Impact of An Infrastructure Failure on Cognitive Performance

By EMTIAZ HOSSAIN HRITAN *†

Natural and human-made disasters can have far-reaching impacts on health and human capital for affected individuals. The 2007 collapse of the I-35W Mississippi River Bridge in Minneapolis, Minnesota, led to a substantial disruption of the learning environment for students in affected communities. The collapse resulted in numerous fatalities and injuries; notably, a school bus carrying 63 students was on the bridge during the collapse, and traffic patterns were disrupted for a year. Using a two-way fixed effects and synthetic difference-in-differences approach, I find that the bridge collapse leads to lower standardized test scores for affected schools relative to similar unaffected schools. Furthermore, I provide evidence that improvements in air quality due to reduced traffic do not outweigh the trauma-induced psychological stress impacts of the disaster.

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† School of Economics, Georgia Institute of Technology, Old C.E. Building 221 Bobby Dodd Way Atlanta, GA 30332, USA, hritan@gatech.edu.

I. Introduction

Approximately 42 percent of bridges in the United States are at least 50 years old, with 7.5 percent designated as structurally deficient, supporting 178 million trips every day (ASCE, 2021). Over the last 20 years, several highly publicized bridge collapses have occurred, including the Minneapolis I-35W bridge collapse in 2007, the I-5 Skagit River bridge collapse in Washington in 2013, the Interstate 85 bridge collapse in Atlanta in 2017, the Florida International University pedestrian bridge collapse in 2018, and the Francis Scott Key bridge collapse in Baltimore in 2024, among others. This paper utilizes the collapse of the I-35W Mississippi River Bridge in Minneapolis, Minnesota, as a natural experiment, which led to a year-long traffic disruption for nearby schools, to estimate the effects of this catastrophic failure on cognitive performance. While there is abundant evidence on the contemporaneous, prenatal, and long-term causal effects of natural disasters on the labor market (Noy, 2009; Cavallo et al., 2013), health (Currie and Rossin-Slater, 2013; Tan et al., 2009; Torche, 2011; Weissbecker et al., 2008), and cognition (Caruso and Miller, 2015; Rosales-Rueda, 2018; Morrill and Westall, 2023), very few papers focus on 'human-instigated disasters' or infrastructure failures such as bridge collapses. Moreover, relatively few causal studies have examined the effects of human-instigated disasters on cognition, focusing instead on environmental hazards like bushfires (Gibbs et al., 2019), explosion fires (Webbink, 2008), forest fires (Paudel, 2023; Rosales-Rueda, 2018; Wen and Burke, 2022), oil spills (Pérez-Pereira et al., 2012), or the effects of in-utero and early life exposures on later life outcomes (Jürges, 2013; Almond, Edlund and Palme, 2009). Consequently, less is known about the contemporaneous and medium-term effects of catastrophic failures on cognitive performance. There is a critical need to study the effects of infrastructure or catastrophic failures on educational outcomes within a well-identified causal inference framework.

This study leverages a natural experiment resulting in a year-long traffic disruption and potential psychological trauma to examine the effects of an infrastructure failure—specifically, a bridge collapse—on cognition. The Interstate 35W Mississippi River Bridge collapsed on August 1, 2007, resulting in 13 fatalities and 145 injuries, with 117 vehicles damaged, including a school bus (Salem and Helmy, 2014). The dramatic effect of the event was highlighted by the media coverage, especially the repeated broadcast of a school bus, carrying 63 children, teetering on the edge of the collapsed bridge's guardrail, on television news (Spence, Nelson and Lachlan, 2010). This catastrophe led to the diversion of traffic from I-35W, significantly reducing traffic volume and altering traffic patterns. Consequently, school-going children in the vicinity of the bridge collapse site were exposed to psychological trauma and increased school commuting times.

To analyze the effect of the bridge collapse on cognition, I utilize standardized test scores from the Minnesota Comprehensive Assessment (MCA) exam published by the Minnesota Department of Education. My empirical strategy compares schools near roadways affected by the collapse with schools near unaffected roadways. Using a two-way fixed effects difference-in-differences (TWFE DiD) model, I find statistically significant negative effects on test scores for schools located near the bridge, with decreases ranging from 0.118 to 0.812 standard deviations. These results are robust to alternative estimation methods, allowing for spillover effects, the use of different treatment and control definitions achieved by adjusting group boundaries, and the application of different control samples. I also find no evidence of student attrition that would suggest the estimates are driven by compositional effects by students changing schools following the disaster.

The collapse of the bridge also resulted in an exogenous change in air pollution levels near the site. Given the contemporaneous (Lavy, Ebenstein and Roth, 2014; Shehab and Pope, 2019) and long-term (Guxens et al., 2018; Currie and Walker, 2011) effects of air pollution on cognition, I investigate air pollution changes as a potential factor influencing test score variations. Air pollution affects respiratory health, the central nervous system, and cognitive development, which may in turn affect student performance on standardized tests. Using Environmental Protection Agency (EPA) air quality monitor data, I estimate that the bridge collapse resulted in 5.938 points reduction in AQI levels at monitors within 2.5 miles from the bridge, a 15.13% improvement in the AQI, primarily driven by 16.40% reduction in $PM_{2.5}$ levels. The absence of a significant positive impact on test scores, despite improvements in air quality within this context suggests that the psychological trauma and direct inconvenience cost mechanisms outweigh any benefits from improved air quality. Using a back-of-the-envelope approach based on estimates from Carneiro, Cole and Strobl (2021), Lavy, Ebenstein and Roth (2014), Gilraine and Zheng (2022), and Persico and Venator (2021), I find that psychological trauma and increased commuting costs alone might reduce test scores by between -0.123 and -0.859 standard deviations.

