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The Effect of High School Shootings on Schools and Student Performance

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Abstract

We analyze how fatal shootings in high schools affect schools and students using data from shooting databases, school report cards and the Common Core of Data. We examine schools' test scores, enrollment, number of teachers, graduation, attendance and suspension rates at schools that experienced a shooting, employing a difference-in-differences strategy that uses other high schools in the same district as the comparison group. Our findings suggest that homicidal shootings significantly decrease the enrollment of students in grade 9 and test scores in math and English standardized tests. Using student-level data from California, we confirm that shootings lower test results for students that remain enrolled.

Keywords: Shootings, Student performance, Education, Violence.

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1 Introduction

Extreme violence between students in high schools may hinder students from learning efficiently. Deadly school shootings have a potentially large effect on students and schools. These incidents can affect students' decision about whether to stay at their school, affect their cognitive skills and influence their behavior at school. Despite the fact that school shootings receive widespread media attention, the educational consequences of deadly school shootings on enrollment and student performance are not well known.

We address three questions related to the consequences of homicidal and suicidal high school shootings. First, we address whether enrollment patterns change after shootings, which would likely be the result of school selection by students and parents, or students dropping out of the school system in response to the shooting. Second, we examine whether deadly shootings lower test scores in schools in subsequent years, which helps to establish medium-term trauma effects. Third, we look at the effects of deadly shootings on a range of behavioral variables such as graduation, attendance and suspension rates.

We estimate the impact of deadly high school shootings by using a difference-in-differences strategy, comparing schools that had fatal shootings with other high schools in the same district that did not experience such shootings. To estimate this, we merge an existing database of fatal shootings with the high-school-level Common Core of Data (CCD) and school report cards to form a panel of schools. Because we compare schools within the same district, our comparison group exhibits an environment similar to our group of interest aside from the turmoil generated by the shooting. Our empirical strategy relies on the assumption that these deadly school shooting incidents are exogenous in their timing.

We find that enrollment in grade nine (the high school entrance grade) drops following a deadly shooting, though we do not observe enrollment effects on subse-

quent grades the year after the shooting. We also find that standardized test scores in math and English are lower in affected schools up to three years after a deadly shooting. However, we do not find statistically significant impacts on behavioral outcomes: graduation, attendance or suspension rates. We find that suicidal shootings have no significant impact on our variables of interest. This suggests that results are driven by the trauma associated with a murder at school.

This leaves open the question of whether students are affected by shootings or if differences in performance instead reflect a composition effect. Composition effects can dominate when high-achieving students leave the school following a shooting, which then results in lower average scores for the school. To address this question, we use student-level data from California. This data allows us to identify the average treatment effect of shootings, conditional on students staying at the same high school after a shooting. Using student-level panel data from California high schools, we find that shootings have a negative effect on continuing students' math and English test scores. We find a decrease in test scores both at the school and student levels.

The rest of this paper is organized as follows: section 2 describes the framework, section 3 provides descriptive statistics, section 4 explains the methodology used, section 5 presents results, section 6 shows robustness results, and section 7 concludes the paper.

2 Framework

Violence in high schools may hinder students from learning efficiently. As mentioned by Cornell and Mayer (2010), school safety and order are essential conditions for learning, but represent a relatively unexplored area. Our paper contributes to the literature that quantifies the impact of school violence on student outcomes by looking at extreme violence: shootings at school.

Four theoretical mechanisms on how violence affects student development are

summarized by Margolin and Gordis (2000). First, psychobiological effects may occur since experiences during childhood and adolescence affect the human brain, particularly due to its malleability (Perry, 1997; Weiss and Wagner, 1998). Second, violence can result in post-traumatic stress disorder (PTSD). Four main PTSD symptoms have been documented in children who have experienced trauma (Terr, 1991).[1] Third, school violence can have cognitive consequences. Research identifies that exposure to trauma can result in damage to the hippocampus (Sapolsky et al., 1990), which is known to be involved in memory integration (Bower and Siver, 1998; McNally, 1998; Teicher et al., 1997). Fourth, school violence can cause peer problems. It is theorized that community violence negatively affects children's formation of relationships by reduced capacity to form secure attachments (Osofky, 1995).

Multiple empirical studies show that exposure to violent crimes causes students to have PTSD. Pynoos et al. (1987) find that elementary school students experienced PTSD after a fatal sniper attack on their school playground.[2] The severity of PTSD was worse for all exposure levels if the students knew the victim well. Likewise, Berman et al. (1996) find that students who have been exposed to violent crimes show a greater number of PTSD symptoms. Among those who were exposed to a violent crime, 44.3 percent were categorized as having "moderate" PTSD symptoms and 18.6 percent as having "severe" PTSD symptoms.[3] Berman et al. find that victims and witnesses exhibit a similar number of PTSD symptoms.

Studies also find that adolescent violence exposure is associated with poor mental health outcomes later in life. Kimmel (2014) identifies that adolescent

[1]These four symptoms are: (1) repeatedly perceiving memories of the event through visualization, (2) engaging in behavioral reenactments and repetitive play related to the event, (3) fears related to the trauma event, and (4) pessimistic attitudes reflecting a sense of hopelessness about the future and life in general.

[2]On Feb 24, 1984, a sniper began firing from a second-story window across the street from an elementary school at children on the school playground. Two children were killed and 13 were injured.

[3]The categorization is based on the Frederick scoring system of the PTSD Reaction Index (PTSD-RI).

victims of violence are more likely to experience depression as an adult. In addition, Hanson et al. (2014) show that exposure to violence early in life causes behavioral problems. These papers provide evidence that exposure to violence has lasting mental health consequences.

Exposure to violent crime may causes PTSD and poor mental health that diminish academic achievement. Ding et al. (2009) identify that depression causes lower student achievement using a set of genetic markers as instruments. McEwen and Sapolsky (1995) demonstrate that stress, which is more common in people afflicted with PTSD, increases the frequency of declarative errors, but has no effect on tasks that have fewer declarative and more procedural components. Declarative knowledge involves explicit knowledge of a fact, whereas procedural knowledge is implicit knowledge of how to do something. Thus, exposure to violent crime causes PTSD and poor mental health that diminish academic achievement.

In addition to PTSD and mental health issues, students may have an impaired ability to concentrate in class because of violent incidents (Glew et al., 2005). Students may also show reduced engagement in group learning activities that could hinder learning (Buhs et al., 2006; Ladd, 2003). Lastly, violence may result in absenteeism, which could lower enrollment and diminish student achievement (Buhs et al., 2006; Chen, 2007).

Recent papers study the effects of school violence on educational outcomes. Poutvaara and Ropponen (2010) analyze the immediate effect of a school shooting in September 2008 at a school in Finland and they find that the shooting decreased average test scores for boys but not for girls.[4]

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[4]Chandler et al. (2011) build a predictive model of shootings, which helps determine which students should be included in a highly targeted and resource-intensive mentorship program in Chicago. Chandler et al. (2011) find that shootings are very hard to predict.

School shootings are not the only form of violence that may impair student outcomes. For example, bullying is identified as a significant source of violence affecting student outcomes. Recent papers identify that bullying has adverse effects on educational achievement as well as long-term outcomes (Brown and Taylor, 2008; Eriksen et al., 2014).

