Hot Days, Unsafe Schools? The Impact of Heat on School Shootings

Seunghyun Lee* Goeun Lee†

Abstract

Using data on school shooting incidents in U.S. K–12 schools from 1981 to 2022, we estimate the causal effects of high temperatures on school shootings and assess the implications of climate change. We find that days with maximum temperatures exceeding 90°F lead to a 80% increase in school shootings relative to days below 70°F. Consistent with theories linking heat exposure to aggression, high temperatures increase homicidal and threat-related shootings but have no effect on accidental or suicidal shootings. Heat-induced shootings occur disproportionately during periods of greater student mobility and reduced supervision, including before and after school hours and lunch periods. Higher temperatures increase shootings involving both student and non-student perpetrators. We project that climate change will increase homicidal and threat-related school shootings in the U.S. by 8% under SSP2–4.5 (moderate emissions) and by 14% under SSP5–8.5 (high emissions) by 2091–2100, corresponding to approximately 23 and 39 additional shootings per decade, respectively. The present discounted value of the resulting social costs is $343 million and $592 million (2025 dollars), respectively.

Keywords: School shootings, Temperature, Climate change, Gun violence

JEL Codes: Q54, K42, I28, Q58, I18

*Department of Agricultural and Resource Economics, North Carolina State University. Email: slee229@ncsu.edu

†Department of Agricultural and Resource Economics, University of California, Davis. Email: gonlee@ucdavis.edu

1 Introduction

School shootings have long been a serious concern in the United States, imposing substantial and persistent social costs (Rossin-Slater et al., 2020; Bharadwaj et al., 2021; Cabral et al., 2021; Pienkny et al., 2024; Brodeur and Yousaf, 2022; Baldwin et al., 2025; Shaik et al., 2025). Over the past two decades, the incidence of school shootings has approximately doubled (Cabral et al., 2021). Existing research has examined a range of contributing factors, including family and peer influences such as bullying and domestic violence, as well as broader economic conditions like unemployment (Leary et al., 2003; Sommer et al., 2014; Pah et al., 2017). By contrast, the role of environmental conditions remains relatively underexplored, although prior studies document causal effects of extreme temperatures on violent behavior in broader, non-school settings (Ranson, 2014; Heilmann et al., 2021; Mukherjee and Sanders, 2021; Annan-Phan and Ba, 2023; Cohen and Gonzalez, 2024). In this paper, we study how short-term temperature shocks affect school shootings and use these estimates to assess the potential impacts of climate change.

School shootings differ in important ways from gun violence in more general settings. Because attendance at K–12 schools is legally compulsory, students—who account for the largest share of both victims and perpetrators in school shooting incidents—have limited ability to avoid or mitigate exposure to environmental stressors and associated violence risks, unlike in most other settings where individuals can choose when and where to be. During much of our sample period (1981–2022), schools also had limited capacity to adapt to heat exposure through infrastructure investments, as air conditioning was far from universal in U.S. classrooms, particularly outside historically hot regions Park et al. (2020b). At the same time, supervision within schools varies systematically over the school day, creating predictable periods of reduced monitoring. Together, these features make schools a distinctive setting for examining how environmental stress influences gun violence in fixed, nonflexible environments and how such effects interact with predictable patterns of supervision.

The consequences of shootings in schools are uniquely severe. Because schools bring large

numbers of children and adolescents together in shared spaces, a single incident can directly affect many individuals. Moreover, these events occur during critical developmental periods, when students are both physically and psychologically vulnerable. Prior research shows that exposure to school shootings can generate persistent losses in mental health, educational attainment, and future economic outcomes (Cabral et al., 2021). Recovery may be particularly difficult because students often remain tied to the site of the trauma: withdrawing from school, transferring, or maintaining prolonged absence is costly or infeasible, and evidence suggests that affected students rarely change schools following an incident (Cabral et al., 2021).

Given that climate change is projected to increase the severity and frequency of extreme heat events, understanding the effects of temperature on school shootings is critical for informing policies to enhance school safety in a climate with frequent temperature shocks. In this paper, we address several important questions. First, we examine how temperature shocks affect the number of school shootings. Second, we explore how temperature impacts different types of shootings, including homicidal, accidental, suicidal, and those related to bullying, romantic, or domestic issues, as well as varying levels of fatality and the specific timing of the incidents. Third, we assess the impacts of climate change on school shootings and estimate the associated social costs.

While high-profile mass shootings such as Columbine, Sandy Hook, and Parkland have drawn significant attention due to their severe casualties, they are relatively rare. To offer a comprehensive perspective on school shootings—including both fatal and non-fatal incidents—we use the Center for Homeland Defense and Security (CHDS) K-12 School Shooting Database (Riedman and O'Neill, 2023). During this period, non-fatal events accounted for 72% of school gun incidents, according to CHDS. Incorporating these non-fatal incidents also distinguishes our approach from studies that rely on datasets recording only fatal events (Riedman and O'Neill, 2023; Soni and Tekin, 2023). The data include details such as school location, incident date, motivation, and timing. For the empirical analysis, we aggregate the

incident-level data to daily county-level counts.

To estimate the effects of temperature on school shootings, we use plausibly exogenous variations in short-term temperature changes within counties. We employ a Poisson quasi-maximum likelihood (PQML) estimator while including state-by-year, county-by-day-of-the-year, and day-of-the-week fixed effects. State-by-year fixed effects remove any annual unobservables specific to a state, such as policy changes related to gun regulation. County-by-day-of-the-year fixed effects absorb differences specific to each county on a given calendar day, such as academic schedules or local seasonal events. Day-of-the-week fixed effects account for systematic variation in shooting likelihood across weekdays, such as reduced in-school activity on weekends.

Our analysis shows that school shootings increase on unusually hot days, with effects concentrated in homicidal and threat-related incidents rather than accidental or suicidal shootings. The temperature response is driven primarily by incidents not associated with bullying, romantic, or domestic conflicts, and is more pronounced for shootings that result in fatal or serious injuries. These effects are most evident during periods of heightened student mobility and reduced supervision—such as before and after school and during lunch periods—highlighting the importance of context in shaping temperature-induced school violence. High temperatures are associated with increased shootings involving both student and non-student perpetrators, indicating that heat-related risks arise from within schools as well as from external actors.

Our assessments of climate change impacts suggest that, by the end of the century (2091–2100), the incidence of homicidal and threat-related school shootings in the United States may increase by 9.6% under a moderate-emissions pathway (SSP2–4.5), implying roughly 16 additional such incidents over a ten-year period relative to the historical baseline (2005–2015). Under a high-emissions pathway (SSP5–8.5), the projected increase rises to 17.4%, corresponding to approximately 30 additional homicidal and threat-related school shootings per decade. Focusing on lost lifetime earnings among exposed students, loss of life, and

injury-related medical costs, the present discounted value of the associated social costs is estimated at $496 million and $876 million (2025 dollars), respectively.

Our study contributes to the literature by providing the first evidence on the causal effects of temperature shocks on school shootings in K–12 schools—an institutional setting characterized by compulsory attendance and structured interaction, where behavioral responses to environmental stress are not readily inferred from existing crime estimates. A large literature examines how environmental conditions affect violent behavior, including specific crime subcategories (Ranson, 2014; Burkhardt et al., 2019; Bondy et al., 2020; Herrnstadt et al., 2021; Heilmann et al., 2021; Jones, 2022; Annan-Phan and Ba, 2023; Ayesh, 2023; Cohen and Gonzalez, 2024). However, this work primarily analyzes violence in general settings and provides limited evidence on temperature effects in school-specific contexts. In contrast, studies examining environmental conditions in educational settings have focused mainly on cognitive performance (Graff Zivin et al., 2018; Park et al., 2020b) and students' time use (Alberto et al., 2021). Our findings suggest that climate conditions can enter the education production function not only through direct effects on learning, but also indirectly through school safety, which shapes educational outcomes.

We also contribute to the literature on temperature and crime by exploring the mechanisms and contextual factors shaping temperature-induced school shootings. The literature examining how various environmental factors contribute to violent behavior (Ranson, 2014; Burkhardt et al., 2019; Bondy et al., 2020; Herrnstadt et al., 2021; Heilmann et al., 2021; Jones, 2022; Annan-Phan and Ba, 2023; Ayesh, 2023; Cohen and Gonzalez, 2024) has evolved from estimating dose-response relationships to analyzing the underlying mechanisms and contextual factors that influence the relationship. For example, Cohen and Gonzalez (2024) suggest that increased interpersonal interaction may explain the rise in crime on hot days, while Colmer and Doleac (2023) show that institutional factors, such as gun laws, influence the temperature–homicide relationship. By conducting a comprehensive heterogeneity analysis of temperature effects across shooting types, injury severity, shooter types, and inci-

dent timing, our study advances understanding of the mechanisms and contexts underlying temperature-induced school shootings.

The remainder of the paper is structured as follows: Section II provides a background of the connection between temperature and school shootings. Section III explains the data sources used in our study. Our empirical methodology is presented in Section IV. Section V presents the primary findings of our investigation. Finally, Section VI presents concluding remarks and a discussion of the broader implications.

2 Background

School shootings have long been a concern for society, and prior studies have investigated various factors influencing these incidents. While some studies focus on interpersonal dynamics, others examine broader societal contexts. One strand of the literature explores family- and peer-related influences, including bullying and domestic violence (Leary et al., 2003; Sommer et al., 2014). Another line of research links shootings to broader social factors, such as rising unemployment (Pah et al., 2017) and the COVID-19 pandemic (Peña and Jena, 2021). However, despite the extensive attention given to societal and interpersonal factors, there remains a noticeable gap in our understanding of how environmental factors—such as temperature—contribute to the incidence of school shootings in the U.S.

The literature on heat and crime suggests that higher temperatures influence violence through both increased social interaction and psychological changes. Cohen and Gonzalez (2024) show that heat raises crime partly by increasing the number of social encounters. Other studies emphasize the direct effect of heat on aggression (Almås et al., 2019; Blakeslee et al., 2021; Mukherjee and Sanders, 2021). In our setting, schools offer a relatively stable environment in terms of who is present and when. Unlike parks or malls, where hot weather might bring more people together and raise the chance of spontaneous interactions, school attendance tends to remain fixed.[1] This helps us focus on the psychological or emotional

[1]Class cancellations due to hot weather are generally uncommon in the U.S. (Alberto et al., 2021).

channels through which heat might lead to violent behavior, without the added complication of large shifts in exposure or foot traffic.

Temperature is a key environmental factor that can affect school shootings by increasing aggression. Previous psychological research and a growing body of economic literature explain how weather can influence emotions and increase aggression toward others (Burke et al., 2015; Almås et al., 2019; Mukherjee and Sanders, 2021). For instance, Almås et al. (2019) find, through controlled laboratory experiments, that heightened temperatures substantially raise the probability of individuals causing damage to others' property. Mukherjee and Sanders (2021) note that on days when the temperature exceeded 80°F, there was a 20% surge in violent interactions and an 18% increase in the likelihood of violent incidents compared to cooler days. This channel not only influences the shooter in the context of our study, but may also amplify violence from the victims' side by elevating their threatening behavior. Annan-Phan and Ba (2023) provide suggestive evidence that police shootings increase as the threatening behavior of suspects rises in hot temperatures. Similarly, individuals involved in disputes, including victims, may respond with more threatening behavior on hotter days, potentially leading to a shooting.

