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THE EFFECT OF COMMUNITY TRAUMATIC EVENTS ON STUDENT ACHIEVEMENT: EVIDENCE FROM THE BELTWAY SNIPER ATTACKS

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ABSTRACT

Community traumatic events such as mass shootings, terrorist attacks, and natural or man-made disasters have the potential to disrupt student learning in numerous ways. For example, these events can reduce instructional time by causing teacher and student absences, school closures, and disturbances to usual classroom routines. Similarly, they might also disrupt home environments. This paper uses a quasi-experimental research design to identify the effects of the 2002 "Beltway Sniper" attacks on student achievement in Virginia's public schools. In order to identify the causal impact of these events, the empirical analysis uses a difference-in-differences strategy that exploits geographic variation in schools' proximity to the attacks. The main results indicate that the attacks significantly reduced school-level proficiency rates in schools within five miles of an attack. Evidence of a causal effect is most robust for third grade reading and third and fifth grade math proficiency, suggesting that the shootings caused a decline in school proficiency rates of about five to nine percentage points. Particularly concerning from an equity standpoint, these effects appear to be entirely driven by achievement declines in schools that serve higher proportions of racial minority and socioeconomically disadvantaged students. Finally, results from supplementary analyses suggest that these deleterious effects faded out in subsequent years.

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I. Introduction

In contrast to the significant drop in crime in the United States over the last two decades, the frequency of community traumatic events, such as terrorist attacks, mass shootings, and natural or man-made disasters has increased during this time period. For example, a study conducted by the Federal Bureau of Investigation (FBI) identified 160 incidents involving active shooters, in which 486 individuals were killed and 557 individuals were wounded between 2000 and 2013 (U.S. Department of Justice, 2013).[1] The frequency with which these events occur has increased significantly during this time period, as an average of 6.4 active shooter incidents occurred annually between 2000 and 2006 compared with an average of 16.4 such incidents per year between 2007 and 2013. Another study focusing on the time interval between incidents reached a similar conclusion (Cohen et al., 2014). This pattern has heightened awareness of the need for effective policies designed to protect children and communities from the direct and indirect effects of such violent acts.[2]

Accumulating evidence indicates that exposure to violent traumatic events, such as terrorism, random school shootings, and community traumatic events in general have deleterious impacts on the health and well-being of children, reflected by depression, aggressive behavior, anxiety and stress, social and emotional problems, and impaired cognitive development and academic achievement (Hoven et al., 2005; Fremont, 2004; Daniels and Haist, 2012; Carrell and Hoekstra, 2010; Danese et al., 2009; Wendling, 2009; Currie and Tekin, 2012; Di Pietro, 2015).

[1] According to the FBI, "Active shooter is a term used by law enforcement to describe a situation in which a shooting is in progress and an aspect of the crime may affect the protocols used in responding to and reacting at the scene of the incident. Unlike a defined crime, such as a murder or mass killing, the active aspect inherently implies that both law enforcement personnel and citizens have the potential to affect the outcome of the event based upon their responses." (U.S. Department of Justice, 2013).

[2] One such example is the Investigative Assistance for Violent Crimes Act of 2012, which authorizes the Department of Justice to investigate mass shootings in public places.

The potential effects of community traumatic events on student learning can operate through both direct and indirect channels. The direct channels can include school absenteeism and poor academic performance at school due to a lack of focus associated with anxiety and fear, while indirect channels can include disruptions to processes of learning from parents and teachers who may experience problems themselves. There is also evidence to suggest that children do not have to be direct victims or witnesses of community traumatic events to be harmed. Accordingly, indirect exposure such as learning about a violent death or serious injury, the fear of death to self or a family member, an increased sense of vulnerability or helplessness, or repeatedly engaging with trauma-related stories via the media can also harm children's well-being (Pfefferbaum et al., 2001; Becker-Blease et al., 2008; Calderoni et al., 2006; Saylor et al., 2003; Holman et al., 2014).

This paper provides insights into the impact of community traumatic events on student achievement using the 2002 "Beltway Sniper" attacks as a natural experiment.[3] As explained in detail in Section II, the Beltway Sniper attacks were a series of coordinated shootings of individuals targeted randomly, but living in Washington D.C. metropolitan area and along Interstate 95 in Virginia. The attacks left 10 people dead and three people critically injured over a period of three weeks in October 2002. The question considered in this paper is an important one because the relationship between community traumatic events and student achievement has implications for both proactive and reactive policymaking. Regarding the former, debates over the costs and benefits of policies to prevent community traumatic events or minimize their harmful consequences on the public could be significantly influenced by evidence that these

[3] Our definition of community traumatic events refers to incidents that affect entire communities by causing physical, emotional, psychological distress or harm to persons living in them. Individuals exposed to these events must experience changes in their daily lives to an extent, which often overwhelms them and leads to conditions beyond their control, often resulting in depression, post-traumatic stress disorder, and even suicidality (Praetorius, 2006).

events have a negative impact on student achievement. For instance, if children who are indirectly exposed to these events suffer significant negative setbacks at school, this would provide another basis for efforts to identify policy interventions designed to prevent these events from occurring as well as to reduce exposure among children. Regarding the latter, the strength of the relationship between community traumatic events and academic achievement and the types of students who are most affected by the trauma associated with these events have important implications for the optimal provision of school and community resources following a traumatic incident.

Our analysis improves upon existing research along several dimensions. First, we carefully address the endogeneity of exposure to community traumatic events by exploiting schools' geographic distances from the locations of each of the sniper attacks as a measure of "intensity of treatment." In other words, variation in the intensity of exposure, as measured by the distance between schools and shooting sites, allows us to identify the causal impact of these attacks on student achievement using a difference-in-difference (DD) estimation strategy. More specifically, we compare the proficiency levels of students attending schools that are located near one of the shooting sites before and after the shooting incident to the proficiency levels of students attending schools farther away from the shooting sites. Proficiency rates are an important, policy relevant measure of schools' academic performance, as they are the measure by which schools are graded by the federal No Child Left Behind Act (NCLB).

Second, unlike most of the extant literature that focuses on outcomes of psychological well-being, we consider academic achievement of children as the outcome measure. Psychological manifestations of traumatic events on children may sometimes be latent or the symptoms may not be promptly recognized by parents. It is also possible that children and parents are reluctant to acknowledge and seek help for these problems due to social stigma. Unlike psychological symptomology, academic outcomes are arguably more objective and easily observable—by parents, teachers, and school administrators—measures of the consequences of psychological trauma associated with exposure to community traumatic events. Because affected students may have negative spillovers on their classmates, a finding of any impact on academic outcomes would also provide a compelling justification for the public and policymakers to be concerned about how to best help affected children (Carrell and Hoekstra, 2010).

Third, our outcome measures are school level proficiency rates obtained from official school records. Therefore, they are not subject to the reporting error potentially inherent in subjective parental reports of their children's academic proficiency. This is potentially an important improvement because parental reports can be particularly problematic in this case if, for example, trauma associated with these events impairs parents' ability to report or remember accurately. Alternatively, some parents may have a tendency to relate any academic problems their children are experiencing to these tragic events.

Finally, unlike most other man-made or natural disasters, terrorist attacks, or school shootings, the beltway sniper attacks were prolonged and intermittent in nature. In this sense, the psychological manifestations caused by the beltway sniper attacks may more closely resemble those caused by the chronic community violence that is endemic to many inner city neighborhoods in the United States.[4] Millions of children suffer from at least one traumatic event while growing up. For example, studies have shown that 15 percent to 43 percent of girls and 14 percent to 43 percent of boys experience at least one traumatic event while growing up

[4] A recent working paper by Monteiro and Rocha (2013) considers drug battles between gangs that take place in favelas (slums) in Rio de Janeiro. Using variation in violence that occurs across time and space when gangs battle over territories, the authors find that exposure to such violence reduces student achievement in math. To the extent that drug related gang violence constitutes an extreme episode of community wide traumatic event, this study is informative for the purposes of our analysis.

(Friedman, 2014). Regardless of the cause of the traumatic stressors, these children are likely to exhibit a wide range of reactions that can impact many facets of their lives, including educational achievement and attainment. Therefore, the results of the current study may provide a more reliable and representative assessment of the impact of childhood exposure to the type of trauma experienced by a large segment of the United States population.

To our knowledge, this is the first comprehensive analysis of the impact of community wide random shootings on student achievement. Having said that, there is a voluminous literature in psychology on the relationship between childhood exposure to traumatic events and psychological well-being. Many studies in this literature suggest an association between exposure to traumatic events and psychological health. However, most of the related literature is based on conceptual considerations and descriptive empirical analyses. Empirical investigations typically rely on information drawn from samples of interviews conducted by individuals who had been exposed to traumatic events such as the September 11th, 2001 terrorist attack (Beuschesne et al., 2002; Halpern-Felsher and Millstein, 2002; Hoven et al., 2005; Neria at al., 2011), the 1995 Oklahoma City bombing (Pfefferbaum et al., 1999, 2000), or Hurricane Katrina (Spell et al., 2008). Several empirical studies acknowledge the potential endogeneity of exposure to community traumatic events, but attempt to address the problem of potential confounders by conditioning on a minimal set of controls in multivariate regressions. This is an important limitation of the literature because children are unlikely to be exposed to these events exogenously. In other words, children who are exposed to community traumatic events may have certain attributes that contribute to their poor outcomes regardless of the traumatic events that they are exposed to. For example, if these events are more likely take place in neighborhoods with high poverty and crime rates or in communities lacking the necessary resources to cope with the aftermath of traumatic events, conclusions drawn from correlational studies may overestimate the true impact of exposure to more specific community traumatic events. Similarly, parenting style and specific behaviors adopted by parents in response to community traumatic events can influence the extent of the harm caused to their children.[5] For example, some parents may attempt to minimize the negative impact of these events on their children by limiting children's exposure to news media or by spending more time with them. Alternatively, rigid work schedules or their own stresses may limit the amount of extra care and emotional support that they are able to provide to their children during these times. Even worse, the stress experienced by parents might even lead to counterproductive behaviors, which may further fuel anxiety and fear among children, for example, by following trauma-related news stories in front of their children. Failing to account for these behavioral responses or changes in parenting styles would cause an upward bias in the case of "negative" parenting style and a downward bias in the case of "positive" parenting style.

