Kann et al., 2017) for the COVID-19 pandemic will likely limit scientists' ability to discern demographically-, spatially- and temporally-explicit socioeconomic effects for both COVID-related and disaster-related school closures. As exemplified in the most recent CDC and Department of Education school reopening guidances (CDC, 2021; U.S. Department of Education, 2021), the focus remains on public health indicators rather than balancing conflicting priorities and developing mitigation strategies that also address food insecurity, internet access, child safety, and so forth.

In 2014, K. K. Wong et al. (2014, p. 13) predicted that "(a) better understanding of the baseline scenario of school closures in the United States allows communities, educators, and public health officials to make more informed decisions in current preparations for school-related effects of major public health events, including a future pandemic." We are at risk of missing the opportunity to develop and incorporate socioeconomic factors into our decisions on school closures and reopening. Interdisciplinary approaches (Esnard & Lai, 2021) and acknowledging community characteristics (e.g., age of school children, proportion of working guardians and children eligible for subsidized school meals, availability of paid leave or remote work options) will allow for the design of targeted emergency management decisions (e.g., alternative childcare options, off-site schooling) and the minimization of unintended consequences.

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