3 Data

Our estimation sample consists of daily county-level data spanning 1981–2022 for the contiguous U.S. As our dependent variable, the number of school shooting incidents, we use comprehensive data from the Center for Homeland Defense and Security (CHDS) K–12 School Shooting Database (Riedman and O'Neill, 2023). In the CHDS database, a school shooting is defined broadly to include any incident in which a gun is fired, brandished (pointed at a person with intent), or a bullet hits school property, regardless of the number of victims, the timing of the incident, or its underlying motive. By adopting this broad definition, we seek to capture a more comprehensive and nuanced set of heat-induced gun-related incidents in K–

12 school settings. The CHDS database compiles information from a wide range of primary sources, including peer-reviewed studies, government reports, media outlets, and non-profit organizations. To enhance accuracy and consistency, CHDS systematically cross-references, filters, and reconciles these sources to construct a comprehensive record of shootings in K–12 schools.

The dataset includes information on the school's location, incident date, incident intent, incident timing, and injury severity. We aggregate this incident-level data to the county level, counting the number of incidents occurring in each county on a given day. If no school shooting occurred on a given date in a given county, we record it as zero, assuming no incident took place. This results in a balanced panel with daily observations for 3,107 counties over 42 years across the U.S.

The dataset enables a comprehensive analysis of school shootings by capturing both fatal and non-fatal incidents. In contrast, previous studies often rely on datasets that focus exclusively on fatal events, which represent only a small share of total shootings. For example, the Mother Jones database includes only shootings with four or more fatalities (Soni and Tekin, 2023), failing to account for many incidents involving fewer or no deaths. According to CHDS data, fatal shootings account for just 28% of all school shooting incidents (Muschert, 2007). Other sources, such as the Report on School-Associated Violent Deaths from the National School Safety Center, also report only fatal shootings. However, studying all incidents—not just fatal ones—is crucial for understanding the full scope of gun violence in schools. Non-fatal incidents, which are more frequent than fatal ones, still have profound psychological, social, and community impacts that require attention (Cabral et al., 2021).

Additionally, the dataset includes school shooting incidents carried out by both students and non-students. Figure A.0.1 shows the distribution of shooters across the top five categories in our sample. Students account for about half of the incidents involving identified shooters. They are followed by individuals with no relation to the school. Non-students who visited the school for athletic events or games represent the next largest group, followed by

former students and parents.

Table 1: Summary Statistics: Dependent Variables

	Mean	Min	Max	N
All Types of Shooting				
All Shooting	0.427	0	3	47,661,380
Intent				
Homicidal/Threat	0.249	0	3	47,661,380
Suicidal	0.031	0	1	47,661,380
Accident	0.043	0	1	47,661,380
Miscellaneous or Missing	0.105	0	1	47,661,380
Motive Type				
Not BRD	0.325	0	3	47,661,380
BRD	0.038	0	1	47,661,380
Missing	0.065	0	1	47,661,380
Fatality				
Fatal or Wounded	0.265	0	1	47,661,380
Minor or No Injury	0.162	0	3	47,661,380
Missing	0.042	0	1	47,661,380
Timing of Incident				
Before/After Class, Lunch	0.140	0	2	47,661,380
Class	0.120	0	2	47,661,380
School Event	0.063	0	2	47,661,380
Miscellaneous or Missing	0.105	0	1	47,661,380
Shooter				
Student	0.169	0	2	47,661,380
Non-Student	0.221	0	2	47,661,380
Miscellaneous or Missing	0.037	0	1	47,661,380

Notes: The table presents summary statistics of key dependent variables. All values in the "Mean" column are expressed as incidence rates per 10,000 county-days. "All Types of Shooting" shows the total number of shooting incidents in a given county on a given day. "BRD" refers to bullying-, romantic-, and domestic-related shooting incidents. "Miscellaneous or Missing" refers to cases that fall outside the specified categories or involve missing information. In the context of intent classification, this category includes entries such as "Intentional Property Damage," "Illegal Activity," "Psychosis," and "Unknown." In the context of timing classification, "Miscellaneous or Missing" includes "Not a school day," "Evening/Night," and "Unknown." "School Event" refers to periods during which sports or other school-related events take place at the school.

Table 1 presents summary statistics for our key dependent variables. School shootings occurred at an average rate of 0.427 cases per 10,000 county-days, highlighting their relative rarity compared to other crime categories. For comparison, general violent crimes in the U.S. were recorded at approximately 7.3 incidents per county per day from 2006 to 2013, according to Burkhardt et al. (2019). When school shootings are categorized by intent, the majority are classified as homicidal or threat-related incidents (0.249 cases per 10,000 county-days), followed by miscellaneous or missing cases (0.105), accidental incidents (0.043), and suicidal incidents (0.031). When categorized by motive, shootings not related to bullying, romantic, or domestic issues account for 0.325 cases per 10,000 county-days, while BRD-related incidents specifically comprise 0.038 cases. School shootings are distributed roughly evenly across periods before or after class and lunch (0.140) and during class time (0.120). Incidents resulting in fatal or wounded outcomes occur more frequently than those involving only minor or no injuries (0.265 versus 0.162 cases per 10,000 county-days). School shootings involve both student and non-student perpetrators, with average incidence rates of 0.169 and 0.221 cases per 10,000 county-days, respectively.

Panels (a) and (b) in Figure 1 depict the total number of school shootings by year and by month, respectively. The annual number of school shootings remained between 10 and 60 cases until around 2010, after which it began to increase, peaking in 2021. Panel (c) in Figure 1 shows the total number of shootings per county over the sample period. Fewer shooting incidents are observed in the northern and central regions of the U.S. compared to the southern, western, and eastern regions.

We source county-level, population-weighted daily measures of maximum temperature and precipitation from Lee and Smith (2025) for the estimation period (1981–2022). These measures are constructed using 4 km–resolution gridded observations produced by the PRISM Climate Group. Figure A.0.2 illustrates the geographic distribution of average daily maximum temperatures and total days with temperatures above 90°F in an average year. Panel (a) shows average daily maximum temperatures across counties, while panel (b) dis-

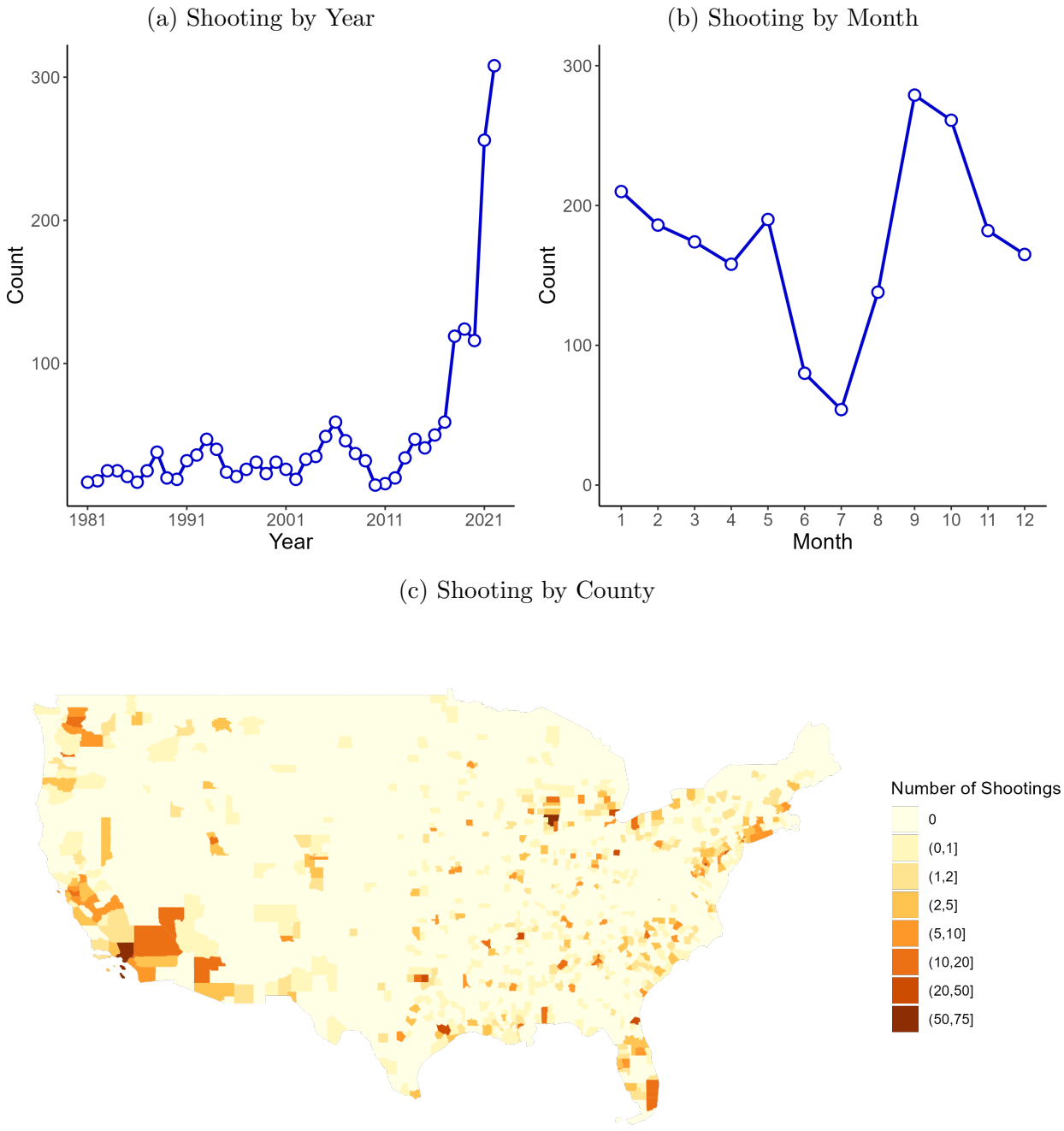


Figure 1: Temporal and Geographical Variations of Shooting

Notes: Panels (a) and (b) in Figure 1 depict the total number of shootings by year and month, respectively. Figure 1 (c) shows the total number of shootings that occurred in each county in the sample period.

plays the spatial distribution of the average annual number of days with maximum temperatures above 90°F. The southern regions—including Texas, Arizona, and parts of Florida–experience both the highest average maximum temperatures and the greatest number of hot days.