Another limitation is that the extant literature largely relies on self-reported retrospective data drawn from interviews of parents about the exposure of their children to these events or interviews of affected older children. Since information on both exposure and reactions come from the same source, these data may suffer from systematic measurement error. For example, parents whose children are performing poorly at school may attribute this problem to past exposure to a traumatic event. Relatedly, as a practical matter, the analysis samples are self-selected in the sense that researchers only have data on individuals who agreed to be interviewed. In summary, credible estimation of the impact of community traumatic events on children's well-being poses numerous challenges that the extant literature has failed to systematically address.

[5] There are studies emphasizing the importance of parental behaviors in influencing the consequences of traumatic events on children (Plybon and Kliewer, 2001; Buka et al., 2001), which have been shown to vary by socioeconomic status (Guryan et al., 2008; Kalil et al., 2012).

We contribute to this literature by applying a DD method to statewide, objective data on primary school proficiency rates that are immune to these concerns.

Our results provide robust evidence in support of a causal relationship between the sniper attacks and third and fifth grade math and reading proficiency. Specifically, the results suggest that the shootings caused a decline in school proficiency rates of about five to nine percentage points. These effects are similar in magnitude to those obtained in Marcotte and Hemelt (2008) of the impact of ten unscheduled snow-related school closures on math and reading assessments of students in the third, fifth, and eighth grades in Maryland. Our estimates are also large enough to have changed the standing of a nontrivial number of schools' Adequate Yearly Progress (AYP) designations in the first year of the No Child Left Behind Act (NCLB). These results are fairly robust to the operationalized definition of "closeness" to a sniper attack, controlling for time-variant school characteristics and school district linear time trends, and accounting for overlap in the schools affected by the 9/11 Pentagon attack, which had occurred in the year preceding the sniper attacks. Particularly concerning from an equity standpoint, harm caused by the sniper attacks appears to be primarily driven by achievement declines in schools that predominantly serve racial minority and socioeconomically disadvantaged students. Finally, we show that the reductions in school proficiency caused by the sniper attacks were relatively short-lived, fading out in subsequent academic years.

The remainder of the paper is organized as follows. Section II provides an overview of the Beltway Sniper attacks. Section III describes our data, while Section IV discusses our econometric method. The results are summarized in Section V and conclusions are presented in Section VI.

II. The Beltway Sniper Attacks

The Beltway sniper attacks were a series of coordinated shootings carried out in the Washington D.C. metropolitan area and along Interstate 95 in Virginia in October 2002. The locations of these shootings are marked in the map displayed in Figure 1. Between October 2nd and 24th, ten people were shot fatally and another three people were critically injured by rifle bullets, fired from some distance with marksman accuracy. Five of the shootings took place in Virginia, resulting in three fatalities and two serious injuries. One of the shootings targeted a 13-year-old student, who was wounded by a single bullet that struck him in the chest “as he waited in front of the school for the doors to be opened” ("John Muhammad v. Maryland," 2007, p. 12). The shootings sparked one the largest criminal manhunts in U.S. history until the two suspects, who were later found guilty of these shootings, were captured on October 24th.[6]

The shootings were sporadic in nature, as victims were shot while mowing grass, reading on a bus station bench, walking in the parking lot of a grocery store, and pumping gas at a gas station. The unexplained and random nature of the shootings inflicted a tremendous deal of stress and fear among people living in and around the communities where the shootings had occurred. This stress and fear prompted many local residents to develop new behaviors or to modify existing patterns of behavior such as skipping work and school, running or weaving through parking lots, cancelling outdoor activities, and avoiding shopping centers and gas stations nearby Interstate 95 (Coppola, 2004; Mitchell, 2007; Zivotofsky, 2005). The shootings also occupied both local and national media attention during this period and this further contributed to public fear and anxiety (Mitchell, 2007). Media coverage was so intense that 503 articles appeared in the Washington Post alone during the three-week period of shootings (Muzzatti and

[6] One of the perpetrators was sentenced to death and his execution was carried out in 2009. The other was sentenced to six consecutive life sentences without the possibility of parole.

Featherstone, 2007).[7]

As fear quickly spread throughout neighboring communities, many parents reacted by preventing their children from taking the school bus or walking home alone and instead driving children to school. Schools went on "lockdown" and cancelled outdoor events such as soccer games and field trips.[8] Schools in Chesterfield, Goochland, Hanover, Henrico and Powhatan counties in Virginia and the city of Richmond closed for multiple days as a result of the shootings (United Press International, October 22, 2012) The number of school children affected by school closings reached about 200,000 in Richmond alone (The Times, October 24, 2002). Furthermore, many parents voluntarily kept their children home even when schools remained open. As a result, there was a significant increase in absenteeism with daily attendance rates falling as low as 10 percent at several elementary schools close to one of the shooting sites (Schulte, 2002).

Porter (2010) provides an in depth qualitative analysis of the experiences of school personnel and the emergency response by school district administrators to the shootings in Montgomery County, Maryland. While this study does not provide any insights into the potential impact of the attacks on student achievement, it is helpful in understanding the psychological ordeal experienced by various actors involved in the lives of children affected by the shootings, including parents, teachers, and school administrators. Aside from this qualitative study, most of our knowledge about the impact of the sniper attacks comes from reviews of newspaper articles and a few studies based on interviews of a small number of parents and children who had lived nearby shooting sites. In these studies, it has been suggested that geographic proximity to the

[7] Accordingly, over 70 percent of citizens reported that they had followed the news more than usual during the weeks of the sniper attacks, which highlights the role of media in shaping the public perceptions during the period (Coppola, 2004; Mitchell, 2007).
[8] See http://www.crimemuseum.org/crime-library/the-washington-dc-sniper.

attack sites is an important contributor to psychological symptomology exhibited by children such as increased vulnerability and stress (Butler et al., 2003; Becker-Blease et al., 2008; Mitchell, 2007).

Becker-Blease et al. (2008) analyzed data from the Developmental Victimization Survey, which was conducted between December 2002 and February 2003. Focusing on the sample of respondents from Maryland (n=30), Virginia (n=49) and Washington, D.C. (n=2), the authors found increased stress and worry among children, with more apparent signs among minority children and those from low-income households. Similarly, these children were also more likely to change their daily routines during the period of shootings. Furthermore, children living in neighborhoods with close proximity to the shooting locations were likely more severely affected than children elsewhere in Virginia and Maryland, as well as the rest of the U.S., not only because the snipers were only targeting people in that area, but also because these children had likely been exposed to more intense levels of local media coverage (Becker-Blease et al., 2008).

Self-Brown et al. (2011) studied the psychological responses of children to the sniper attacks through telephone interviews conducted in May 2003 by 355 parents who had children between ages 2 and 27 and had lived in Washington D.C. or in the surrounding counties during the sniper attacks. About 32 percent of parents participating in the interviews reported that their children had experienced at least one psychological stress symptom related to the sniper attacks.

There is also evidence to suggest that the shootings took a toll on the psychological well-being of both the parents and the teachers (Schulden et al., 2006; Porter, 2010). Using data collected from a survey of 1,205 adults who had lived in the communities affected by the shootings in October 2002, Schulden et al. (2006) showed that 44 percent of parents had experienced at least one traumatic stress symptom and 7 percent reported symptoms consistent with a diagnosis of posttraumatic stress disorder. Furthermore, the authors found that females who lived within five miles of any sniper attack were at greatest risk for traumatic stress.

In summary, there is widespread evidence to suggest that the sniper attacks of October 2002 had a negative impact on the psychological well-being of citizens, especially children and those from socioeconomically disadvantaged backgrounds, and those living in neighboring communities. Given the well-documented relationship between psychological well-being and school outcomes (e.g., Carrell and Hoekstra, 2010), exposure to these attacks might have also affected student achievement, although this question has not been studied to date. The goal of the present study is to fill this gap in the literature.

III. Data

Academic performance is measured annually at the school level in the form of proficiency rates. These rates measure the percentage of students who score at or above a pre-determined “proficiency score” on Standards of Learning (SOL) standardized tests administered each spring in Virginia’s public schools. These school-level proficiency rates are made publicly available by the Virginia Department of Education and are based on student performance on SOL tests that are typically administered each May.[9] We focus on third, fifth, and eighth grade proficiency in mathematics and English Language Arts (ELA) as these SOL tests have been administered annually by the state since the spring of 1998. Importantly, while the tests themselves have evolved over time, the basic reporting of schools’ proficiency rates has not.

Our primary analysis focuses on the academic years 1997-98 through 2002-03. Henceforth, we refer to academic years by the spring semester (when the tests were administered), so the impact of the sniper attacks on test scores would appear in 2003. The DD

[9] See http://www.pen.k12.va.us/testing/achievement_data/archived/index.shtml.

identification strategy exploits variation in schools' geographic proximity to the attack locations. We argue that this is a plausible measure of the intensity of treatment (i.e., exposure to the sniper attacks), though arguably all children in the state might have been affected via exposure to intense media coverage. Therefore, there may have been spillover effects on the "control" schools that were farther away from the attacks. However, it is important to note that such a bias would work *against* finding significant effects of these attacks on school proficiency rates, and thus our estimates may be interpreted as lower bounds of the "true" treatment effects. Sensitivity analyses consider various definitions of schools' treatment statuses, or "closeness," to the attacks.