Other papers study the effect of neighborhood violence on student performance, including Grogger (1997), Sharkey (2010), and Sharkey et al. (2014). These papers show that students are negatively affected by violence in their neighborhood. Grogger (1997) studies how local violence, defined as a combination of school violence and neighborhood violence, negatively affects educational attainment. Sharkey (2010) and Sharkey et al. (2014) identify the negative effects of exposure to a local violent crime on the cognitive performance of children.

Our study contributes to the literature by using extreme violent incidents (school shooting) to minimize the selection bias that is generated by the concentration of violence in disadvantaged neighborhoods in a non-experimental analysis. With a reasonable assumption that fatal school shootings are exogenous in their timing, the identified estimates show the unbiased effect of extreme violence in schools on educational outcomes. Also, separating the effect of violence taking place in schools from neighborhood violence is an additional contribution of the paper. Thus, our study improves school safety research by providing evidence of the causal effect of extreme school violence. Our results highlight a few facts about school shootings. Our analysis suggests that lower test scores in math and English result from homicidal shootings, but not suicidal shootings. Our results using student-level data from California show that student test scores are affected by shootings and that the difference in performance in schools with shootings is not only through a composition effect due to good students not attending the schools. We can therefore conclude that there is a decrease in test scores for the school overall and for individual students; the lower test scores are present up to three years after a shooting. We also

show that the effect is not through school absenteeism, as behavioral variables are not statistically significantly affected. Our analysis suggests that school resources might be an important factor, as affluent schools are not statistically significantly affected by school shootings.

3 Data and Descriptive Statistics

Our main data source of shooting incidents is the Report on School Associated Violent Deaths from the National School Safety Center (2010). The report uses newspaper articles to track shootings between 1994 and 2009.[5] Additional school shooting data is from Washington Ceasefire and the National School Safety and Security Services, which we verified with information from newspaper clippings.

We use the National School Safety Center's definition of a deadly school shooting, which is any homicidal or suicidal gun-related death in the United States that occurred on the property of a functioning public, private or parochial secondary school; on the way to or from regular sessions at such a school; while a person was attending or was on the way to or from a school-sponsored event; or as an obvious direct result of school incidents, functions or activities, whether on or off a school bus, school vehicle or school property.

As shown in Figure I, we document 157 shootings in high schools between 1994 and 2009 that resulted in one or more deaths. These schools where shootings occurred contained approximately 245,391 enrolled students, who may have suffered negative direct or indirect consequences from the event. We do not detect any trend in the annual number of deadly shootings. Among the 157 shootings that occurred in high schools, 104 are categorized as homicidal and 53 are suicidal incidents. Among the 104 homicidal shootings, 27 involve multiple deaths (ranging from 2 to

[5]We use the year of the fall semester to indicate the school year. For instance, we refer to the 2001-02 school year as 2001.

15 people).[6]

Data on school characteristics is from the Common Core of Data (CCD) from the National Center for Education Statistics (NCES) from 1990 to 2009. The data set provides a complete listing of all public elementary and secondary schools in the U.S. and provides basic information and descriptive statistics on schools, their students and their teachers. We use CCD data for enrollment per grade (grades 9 to 12) and number of teachers.[7]

We define our comparison group as other high schools in the same district. Schools in the same district have many similar unobservable characteristics. As Figure II reveals, enrollment in other schools in the same district is not affected by shootings. Thus, it is very unlikely that we double count the movement of students from schools where shootings have occurred to comparison schools. Our estimates can be viewed as a lower bound of the true effect of school shootings on student outcomes because the comparison schools could be influenced due to their physical proximity, albeit at a different magnitude. Figure II shows a permanent decrease in entrance grade 9 enrollment after a shooting takes place. Figure II also shows a similar trend for control and treatment schools before the shooting occurs.

School performance data is from each state's Department of Education website. A student's ability in math and English is tested at least once during high school using a standardized test. Information is extracted from each school's report card and from data files posted by each state's Department of Education. We focus on data from 2002 to 2010 due to availability. The *No Child Left Behind Act* passed in 2001 requires all schools receiving federal funding to administer a state-wide standardized test; in most states, these results are posted online. Most states only publish the proportion of a school's students who fall into various categories of achievement,

[6]When a person killed someone else and then committed suicide, we categorized the incident as a homicidal shooting. We classify accidental gun-related deaths in the homicidal category.

[7]There is no information on teacher turnover at the school level in the CCD.

such as “minimum,” “basic,” “proficient” and “advanced” performance, rather than the actual mean scores of the schools. We use the proportion of students achieving a proficient or advanced level on math and English state-wide standardized tests for each school, which we refer to as the “proficiency rate”, as the outcome variable.

These tests vary from state to state but are identical within a state for any given year.[8] As Table I shows, the mean proficiency rate is not statistically different between “treated schools” and comparison schools. Table I shows that schools that experience shootings are larger than average, both in terms of the number of total enrolled students and in full-time equivalent teachers (FTEs). Figures III and IV display the average proficiency rate for the years before and after any shootings for treated schools and comparison schools, which show a decline in the math and English proficiency rates in the years following a homicidal shooting for schools that experienced a shooting. As in Figure II, Figures III and IV also show similar trends for control and treatment schools before the shooting occurs.

***INSERT TABLE 1 ***

In addition, we collect school-level graduation rates, average daily attendance rates and the number of suspensions per 100 students for all schools in the districts that experienced shootings in all available states.[9]

We use student-level data from California. The data is provided by the California Department of Education (CDE) for 2007 to 2010. During that period, seven deadly high school shootings occurred in seven school districts. The seven affected

[8]We examine the relationship between 36 high school shootings and the proportion of students achieving a proficient- or advanced-level result on English tests in 14 states. We also examine the relationship between 34 high school shootings and the proportion of students achieving a proficient- or advanced-level result on math tests in 13 states. Not all states have both test results posted on their Department of Education websites, which is the reason why the sample size is different for math and English tests. English and math test results are available for Alabama, California, Florida, Louisiana, Michigan, Nevada, North Carolina, South Carolina, Tennessee, Utah, Washington, and Wisconsin. English test results only are available for Minnesota.

[9]We have information on graduation rates and attendance rates for shooting-affected school districts for ten shootings in five states (Nevada, North Carolina, South Carolina, Tennessee, and Utah) and information on numbers of suspensions per 100 students for seven shootings in three states (Nevada, North Carolina, and Tennessee).

school districts have 195 high schools within their boundaries and a large number of students. The data contains test results on the California Standards Tests (CST). The CSTs, which are part of the California Standardized Testing and Reporting (STAR) program, are taken by students from grades 2 through 11 in many subjects. We use only math and English results from grades 9 through 11. We have measures of the proficiency level in math and English standardized tests for students in the seven districts. The possible levels of math and English proficiency for students in the seven districts are: far below basic (1), below basic (2), basic (3), proficient (4) and advanced (5). We also have information on the sex of the students, which allows us to determine whether shootings affect males and females differently.