Although the CHDS data are more comprehensive—collecting information on school shooting incidents from multiple sources, as noted above—than other available datasets, it may still be difficult to rule out underreporting in the earlier years of the CHDS database, particularly for less severe incidents. One plausible explanation is that information dissemination through social media and other online platforms was more limited in earlier periods, which may have contributed to lower media coverage of school shootings, particularly non-fatal incidents, as well as the limited availability of digitized media archives for older events (Heller et al., 2024). Between 1980 and 2000, non-fatal shootings were recorded at approximately twice the rate of fatal shootings; from 2001 to 2022, this ratio increased to about four to one. This shift suggests that earlier records may have disproportionately captured only the most severe cases. This indicates that more recent data are likely capturing a broader range of less severe events—cases that may have gone unreported in earlier years. Although it is difficult to precisely quantify how data quality has changed over the sample period, it is worth noting that such changes likely exist. In Section 5, we show that the sensitivity of school shootings to high temperatures tends to be larger and more precisely estimated in later subperiods.

4 Research Design

To assess the effects of temperature on incidents of school shootings, we use daily variations in ambient temperature at the county level. Many prior studies have employed these short-term, local-level temperature variations to estimate the impacts of temperature on various outcomes such as crime, human capital, and immigration adjudications (Ranson,

2014; Graff Zivin et al., 2018; Heyes and Saberian, 2019; Heilmann et al., 2021). Local daily variation in temperature is largely exogenous to other factors, primarily driven by natural atmospheric processes that are random and not influenced by socioeconomic conditions or human decisions. This helps ensure that temperature is independent of factors like school policies, law enforcement presence, or the broader socio-political environment, which might otherwise affect school shootings.

Given the non-negative count nature of the dependent variable, we use the Poisson quasi-maximum likelihood (PQML) estimator. This approach aligns with prior studies examining the effects of environmental conditions on crime (Ranson, 2014; Burkhardt et al., 2019; Bondy et al., 2020; Johnson et al., 2020). The PQML estimator is consistent in the presence of fixed effects and accommodates zeros in the dependent variable without transformation. Its consistency does not depend on distributional assumptions; it requires only correct specification of the conditional mean. Additionally, the PQML estimator yields robust standard errors even in the presence of overdispersion or underdispersion, where the equidispersion assumption does not hold (Silva and Tenreyro, 2011).

We model the number of school shootings Shooting_{cd} in county c on date d using a Poisson pseudo–maximum likelihood (PQML) estimator. Specifically, we assume that Shooting_{cd} follows a Poisson distribution with conditional mean $\mu(X_{cd})$, such that

$$f(\text{Shooting}_{cd} \mid X_{cd}) = \frac{\exp(-\mu(X_{cd}))\,\mu(X_{cd})^{\text{Shooting}_{cd}}}{\text{Shooting}_{cd}!}, \tag{1}$$

where X_{cd} denotes the set of observed covariates and $\mu(X_{cd}) = \mathbb{E}[\text{Shooting}_{cd} \mid X_{cd}]$ is the conditional mean function. Following standard practice, we parameterize the conditional mean using an exponential link:

$$\mu(X_{cd}) = \exp\left(\sum_{k=1}^{K} \beta_k \,\mathbb{I}(TMAX_{cd} \in k) + \sum_{l=1}^{L} \delta_l \,\mathbb{I}(PREC_{cd} \in l) + \pi_{sy} + \gamma_{c\times yday} + \theta_w\right). \tag{2}$$

Shooting_{cd} denotes the number of school shootings that occurred in county c on date d. Daily maximum temperature, $TMAX_{cd}$, is discretized into 10°F bins, with $K \in \{[70°\text{F}, 80°\text{F}), [80°\text{F}, 90°\text{F}), [90°\text{F}, \infty)\}$, and temperatures below 70°F omitted as the reference category. The coefficients β_k capture the relative change in the expected number of

shootings compared to days with maximum temperatures below 70°F. For robustness, we also present our main results using an alternative binning scheme that starts from below 40°F and omits the 60–70°F bin, as shown in Table A.0.1. Because school shootings are rare events—with approximately 2,000 cases over 42 years—we avoid dividing temperature into overly granular bins to maintain statistical power and minimize sparsity across the temperature distribution. Precipitation, $PREC_{cd}$, is discretized analogously into 0.5-inch intervals up to 1 inch, with $L \in \{(0, 0.5], (0.5, 1.0], (1.0, \infty)\}$ (in inches), and zero precipitation serving as the omitted reference category.

We include a range of fixed effects in the model. State-by-year fixed effects (π_{sy}) account for any time-varying, statewide policies or economic shocks that could influence school shootings. For instance, these fixed effects capture the implementation of more stringent gun laws, which may reduce school shootings, or a significant rise in the unemployment rate within a given year, which could affect the number of shooting incidents. County-by-day-of-year fixed effects ($\gamma_{c \times yday}$) control for seasonal factors within a county, such as school vacations or holidays, which may impact shootings. Additionally, we include day-of-week fixed effects (θ_w) to account for differences across weekdays, such as school schedules. To account for potential correlations within counties, we cluster standard errors at the county level. We examine alternative clustering schemes as robustness checks in the Appendix. We weight the regressions by 2020 county population, rather than assigning equal weight to each county.

5 Results

5.1 Main Results

Table 2: Temperature Effects on School Shootings (All Types of Shooting)

	(1)	(2)	(3)
70-80F	0.0405	0.0524	0.0774
	(0.0815)	(0.0907)	(0.0980)
80-90F	0.5136***	0.2692**	0.4691***
	(0.1433)	(0.1276)	(0.1439)
Above 90F	0.4262**	0.4495**	0.5882***
	(0.1937)	(0.1869)	(0.1921)
Observations	47,661,380	47,661,380	47,661,380
Precipitation Controls	✓	✓	✓
County fixed effects	✓		
Date fixed effects	✓		
County x Month x Year fixed effects		✓	
State x Year fixed effects			✓
Day of Week fixed effects			✓
County x DOY fixed effects			✓

Note: Column (4) in Table 2 presents the regression results from our preferred specification (Equation 2), while columns (1)–(3) report results from alternative fixed effects specifications. All models include precipitation controls and are estimated using the Poisson quasi-maximum likelihood estimator. Each coefficient represents the semi-elasticity of school shootings with respect to the indicated bin of daily maximum temperature, relative to the omitted category: days with daily maximum temperatures below 70°F. DOY fixed effects refer to day-of-year fixed effects. The regression is weighted using population counts from the 2020 U.S. Census Bureau. Standard errors are clustered at the county level. * $p < 0.1$. ** $p < 0.05$. *** $p < 0.01$.

Table 2 presents the impact of daily maximum temperatures on school shooting incidence, with different sets of fixed effects used in each column. As shown across all four columns, high temperatures tend to increase school shootings overall. Column (3) reports results from our preferred specification, which includes state-by-year, county-by-day-of-year, and day-of-week fixed effects. We find that on days with temperatures between 80–90°F and above 90°F, the incidence of shootings increases by 59.9% and 80.1%, respectively, compared to days with temperatures below 70°F. These percentage effects are calculated as $(\exp(\hat{\beta}) - 1) \times 100\%$, where $\hat{\beta}$ denotes the estimated coefficient from the PQML estimator reported in Table 2.

Column (1) displays the regression results from a simple two-way fixed effects model using county and date fixed effects. This model does not account for region-specific, time-varying unobserved heterogeneity. The coefficient for the temperature bin above 90°F in this model is 0.43, which is smaller and less precisely estimated than the corresponding estimate from our preferred specification (0.59). The smaller and less precise estimate from a model that does not account for regional seasonality suggests that the identifying variation in the simple two-way fixed effects model may contain more noise than signal when estimating the relationship between heat and school shooting incidence.

In Column (2), we use county-by-year-by-month fixed effects, which remove all common shocks specific to each county-year-month. However, these fixed effects may absorb potentially meaningful variation in temperature, since temperatures can be temporally correlated within a given county, year, and month. Although the coefficient for the temperature bin above 90°F is relatively similar to the one from our preferred specification, the coefficient for the 80–90°F bin (0.27) is much smaller than that from our preferred model (0.47). The key distinction between the models in Columns (3) and (3) is the inclusion of either county-by-week-of-year or county-by-day-of-year fixed effects. The coefficients in column (3) are smaller than those in column (2), suggesting that controlling for county-specific seasonality at the daily level (rather than the weekly level) better isolates the temperature–school shooting relationship.

The results are consistent with previous studies that find strong effects of extreme temperatures on violent crime (Ranson, 2014). In particular, using administrative crime data from Mexico, Cohen and Gonzalez (2024) report that violent crimes—including homicide, rape, sexual aggression, and weapon possession—increase by 50% on hot days (temperatures above 89.6°F) relative to cold days (below 50°F). In another study using U.S. crime data, Colmer and Doleac (2023) estimate the linear effect of temperature on homicide. To facilitate direct comparison, we approximate their estimate using our categorical temperature bins, with days below 70°F as the omitted category. Their results imply that homicide rates increase by approximately 47.8% on days with temperatures between 80–90°F and by 71.7% on days above 90°F, relative to days below 70°F. These responses are similar to our corresponding estimates, 59.9% and 80.1%.

To assess whether the sensitivity of school shootings to temperature has changed over time, we re-estimate our preferred specification in Equation 2—corresponding to column (3) of Table 2—separately for two periods: 1980–2000 and 2001–2022. As shown in Figure 2, the estimated temperature effects in the 70–80°F and 80–90°F bins are substantially smaller in the 1980–2000 period than in 2001–2022. One plausible explanation is underreporting of incidents, particularly in earlier years, as discussed in detail in Section 3. Such underreporting is likely to be more pronounced for less severe or non-fatal cases that received limited media coverage, particularly in earlier years when information dissemination through social media and online platforms was more limited. If underreporting was more prevalent during the earlier period, it would likely lead to attenuation bias, resulting in weaker and less precise estimates of the temperature effect on school shootings. Because our estimation sample spans the entire period and the early-period sample may suffer from underreporting, our estimates should be interpreted as a lower bound on the true temperature effects on school shootings.