Closeness can be defined by either the "commute" or "crow flies" distance between each school's street address and that of the nearest sniper shooting.[10] The results are quite robust to which of these definitions is used to construct measures of "closeness," so we focus on the "crow flies" distance for simplicity. After choosing how to measure the distance between each school and its nearest sniper attack, we then must assume a functional form through which distance enters the econometric model. The preferred baseline model uses a simple binary indicator for "within 5 miles" of at least one shooting. However, as shown in Appendix Table A1, the main results are robust to using alternative definitions such as "within 10 miles," multiple categorical indicators (i.e., within 5 miles, 5 to 10 miles, and > 10 miles), and a continuous quadratic function of miles to the nearest attack. Again, these alternatives yield qualitatively similar results, so we focus on the "within 5 miles" binary measure of "treatment" for simplicity.

[10] Both types of distances were generated by the website freemaptools.com/how-far-is-it-between.htm, which uses an algorithm that evaluates potential driving routes to identify the shortest route between two geocoded addresses for the "commute" distance and latitude and longitude geocodes to compute straight line "as the crow flies" distances.

Our identification strategy assumes that sniper attacks had either no or little impact on children who attended schools relatively far from the attacks. This assumption does not require the proficiency levels of these students to be similar to those of their counterparts who attended schools located in close proximity to the shootings. Instead, it requires the proficiency levels to be trended similarly between the two groups of students. Indeed, schools that are farther away from the shooting sites are mostly located in rural counties. As a result, the composition of students attending these schools differs from that in schools close to shooting sites in several dimensions including race, socioeconomic status, and academic achievement. There are also corresponding differences in school characteristics such as school enrollment (size) and student-teacher ratio. While this does not necessarily constitute a problem for our analysis, we exclude schools that are outside a 50-mile radius of all sniper shootings from the analytic sample in an attempt to create a control group that resembles the treatment group more closely. Exclusion of these schools also amounts to a conservative approach since, if anything, it would bias our analysis against finding an effect given the likelihood of spillover effects on the control group. Finally, eliminating these schools guards against the possibility that proficiency levels of students in rural schools were trending differently than those of relatively more urban schools in the Washington, D.C. suburbs, perhaps due to differences in district-level policies. This is not an implausible scenario since district policies may reflect in part the political and cultural preferences of citizens, which are likely to differ significantly between rural and urban communities. Nonetheless, the main results are robust to using alternative cut-offs such as 40 miles or 60 miles and to including all Virginia schools in the analytic sample.

We augment the school-level proficiency and “closeness to sniper attack” data with information on time-variant school-level characteristics that are publicly provided in the National

Center for Education Statistics' Common Core of Data.[11] Specifically, these variables include total enrollment, percent black, percent Hispanic, percent eligible for free or reduced price lunch, number of full time equivalent teachers (FTE), and pupil-teacher ratio. All but the last two variables have been collected since 1998, while FTE and pupil-teacher ratios are only available from 1999 forward. We therefore imputed 1998 values of FTE and pupil-teacher ratio, though we also consider models that exclude these two imputed variables and the main results are robust.[12] Importantly, controlling for these time-variant school characteristics in the DD regression models increases the precision of the DD estimates and controls for potentially confounding changes in schools' student and teacher characteristics.

Table 1 shows that while only 5 of the 13 sniper shootings occurred in Virginia, the shootings that occurred in Maryland and in Washington D.C. plausibly affected Virginia's public school students as well, given the proximity and overlap in media coverage between Northern Virginia and the areas outside Virginia in which sniper attacks occurred. For example, the October 3rd sniper shooting in Kensington, Maryland was within 5 miles of two Virginia public schools and within 10 miles of 72 Virginia public schools. Similarly, all but two of the Maryland attacks were within 10 miles of at least one Virginia public school and four of the Maryland attacks were within 10 miles of more than ten Virginia public schools. Thus, Table 1 suggests that the earlier attacks that occurred in Maryland and in Washington D.C. potentially affected residents of Virginia and contribute to the geographic variation in "treatment status."

Table 2 summarizes the proficiency rates of the universe of elementary and middle schools in Virginia, both overall and separately by distance to the nearest sniper attack.

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[11] See http://nces.ed.gov/ccd/.

[12] Values were imputed as the fitted values of linear regressions containing school fixed effects, linear time trends, observed total enrollment, percent black, percent Hispanic, and percent eligible for free or reduced price lunch. Results are robust to only controlling for the four school-level characteristics that are observed starting in 1998.

Proficiency rates ranged from about 60 to 80 percent. To put these numbers in perspective, the thresholds for making AYP in Virginia in the first two years of NCLB were 61 in ELA and 59 in mathematics (Virginia Board of Education, 2010). Interestingly, columns 2 and 3 show that there are statistically significant differences between "treated" and "control" schools in average proficiency rates. This suggests that there were some systematic differences between schools by schools' proximities to an attack, which is unsurprising as the attacks were relatively close to the Washington, D.C. metropolitan area. These differences further motivate our decision to restrict the sample to schools within 50 miles of at least one attack and highlight the importance of accounting for preexisting differences between "treated" and "control" schools in the econometric model.

Columns 4-6 of Table 2 present the same summary statistics for the analytic sample of schools within 50 "as the crow flies" miles of at least one sniper attack. It is immediately obvious that these control schools more closely resemble the treated schools, as proficiency gaps between treated and control schools tend to be smaller and lose their statistical significance. This is the analytic sample that all subsequent analyses utilize.

Table 3 similarly summarizes schools' distances to the sniper attacks and the time-variant school characteristics observed in the Common Core of Data. A nontrivial number of Virginia public schools were proximate to at least one sniper attack. Among the elementary schools summarized in columns 1-3, which typically provide kindergarten through fifth grade, the average school in the analytic sample (within 50 miles of at least one sniper attack) was about 16 miles from at least one sniper attack. About 16 percent of elementary schools were within 5 miles "as the crow flies" of a sniper attack and 37 percent were within 10 miles. There are several differences between treated and control elementary schools, as defined by the "5 mile" treatment. Treated schools tend to be smaller, but this difference is not significantly different from zero. Racial, ethnic, and socioeconomic differences in enrollments are statistically significant, however, as treated schools' enrollments are less black, more Hispanic, and more poor. Despite being smaller, on average, treated elementary schools have significantly more FTE teachers and significantly lower pupil-teacher ratios.

Columns 4-6 of Table 3 similarly summarize middle schools, which typically serve grades 6-8. On average, middle schools are about 3 miles farther away from the nearest sniper shooting than are their elementary school counterparts. This is due to the centralized nature and smaller number of middle schools, as multiple elementary schools typically feed into each middle school. Still, the percentages of middle schools within 5 or 10 miles of a sniper shooting are quite similar to those of elementary schools. Middle schools are much larger than elementary schools, on average, again because it is generally the case that several elementary schools feed into each middle school. The demographic and socioeconomic compositions of middle schools' student enrollments are similar to those of elementary schools. Furthermore, the differences in student background between treated and control middle schools also follow a pattern similar to that of elementary schools. The same is also true for pupil-teacher ratios. Again, these similarities are unsurprising because both types of schools are serving the same communities and school districts.

IV. Econometric Model

Our goal is to estimate the impact of exposure to the beltway sniper attacks on academic achievement. To accomplish this goal, we specify the following reduced form empirical model:

$$y_{st} = \beta_0 + \beta_1 X_{st} + \beta_2 Close_s \times d_{2003} + \lambda_t + \delta_s + \varepsilon_{st}, \quad (1)$$

where y_{st} is the proficiency rate of school s in academic year t in a particular grade and subject.[13] The time-varying school characteristics described in the previous section are represented by the vector X_{st}. The variable "$Close_s$" is a binary indicator equal to one if the school is within 5 miles of any shooting location, and zero otherwise. Sensitivity analyses reported in Appendix Table A1 specify "closeness" as either a continuous quadratic function of the school's distance to the closest attack site or a pair of mutually exclusive categorical indicators for "within 5 miles" and "5 to 10 miles from a sniper attack," with the omitted reference category being "more than 10 miles from an attack." The binary indicator d_{2003} equals one in the academic year 2003, which is the treatment year in which the sniper attacks occurred, and zero otherwise. Year fixed effects (λ_t) control for any secular time trends in the outcome variables and year-specific statewide shocks to academic achievement associated with, for example, national or state level policies. School fixed effects (δ_s) account for any unobserved time-invariant heterogeneity between schools in Virginia. Finally, ε_{st} represents an idiosyncratic error term. The coefficient of interest is β_2, which represents the average effect of being within five miles of a sniper attack on school proficiency. All versions of equation (1) are estimated using the Ordinary Least Squares (OLS).[14] In all analyses standard errors are robust to clustering at the school level, making statistical inference robust to arbitrary forms of both heteroskedasticity and serial correlation within schools over time.[15]

A causal interpretation of the estimate of β_2 in equation (1) hinges on the "parallel trends" assumption required by the DD method. Intuitively, this means that while there may be pre-

[13] We estimated equation (1) using the natural logarithm of the outcome variables instead of levels. These results are similar to those presented in our paper and are available from the authors upon request.

[14] We also estimated the models by Weighted Least Squares (WLS) using schools' enrollments as weights (Solon, Haider, and Wooldridge, 2013). These estimates are similar to those presented in our paper and are available from the authors upon request.