4 Methodology

We use a difference-in-differences strategy to analyze the effect of deadly homicidal high school shootings. The comparison group consists of all other high schools in the same district. We estimate

$$Y_{it} = \beta_0 + \beta_1 After_{it} + \beta_2 After_{it} * Shooting_i + \mu_i + \theta_t + \varepsilon_{it}$$

where Y_{it} is one of several different outcome variables for school ***i*** in year ***t***; $Shooting_i$ is a bivariate variable that takes a value of 1 if there was ever a shooting in school *i* and 0 otherwise; and $After_{it}$ is an indicator for the period after the shootings.10 The coefficient of the interaction variable ($After_{it} * Shooting_i$) is of primary interest, as it captures the effect of school shootings on various outcomes. The outcomes of interest are: enrollment per grade (9 to 12), number of teachers,

[10]The "after" period is defined differently for the enrollment analysis and the proficiency rate analysis. For the enrollment analysis, the "after" period starts the school year following the shooting, since enrollment data is typically generated very early in the school year (usually in September or October). For proficiency rate analysis, the "after" period starts the same year as the shooting, since the tests are administered towards the end of a school year.

proficiency rate (in math and English) and behavioral variables (graduation, suspension and attendance rates). We include school fixed effects, μ_i for school i, to control for any time-invariant school-level factors that may be correlated with shootings and the outcome variables. School fixed effects are as helpful as many detailed control variables in the regression because school size, racial composition and many other school characteristics do not fluctuate a lot over the short time period that the sample covers. We presents analysis controlling for additional school and district time-varying characteristics in Appendix Table A.1 and results are similar. We also include year fixed effects to control for any national policy changes or trends from 1994 to 2009.[11] We use clustered standard errors at the district level to incorporate the correlations among schools in the same school district. We use a three-year window around the shooting year.[12]

The identification assumption for the difference-in-differences estimator is that there exists common trends between schools that experience a shooting and the comparison schools before the shooting incident. Figures II, III, and IV show the trends prior to shooting incidents between two groups of schools. The trends are similar, which suggests that it is appropriate to use difference-in-differences estimation.

[11]We tested different specifications of the model, such as using district and year fixed effects, which lead to similar results. Results for these specifications can be provided upon request.

[12]The nature of difference-in-differences estimation requires us to check whether the schools and districts have multiple shootings over the sample period. Multiple shootings in one school or district could bias our estimates because the "before" and "after" periods of the shootings could overlap with those of another shooting in the same school or district. High school shootings occur only once in most school districts over the 16 school years; 103 school districts had one shooting, 12 school districts had two shootings, and six school districts had three or more shootings. In our analysis, additional to all initial shootings in a district, we include subsequent shootings in a district if they are six or more years apart. We view shootings six or more years apart as distinct because almost all students who experience a shooting leave their school within three years, which could be interpreted as the school returning to its pre-shooting environment. Another rationale for a three-year window around the year of shootings is that using the entire sample for the difference-in-differences estimator will contain noise in years far from the shooting incidents.

For robustness, we also present a pooled interrupted time series design and matching regression estimates based on four school characteristics: state, area (city, suburb, town or rural), size of the school and number of teachers. Using these variables, Kernel, Caliper and Nearest Neighbor matching estimators are employed.

In addition, we use student-level data from California and condition on having a test result before and after a shooting at the same school. This analysis identifies whether negative effects of school shootings result from students being directly affected by shootings or from a composition effect (e.g. students with a high level of achievement might not stay or register at a school after a shooting).[13] We use a similar empirical strategy for student-level data as for school-level data, so that we can exploit the panel aspect of the data at the student level. We estimate conditional logit models with student-level fixed effects. The primary outcome variables of interest are whether a student is proficient in English and math standardized tests (whether the student achieves level 4 or 5 in California).

We also investigate the possibility that shootings have heterogeneous effects in two ways. First, we investigate whether shootings affect students in various parts of the test-score distribution differently. To study the most affected part of the distribution, we change the outcome variables in the same regression to the probability of being in level 2 to 5, level 3 to 5, and level 5 to identify which part of the distribution is generating the lower level of test results in schools that experienced a shooting. Second, we study whether males are affected differently than females.

[13] Similar results are found if we restrict the sample to two observations per student, one before and one after a shooting (balanced panel).

5 Results

5.1 The Effect of Shootings

Figure II reveals that schools where homicidal shootings have occurred experience a decline in grade 9 enrollment relative to other schools in the same district.[14] Table II shows that a shooting reduces enrollment in grade 9 by 28 students on average, which represents a 5.8 percent decline in grade 9 enrollment for the average school experiencing a shooting. This decrease in grade 9 enrollment represents a large change in school selection by students entering high school. The large decline in grade 9 enrollment suggests that middle school students and their parents try to avoid the school that had the shooting.[15]

***INSERT TABLE 2 ***

Enrollment in other grades and the number of teachers employed do not statistically significantly change after a shooting.[16] No significant impact for students already enrolled suggests that students have established connections that raise the cost of transferring to another school.[17] It is also administratively difficult for continuing students to transfer.

Figures III and IV show that the proficiency rate decreases after homicidal shootings in those schools relative to comparison schools. Table II indicates that the proficiency rate in math is reduced by 4.9 percentage points. For English standardized tests, the effect of shootings is of a slightly smaller magnitude,

[14]We use a subset of high schools for the enrollment analysis, which is high schools where the lowest grade is grade 9 and highest grade is grade 12, to ensure a clear interpretation of the coefficient. Among the 157 high school shootings, 136 occurred in high schools that have grades 9 through 12 over the sample period. Results are robust to the inclusion of all high schools.

[15]This pattern is confirmed by Abouk and Adams (2013), who find an increase in private high school enrollment following school shootings.

[16]We do not have information on teacher turnover in the data. It is possible that some teachers leave after a shooting and are replaced by younger teachers. An alternative approach would be to use the student-to-teacher ratio as an outcome variable. The coefficient for the student-to-teacher ratio is positive but not significant. Results are available upon request.

[17]Coefficients for upper grades are statistically different than enrollment in grade 9 (Hausman test).

3.9 percentage points lower than the comparison schools. Columns 3 to 5 of Table II show the effect of deadly shootings on graduation rates, average daily attendance rates and the number of suspensions per 100 students. We do not find any statistically significant results for these three outcomes.

In addition, Table A.2 shows regression results for enrollment in grades 10 and 11, excluding either the first year or the first two years following a shooting. It shows that a decrease in enrollment for the entrance grade (grade 9) immediately following a shooting is followed by a decrease in the number of student enrolled in grade 10 (after one year) and grade 11 (after two years).

5.2 Heterogeneity of the Effects of Shootings

Tables III and IV show the heterogeneity of the effects of shootings on the three main outcomes: grade 9 enrollment, and test results in math and English. Table III presents results by type of shooting: single homicides, multiple homicides and suicides. Results for all three outcomes are significant for both single-death homicides and multiple-death homicides. The effect of single and multiple death homicides on grade 9 enrollment are not significantly different from each other; however, the effect on test results is significantly larger for multiple-death homicides than single-death homicides.[18] This suggests that the negative effect of school shootings on student achievement is aggravated with multiple deaths. Table III also shows that suicidal shootings have no significant impact on any outcome of interest and the coefficient is significantly different than homicide shootings. This suggests that homicidal and suicidal shootings have different effects on educational outcomes, and that the negative impact on grade 9 enrollment and test results is due to trauma associated with a murder at school.

***INSERT TABLE 3 ***

[18]We use a Hausman test and interaction terms to test the differences in coefficients. Both test provide the same conclusion.