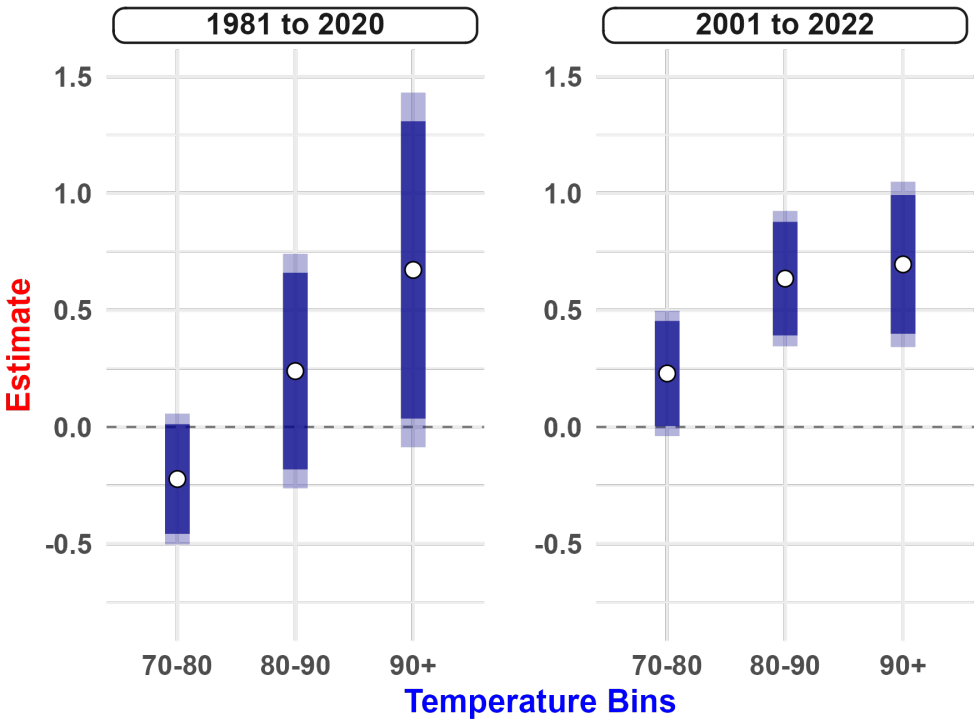


Figure 2: Estimated Effect of Temperature on Shootings: 1980–2000 vs. 2001–2022

Notes: Figure 2 presents regression results from Equation 2, estimated separately for the 1980–2000 and 2001–2022 subsamples. White dots denote point estimates. Dark vertical bands indicate 90% confidence intervals, while lighter bands indicate 95% confidence intervals. All models include precipitation controls and are estimated using the Poisson quasi-maximum likelihood estimator. Each coefficient represents the semi-elasticity of school shootings with respect to the indicated bin of daily maximum temperature, relative to the omitted category: days with daily maximum temperatures below 70°F. The regression is weighted using population counts from the 2020 U.S. Census Bureau. Standard errors are clustered at the county level.

5.1.1 Robustness checks

We first implement a series of falsification tests. Specifically, we randomly reassign temperatures across different units in our sample (e.g., county, month, and year) and re-estimate the main results using Equation 2, which produced Table 2. By simulating random temperature assignments, we aim to ensure that our results are not driven by spurious correlations between temperature and shootings, but instead reflect true causal relationships. In Figure A.0.3, we present the results of the regression analysis using Equation 2, in which the test samples are generated by randomly reassigning temperatures to observations. The leftmost panel shows estimates from a sample where temperatures are reshuffled across days within each county. The middle and rightmost panels present estimates from samples in which temperatures are shuffled across counties within the same month and year, respectively. All estimates are statistically insignificant and close to zero.

Next, we check whether our results are robust to alternative temperature bins that disaggregate the bin for temperatures below 70°F. Specifically, we divide the below-70°F bin into multiple bins: below 40°F, 40–50°F, 50–60°F, and 60–70°F. Table A.0.1 presents the results from estimating Equation 2 with this finer breakdown of temperatures, using 60–70°F as the reference category. The results confirm that our main finding—that high temperatures above 80°F increase the likelihood of school shootings—remains robust to alternative temperature binning. In contrast, although the coefficients on the colder temperature bins (30–50°F and below 40°F) are negative, they are not statistically significant.

COVID-related disruptions may have altered the relationship between temperature and school shooting by affecting school attendance, mobility, and broader social factors such as unemployment. While our state-by-year fixed effects absorb annual shocks at the state level—likely capturing COVID-related unobservables to some extent—we further test robustness by excluding 2020, the year most affected by the pandemic, and re-estimating Equation 2. Table A.0.2 presents the results. The estimated effects of high temperatures decrease slightly but remain statistically significant, reinforcing the robustness of our findings.

We also conduct a robustness check using alternative clustering specifications. Figure A.0.4 presents estimation results under different clustering approaches. In addition to clustering at the county level, we apply clustering by county-year, state, and state-year. The results remain consistent across all clustering levels.

5.2 Heterogeneous Effects of Temperature on School Shootings

To gain further insight into how temperature may be related to school shootings, we conduct heterogeneity analyses across several dimensions. Specifically, we assess how the relationship differs by the intent and motive behind the shootings, the severity of the incident (fatal vs. non-fatal), and the timing of the event during the school day.

5.2.1 Heterogeneity by Intent and Drivers

Table 3: Temperature Effects by Shooting Intent and Contributing Drivers

	Homicidal/Threat	Accidental	Suicidal	Not BRD	BRD
	(1)	(2)	(3)	(4)	(5)
70-80F	0.1048	0.5587**	-0.5385	0.0339	1.442
	(0.1341)	(0.2212)	(0.7268)	(0.0921)	(0.9966)
80-90F	0.5681***	0.7213	0.3936	0.5410***	0.9401
	(0.1290)	(0.5556)	(0.6752)	(0.1465)	(0.6758)
Above 90F	0.6176***	0.2640	-0.6045	0.5804**	0.0526
	(0.2210)	(0.7451)	(0.7667)	(0.2454)	(0.9818)
Observations	47,661,380	47,661,380	47,661,380	47,661,380	47,661,380
Precipitation Controls	✓	✓	✓	✓	✓
State x Year fixed effects	✓	✓	✓	✓	✓
County x DOY fixed effects	✓	✓	✓	✓	✓
Day of week fixed effects	✓	✓	✓	✓	✓

Note: The table presents regression results from our preferred specification (Equation 2), estimated separately by shooting type, classified according to intent and contributing drivers. All models include precipitation controls and are estimated using the Poisson quasi-maximum likelihood estimator. Each coefficient represents the semi-elasticity of school shootings with respect to the indicated bin of daily maximum temperature, relative to the omitted category: days with daily maximum temperatures below 70°F. DOY fixed effects refer to day-of-year fixed effects. The regression is weighted using population counts from the 2020 U.S. Census Bureau. Standard errors are clustered at the county level. * $p < 0.1$. ** $p < 0.05$. *** $p < 0.01$.

First, we examine whether temperature affects shootings differently depending on their intent and underlying motivation. Specifically, we categorize shootings by intent (homicidal/threat, accidental, or suicidal) and by motivation (bullying, romantic, or domestic [BRD] issues versus non-BRD issues). As discussed in Section 2, higher temperatures are associated with increased aggression (Burke et al., 2015; Almås et al., 2019; Mukherjee and Sanders, 2021), which may contribute to a rise in shootings with homicidal or threatening intent. Table 3 presents results categorized by the intent and context of school shootings. We find that on days when maximum temperatures exceed 90°F, shootings motivated by homicide or threats increase by 85.4% relative to days with temperatures below 70°F.[2] Days with maximum temperatures between 80 and 90°F exhibit similarly large effects (76.5%). These large, heat-induced increases in incidents involving explicit homicidal or threatening intent underscore that higher temperatures result in a greater incidence of deliberate and potentially tragic violence in school settings.

As column (2) of Table 3 shows, we find no statistical evidence of heat effects on accidental shootings. Although prior research documents adverse effects of high temperatures on cognitive functioning (Park et al., 2020a), our results suggest that school shootings are driven more by aggression than by cognitive impairments, such as reduced attention. We also find no evidence that high temperatures lead to an increase in suicide-related shootings. Specifically, the estimated coefficients for these incidents are not statistically significant. While prior research has documented a positive relationship between high temperatures and suicide in the general population across various settings (Burke et al., 2018), our findings suggest that this association may not extend to school-based shootings. In the U.S., about three-quarters of suicides occur at home (Harvard T.H. Chan School of Public Health, 2024), suggesting that most suicides take place in private, often isolated settings rather than in public spaces. This pattern may limit the influence of temperature on suicide-related shootings

[2]The homicidal/threat category includes incidents involving targeted aggression, interpersonal escalation, or indiscriminate violence, such as Anger Over Grade/Suspension/Discipline, Escalation of Dispute, Domestic with Targeted Victim, Bullying, Indiscriminate Shooting, Drive-by Shooting, Racial, Self-defense, Hostage/Standoff, Officer-Involved Shooting, and Murder/Suicide.

in school.

Next, we examine the impact of temperature on school shootings related to bullying and conflicts in romantic or domestic relationships (BRD), as well as shootings unrelated to BRD. Column (4) of Table 3 shows that days with daily maximum temperatures above 80°F are associated with a statistically significant increase of 71–79% in school shootings unrelated to BRD, relative to days with temperatures below 70°F. This pattern suggests that shootings influenced by environmental stressors such as heat may occur in the absence of clear interpersonal triggers, making them more difficult to anticipate using traditional threat assessment approaches. Consequently, prevention strategies that focus narrowly on bullying, romantic rejection, or domestic conflict may be insufficient to address or mitigate heat-induced school shootings. As shown in column (5) of Table 3, BRD-related shootings, by contrast, do not appear to occur independently of weather conditions. This likely reflects the fact that the motives underlying BRD-related shootings tend to build up gradually, with weather playing little role as a decisive factor in the timing of these incidents.

5.2.2 Heterogeneity by Injury Severity and Incident Timing

Table 4: Temperature Effects by Injury Severity and Incident Timing

	Fatal or Wounded	Minor or No Injury	Before/After Class, Lunch	Class	Event
	(1)	(2)	(3)	(4)	(5)
70-80F	0.0923	0.1228	0.1843	0.4022	0.6053
	(0.2055)	(0.1998)	(0.1409)	(0.2645)	(0.5395)
80-90F	0.5331***	0.4012**	0.8995**	0.1879	0.5271
	(0.1748)	(0.1821)	(0.3674)	(0.1606)	(0.4703)
Above 90F	0.6817**	0.3252	1.199***	0.1797	0.2909
	(0.2890)	(0.3589)	(0.3777)	(0.4249)	(0.3717)
Observations	47,661,380	47,661,380	47,661,380	47,661,380	47,661,380
Precipitation Controls	✓	✓	✓	✓	✓
State x Year fixed effects	✓	✓	✓	✓	✓
Day of week fixed effects	✓	✓	✓	✓	✓
County x DOY fixed effects	✓	✓	✓	✓	✓

Note: The table presents regression results from our preferred specification (Equation 2), estimated separately by injury severity and incident timing. All models include precipitation controls and are estimated using the Poisson quasi-maximum likelihood estimator. Each coefficient represents the semi-elasticity of school shootings with respect to the indicated bin of daily maximum temperature, relative to the omitted category: days with daily maximum temperatures below 70°F. DOY fixed effects refer to day-of-year fixed effects. The regression is weighted using population counts from the 2020 U.S. Census Bureau. Standard errors are clustered at the county level. * $p < 0.1$. ** $p < 0.05$. *** $p < 0.01$.

We next explore whether and how the sensitivity of shootings to heat varies by incident fatality. The literature on gun violence and media attention has predominantly focused on fatal incidents (Kaufman et al., 2020). However, Cabral et al. (2021) show that non-fatal school shootings can also have both short- and long-term consequences. In the short term, such incidents are associated with increased absenteeism and grade repetition; in the long term, they may reduce employment and earnings, potentially affecting the educational and career trajectories of affected students.