[15] Clustering at the district level yields nearly identical statistical inference, which is unsurprising because schools are nested in districts and all models condition on school fixed effects. We prefer clustering at the school level because the treatment varies at the school level.

existing differences between “treated” and “control” schools, there are no pre-existing differential trends between “treated” and “control” schools. We examine the implications of this assumption in two ways. First, we follow Marcotte and Hemelt (2008) in explicitly relaxing the “parallel trends” assumption by estimating an augmented version of equation (1) that controls for school district-specific linear time trends. This specification accounts for any unobservable district level characteristics and policies that are trending linearly over time and predict proficiency rates, which is potentially important given that policies and decisions regarding school closures are typically made at the district level (Marcotte & Hemelt, 2008). Note that an alternative approach could be to estimate models with school-specific linear trends. However, with about 540 elementary schools and 260 middle schools in the analytic sample and only 6 years of data, we lose a commensurate number of degrees of freedom by doing so. As a result, estimates of β_2 in models that condition on school specific linear trends are less precise, though are generally of the same sign as those obtained from the estimation of equation (1) and its district trend analog. For these reasons, we present variants of equation (1) that condition on school-district time trends. Given that school policies are typically determined at the district level, schools within districts are likely to be trending similarly.

Second, we relax and directly test the “parallel trends” assumption by estimating an event-study specification that allows the treatment to have an effect in the years prior to the sniper attacks. If these placebo effects are meaningful in the statistical sense, particularly in the year before the sniper attacks, we would worry that the “parallel trends” assumption fails and that significant estimates of β_2 in the baseline equation (1) are spuriously driven by pre-existing differential trends in the treated schools. It is reassuring, then, that in the results presented below both the district-trend and event-study models provide evidence that is consistent with the sniper attacks having a causal effect on schools' math and ELA proficiency rates.

Finally, we estimate the baseline and district trend models separately by school type to test for the presence of heterogeneous effects, as there are several reasons why schools serving different student populations might be differentially affected by community traumatic events. Specifically, because the aggregate data do not distinguish between proficiency rates of different student subgroups, we divide schools into terciles based on the percentage of total 2003 enrollment that is black, and the percentage of total 2003 enrollment that is eligible for free or reduced price lunch (FRL). There are at least two reasons to expect that the academic achievement of socioeconomically disadvantaged and racial minority students was disproportionately harmed by the disruptions and stress caused by the sniper attacks. First, as discussed in section II, parental behaviors have the potential to mitigate the impact of community traumatic events on children (Plybon and Kliewer, 2001; Buka et al., 2001). Given the large research literature documenting the differences by SES in both the quality and quantity of time parents spend with school-age children (e.g., Guryan et al., 2008; Kalil et al., 2012), it is plausible that high-SES parents had the resources necessary to provide support at home and outside the traditional school day to help children cope with the trauma. Second, recent research on the effects of weather-induced school closures and student absences on academic achievement finds that, at least in certain subjects and grade levels, the harmful effects of lost instructional time are greater in poorer schools (Marcotte & Hemelt, 2008; Goodman, 2014). Given that school closures and student absences are potential mechanisms through which the sniper attacks affected achievement, the harmful effects of sniper-induced absences and school closures might be greater in disadvantaged schools, if such schools are less able to provide the appropriate counseling and, more generally, struggle to solve the coordination problem inherent in public education (i.e., Lazear, 2001). Moreover, given that absenteeism rates are higher in disadvantaged schools (Goodman, 2014), another potential source of heterogeneity in the sniper attacks' effects on academic achievement is through larger effects of the attacks on student absences in low-SES schools.

V. Results

Our main results are presented in Table 4. Each cell in Table 4 contains the estimate of β_2 in a unique regression, which measures the effect of being within five miles of a sniper attack. We present estimates separately for both the ELA and math proficiency rates for each of grades three, five and eight. Column 1 of Table 4 reports estimates of β_2 in specifications that exclude time-variant school characteristics from the model while the estimates displayed in columns 2 and 3 successively add time-variant school characteristics and linear district time trends to the specification in column 1. All three sets of specifications condition on school and year fixed effects.

Column 1 of Table 4 shows that being within a five mile radius of a sniper attack is associated with lower pass rates in both subjects for all three grade levels. The estimated effects on five of the six proficiency rates are statistically significant at the one percent level and the sixth is statistically significant at the five percent level. Furthermore, the magnitudes are sizeable, ranging from about three to five percentage points. Taking the means presented in Table 2 as a basis, these estimates translate into effect sizes in the range of four percent for fifth grade ELA to 8.2 percent for fifth grade math.[16] Column 2 shows that these estimates are robust to controlling for time-variant school characteristics. Appendix Table A1 shows that these findings are robust to how "closeness" to a sniper attack is measured, as both continuous and nonparametric specifications strongly suggest that schools closer to sniper attacks experienced significant declines in proficiency rates in 2003 relative to schools that were farther away.

Column 3 of Table 4 presents estimates from a specification with district trends that relaxes the parallel slopes assumption. At first glance, these estimates are less precisely estimated than those in columns 1 and 2 and this difference is primarily due to a reduction in the size of the point estimates. Specifically, the magnitudes of the estimates in column 3 are smaller than those in columns 1 and 2 by about a factor of two. Nonetheless, after conditioning on linear district time trends we observe that being within a five mile radius of a sniper attack site is still associated with a statistically significant decrease in proficiency rates on third grade ELA and third and fifth grade math tests. In other words, while there is some evidence of differential trends in districts nearby the sniper attacks, the sniper attacks are associated with statistically significant negative deviations from those trends in three subjects. This result is consistent with previous research on the harmful effects of disruptions to learning, which finds that weather-related school closures have relatively larger effects on achievement in the lower grade levels (Marcotte & Hemelt, 2008). Moreover, it is important to emphasize that the estimated effects on math proficiency are the most robust to conditioning on district trends. This is consistent with the previous literature on the efficacy of school inputs that routinely shows that math achievement scores are more sensitive than ELA scores to shocks to school environments (e.g., Hanushek & Rivkin, 2010). Currie and Thomas (2001) speculate that this may be because

[16] The effect sizes are as follows for each of the six outcomes: 7.9 percent, 4.0 percent, and 8.2 percent for third, fifth, and eighth grade ELA and 6.2 percent, 8.2 percent, and 8.1 percent for third, fifth, and eight grade math, respectively.

children are more apt to learn reading skills at home, which suggests that, to the extent that the sniper attacks caused absences, school closures, and displaced instructional time during school days, it makes sense to see larger effects on math achievement.

Next we estimate an event-study version of equation (1) to trace out the trends in proficiency rates, separately for treated and control schools, year-by-year for the periods leading up to the year of the sniper shootings. As discussed in section IV, this provides a simple test of the "parallel trends" assumption required for consistency by the DD specification given in equation (1). Formally, this is done by augmenting equation (1) to include interactions between each of the year indicators with the *Close* treatment indicator. Event study estimates of specifications that control for time-variant school characteristics are presented in Table 5. Consistent with our earlier findings, the estimates of the coefficients on the interaction between the *Close* and 2003 (treatment year) indicators are negative and statistically significant for all six tests. Importantly, these treatment effect estimates are larger in magnitude than all of the other interaction terms. Intuitively, the goal of the event study analysis is to examine the differences between treatment and control schools in the years leading up to 2003, the academic year in which the sniper attacks took place. This is most easily accomplished visually, so we plot the interactions terms reported in Table 5, along with their 95 percent confidence intervals, in Figure 2.

As illustrated in Figure 2, there is a clear overall pattern of a statistically significant divergence in 2003 from the pre-sniper attack period trends. The aforementioned pattern is most pronounced for fifth and eighth grade English and third and fifth grade math. Furthermore, the estimates on the year indicators suggest that average pass rates had been increasing consistently over the analysis period. Interpreting the estimates on the interaction terms in conjunction with the individual year indicators supports the hypothesis that the sniper attacks decreased proficiency rates in nearby schools.

Given the evidence presented to this point, which suggests that the sniper attacks caused a statistically significant decrease in school proficiency rates in third grade ELA and third and fifth grade math, a natural question to consider is whether the trauma persisted into subsequent school years. The SOL tests continued in a similar form for two additional years following the academic year in which the sniper attacks had occurred. Accordingly, Table 6 presents estimates from models that utilize data through 2005. These models include the usual $Close \times d_{2003}$ interaction term and $Close \times Post$ interaction terms, where *Post* equals one if the academic year is 2004 or 2005, and zero otherwise. The specifications estimated in Table 6 are otherwise identical to the baseline specifications estimated in Table 4. Once again, the results presented in Table 6 are consistent with the sniper attacks having had a negative impact on students' academic achievement. Even in the most conservative models that condition on linear district time trends, reported in panel C of Table 6, the estimated effects of being within 5 miles of a sniper attack are uniformly negative and are statistically significant in three subjects: third grade ELA and third and fifth grade math. However, these effects do not appear to persist, as the estimated effects of proximity to a sniper attack in subsequent years tend to be statistically indistinguishable from zero and small in magnitude. It is perhaps unsurprising that we detect no persistent effects of the sniper attacks on proficiency rates in subsequent years, as the attacks occurred in October of 2002 and the 2004 tests were administered in May 2004, more than 18 months later. One possible explanation for the lack of persistent effects is that parents and school administrators recognized the decline in achievement in affected schools and responded in the following academic year to reverse these negative effects. Our data do not allow us to test these hypotheses. However, this is not an implausible scenario especially considering the strong incentives imposed by the NCLB to meet minimum achievement thresholds at the time. Regardless, this is a comforting finding in the sense that the negative impacts on school achievement associated with the sniper attacks appear to be relatively short-lived. Even though it may be possible to reverse the harmful impacts of community traumatic events on student achievement, doing so would still to come at a cost given the private parental and public resources that need to be reallocated towards remedying these problems. Therefore, efficiency losses associated with these attacks should not be overlooked. It is also important to note that while the effects on test scores may have faded out, effects on socio-emotional outcomes might persist, as Chetty et al. (2011) find that effects of primary school classroom quality on test scores "fade out" quickly, effects on non-cognitive measures in later grades and on earnings in adulthood persist.