Table IV shows the heterogeneity of the effect of shootings by school and neighborhood characteristics. It shows that shootings have a similar effect regardless of whether a school is located in a city or a non-city environment. In contrast, the effects of homicidal shootings are more pronounced among schools located in low-crime areas. The effect of a shooting is larger for schools with high-poverty.[18] The coefficients for affluent schools are not statistically significant for all outcome variables, and the coefficients for affluent schools and non-affluent schools are statistically different from each other. This suggests that school resources in the aftermath of shootings might be an important factor. In addition, Table IV shows the decrease in grade 9 enrollment is only significant for shootings in states with open enrollment.[19] However, there is a decrease in test scores regardless of open enrollment status. These results suggest that the trauma associated with a murder at school is a key factor explaining the results.

***INSERT TABLE 4 ***

5.3 Student-Level Effects

Results from the school-level analysis indicate that a large number of students are likely to change their school selection due to shootings. This implies that the identified school-level effect is a total effect, which is a sum of compositional change and individual effect. The total effect has a high policy relevance. However, separating the individual effect will allow us to isolate the true shock to students' educational outcomes resulting from school shootings. The individual effect is identified by using student-level data and by conditioning on students staying in the same schools after shooting incidents.

Using California student-level data, Table V shows 4.2 and 10.2 percentage point decreases in the probability of achieving a proficient-level result (achievement level 4 or 5 in California) in math and English, respectively. These results suggest that the decrease in test scores is not solely due to composition effect, e.g. fewer high-achieving students attending schools where shootings occurred.[20] Also, student-

[19]Also shown in Figure B.1

[20]Also shown in Figure B.2

level results control for student transfers to other schools that could generate an upward bias in the school-level results if high-achieving students are more likely to transfer out of schools where shootings have occurred.[21] This allows us to conclude that students' academic achievement worsens after fatal shooting incidents in high schools.

***INSERT TABLE 5 ***

The individual effect identified by student-level analysis shows that students' math and English test scores are directly affected by school shootings. These results confirm that the effect of school shootings are coming from both compositional changes and individual effects.

Table C.1 identifies the effect of shootings on the probability of reaching various achievement levels. It shows that shootings have heterogeneous effects on math standardized test results. For math tests, the negative effects are concentrated on students who are at the high achievement part of the distribution. The negative effect of shootings on the probability of reaching achievement level 5 in math tests is large, 10.4 percentage points. The magnitude of the effect of shootings decreases as the achievement level of interest goes down, almost disappearing when looking at the probability of achieving level 3 or higher. However, the negative effect is consistent throughout the distribution for English test results. Lastly, when we analyze the effects of shooting by gender, we find that male and female students are both similarly affected by shootings with respect to their test results (see Table C.2).

6 Robustness

We do several tests to ensure that our results are robust and valid.

We first do a placebo test on outcome variables three years before a shooting.

[21] The results are similar when we restrict the sample to students who stay in the same school district as well as to those who do not repeat a grade following a shooting. Table C.3 shows results from mixed effects logistics regressions that are similar to fixed effects model results.

[22] Estimates from the student-level data are intent-to-treat estimates because we do not have daily attendance data on the day of shootings.

We test whether schools that experienced shootings were different three years before the shooting than the comparison group for grade 9 enrollment, and math and English test scores. Table A.3 shows that estimates for these three main outcome variables are not significant.[23] Figures II, III, and IV, as well as figures in Appendix B based on heterogeneity, show the trends prior to shooting incidents between the treatment and comparison group that are similar and provide confidence in our empirical strategy.

Furthermore, we also investigate if results are robust to alternate specifications or to using more time-varying controls. We add school- and district-level characteristics to the main school fixed-effects model (Equation (1)) to check whether results are robust to the inclusion of time-varying variables. Table A.1 shows that estimates are qualitatively the same. Appendix Table A.4 presents matching regression estimates based on state, area (city, suburb, town or rural), enrolment and number of teachers. We get similar estimates from three types of matching estimates (Kernel, Caliper and nearest neighbor), but larger coefficients than our main results. This implies that our preferred estimates could be a lower bound of the true effect of deadly school shootings on educational outcomes. In addition, Appendix Table A.5 presents results using a pooled-interrupted time series with a shooting being the interruption. Results are once again similar.

Lastly, we do a permutation test. We randomize the shootings within the school districts for the year the shooting took place and re-run baseline regressions for our main outcome variables: the proficiency rate in math and English, as well as enrollment in grade 9. The rationale behind this randomization is to provide confidence that our significant results are not caused by a factor other than the shootings. We do 1,000 replications and find that it is unlikely that the results are due to chance. Figures B.4 and B.5 present histograms of t-values and coefficients by intervals for our main variable of interest. Results from this randomization and these figures provide additional confidence in our results.

[23]Results of the placebo are robust to using 4 years or 2 years before the ban.

7 Conclusion

In this paper, we analyze the effects of deadly high school shootings on educational outcomes. We find that enrollment declines in grade 9 (the high school entrance grade) in schools that experience homicidal shootings. Furthermore, math and English standardized test results drop significantly in schools that experience a shooting. However, we do not find a detrimental effect of shootings on suspension, graduation or average daily attendance rates. We find that suicidal shootings have no significant impact on educational outcomes. To determine whether students are directly affected by shootings or if it is rather a composition effect, we use student-level data from California. We find that students are directly affected by shootings. There is a decrease in the probability of achieving a proficiency level 4 or 5 (a high achievement level) on math and English standardized tests.

Although we study the short-run consequences of school shootings on students, it is likely that these events have long-run consequences as well. The negative effect of shootings on student achievement on math and English standardized tests may be an important factor in determining wages and employment for these students in the long-run. If students attending schools that experienced a shooting have lower test scores, they might be accepted into less selective colleges, which could lead to lower earnings later in life (eg. Hoekstra, 2009).[24] Future research should try to evaluate some of these long-term effects.

Our estimates indicate that students, on average, are highly affected when there is a homicidal shooting. These results indicate that policymakers should consider

[24]There is a debate as to how successful standardized test scores are at measuring actual student achievement (eg. Haladyna et al. 1991; Reynolds et al. 2010)

preventive measures such as gun control (Duggan, 2001; Marvell, 2001; Lott and Whitley, 2001), and more resources should be made available to students (Borum et al., 2010; Carrell and Hoekstra, 2011), especially in the aftermath of shootings. Our heterogeneity section also points to this effect. More research should be done regarding the negative effects of high school shootings and other school violence.