Columns (1)–(2) of Table 4 present results separately for incidents resulting in fatal or wounded outcomes and those involving minor or no injuries. Relative to days below 70°F, shootings resulting in fatal or wounded outcomes increase by about 70% on days with maximum temperatures between 80–90°F and by approximately 98% on days above 90°F. Incidents involving minor or no injuries also increase with temperature, but the estimated effects are much smaller in magnitude and less precisely estimated; specifically, such incidents rise by about 49% on days with maximum temperatures between 80–90°F and by roughly 38%

on days above 90°F, with the latter not statistically significant. One plausible explanation for this discrepancy is that extreme heat may exacerbate emotional distress, impulsivity, and aggression in ways that increase not only the likelihood of a shooting but also its severity, for example through reduced self-control or heightened confrontation intensity. In contrast, less severe incidents may be driven more by situational or accidental factors that are less sensitive to short-term temperature shocks.

Next, we examine heterogeneity in the effects of temperature on school shooting incidents by event timing: before or after class and during lunchtime, during class time, and during school-sponsored events, such as sports activities and other school-organized functions. Columns (3)–(5) of Table 4 report the results. We find that the effects of high temperatures on school shootings are concentrated in periods before or after class and during lunchtime. Specifically, on days with maximum temperatures between 80–90°F and above 90°F, school shootings increase by 144.9% and 231.7%, respectively, during these periods. In contrast, we find no evidence that high temperatures affect shootings during class time or during school-sponsored events, characterized by structured activities and adult oversight.

These findings have important implications for understanding the mechanisms through which temperature affects school shootings and for designing targeted prevention strategies. The concentration of heat-related effects before or after class and during lunchtime suggests that aggressive or impulsive tendencies heightened by high temperatures are more likely to be realized in less structured settings, where supervision is limited and students have greater autonomy. In contrast, the absence of temperature effects during class time or school-sponsored events—periods characterized by structured activities and adult oversight—highlights the potential mitigating role of institutional supervision and routine. Together, these patterns suggest that targeted interventions in less structured settings may be more effective in reducing heat-induced school shootings.

Table 5: Temperature Effects by Shooter Type (Student vs. Non-Student)

	Student	Non Student
	(1)	(2)
70-80F	0.0994	0.1512
	(0.0888)	(0.1799)
80-90F	0.6003***	0.6075***
	(0.1628)	(0.2181)
Above 90F	0.6786***	0.8533***
	(0.2526)	(0.2469)
Observations	47,661,380	47,661,380
Precipitation Controls	✓	✓
State x Year fixed effects	✓	✓
Day of week fixed effects	✓	✓
County x DOY fixed effects	✓	✓

Note: The table presents regression results from our preferred specification (Equation 2), distinguishing between shootings by students and non-students. All models include precipitation controls and are estimated using the Poisson quasi-maximum likelihood estimator. Each coefficient represents the semi-elasticity of school shootings with respect to the indicated bin of daily maximum temperature, relative to the omitted category: days with daily maximum temperatures below 70°F. DOY fixed effects refer to day-of-year fixed effects. The regression is weighted using population counts from the 2020 U.S. Census Bureau. Standard errors are clustered at the county level. * $p < 0.1$. ** $p < 0.05$. *** $p < 0.01$.

Next, we examine heterogeneity in temperature effects by shooter type, distinguishing between incidents involving student shooters and non-student shooters. Table 5 shows that higher temperatures increase shootings by both student and non-student perpetrators (at 80–90°F, shootings rise by about 82% for student and 84% for non-student perpetrators; above 90°F, shootings increase by roughly 97% and 134%, respectively). These findings indicate that heat-related increases in school shootings are not confined to incidents originating within the student population but also extend to shootings committed by non-students, many of them do not have any relation with school. As a result, prevention and mitigation efforts during periods of extreme heat may need to address risks arising both from within schools and from external actors.

5.3 Climate Change Impact Assessments

In this section, we assess how projected climate change may affect school shootings. We apply climate simulation data from the Coupled Model Intercomparison Project Phase 6 (CMIP6) to the estimates for homicidal/threat school shootings, presented in column (1) of Table 3. Hereinafter, the term *school shootings* refers to this specific category of incidents. We focus on homicidal/threat shootings because, relative to accidental and suicidal shootings, they tend to generate substantially larger social damages, including greater loss of life, injuries, and broader spillover effects on students, families, and communities. As in many other studies, we focus on changes in climatic factors to isolate their effects from other influences, such as socioeconomic conditions and regulatory changes. We first describe the climate change projection data, assess climate change impacts on school shootings, and then calculate the associated social costs.

5.3.1 Climate Change Projection Data

We rely on seven downscaled climate projections drawn from seven CMIP6 global climate models (GCMs) provided by the NASA NEX Global Daily Downscaled Projections (NEX-

GDDP-CMIP6) archive.[3] GCMs are large-scale numerical representations of the Earth system that generate projections of future climate conditions, typically at spatial resolutions on the order of 100–200 km. Each GCM, produced by research institutions worldwide, relies on different assumptions, parameterizations, and algorithms, resulting in variation in projected temperature, precipitation, and other climate variables. The NEX-GDDP-CMIP6 product applies a statistical bias-correction and spatial disaggregation procedure to CMIP6 outputs, producing daily climate variables on a 0.25° (approximately 25 km) grid for the contiguous United States (Thrasher et al., 2022). This downscaling substantially enhances the applicability of global climate projections for regional and county-level analyses. Using an ensemble of multiple GCMs mitigates the risk that findings are driven by structural assumptions specific to any single model.

Our analysis uses daily maximum temperature and precipitation from the seven CMIP6 models for three time windows: a historical period (2005–2014), a mid-century period (2051–2060), and a late-century period (2091–2100). We consider two alternative greenhouse gas concentration pathways: a medium-emissions scenario (SSP2–4.5), characterized by emissions stabilizing around mid-century, and a high-emissions scenario (SSP5–8.5), which assumes continued growth in emissions throughout the twenty-first century. To maintain consistency with the observed weather data used in estimation, daily gridded climate variables are first aggregated to the county level using population-weighted means (see Figure A.0.5 for the spatial variation in population estimates across grids). These county-level daily temperature and precipitation measures are then grouped into discrete bins.

Figure 3 illustrates projected shifts in the distributions of daily maximum temperature and precipitation for a representative U.S. county, based on the ensemble of seven downscaled CMIP6 models. The figure compares mid-century (2051–2060) and end-of-century (2091–2100) outcomes to the historical baseline (2005–2014). The top panel shows a pronounced increase in the prevalence of extremely hot days (maximum temperature exceeding

[3]The CMIP6 models used in this study are GFDL-CM4, GFDL-ESM4, IPSL-CM6A-LR, MIROC6, MPI-ESM1-2-HR, NorESM2-MM, and TaiESM1.

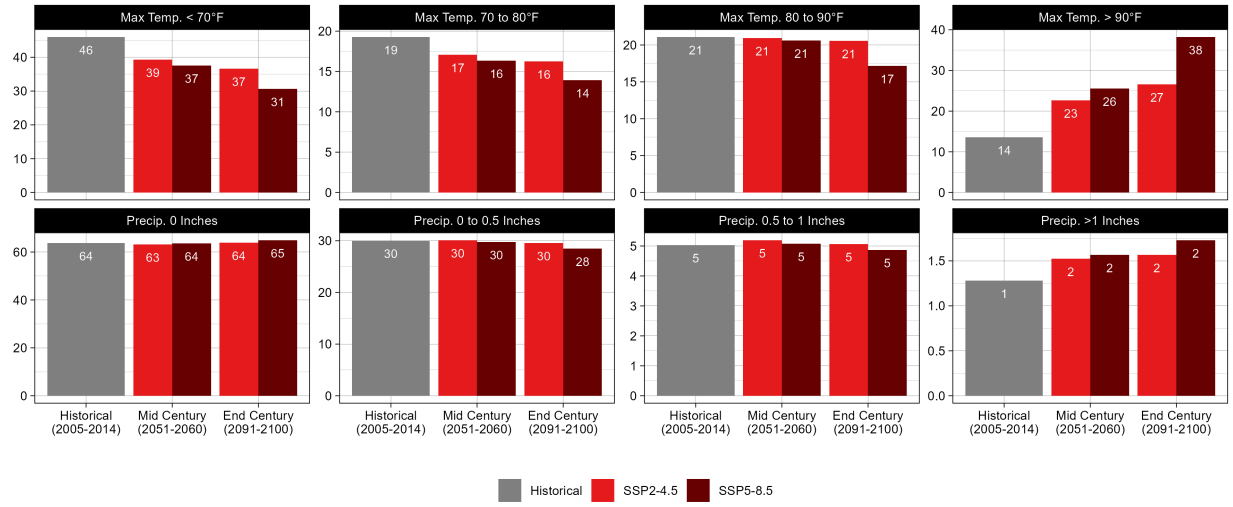


Figure 3: Projected Shifts in Daily Temperature and Precipitation Distributions Under Historical and Future Climate Scenarios

Note: Notes: This figure displays the average proportion of days falling into specified temperature and precipitation bins across U.S. counties, based on averages across seven downscaled CMIP6 climate simulations. SSP2–4.5 represents a stabilization pathway with moderate mitigation, while SSP5–8.5 represents a high-emissions, no-mitigation trajectory. Values reflect the mean percentage of days for each scenario and time period.

90°F), rising from roughly 14% historically to 23–26% by mid-century and 27–38% by late century, accompanied by declines in the frequency of milder temperature ranges (60–70°F and 70–80°F). In contrast, the lower panel indicates that projected changes in precipitation distributions are comparatively modest across both future horizons.