The 2002 Pentagon Attack

It is important to note that the impact of any other traumatic event that might have happened elsewhere in the country during our analysis period would be captured by our year fixed effects. One potential exception is the terrorist attack on the Pentagon that occurred on September 11, 2001.[17] Given the close proximity of the Pentagon to several of the Virginia communities affected by the sniper attacks that occurred almost one year later, it is possible that persistent psychological symptomology of trauma associated with the September 2001 attacks,

[17] The attack on the Pentagon was part of a larger, coordinated terrorist attack by the terrorist group Al-Qaeda on the United States. On September 11, 2001, two planes crashed into the World Trade Center buildings in New York City. On the same day, a third plane crashed into the Pentagon causing a partial collapse of the headquarters. A fourth plane, which was heading to Washington D.C., crashed in a field in Pennsylvania. A total of 2,996 individuals were killed in the attacks. The total number of casualties at the Pentagon crash was 189, including 59 passengers, 125 people who were in the building at the time, and 5 terrorists. As the deadliest terrorist attack ever carried out in the U.S., the events of September 11, 2001 caused a tremendous amount of fear and anxiety.

and with the Pentagon crash in particular, might confound our analysis of the 2002 sniper attacks. In other words, the effects of the sniper attacks documented above might be at least partly attributable to the Pentagon attack of September 11, 2001. Thus, we remove school-year observations in 2002 that were within 5 miles of the Pentagon from the baseline analytic sample to reduce potential contamination of the pre-treatment control group, though the main results are robust to either not making this sample restriction or to excluding these schools from all six years of data. Still, this does not rule out the possibility that the sniper attacks compounded or triggered existing trauma in communities that had previously been affected by the September 11, 2001 attack on the Pentagon. However, any direct impact of the Pentagon attack on 2002 proficiency rates would also be accounted for in the event-study analysis.

To provide further insights into the issue, we consider a version of equation (1) in which the treatment is redefined as being within a five-mile radius of the sniper attacks in October 2002 or within a five-mile radius of the Pentagon in 2001. In addition to providing evidence on the sensitivity of our main results, this analysis is interesting in its own right, as it provides evidence on the average impact of both the Pentagon and sniper attacks. As shown in Table A2, these estimates are similar to those of the baseline specification.

Heterogeneity in the Sniper Effects

Finally, we conclude our analysis with an investigation of potential heterogeneity in the effects of the community trauma associated with the 2002 sniper attacks on school proficiency rates. As discussed above, this analysis is motivated by the common finding in the literature on the psychological effects of community traumatic events that signs of trauma are disproportionately concentrated among racial minority and socioeconomically disadvantaged children (Shannon et al., 1994; Becker-Blease et al., 2008, Neria et al., 2006). To answer this question, we ordered schools based on the percentage of students in 2003 who were eligible for FRL and the percentage of students who were black. Then we divided each of the distributions into three equal parts and estimated the baseline models separately for schools in the bottom and top terciles. The bottom terciles contain relatively advantaged schools while the top terciles contain relatively disadvantaged schools. Columns 1-4 of Table 7 report baseline estimates of equation (1) that control for time-variant school characteristics. Columns 5-8 of Table 7 report analogous estimates of specifications that also condition on district linear time trends.

Columns 1 and 2 of Table 7 report the baseline estimates for schools in the bottom and top terciles of the FRL distribution, respectively. Based on previous research, we expect the effects of the sniper attacks on proficiency rates to be more pronounced among the relatively poorer schools in column 2. Indeed, this is exactly what we see: the point estimates for the bottom tercile sample in column 1 are relatively small in magnitude and indistinguishable from zero while those for the top tercile of the FRL distribution reported in column 2 are negative, larger in magnitude, and statistically significant at the 1 percent confidence level. Reductions in the poorer (top-tercile) schools' proficiency rates caused by the sniper attacks are large—more than twice the size of the baseline estimates that restricted the effect to be homogeneous for all schools—at more than 10 percentage points for each ELA and math test. The estimates reported in columns 3 and 4 of Table 7 show a similar result: harmful effects of proximity to the sniper attacks are significantly larger in schools that serve predominantly black student populations, which are similar in size to the effects observed in the relatively poor schools. Again, this result is consistent with the extant literature that predicts racial minority children to be more adversely affected by community traumatic events.

Next, the remaining four columns of Table 7 re-estimate the same models separately by school type, this time controlling for district linear time trends. The estimated impacts of proximity to a sniper attack on proficiency rates in schools in the wealthiest tercile of the distribution, which are reported in column 5, are once again indistinguishable from zero. However, the corresponding estimates for the poorest tercile of schools, shown in column 6, remain large in magnitude and statistically significant for four of the six math and ELA outcomes. Like in the models that did not condition on district time trends, the adverse effect of proximity to a sniper attack is similarly larger in schools serving higher proportions of black students.

Importantly, the results presented in Table 7 indicate that the October 2002 sniper attacks had harmful, statistically significant effects on academic achievement in schools serving disadvantaged populations, and that these effects were not driven by districtwide trends in performance. Rather, these effects represent negative deviations from trends and suggest that the findings documented throughout much of this paper—that the 2002 Beltway sniper attacks reduced academic achievement in Virginia's public schools—were largely driven by declines in student achievement in schools serving socioeconomically disadvantaged and racial minority students. This is unsurprising, as these students, communities, and schools are regularly subjected to numerous other stressors and have relatively fewer resources with which to cope with unanticipated shocks such as the sniper attacks, which presented yet another hurdle for students, teachers, and administrators in these schools to overcome.

In light of our earlier finding that the negative effects of the sniper attacks on student achievement did not persist beyond the academic year of 2002-2003, it is important to assess whether the same pattern holds for the heterogeneity analysis. Thus, we conducted the heterogeneity analysis utilizing data through 2005, similar to what we did in Table 6. As shown in Table 8, these results are largely consistent with those reported in Tables 6 and 7, i.e., the sniper attacks caused a reduction in student achievement in 2003 but mostly for students attending disadvantaged schools. But again, the patterns of estimates shown in Table 8 indicate that these effects are relatively short-lived where none of the estimates for 2004 or 2005 for disadvantaged schools shown in columns 2 and 4 are estimated with statistical precision, with the only exception of the 8th grade Math achievement scores. Furthermore, these estimates are smaller in magnitude in most cases. We interpret the estimates in Table 8 to be largely consistent with the picture to have emerged from the previous Tables.

VI. Conclusions

The increased frequency of community traumatic events in the United States places a significant and rising number of children at an enormous risk for psychological problems. The current study documents that these types of events not only undermine the psychological well-being of children, but can also significantly disrupt their cognitive development, especially in the short run. Difference-in-difference estimates that leverage the natural experiment created by the October 2002 “Beltway Sniper” attacks indicate that children who attended schools close to the shooting locations experienced lower academic achievement than their counterparts who attended schools farther away. The estimates are most robust for proficiency in third and fifth grade math and ELA, suggesting that shootings caused a decline in school proficiency rates of about five to nine percentage points. Particularly concerning from an equity standpoint, these effects appear to be entirely driven by achievement declines in schools that enroll large numbers of racial minority and socioeconomically disadvantaged students.

The plausibility and practical significance of these results can be interpreted in a couple of ways. First, to put the magnitude of our estimates in perspective, recall that a likely mechanism through which the sniper attacks affected achievement was the disruption of school routines and associated reductions in instructional time. It is useful, then, to compare our point estimates to those of similar analyses of the impact of disruptions to the school schedule on school-level proficiency rates. For example, Marcotte and Hemelt (2008) estimated the impact of unscheduled school closings on school proficiency rates in Maryland by exploiting the natural experiment created by temporal and geographic variation in snowfall. The authors found that ten unscheduled, weather-related school closings reduced third and fifth grade math proficiency rates by between 5 and 7 percentage points. These effects are remarkably similar in magnitude to the effects of the sniper attacks documented in the current study. The current study thus furthers our understanding of how external disruptions to school environments and school schedules can affect student achievement.

Second, one dimension of the policy relevance of our findings can be inferred by considering how the sniper-induced reductions in proficiency rates affected schools' standing under the No Child Left Behind (NCLB) accountability policy, which was first implemented in the same school year that the sniper shootings occurred. Importantly, math and ELA proficiency rates play a critical role in determining whether schools made Adequate Yearly Progress (AYP) under NCLB. To make AYP, among other things, schools' overall proficiency rates must meet or exceed a threshold predetermined by the state. In 2003 the ELA and math proficiency thresholds were 61 and 59, respectively (Virginia Board of Education, 2010). Under NCLB, failing to make AYP in two consecutive years made schools subject to potentially severe sanctions.

Table 9 reports tabulations from a simple back-of-the envelope calculation of the number of schools whose proficiency rating would have crossed the AYP threshold had they (not) been within 5 miles of the sniper attacks. Specifically, we use the conservative district-trend estimates reported in Tables 4 and 7 to compute two counterfactuals: the number of treated schools that failed but would have passed had they been outside the 5 mile radius of the nearest sniper shooting and the number of control schools that passed but would have failed had they been inside a 5 mile radius of the nearest sniper shooting. Overall, the sniper shootings changed between 1 and 2 percent of schools' positions relative to the AYP threshold. However, this figure is significantly higher for schools in the top terciles of the distributions of the percentage of students eligible for FRL and the percentage of black students. In these relatively disadvantaged schools, between 7 and 20 percent of elementary schools' and between 18 and 44 percent of middle schools' positions relative to the AYP threshold changed as a result of the sniper attacks. This is consistent with results presented in Table 7, which show that disadvantaged schools were particularly harmed by the sniper attacks, but is also driven by the fact that many disadvantaged schools were initially closer to the AYP thresholds due to their relatively lower proficiency rates. Accordingly, it is important that state and federal consequential K-12 accountability policies recognize the impacts that community traumatic events can have on the student test scores that determine sanctions, as failing to do so might expand existing inequities between schools.