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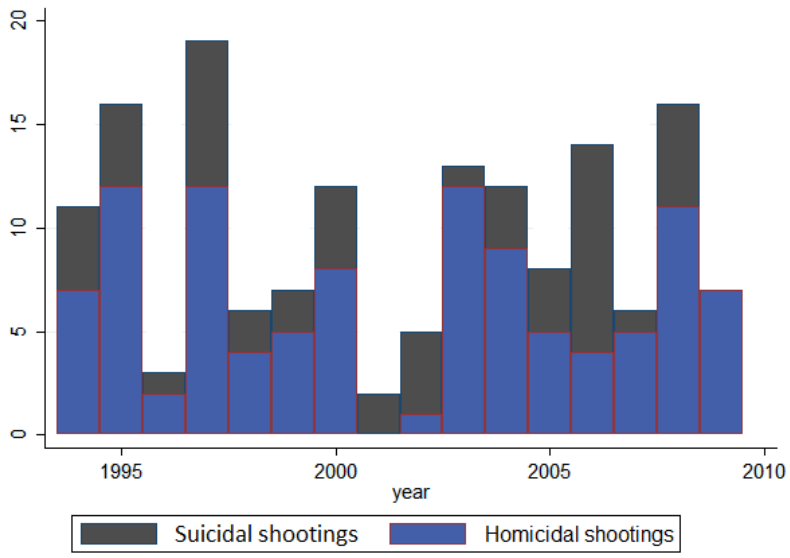

Figure I: Number of Shootings By Type of Shooting
Source: Report on School Associated Violent Deaths from the National School Safety Center (2010), Washington Ceasefire, and the National School Safety and Security Services.

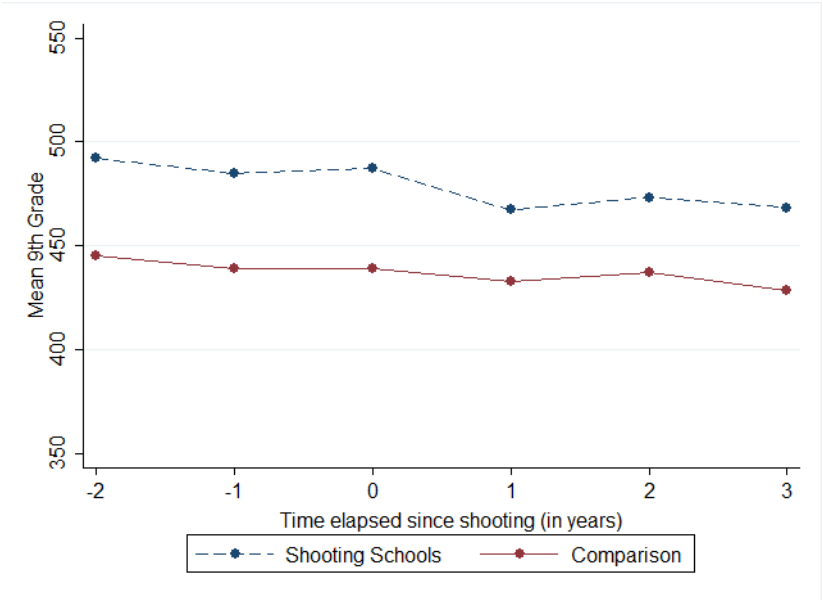

Figure II: The Effect of Shootings on Grade 9 Enrollment (Entrance Grade)
Source: Common Core of Data (CCD) from the National Center for Education Statistics (NCES).

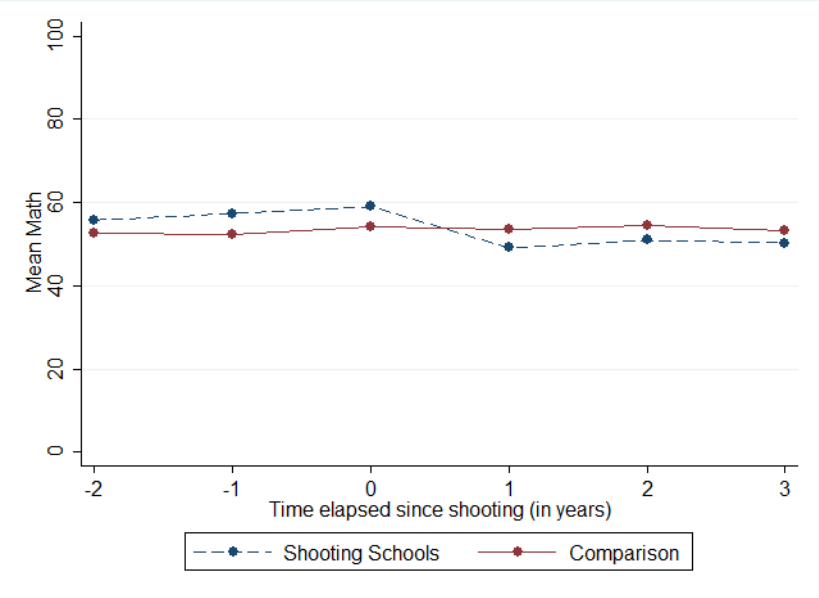

Figure III: The Effect of Shootings on Math Proficiency Rate
Source: Information was extracted from each school's report card and from data files posted by each state's Department of Education.

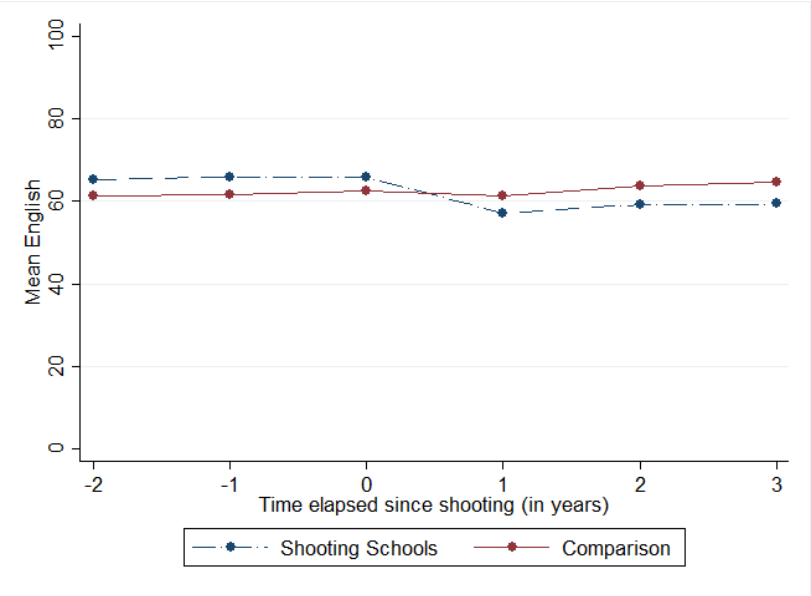

Figure IV: The Effect of Shootings on English Proficiency Rate
Source: Information was extracted from each school's report card and from data files posted by each state's Department of Education.

Table I: Summary Statistics - High Schools before a Shooting

	All Shooting Schools		Comparison Schools	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
Enrollment in				
Grade 9	486	283	436	344
Grade 10	426	238	378	289
Grade 11	352	196	314	240
Grade 12	298	171	262	202
Total Students	1587	835	1408	1044
FTE Teachers	80	37	73	47
English	65.4	23.0	60.5	27.9
Math	57.8	24.3	52.9	28.6
Graduation Rate	71.5	13.6	72.3	17.8
Attendance Rate	92.8	3.5	91.3	3.9
Suspension Rate	19.6	17.7	18.3	18.0

Note: Table I presents descriptive statistics for key variables for shooting schools and our comparison schools for the three years before a shooting. Enrollment and teacher variables are from the Common Core of Data. Test results and behavioral variables are from school report cards. Only high schools with grades 9 to 12 are included in the enrollment and teacher sample. All high schools are included in the test results and behavioral sample. Math and English variables are the proficiency rate from standardized tests. FTE Teachers are the number of full-time-equivalent teachers. Suspension Rate is number of suspensions per 100 students. The comparison schools are all other schools in the same district as the school that experienced a shooting. Using a t-test or Wilcoxson test, we find that shooting schools are statistically different in terms of number of students (grade 9 to 12 and total students) and number of teachers but not for proficiency in English and math, as well as graduation, attendance, and suspension rates.