Figure 4 illustrates projected changes in the frequency of days with daily maximum temperature exceeding 90°F across U.S. counties under alternative emissions scenarios and time horizons. Under mid-century projections, increases in extreme heat days are already evident across much of the southern United States, particularly in the Southwest, Gulf Coast, and Southeast, while changes remain relatively modest in northern regions, with consistently larger increases under the high-emissions pathway. By the end of the century, these patterns intensify substantially: under SSP2–4.5, sharp increases in the share of days above 90°F emerge across most southern and central counties, while under SSP5–8.5, extreme heat becomes pervasive nationwide, including in regions that historically experienced fewer very

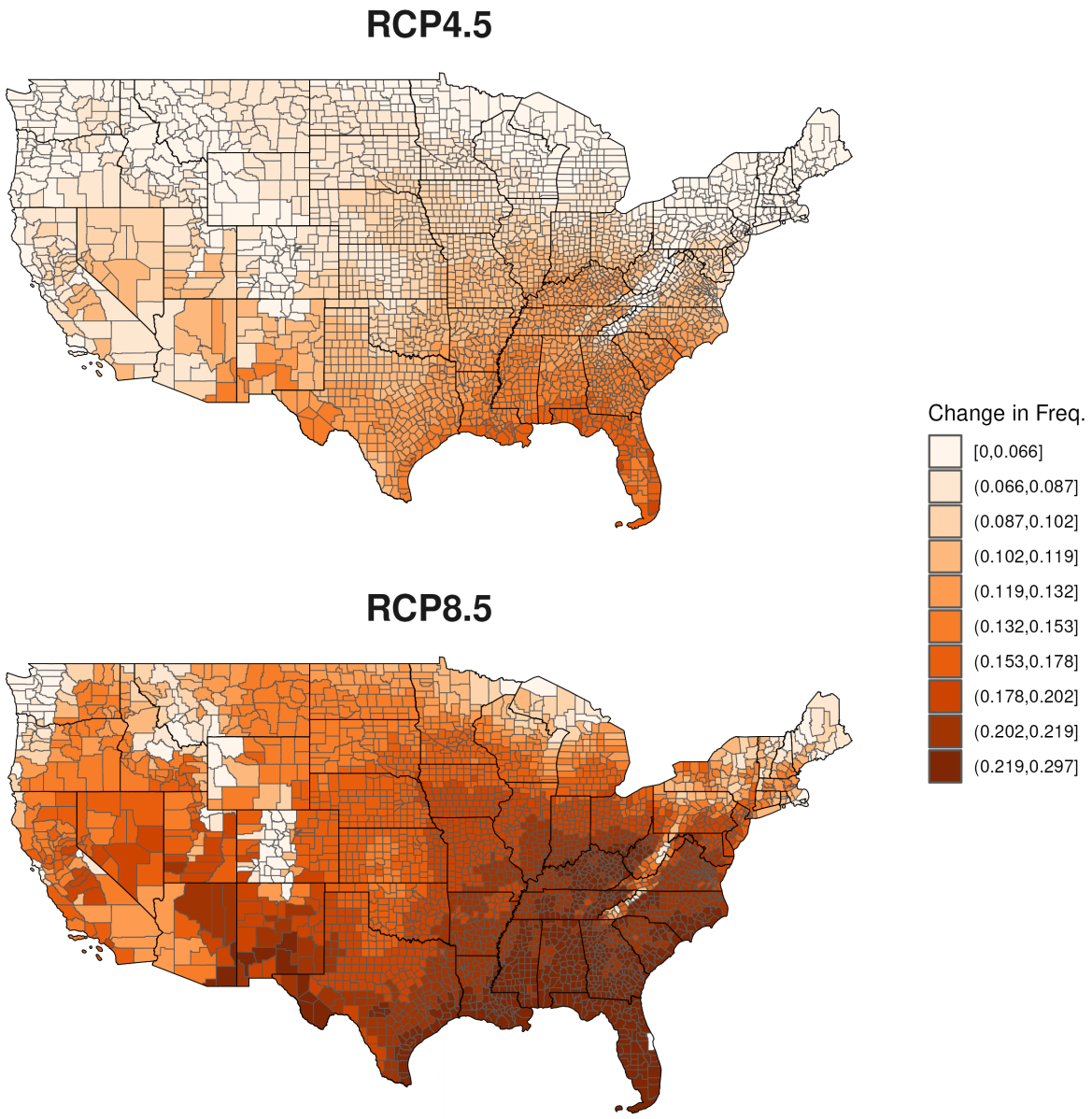


Figure 4: Change in the Frequency of Daily Maximum Temperature above 90° F

Note: Each county-level value represents the ensemble mean across seven downscaled CMIP6 climate models. Changes are computed relative to the baseline period 2005–2014. The mid-century period corresponds to 2051–2060, and the end-century period corresponds to 2091–2100. Results are shown separately for the SSP2–4.5 and SSP5–8.5 scenarios.

hot days.

5.3.2 Projected Impacts on School Shootings

We estimate the county-level percentage impact of climate change on school shootings by

$$\%\Delta\hat{Y}_{c,s} = \left(\exp\left(\Delta W'_{c,s}\hat{\beta}\right) - 1\right) \times 100\% \tag{3}$$

where $\Delta W_{c,s} = W_{c,s}^{future} - W_{c,s}^{historical}$; the vectors $W_{c,s}^{historical}$ and $W_{c,s}^{future}$ represent the ensemble-average frequencies of temperature and precipitation bins for the historical period and the projected future periods (either mid-century (2051–2060) or late-century (2091–2100)), under emissions scenario s in county c. Table 6 summarizes the projected impacts of climate change on school schootings. To compute the aggregate percentage impact, we use county-level population estimates from 2024 as weights when averaging, although this population weighting makes little difference relative to estimates based on simple averages.

Table 6 summarizes the projected impacts of climate change on school shootings across future periods and emissions scenarios. The estimates indicate a clear gradient across both time horizons and scenarios, with larger impacts under higher emissions and toward the end of the century. Under the mid-century period (2051–2060), the projected percentage impact ranges from 5.65% under SSP2–4.5 to 7.47% under SSP5–8.5, corresponding to an additional 15.93 to 21.07 school shootings per decade in the United States. These effects become substantially larger by the end of the century (2091–2100), particularly under the high-emissions scenario. Under SSP5–8.5, the projected percentage impact increases to 13.99%, implying approximately 39.48 additional school shootings per decade relative to the historical baseline. Even under the moderate-emissions pathway (SSP2–4.5), end-century impacts remain sizable, with an estimated 8.11% increase and roughly 22.88 additional incidents per decade. Across all scenarios, the confidence intervals exclude zero, indicating that the projected effects are statistically distinguishable from no impact. The widening gap between SSP2–4.5 and SSP5–8.5 over time highlights the role of emissions trajectories

in shaping long-run outcomes. Taken together, these projections suggest that continued warming may meaningfully exacerbate the incidence of school shootings, and that mitigation efforts limiting future temperature increases could substantially reduce these risks.

To place our projected impacts in context, we compare our estimates with those from one of the most closely related studies, Ranson (2014), which examines the effects of climate change on violent crime in the United States. That study considers the A1B scenario—a "middle-of-the-road" emissions pathway broadly comparable to SSP2–4.5—and reports projected changes based on end-of-century climate conditions (2090–2099) relative to the early century (2000–2009). Under this scenario, Ranson (2014) estimates a 3.6% increase in murder and a 3.1% increase in aggravated assault. These magnitudes are substantially smaller than our corresponding projected percentage impact on school shootings (8.11% under SSP2–4.5 by the end of the century). One potential explanation for this discrepancy is differences in temporal aggregation: the prior study relies on monthly crime data, whereas our analysis uses daily data, although both are conducted at the county level. Estimating weather–crime relationships using monthly data may smooth out short-term temperature effects on murder and aggravated assault.

Table 6: Projected Impacts by Period and Scenario (95% Confidence Intervals).

Period	Scenario	% Impact	U.S. School Shootings (Decadal)
Mid-century (2051–2060)	SSP245	5.65 (2.82, 8.59)	15.93 (7.95, 24.24)
Mid-century (2051–2060)	SSP585	7.47 (3.64, 11.49)	21.07 (10.27, 32.43)
End-century (2091–2100)	SSP245	8.11 (3.87, 12.57)	22.88 (10.93, 35.47)
End-century (2091–2100)	SSP585	13.99 (5.88, 22.77)	39.48 (16.60, 64.27)

Figure 5 illustrates the projected spatial distribution of climate change–induced impacts on school shootings across U.S. counties under alternative emissions scenarios and time horizons. Under the moderate-emissions scenario (SSP2–4.5), projected impacts are relatively modest at mid-century, with increases concentrated primarily in parts of the Southwest, Southern Plains, and Southeast. By the end of the century, these effects become more

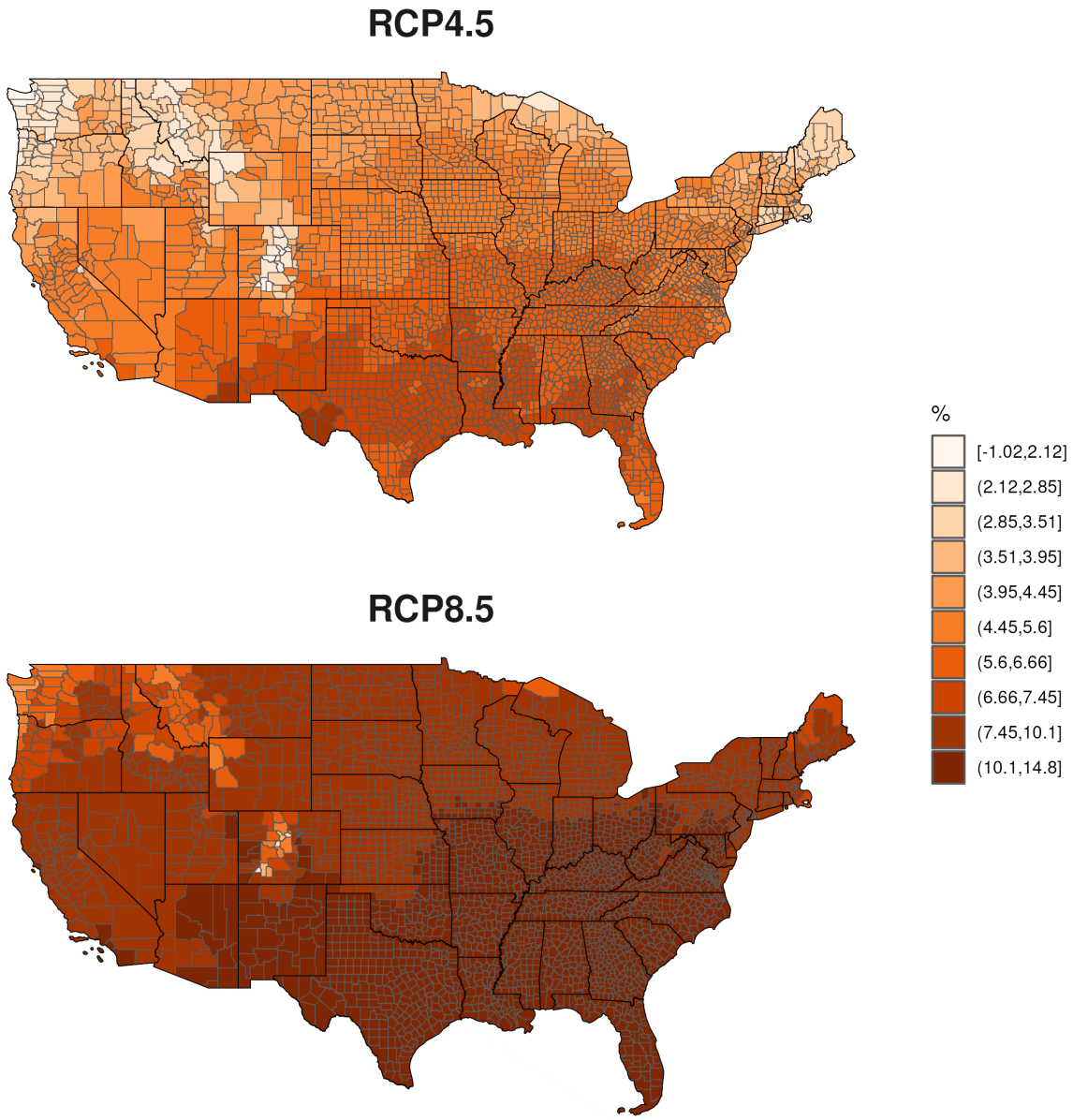


Figure 5: Projected Impacts of Climate Change on School Shootings

Notes: Projections are based on estimated relationships between historical climate variables (temperature and precipitation bins) and school shooting incidence, applied to bias-corrected CMIP6 ensemble climate data.

widespread and pronounced, particularly across the southern and central United States. Under the high-emissions scenario (SSP5–8.5), projected impacts are substantially larger at both horizons, with broad and intensifying increases across nearly all regions by the end of the century. The figure also underscores how higher emissions substantially amplify both the magnitude and geographic extent of climate change–induced school shooting risks.