More generally, these findings suggest that local and state education systems might respond to community traumatic events by providing additional resources, support, and guidance to affected schools and communities. For example, Weems et al. (2009) describe a school-based intervention that significantly reduced test anxiety among racial minority students who were exposed to Hurricane Katrina. Moreover, targeted support would be justified, given that disadvantaged schools and communities appear to bear a disproportionate burden of the harmful effects. There are also implications for proactive policies designed to eliminate or minimize the proclivity of manmade community traumatic events, as doing so in an efficient manner requires equating the marginal cost and marginal benefit of such efforts. The results presented here suggest that the costs of random shooting incidents may be larger than previously thought, as the psychic and emotional costs recognized by previous research spill over into schools and affect students' cognitive development and exam performance some five months after the event.

Finally, our auxiliary analysis shows suggests that the deleterious impact of the sniper shootings on student achievement might have not persisted into the subsequent academic year, at least as measured by SOL proficiency rates. When we repeated our analysis with data extending to the end of the academic years 2004 and 2005, estimated treatment effects in these later years are smaller in magnitude and less precisely estimated than those in the academic year 2003. On the one hand, this finding can be interpreted as a glimpse of positive news since there might have been a correction to the disruption caused by the sniper attacks that brought achievement trends back to their pre-attack trajectories. However, this should not lessen concerns over the impact of community wide traumatic events on student development for at least two reasons. First, any public and private efforts expended to counter the harmful effect of these attacks on student achievement would still represent an efficiency loss for society in light of the scarcity of educational resources. Second, educational interventions that affect both test scores and non-cognitive skills often have long-run impacts on socioeconomic outcomes (e.g., labor market success) even when their effects on test scores fade out relatively quickly (Chetty et al., 2011).

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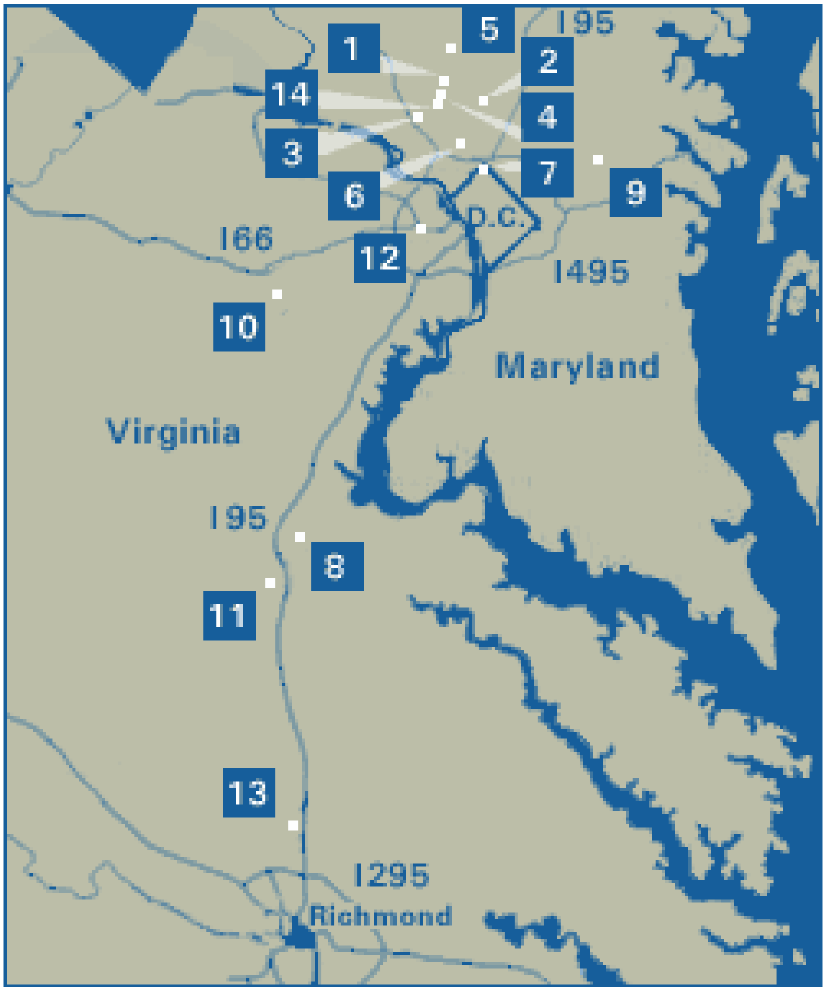
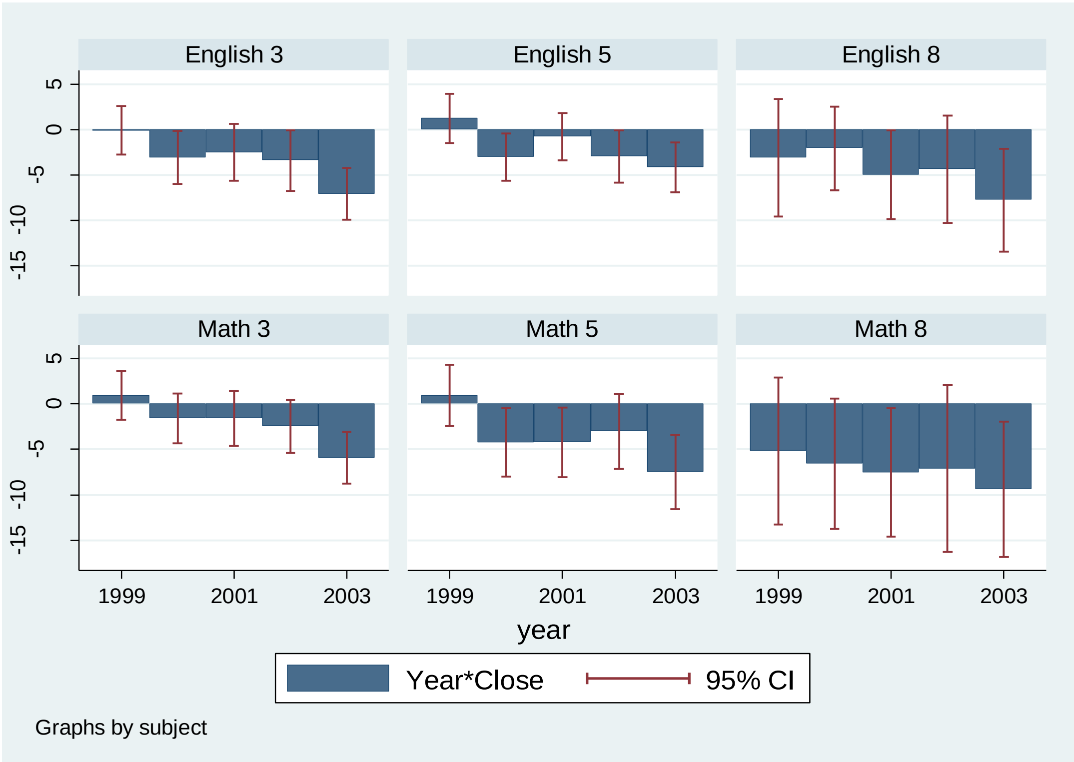
Figure 1: Locations of the Beltway Sniper Attacks



Source: Clark County Prosecutor,
http://www.clarkprosecutor.org/html/death/US/muhammad1181.htm.

Figure 2: Event Study Estimates of the Impact of Sniper Attacks on Pass Rates



Notes: Brackets represent 95percent confidence intervals, robust to clustering at school level. The bars represent the estimated interaction terms reported in Table 5, from event study models that control for time-varying school characteristics, school and year fixed effects.

Table 1: Description of Sniper Attacks' Proximities to Virginia (VA) Schools

#	Date	Fatal	City	State	Distance to nearest VA school	VA schools within 5 mi	VA schools within 10 mi
1	October 2	Yes	Silver Spring	MD	9.88	0	1
2	October 3	Yes	Rockville	MD	7.08	0	13
3	October 3	Yes	Rockville	MD	7.08	0	14
4	October 3	Yes	Silver spring	MD	7.07	0	14
5	October 3	Yes	Kensington	MD	4.49	2	72
6	October 3	Yes	Washington	DC	7.07	0	33
7	October 4	No	Fredericksburg	VA	1.20	18	34
8	October 7	No	Bowie	MD	18.76	0	0
9	October 9	Yes	Manassas	VA	0.28	28	62
10	October 11	Yes	Fredericksburg	VA	1.02	20	34
11	October 14	Yes	Falls Church	VA	0.71	82	170
12	October 19	No	Ashland	VA	0.97	5	33
13	October 22	Yes	Silver Spring	MD	10.24	0	0

Note: Distances are measured in miles "as the crow flies."

Table 2: Descriptive Statistics for School Pass Rates

	All schools			Schools within 50 miles		
	All	Outside 5 miles	Within 5 miles	All	Outside 5 miles	Within 5 miles
	(1)	(2)	(3)	(4)	(5)	(6)
English 3	63.36	63.02	67.58***	67.25	67.19	67.58
	(17.19)	(17.37)	(14.09)	(17.31)	(17.88)	(14.09)
	[6312]	[5837]	[475]	[2882]	[2407]	[475]
English 5	72.29	72.04	75.38***	74.86	74.76	75.38
	(16.45)	(16.65)	(13.44)	(16.76)	(17.33)	(13.44)
	[6284]	[5809]	[475]	[2913]	[2438]	[475]
English 8	59.19	58.84	64.28*	62.24	61.85	64.28
	(23.23)	(23.27)	(22.05)	(24.08)	(24.43)	(22.05)
	[2444]	[2288]	[156]	[992]	[836]	[156]
Math 3	73.23	72.91	77.19***	76.09	75.87	77.19
	(16.68)	(16.94)	(12.39)	(16.70)	(17.42)	(12.39)
	[6310]	[5836]	[474]	[2879]	[2405]	[474]
Math 5	60.84	60.39	66.37***	65.09	64.84	66.37
	(21.85)	(22.08)	(17.87)	(21.49)	(22.12)	(17.87)
	[6283]	[5810]	[473]	[2909]	[2436]	[473]
Math 8	54.92	54.36	62.86**	59.96	59.41	62.86
	(26.54)	(26.53)	(25.52)	(27.51)	(27.85)	(25.52)
	[2507]	[2342]	[165]	[1038]	[873]	[165]

Notes: Standard deviations are reported in parentheses. Sample sizes are reported in brackets. "Within 'x' miles" refers to schools' proximity to the nearest sniper attack. ***, **, and * indicate statistically significant differences between treated (within 5 miles) and control groups at the 99th, 95th, and 90th percent level of confidence, respectively.