Table II: The Effect of Homicidal Shootings

	Enrollment in Grade					# of
	9	10	11	12	Total	Teachers
After	-3.48	-6.46	-8.08**	0.92	-14.27	0.57
	(7.03)	(4.51)	(4.09)	(2.62)	(12.61)	(1.25)
After*Shooting	-28.41***	-8.84	6.96	-3.71	-37.79	-1.78
	(10.92)	(8.37)	(9.30)	(6.69)	(23.97)	(1.28)

	Fraction Proficient in			Rate of	
	Math	English	Graduation	Attendance	Suspension
After	-3.48	-3.52**	0.81	-1.29***	1.02
	(2.31)	(1.58)	(1.34)	(0.46)	(1.34)
After*Shooting	-4.92***	-3.93***	0.40	0.62	-2.28
	(1.18)	(1.07)	(1.19)	(0.39)	(1.55)

Note: Table II presents difference-in-differences regression estimates for the number of student in grades 9 to 12 and the number of teachers, as well as math and English proficiency rate, and graduation, attendance and suspension rates. The coefficient of interest is After*Shooting School. We use clustered standard errors at the district level. Coefficients for school and year fixed effects are not shown. *** p<0.01, ** p<0.05, * p<0.1.

Source: Common Core of Data (CCD) from the National Center for Education Statistics (NCES). Test results and other variables are extracted from each school's report card and from data files posted by each state's Department of Education.

Table III: Heterogeneity of the Effects of Shootings, by Shooting Type

	Single-Death Homicides			Multiple-Death Homicides			Suicidal Shootings		
	Grade 9	Math	English	Grade 9	Math	English	Grade 9	Math	English
After*Shooting	-35.64***	-4.71***	-4.85***	-29.77**	-8.85***	-8.63***	22.70	7.50	-5.59
	(13.65)	(1.46)	(1.26)	(14.65)	(1.98)	(2.24)	(17.71)	(10.59)	(6.29)

Note: Table III presents difference-in-differences regression estimates for the number of students in grades 9 as well as the math and English proficiency rates. The coefficient of interest is After*Shooting School. We use clustered standard errors at the district level. Coefficients for school and year fixed effects are not shown. *** p<0.01, ** p<0.05, * p<0.1.

Source: Common Core of Data (CCD) from the National Center for Education Statistics (NCES). Test results and other variables are extracted from each school's report card and from data files posted by each state's Department of Education.

Table IV: Heterogeneity of the Effects of Homicidal Shootings, by School Characteristics

	Schools in City			Schools not in City		
	Grade 9	Math	English	Grade 9	Math	English
After*Shooting	-26.69**	-4.60**	-3.43*	-22.65	-5.21***	-4.06***
	(13.00)	(2.03)	(1.98)	(16.94)	(1.49)	(1.33)
	High-Crime-Area Schools			Low-Crime-Area Schools		
	Grade 9	Math	English	Grade 9	Math	English
After*Shooting	-25.14	-3.32	-3.74	-34.33***	-4.58***	-3.33***
	(18.28)	(3.81)	(3.66)	(11.67)	(1.22)	(1.08)
	High-Poverty Schools			Affluent Schools		
	Grade 9	Math	English	Grade 9	Math	English
After*Shooting	-31.28**	-5.78***	-5.30***	-18.93	-2.84	0.37
	(12.25)	(1.38)	(1.19)	(22.09)	(3.92)	(2.47)
	Open Enrollment Schools			Non-Open Enrollment Schools		
	Grade 9	Math	English	Grade 9	Math	English
After*Shooting	-34.24***	-5.66***	-4.52***	21.41	-4.70**	-4.82**
	(11.72)	(1.11)	(1.13)	(15.81)	(2.06)	(1.77)
	Large Schools			Small Schools		
	Grade 9	Math	English	Grade 9	Math	English
After*Shooting	-46.32**	-4.48***	-4.25***	-0.85	-4.49***	-3.45**
	(18.12)	(1.48)	(1.39)	(10.21)	(1.65)	(1.38)

Note: Table IV presents difference-in-differences regression estimates for the number of students in grades 9 as well as the math and English proficiency rates. The coefficient of interest is After*Shooting School. We use clustered standard errors at the district level. Coefficients for school and year fixed effects are not shown. *** p<0.01, ** p<0.05, * p<0.1.

Source: Common Core of Data (CCD) from the National Center for Education Statistics (NCES). Test results and other variables are extracted from each school's report card and from data files posted by each state's Department of Education.

Table V: Effect of Shootings using California Student-Level Data - 2007-2011

	Probability of Proficiency Level in	
	Math(Level 4 or 5)	English (Level 4 or 5)
After	-0.079***	-0.015
	(0.010)	(0.009)
After*Shooting	-0.042**	-0.102***
	(0.017)	(0.017)
Observations	246,864	270,114
Number of Students	120,924	125,949

Note: Table V investigates the impact of shootings on students using student-level data from the California Department of Education. Using conditional fixed effects logit models with student-level fixed effects, we study the probability of students achieving level 4 or 5 in math and English. The sample is restricted to students who took tests both before and after a shooting. The level of math and English proficiency for students in the seven districts are: far below basic (1), below basic (2), basic (3), proficient (4), and advanced (5).To correct for autocorrelation, we cluster errors at the district level. Estimates for student and year fixed effects are not shown. *** p<0.01, ** p<0.05, * p<0.1.

Source: Student-level data from California provided by the California Department of Education (CDE).

Appendix

Appendix A

Table A.1: Effect of Homicidal Shootings with Control Variables

	Enrollment in Grade					# of
	9	10	11	12	Total	Teachers
After	4.87	-8.26	-2.78	0.18	-1.97	-1.08
	(9.78)	(5.62)	(4.23)	(3.56)	(16.68)	(0.82)
After*Shooting	-34.15***	-7.41	-0.79	-1.69	-25.96*	-1.45
	(13.07)	(9.44)	(9.45)	(7.50)	(15.48)	(1.32)

	Fraction Proficient in			Rate of	
	Math	English	Graduation	Attendance	Suspension
After	-0.71	-4.39	-4.09	-3.33***	5.34
	(3.50)	(3.17)	(4.92)	(1.14)	(4.02)
After*Shooting	-3.86***	-3.46***	1.61*	0.62	-2.77
	(0.98)	(0.93)	(0.96)	(0.48)	(1.74)

Note: Table A.1 presents difference-in-differences regression estimates for the number of students in grades 9 to 12, the number of teachers, math and English proficiency rates, and graduation, attendance and suspension rates. The coefficient of interest is After*Shooting School. We use clustered standard errors at the district level. Coefficients for control variables and school and year fixed effects are not shown. Included control variables are total school enrollment before the sample period, number of schools in the district, number of students per school in the district, the fraction of students with free lunch status in the district, the fraction of students with free lunch status in the school, the faculty-to-student ratio in the district, the faculty-to-student ratio in school, the fraction of students in the district who are visible minorities, and the fraction of students in the school who are visible minorities. *** p<0.01, ** p<0.05, * p<0.1.