Some caveats are important when interpreting these projections. Our estimates capture short-run behavioral responses to temperature fluctuations but do not incorporate potential longer-run adaptation mechanisms. If climate change leads to a persistent increase in the frequency of school shootings, schools and communities may respond through institutional adjustments, such as enhanced security measures, changes in school schedules or outdoor activities, and increased monitoring during periods of extreme heat. Families, students, and educators may also adapt by modifying behavior in ways that reduce exposure to high-risk situations. To the extent that such adaptive responses mitigate the relationship between extreme heat and violent incidents in school settings, the projected impacts presented here may overstate the realized long-run effects of climate change on school shootings. As a result, our estimates should be interpreted as reflecting an upper bound on the potential consequences of climate-induced increases in extreme temperatures absent substantial adaptation.

5.3.3 Social Costs of Climate Change-Induced School Shootings

Quantifying the social costs of school shootings is inherently challenging, as it is difficult to precisely identify the full set of individuals directly and indirectly affected and to assign monetary values to their lifetime losses. Despite these limitations, we provide a conservative estimate of the social costs associated with climate change–induced increases in school shootings in the United States, focusing on three components: lost lifetime earnings among exposed students, loss of life, and injury-related medical costs.

Using the same school-shooting dataset as in our analysis, Cabral et al. (2021) estimate that exposure to a school shooting is associated with a $128,859 reduction (in 2025 dollars)

in the present discounted value of lifetime earnings per exposed student. For the purposes of our valuation exercise, we assume that each school shooting affects 900 students on average.[4] In addition to earnings losses, school shootings are associated with direct medical costs and mortality losses. In our estimation sample, each incident results, on average, in 1.18 injured individuals and 0.32 fatalities. We assume an initial hospital care cost of $40,256 per injured individual and a value of a statistical life (VSL) of $13 million per fatality.[5] Finally, based on the projected impacts reported in Table 6, we assume that climate change leads to additional school shootings in the United States in both the mid- and end-of-century decades. Specifically, the annual number of incidents increases by 1.1 (SSP2–4.5) and 1.5 (SSP5–8.5) during 2051–2060, and by 1.7 and 3.0, respectively, during 2091–2100.

Under these assumptions and applying a 3% annual discount rate, our estimates imply that the present value of the social costs of climate change–induced school shootings is $780 million under SSP2–4.5 and $1.03 billion under SSP5–8.5 for the mid-century decade (2051–2060), with lifetime lost earnings accounting for over 95% of total costs. The corresponding present values for the end-of-century decade (2091–2100) are lower—$343 million and $593 million, respectively—even though climate change is projected to induce more additional school shootings later in the century. The smaller present value for the end-of-century period arises because these damages occur farther in the future and are discounted more heavily, outweighing the larger number of projected shootings. It is worth noting that these figures capture only a subset of the broader economic and social damages associated with school shootings, as they do not account for additional costs such as mental health impacts on students and families, spillover effects on teachers and communities, and costs associated

[4]According to the *Washington Post* school shooting database (`https://www.washingtonpost.com/education/interactive/school-shootings-database/`, accessed January 6, 2026), there have been 435 gun-violence incidents at schools since the Columbine attack in 1999, exposing more than 398,000 students. This implies that, on average, approximately 915 students are exposed per school shooting.

[5]VSL estimates follow U.S. Department of Transportation guidance (`https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-on-valuation-of-a-statistical-life-in-economic-analysis`); medical cost estimates are drawn from U.S. Government Accountability Office estimates (`https://www.gao.gov/assets/gao-21-515.pdf`).

with institutional and societal responses.

6 Conclusion

This study provides robust evidence that high temperatures significantly increase the incidence of school shootings. We show that heat-induced shootings are primarily driven by homicidal and threat-related incidents, and that both fatal and nonfatal shootings become more frequent on hotter days. These incidents tend to occur in less structured settings outside regular class time. Moreover, days with maximum temperatures above 90°F disproportionately increase shootings involving student perpetrators. Finally, our projections indicate that continued warming is likely to intensify heat-driven school shootings in the future. Together, these findings highlight school safety as an additional and underappreciated dimension of the social costs of rising temperatures.

From a policy perspective, our findings suggest that schools may benefit from targeted, short-term responses on hot days, particularly as climate change increases the frequency of extreme heat events. Enhanced supervision during periods of limited monitoring—such as before and after school and during lunch periods—may help mitigate elevated risks associated with high temperatures. While most weather-related school closures in the United States currently occur due to snow or cold conditions (Wong et al., 2014), analogous protocols for extreme heat could be considered in high-risk settings. Over the longer term, investments in heat-mitigation infrastructure, including expanded access to air conditioning, may yield co-benefits by reducing both thermal stress and heat-related behavioral risks (Park et al., 2020b). More broadly, our findings indicate that managing heat exposure in school environments may be relevant for violence risk and school safety, in addition to its well-documented effects on learning.

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A Appendix

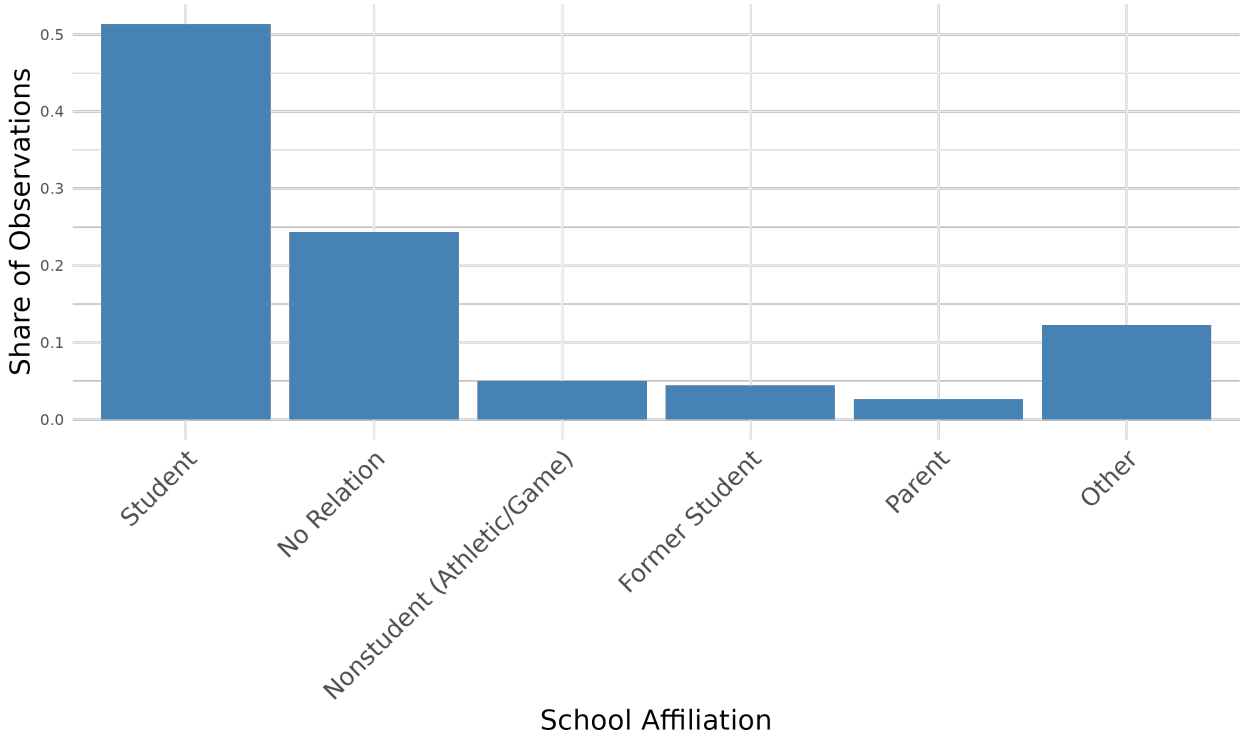
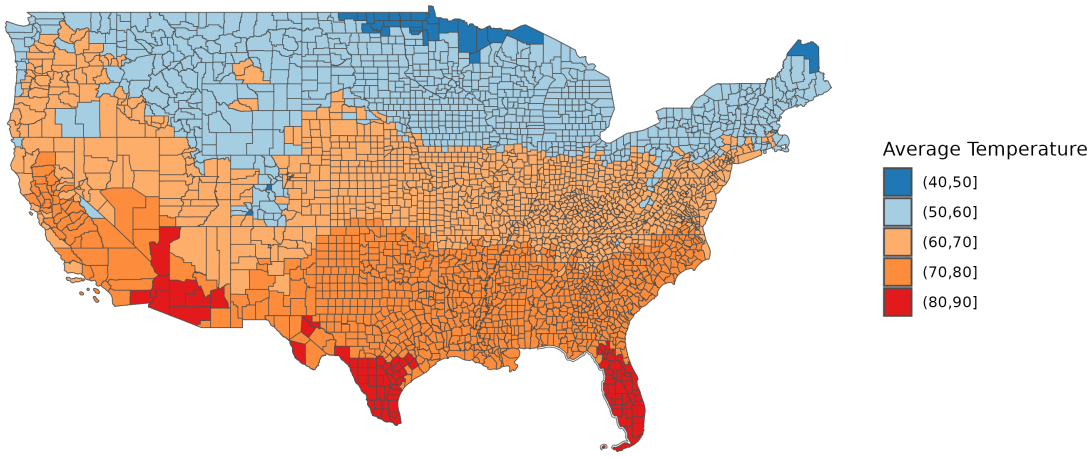


Figure A.0.1: Top 5 Shooter Categories and Others

Notes: Figure A.0.1 displays the share of each shooter category in our sample, highlighting the distribution of affiliations across different groups, such as students, individuals with no relation to the school, and others. Based on our data, the shares represent the proportion of incidents in which the shooter belonged to a particular category. Nonstudent (Athletic/Game) refers to individuals using athletic facilities or attending games.