Table 3: Descriptive Statistics for School Characteristics

Sample:	Elementary Schools			Middle Schools		
	All	Treated	Control	All	Treated	Control
	(1)	(2)	(3)	(4)	(5)	(6)
Miles	15.73	2.93	18.23***	17.93	3.12	20.75***
	(11.88)	(1.15)	(11.42)	(13.25)	(1.06)	(12.62)
Within 5 mi	0.16	1.00	0.00***	0.16	1.00	0.00***
Within 10 mi	0.37	1.00	0.25***	0.35	1.00	0.22***
Enrollment	566.53	544.18	570.88	984.84	1006.13	980.79
	(195.16)	(163.43)	(200.49)	(571.18)	(423.86)	(595.18)
% black	0.25	0.16	0.26***	0.27	0.16	0.29***
	(0.27)	(0.11)	(0.28)	(0.25)	(0.11)	(0.27)
% Hispanic	0.08	0.21	0.06***	0.06	0.17	0.04***
	(0.12)	(0.17)	(0.08)	(0.09)	(0.13)	(0.06)
% FRL	0.29	0.33	0.28*	0.26	0.28	0.25
	(0.24)	(0.21)	(0.24)	(0.20)	(0.18)	(0.21)
FTE	37.89	40.90	37.31***	70.99	79.75	69.33*
	(13.51)	(13.13)	(13.51)	(41.00)	(37.53)	(41.44)
Pupil-teacher ratio	15.65	13.34	16.10***	14.45	12.89	14.75***
	(9.32)	(2.67)	(10.06)	(7.96)	(1.98)	(8.61)
N	2878	460	2418	1002	160	842

Notes: Standard deviations are reported in parentheses. ***, **, and * indicate statistically significant differences between treated (within 5 miles) and control groups at the 99^{th}, 95^{th}, and 90^{th} percent level of confidence, respectively. Sample restricted to schools within 50 miles "as the crow flies" of at least one attack. FRL = free or reduced price lunch. FTE = full time equivalent teachers.

Table 4: Baseline Estimates of Effect of Proximity to Sniper Attacks on School Pass Rates

Specification:	Parsimonious	Baseline	Trends
Outcome	(1)	(2)	(3)
English 3	-5.305	-5.221	-1.924
[2,851]	(0.956)***	(0.993)***	(1.087)*
English 5	-2.968	-3.013	-1.376
[2,881]	(1.083)***	(1.099)***	(1.167)
English 8	-5.073	-4.786	-3.049
[954]	(1.755)***	(1.786)***	(2.027)
Math 3	-4.692	-4.950	-2.624
[2,848]	(0.941)***	(0.929)***	(0.964)***
Math 5	-5.321	-5.285	-2.974
[2,878]	(1.339)***	(1.310)***	(1.350)**
Math 8	-4.880	-3.930	0.470
[1,002]	(1.643)***	(1.653)**	(2.288)
School fixed effects	Yes	Yes	Yes
Controls	No	Yes	Yes
District Trends	No	No	Yes

Notes: Each cell reports the interaction term (treatment effect) from a distinct regression. Standard errors are reported in parentheses and are robust to clustering at the school level. ***, **, and * indicate statistical significance at the 99th, 95th, and 90th percent level of confidence, respectively. Sample sizes are reported in brackets. Analytic samples restricted to schools within 50 miles of at least one sniper shooting. School controls in columns 2 and 3 include FTE teachers, student-teacher ratio, total school enrollment, percent black, percent Hispanic, and percent FRL eligible. All models control for school and year fixed effects. Sample contains data from 1998-2003 school years (6 years). Observations in 2002 for schools within 5 miles of the Pentagon are excluded from the analytic samples.

Table 5: Event Study Estimates of Effect of Proximity to Sniper Attacks on School Pass Rates

Outcome	ELA 3	ELA 5	ELA 8	Math 3	Math 5	Math 8
	(1)	(2)	(3)	(4)	(5)	(6)
1999	6.705	0.999	0.671	3.557	3.616	6.002
	(0.582)***	(0.478)**	(0.719)	(0.554)***	(0.657)***	(0.865)***
2000	5.958	0.371	4.091	7.398	17.295	8.932
	(0.620)***	(0.562)	(0.768)***	(0.634)***	(0.783)***	(1.142)***
2001	9.194	4.227	7.573	11.583	19.310	13.885
	(0.673)***	(0.591)***	(1.063)***	(0.726)***	(0.878)***	(1.228)***
2002	16.779	8.075	4.885	14.566	23.307	17.848
	(0.841)***	(0.734)***	(1.048)***	(0.877)***	(1.040)***	(1.583)***
2003	17.076	14.124	6.456	19.146	27.602	22.971
	(0.909)***	(0.857)***	(1.480)***	(1.036)***	(1.189)***	(2.088)***
1999×*Close*	-0.099	1.235	-3.132	0.936	0.941	-5.182
	(1.332)	(1.351)	(3.227)	(1.331)	(1.697)	(4.036)
2000× *Close*	-3.085	-3.063	-2.082	-1.594	-4.245	-6.595
	(1.448)**	(1.309)**	(2.309)	(1.385)	(1.890)**	(3.600)*
2001× *Close*	-2.534	-0.796	-4.993	-1.596	-4.215	-7.554
	(1.563)	(1.311)	(2.437)**	(1.523)	(1.920)**	(3.540)**
2002× *Close*	-3.415	-2.969	-4.392	-2.463	-3.030	-7.121
	(1.678)**	(1.444)**	(2.948)	(1.457)*	(2.056)	(4.588)
2003× *Close*	-7.100	-4.162	-7.787	-5.931	-7.488	-9.398
	(1.414)***	(1.377)***	(2.841)***	(1.422)***	(2.033)***	(3.725)**
School-years (N)	2,851	2,881	954	2,848	2,878	1,002
Schools (clusters)	513	546	242	511	541	261

Notes: Standard errors are reported in parentheses and are robust to clustering at the school level. ***, **, and * indicate statistical significance at the 99^{th}, 95^{th}, and 90^{th} percent level of confidence, respectively. Analytic samples restricted to schools within 50 miles of at least one sniper shooting. All models control for school and year fixed effects and the following time-variant school controls: FTE teachers, student-teacher ratio, total school enrollment, percent black, percent Hispanic, and percent FRL eligible. Sample contains data from 1998-2003 school years (6 years). Observations in 2002 for schools within 5 miles of the Pentagon are excluded from the analytic samples.

Table 6: Persistence in Effect of Sniper Attacks on School Pass Rates

Subject:	English 3	English 5	English 8	Math 3	Math 5	Math 8
	(1)	(2)	(3)	(4)	(5)	(6)
A. No school controls						
2003×*Close*	-5.188	-3.173	-4.126	-4.567	-5.107	-4.284
	(0.950)***	(1.049)***	(1.714)**	(0.950)***	(1.330)***	(1.672)**
2004/5×*Close*	-3.089	-0.727	-3.764	-3.482	-4.543	-5.656
	(1.021)***	(1.126)	(1.402)***	(1.079)***	(1.341)***	(1.693)***
Diff. (*p*)	0.05	0.011	0.841	0.177	0.635	0.313
B. School controls						
2003×*Close*	-5.314	-3.414	-3.096	-4.749	-5.258	-3.431
	(0.968)***	(1.044)***	(1.830)*	(0.960)***	(1.298)***	(1.764)*
2004/5×*Close*	-2.808	-0.480	-3.200	-2.986	-4.190	-4.913
	(1.031)***	(1.085)	(1.532)**	(1.047)***	(1.304)***	(1.756)***
Diff. (*p*)	0.021	0.003	0.96	0.035	0.383	0.366
C. School controls and linear district time trends						
2003×*Close*	-2.609	-1.518	-2.034	-2.341	-2.802	-0.356
	(1.003)***	(1.067)	(1.872)	(0.898)***	(1.255)**	(1.872)
2004/5×*Close*	1.318	2.370	-0.954	0.663	-0.348	0.296
	(1.133)	(1.202)**	(1.364)	(1.152)	(1.333)	(2.016)
Diff. (*p*)	0.001	0.0001	0.604	0.001	0.054	0.688
N	3,835	3,877	1,333	3,835	3,876	1,515

Notes: The omitted category is pre-2003×*Close*, where *Close* is defined as 0 to 5 miles. Standard errors in parentheses are robust to clustering at the school level. ***, **, and * indicate statistical significance at the 99^{th}, 95^{th}, and 90^{th} percent level of confidence, respectively. Analytic samples restricted to schools within 50 miles of at least one sniper shooting. School controls include FTE teachers, student-teacher ratio, total school enrollment, percent black, percent Hispanic, and percent FRL. All models control for school and year fixed effects. Sample contains data from 1998-2005 school years (8 years). Observations in 2002 for schools within 5 miles of the Pentagon are excluded from the analytic samples.