Source: Common Core of Data (CCD) from the National Center for Education Statistics (NCES). Test results and other variables are extracted from each school's report card and from data files posted by each state's Department of Education.

Table A.2: Effect of Shootings on Future Years' Enrollment

Variables	Grade10	Grade11	Total	Total
After	1.201	-2.881	3.982	-9.118
	(6.251)	(9.900)	(24.09)	(34.38)
After*Shooting	-41.40*	-35.92*	-130.2*	-196.0**
	(22.28)	(21.81)	(75.40)	(83.04)
EXCLUDED 1st Yr	Y	Y	Y	Y
EXCLUDED 2nd Yr		Y		Y

Note: Table A.2 presents difference-in-differences regression estimates for the number of students in grades 10 and 11, and the total number of students, by excluding the first year or the first two years after a shooting. The coefficient of interest is After*Shooting School. We use clustered standard errors at the district level. Coefficients for school and year fixed effects are not shown. *** p<0.01, ** p<0.05, * p<0.1.

Source: Common Core of Data (CCD) from the National Center for Education Statistics (NCES).

Table A.3: Placebo: Effect of Homicidal Shootings on Outcomes before Shootings

	Enrollment in Grade 9	Fraction Proficient in Math	English
After	-6.30	-9.65	-13.25
	(9.62)	(9.41)	(9.78)
After*Shooting	-23.51	-3.16	-2.22
	(19.43)	(9.06)	(8.15)

Note: Table A.3 presents difference-in-differences regression estimates using outcomes three years before shootings for the number of student in grades 9 as well as for math and English proficiency rates. The coefficient of interest is After*Shooting School. We use clustered standard errors at the district level. Coefficients for school and year fixed effects are not shown. *** p<0.01, ** p<0.05, * p<0.1.

Source: Common Core of Data (CCD) from the National Center for Education Statistics (NCES). Test results and other variables are extracted from each school's report card and from data files posted by each state's Department of Education.

Table A.4: Effect of Homicidal Shootings on Test Results - Matching Estimates

	(1)	(2)
	Fraction Proficient in	
	Math	English
Kernel	-10.17***	-8.43***
	(2.47)	(2.40)
Caliper	-10.75***	-9.17***
	(2.48)	(2.41)
Nearest Neighbor	-7.79***	-5.15*
	(3.58)	(3.13)

Note: Table A.4 presents matching regression estimates for math and English proficiency rate. Matching regressions are based on state, area (city, suburb, town or rural), size of school and number of teachers. Table A.4 presents three types of matching estimates: Kernel, Caliper and Nearest Neighbor. The reported coefficient is the variable of interest: the shooting variable. *** p<0.01, ** p<0.05, * p<0.1.

Source: Test results and other variables are extracted from each school's report card and from data files posted by each state's Department of Education.

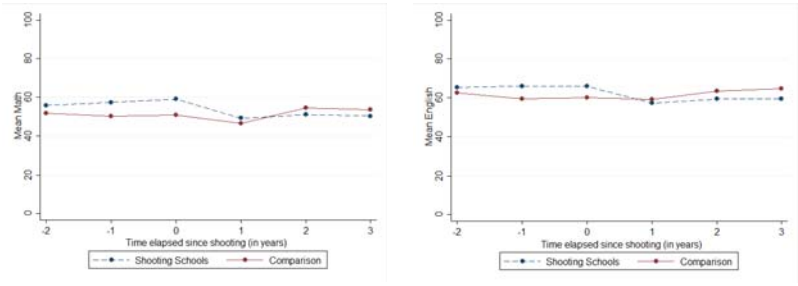

Figure A.1: Effect of Shootings using Propensity Matching Estimator

Table A.5: Effect of Homicidal Shootings on Test Results - Pooled Interrupted Time Series Estimates

	(1) Fraction Proficient in Math	(2) Fraction Proficient in English
After*Shooting	-4.56*	-3.39*
	(2.42)	(2.20)
After*Shooting*Time	-0.15	-0.20
	(0.54)	(0.59)
Absolute Effect 2 years after shooting	-4.85***	-3.80**
	(1.59)	(1.61)

Note: Table A.5 presents pooled interrupted time series design estimates for math and English proficiency rates. After*Shooting represents the change in level after a shooting. After*Shooting*Time represents the change in trend. *** p<0.01, ** p<0.05, * p<0.1.
Source: Test results and other variables are extracted from each school's report card and from data files posted by each state's Department of Education.