(a) Mean Temperature (°F)



(b) Days above 90°F

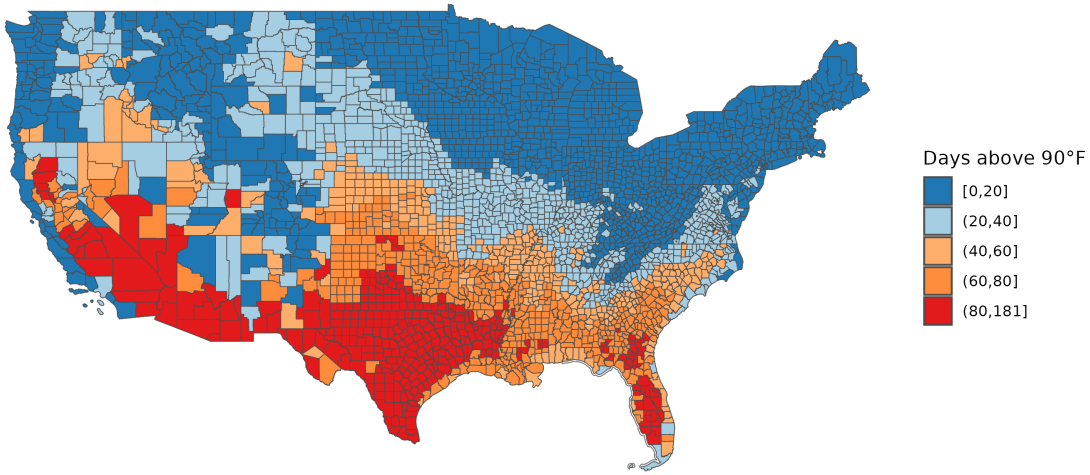


Figure A.0.2: Spatial Variations of Temperature

Notes: Panel (a) in Figure A.0.2 shows the average daily maximum temperature for each county, while panel (b) displays the annual average number of days above 90°F for each county in the U.S.

Table A.0.1: Main Results: Alternative Temperature Bins

	(1)	(2)	(3)
Below 40F	-0.2430	-0.3585**	-0.4082*
	(0.1553)	(0.1706)	(0.2169)
40-50F	0.0696	0.1015	0.1107
	(0.1305)	(0.2364)	(0.2932)
50-60F	0.1115	0.1360	0.1676
	(0.1094)	(0.1719)	(0.2038)
70-80F	0.0718	0.1023	0.1193
	(0.0992)	(0.1227)	(0.1335)
80-90F	0.5518***	0.3094**	0.5080***
	(0.1533)	(0.1490)	(0.1813)
Above 90F	0.4730**	0.5117**	0.6257***
	(0.1897)	(0.2203)	(0.2298)
Observations	47,661,380	47,661,380	47,661,380
Precipitation Controls	✓	✓	✓
County fixed effects	✓		
Date fixed effects	✓		
County x Month x Year fixed effects		✓	
State x Year fixed effects			✓
Day of Week fixed effects			✓
County x DOY fixed effects			✓

Note: The table replicates the main results in Table 2 using an expanded set of temperature bins. The omitted category corresponds to mild temperatures between 60–70°F. DOY fixed effects denote day-of-the-year fixed effects.

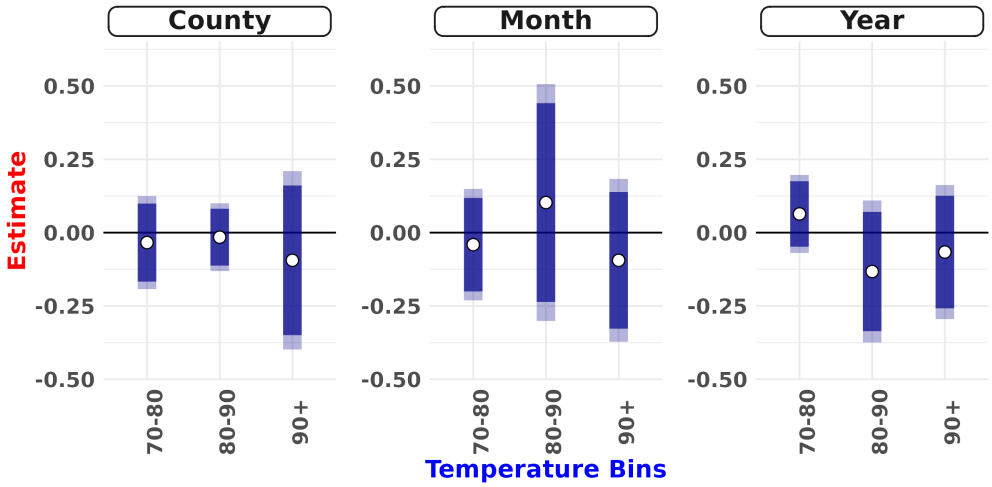


Figure A.0.3: Falsification

Notes: In Figure A.0.3, we present the results of the regression analysis using equation 2, where temperatures are randomly reassigned to observations. The leftmost figure displays estimates when temperatures are randomly assigned within the same county across days. The middle and rightmost figures illustrate estimates when temperatures are randomly reassigned within the same month or year across counties, respectively.

Table A.0.2: Main Results: Sample Excludes COVID Period

	(1)	(2)	(3)
70-80F	0.0502	0.0883	0.0911
	(0.0917)	(0.1062)	(0.1163)
80-90F	0.4959***	0.2866**	0.4523***
	(0.1495)	(0.1418)	(0.1746)
Above 90F	0.3907**	0.4517**	0.5589***
	(0.1923)	(0.1831)	(0.2056)
Observations	46,524,218	46,524,218	46,524,218
Precipitation Controls	✓	✓	✓
County fixed effects	✓		
Date fixed effects	✓		
County x Month x Year fixed effects		✓	
County x DOY fixed effects			✓
State x Year fixed effects			✓
Day of Week fixed effects			✓

Note: This table reports the results from the same models as in Table 2, but excluding data from 2020—the year most affected by COVID-19 in terms of school participation. Column (4) in Table 2 presents the regression results from our preferred specification (Equation 2), while columns (1)–(3) report results from alternative fixed effects specifications. All models include precipitation controls and are estimated using the Poisson quasi-maximum likelihood estimator. Each coefficient represents the semi-elasticity of school shootings with respect to the indicated bin of daily maximum temperature, relative to the omitted category: days with temperatures below 70°F. DOY fixed effects refer to day-of-year fixed effects.

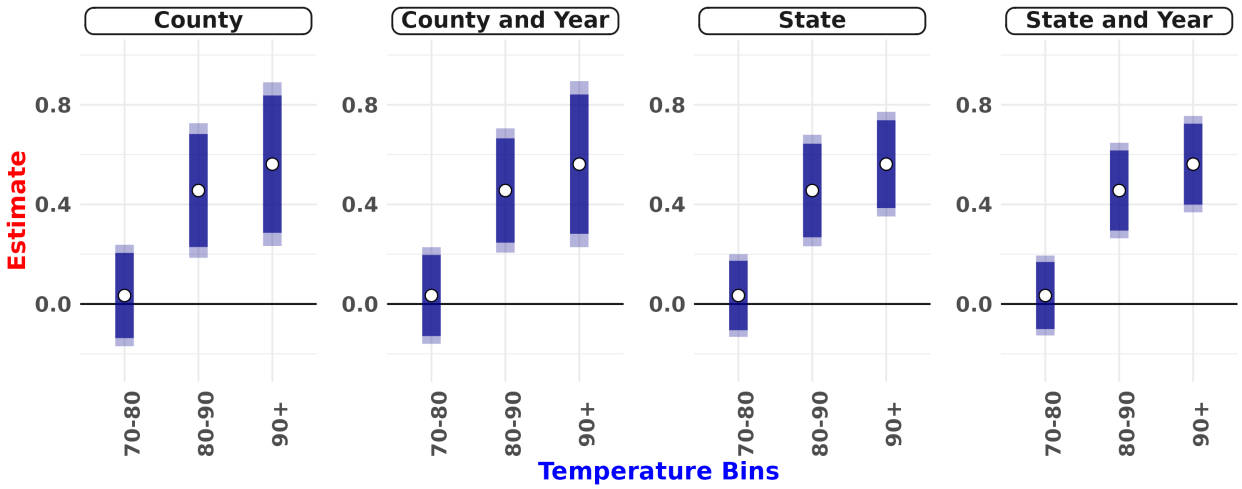


Figure A.0.4: Cluster

Notes: The figure presents estimated coefficients following equation 2, with clustering conducted at various levels: county, county and year, state, and state and year. The x-axis represents temperature bins (in degrees Fahrenheit), while the y-axis shows the corresponding estimates of the effect.

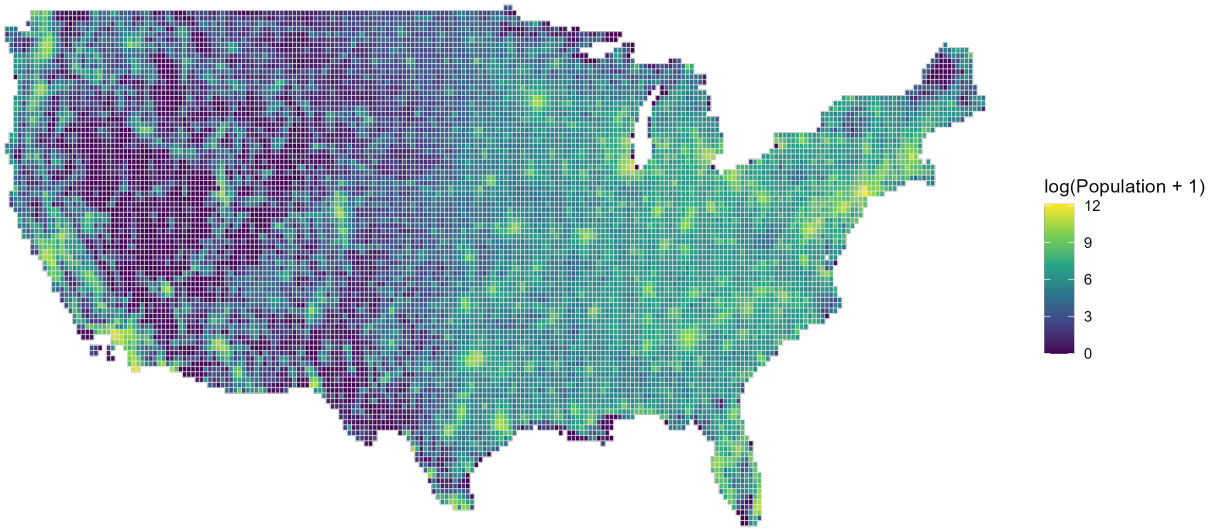


Figure A.0.5: Population Weight for Each NEX-GDDP-CMIP6 Grid

Notes: The figure displays log(population + 1) at the native 25-km NEX-GDDP-CMIP6 resolution. Population weights are constructed by overlaying 30-m gridded population data with the NEX-GDDP-CMIP6 grid and averaging population counts within each cell. These weights are used to aggregate climate simulations to the county level.