Table 7: Heterogeneity in Effects of Proximity (5 miles) to Sniper Attacks on School Pass Rates

Sample:	Bottom tercile FRL enrollment	Top tercile FRL enrollment	Bottom tercile black enrollment	Top tercile black enrollment	Bottom tercile FRL enrollment	Top tercile FRL enrollment	Bottom tercile black enrollment	Top tercile black enrollment
Outcome	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
English 3	-1.599	-10.294	-2.834	-8.246	-1.570	-3.107	-0.206	-2.391
	(1.495)	(1.750)***	(1.429)**	(1.531)***	(1.511)	(2.129)	(1.422)	(1.689)
English 5	0.571	-6.751	-1.064	-5.883	1.026	-3.803	0.424	-3.989
	(1.141)	(2.111)***	(1.179)	(1.747)***	(1.279)	(2.456)	(1.216)	(2.013)**
English 8	2.954	-12.781	-0.980	-8.131	5.249	-10.770	1.060	-8.669
	(3.403)	(2.713)***	(2.972)	(2.980)***	(5.083)	(2.583)***	(3.771)	(2.676)***
Math 3	0.170	-11.471	-0.708	-9.470	-1.248	-3.965	0.855	-4.044
	(1.293)	(1.883)***	(1.087)	(1.520)***	(1.313)	(2.157)*	(1.408)	(1.680)**
Math 5	-2.118	-11.160	-3.047	-9.170	-1.044	-5.336	-0.779	-4.787
	(1.774)	(2.733)***	(1.585)*	(2.138)***	(1.700)	(2.823)*	(1.470)	(2.270)**
Math 8	3.234	-11.557	0.999	-10.289	9.005	-9.497	5.675	-8.712
	(3.988)	(2.752)***	(3.294)	(2.334)***	(6.803)	(3.038)***	(4.532)	(2.460)***
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
School & year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District trends	No	No	No	No	Yes	Yes	Yes	Yes

Notes: Each cell reports the interaction term (treatment effect) from a distinct regression. Standard errors are reported in parentheses and are robust to clustering at the school level. ***, **, and * indicate statistical significance at the 99th, 95th, and 90th percent level of confidence, respectively. Sample sizes are reported in brackets. Analytic samples restricted to schools within 50 miles of at least one sniper shooting. School controls in columns 2 and 4 include FTE teachers, student-teacher ratio, total school enrollment, percent black, percent Hispanic, and percent FRL eligible. All models control for school and year fixed effects. Sample contains data from 1998-2003 school years (6 years). Observations in 2002 for schools within 5 miles of the Pentagon are excluded from the analytic samples. The % FRL terciles are 18 and 47. The % black terciles are 9 and 34.

Table 8: Persistence in Heterogeneous Effects of Proximity (5 miles) to Sniper Attacks on School Pass Rates

Sample:	Bottom tercile FRL enrollment	Top tercile FRL enrollment	Bottom tercile black enrollment	Top tercile black enrollment
Outcome	(1)	(2)	(3)	(4)
English 3 (2003)	-2.300	-3.750	-1.010	-3.151
	(1.548)	(1.917)*	(1.331)	(1.564)**
(2004/5)	-0.285	0.938	4.167	1.285
	(1.404)	(2.389)	(1.527)***	(1.859)
English 5 (2003)	0.648	-2.990	-0.124	-3.319
	(1.100)	(2.220)	(1.086)	(1.835)*
(2004/5)	0.847	0.883	4.099	0.537
	(1.152)	(2.606)	(1.122)***	(2.151)
English 8 (2003)	3.731	-9.828	0.571	-7.973
	(4.347)	(2.986)***	(2.985)	(2.760)***
(2004/5)	0.788	-3.411	-4.052	-1.837
	(4.674)	(2.192)	(3.507)	(2.078)
Math 3 (2003)	-1.157	-4.209	0.655	-4.027
	(1.283)	(1.927)**	(1.166)	(1.523)***
(2004/5)	-1.329	1.178	3.892	0.753
	(1.649)	(2.433)	(1.580)**	(1.917)
Math 5 (2003)	-1.922	-5.294	-0.761	-4.362
	(1.490)	(2.469)**	(1.520)	(2.043)**
(2004/5)	1.012	-3.567	4.138	-2.826
	(1.705)	(2.502)	(1.952)**	(2.177)
Math 8 (2003)	8.220	-11.668	2.786	-8.613
	(6.206)	(3.566)***	(3.446)	(2.614)***
(2004/5)	7.461	-11.175	3.694	-4.521
	(6.544)	(3.094)***	(2.739)	(3.523)

Notes: Each cell reports the interaction term (treatment effect) from a distinct regression. Standard errors are reported in parentheses and are robust to clustering at the school level. ***, **, and * indicate statistical significance at the 99^{th}, 95^{th}, and 90^{th} percent level of confidence, respectively. Sample sizes are reported in brackets. Analytic samples restricted to schools within 50 miles of at least one sniper shooting. School controls in columns 2 and 4 include FTE teachers, student-teacher ratio, total school enrollment, percent black, percent Hispanic, and percent FRL eligible. All models control for school and year fixed effects, time-variant school controls, and district linear time trends. Sample contains data from 1998-2003 school years (6 years). Observations in 2002 for schools within 5 miles of the Pentagon are excluded from the analytic samples. The % FRL terciles are 18 and 47. The % black terciles are 9 and 34.

Table 9: Schools whose Adequate Yearly Progress Proficiency Status Affected by Sniper Attacks

	Treated schools (would have passed)			Control schools (would have failed)		
	All schools	Top tercile FRL	Top tercile black	All schools	Top tercile FRL	Top tercile black
	1	2	3	4	5	6
Elementary Schools						
English 3	3	-	-	11	-	-
Math 3	0	0	0	1	5	6
English 5	-	-	0	-	-	2
Math 5	4	5	3	18	15	17
Total	7	5	3	30	20	25
Percent	1.5%	18.5%	7.0%	1.3%	19.8%	17.1%
Middle Schools						
English 8	2	4	5	3	6	11
Math 8	-	0	0	-	3	3
Total	2	4	5	3	9	14
Percent	1.3%	44.4%	38.5%	0.4%	18.4%	30.4%

Notes: Based on conservative estimates that condition on district trends (Tables 4 and 7). Numbers are only reported for tests on which there were statistically significant effects.

Appendix Table A1: Sensitivity of Baseline Estimates to Functional Form of Distance

Subject:	English 3	English 5	English 8	Math 3	Math 5	Math 8
	(1)	(2)	(3)	(4)	(5)	(6)
A. Quadratic in miles						
Miles	0.680	0.497	0.397	0.680	0.668	0.450
	(0.124)***	(0.136)***	(0.277)	(0.129)***	(0.172)***	(0.343)
$Miles^2$	-0.013	-0.009	-0.007	-0.012	-0.012	-0.008
	(0.003)***	(0.003)***	(0.005)	(0.003)***	(0.004)***	(0.007)
APE	0.609	0.445	0.346	0.615	0.601	0.397
	(0.110)***	(0.120)***	(0.240)	(0.114)***	(0.152)***	(0.294)
B. Multiple discrete distance categories						
0 to 5 miles	-5.406	-4.818	-6.734	-5.475	-6.071	-2.590
	(1.939)***	(5.959)	(5.105)	(1.011)***	(1.000)***	(1.285)**
5 to 10 miles	-2.142	4.281	2.185	-3.056	-3.808	1.119
	(2.447)	(5.505)	(4.698)	(1.215)**	(1.076)***	(1.078)
Diff. (*p*)	0.003***	0.364	0.185	0.050*	0.049**	0.633
N	2,851	2,881	954	2,848	2,878	1,002

Notes: The omitted category in panel B is (> 10 mi. from attack). Standard errors in parentheses are robust to clustering at the school level. ***, **, and * indicate statistical significance at the 99th, 95th, and 90th percent level of confidence, respectively. Analytic samples restricted to schools within 50 miles of at least one sniper shooting. All models control for school and year fixed effects and time-variant school controls including FTE teachers, student-teacher ratio, total school enrollment, percent black, percent Hispanic, and percent FRL. Sample contains data from 1998-2003 school years (6 years). Observations in 2002 for schools within 5 miles of the Pentagon are excluded from the analytic samples.

Appendix Table A2: Effect of Proximity (5 miles) to Pentagon or Sniper Attack on School Pass Rates

Specification:	Parsimonious	Baseline	Trends
Outcome	(1)	(2)	(3)
English 3	-5.734	-5.880	-2.640
[2,880]	(0.872)***	(0.912)***	(1.071)**
English 5	-2.164	-2.391	-1.205
[2,911]	(1.135)*	(1.113)**	(1.224)
English 8	-4.749	-4.767	-3.116
[962]	(1.533)***	(1.577)***	(1.805)*
Math 3	-4.094	-4.477	-2.258
[2,877]	(0.850)***	(0.810)***	(0.848)***
Math 5	-4.275	-4.485	-2.183
[2,907]	(1.198)***	(1.123)***	(1.257)*
Math 8	-5.093	-4.359	-0.061
[1,010]	(1.385)***	(1.372)***	(2.080)
School fixed effects	Yes	Yes	Yes
Controls	No	Yes	Yes
District Trends	No	No	Yes

Notes: Each cell reports the interaction term (treatment effect) from a distinct regression, in which the treatment term indicator equals one if the school was within 5 miles of the Pentagon in 2002 or was within 5 miles of a sniper attack in 2003. Standard errors are reported in parentheses and are robust to clustering at the school level. ***, **, and * indicate statistical significance at the 99th, 95th, and 90th percent level of confidence, respectively. Sample sizes are reported in brackets. Analytic samples restricted to schools within 50 miles of at least one sniper shooting. School controls include FTE teachers, student-teacher ratio, total school enrollment, percent black, percent Hispanic, and percent FRL eligible. All models control for school and year fixed effects. Sample contains data from 1998-2003 school years (6 years). Observations in 2002 for schools within 5 miles of the Pentagon are excluded from the analytic samples.