Appendix B

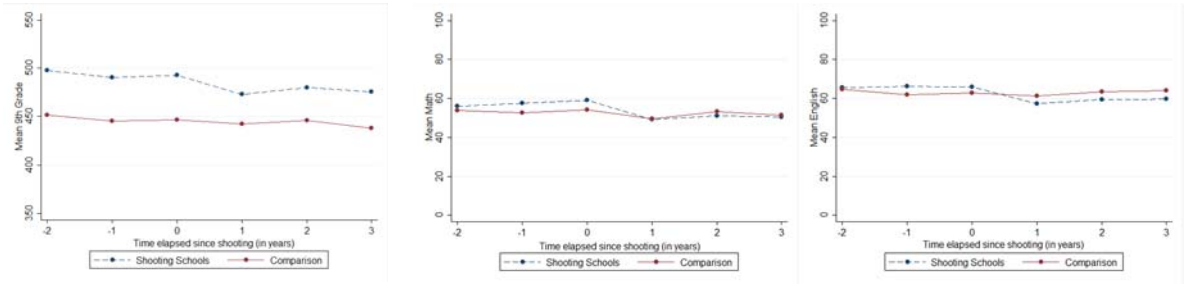

Figure B.1: Effect of Shootings on High-Poverty Schools

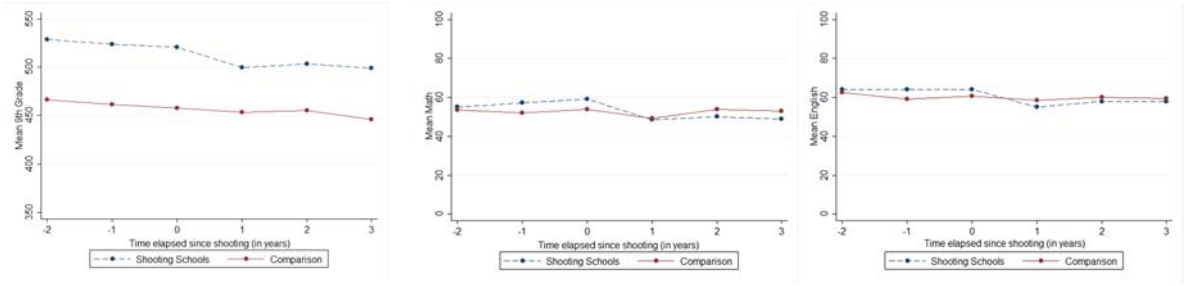

Figure B.2: Effect of Shootings on Schools with Open-Enrollment

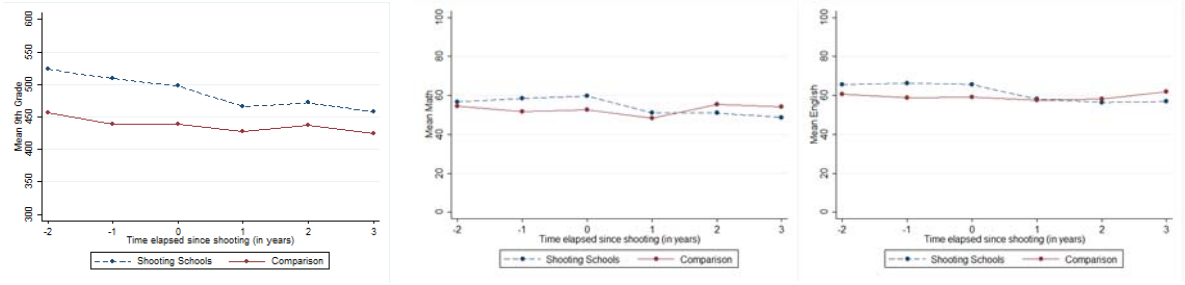

Figure B.3: Effect of Multiple-Homicide Shootings

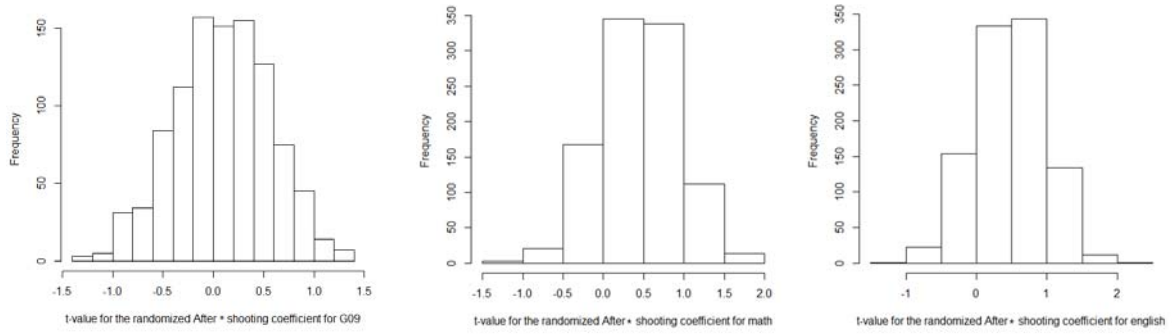

Figure B.4: Distribution of t-values from Randomization for Enrollment in Grade 9 and Math and English Proficiency Rates

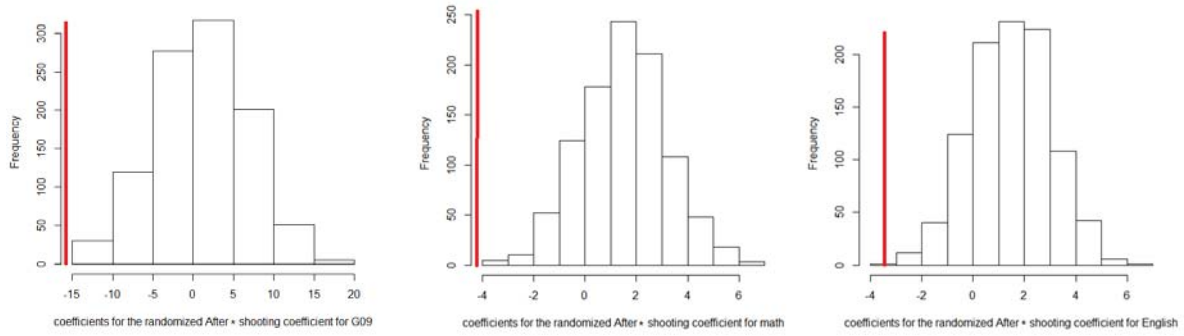

Figure B.5: Distribution of Coefficients from Randomization for Enrollment in Grade 9 and Math and English Proficiency Rates. Vertical line represents estimates from our main specification.

Appendix C

Table C.1: Effect of Shootings on Cumulative Level of Achievement

	Probability of Student Reaching Achievement Level			
	2, 3, 4, or 5	3, 4 or 5	4 or 5	5
Math Test	0.005	-0.012	-0.042**	-0.104***
	(0.015)	(0.012)	(0.017)	(0.039)
English Test	-0.106***	-0.116***	-0.102***	-0.104***
	(0.020)	(0.017)	(0.017)	(0.019)

Note: Table C.1 investigates the distributional impact of shootings on students using student-level data from the California Department of Education. Using conditional fixed effects logit models with student-level fixed effects, we study the probability of students achieving various levels on math and English tests after a shooting. The sample is restricted to students who took tests both before and after a shooting. The level of math and English proficiency for students in the seven districts are: far below basic (1), below basic (2), basic (3), proficient (4), and advanced (5). Column 1 estimates the probability of reaching achievement level 2, 3, 4, or 5 after the shooting. As we move right from column 1, the remaining columns restrict the outcome to higher levels of achievement. The coefficient of interest is After*Shooting School for math and English tests. Estimates for student and year fixed effects are not shown.
*** p<0.01, ** p<0.05, * p<0.1.
Source: Student-level data from California provided by the California Department of Education (CDE).

Table C.2: Effect of Shootings by Gender using Student-Level Data

Male Students	Probability of Achieving Proficiency in Math (Level 4 or 5)	Probability of Achieving Proficiency in English (Level 4 or 5)
After	-0.062***	-0.010
	(0.014)	(0.013)
After*Shooting	-0.030	-0.094***
	(0.023)	(0.024)
Observations	125,649	138,731
Number of Students	62,238	65,190

Female Students	Probability of Achieving Proficiency in Math (Level 4 or 5)	Probability of Achieving Proficiency in English (Level 4 or 5)
After	-0.098***	-0.020
	(0.015)	(0.013)
After*Shooting	-0.054**	-0.110***
	(0.024)	(0.024)
Observations	121,215	131,383
Number of Students	58,755	60,841

Note: Table C.2 investigates the impact of shootings on students by gender using student-level data from the California Department of Education. Using conditional fixed effects logit models with student-level fixed effects, we study the probability of students reaching level 4 or 5 on math and English tests. The sample is restricted to students who took tests both before and after a shooting. Estimates for student and year fixed effects are not shown. *** p<0.01, ** p<0.05, * p<0.1.

Source: Student-level data from California provided by the California Department of Education (CDE).

Table C.3: The Effect of Shootings using Mixed Effects Model

	Probability of Proficiency Level in	
	Math(Level 4 or 5)	English (Level 4 or 5)
	Odds Ratio	
After	0.820***	1.052**
	(0.025)	(0.024)
After*Shooting	0.858***	0.934*
	(0.042)	(0.034)

Note: Table C.3 investigates the impact of shootings on students using student-level data from the California Department of Education. Using mixed effects logistic models with school level random effects, we study the probability of students achieving level 4 or 5 in math and English. The sample is restricted to students who took tests both before and after a shooting. The level of math and English proficiency for students in the 7 districts are: far below basic (1), below basic (2), basic (3), proficient (4), and advanced (5). We use standard errors that do not make parametric assumptions. *** p<0.01, ** p<0.05, * p<0.1.
Source: Student-level data from California provided by the California Department of Education (CDE).