Disasters, whether natural or human-made, may significantly affect students' cognitive performance through various mechanisms, including stress, trauma, and other psychological factors, effects on child brain development, and disruptions to school transportation. Children, due to their critical stages of mental, social, and physical development, are particularly susceptible to the adverse effects of disasters (Weissbecker et al., 2008; Madrid et al., 2006; Markenson and Reynolds, 2006). Even children as young as five are capable of understanding the consequences of disasters, which can lead to a spectrum of short-term psychological responses such as aggressiveness, inattentiveness, and irritability (Weissbecker et al., 2008; Madrid et al., 2006). Disasters have been shown to have a more significant impact on children compared to adults, with signs of Post-Traumatic Stress Disorder (PTSD) persisting even two years post-disaster (Weissbecker et al., 2008; Norris et al., 2002; Najarian et al., 1996).

Disruptions in school transportation due to disasters can affect academic performance by increasing commute times and distances, as well as altering modes of transportation. Kobus, Van Ommeren and Rietveld (2015) estimated that a standard deviation increase in commute time results in a reduction of average grades by approximately one-third of a standard deviation, which they attributed to factors such as travel fatigue and the exhaustive nature of long university days. Similarly, Falch, Lujala and Strøm (2013) showed that longer travel times to school decrease the likelihood of graduating on time, while proximity to diverse study options positively affects graduation rates. Yeung and Nguyen-Hoang (2020) noted that students commuting by private vehicle or on foot outperform those traveling by bus, suggesting that the fitness benefits of active transport and shorter commute times contribute to higher academic achievement. These findings highlight the significant role of commute characteristics in educational outcomes.

This paper differs from previous studies in several ways. First, while most papers exploring the relationship between disasters and cognitive performance focus on the exposure to natural disasters such as hurricanes (Imberman, Kugler and Sacerdote, 2012; Morrill and Westall, 2023), floods (Rosales-Rueda, 2018), storms (Doyle, Lockwood and Comiskey, 2017), and earthquakes (Shidiqi, Di Paolo and Choi, 2023; Tian, Gong and Zhai, 2022; Caruso and Miller, 2015), this study is among the few that examine the effects of anthropogenic hazards—referred to as 'human-instigated disasters,' 'man-made disasters', or 'infrastructure failures'—on cognitive performance. Shidiqi, Di Paolo and Choi (2023) and Tian, Gong and Zhai (2022) both found that earthquakes in Indonesia and Tangshan significantly reduced educational outcomes, including years of schooling and completion rates, with maternal psychological stress suggested as a possible mechanism for the observed impacts for the Tangshan earthquake. School shootings, one type of human-instigated disaster, have received significant attention in the literature. Typical estimates suggest a substantial negative impact on student achievement, with psychological trauma often cited as the primary mechanism (Cabral et al., 2020; Beland and Kim, 2016; Poutvaara and Ropponen, 2018; Levine and McKnight, 2020).

Second, the existing literature on the relationship between human-instigated disasters and cognitive ability generally focuses on later-life academic performance, attributed either to fetal exposure (the 'fetal hypothesis') or to early life exposure to catastrophic failure. My paper positions itself uniquely between these two extremes, as the effects estimated herein are neither due to early life exposure nor a test of the fetal hypothesis. Instead, this study explores the short- to medium-term effects of an infrastructure failure on test scores. Almond, Edlund and Palme (2009) utilized the cesium fallout in Sweden during the 1986 Chernobyl accident as a natural experiment to estimate the effects of prenatal radiation exposure on cognitive ability. They found that cohorts born in 1986, who were at the gestational age of 8-25 weeks at the time of the accident, performed worse in the final year of compulsory school, especially in mathematics. Jürges (2013) discovered that the birth cohort born right after World War II, during the food crisis in Germany, received lower educational attainment and occupational success, offering undernutrition as an explanation for the negative impact of this post-war famine. Third, to the best of my knowledge, this is the first paper to examine the impact of a transportation hazard—specifically, a bridge collapse and the consequent traffic disruption—on educational outcomes. Finally, while most papers focus on the deleterious effects of disasters on human health or capital, this paper uniquely explores the improved air quality—a positive externality arising from a disaster—as a potential mechanism. Whereas most research in this field examines the effects of relocation, peer effects, school closures, and psychological trauma from disasters as potential mechanisms for their negative impact on test scores, this study additionally investigates the exogenous changes in air pollution as a mechanism.

Given the demonstrated negative impact of the bridge collapse on student test scores, it becomes imperative for policy-makers to consider interventions that address the aftermath of such disasters. These could include allocating additional funds for free counseling in schools to combat psychological stress and trauma, and enhancing transportation options to mitigate the effects of infrastructure failure. Moreover, the costs of bridge collapses extend beyond cleanup and replacement, highlighting the need for governments to invest more in infrastructure maintenance.

The remainder of this paper is organized as follows. Section II provides background information about the I-35W Bridge collapse, a natural experiment explored in this study. Section III outlines the data and its summary statistics, while section IV delves into the research design. Section V details model specifications. Section VI provides and interprets analysis results, and in section VII, robustness checks are performed. Further discussion on the mechanism is found in section VIII, with conclusions, limitations, and research suggestions in section IX.

II. Background

A. Bridge Collapse and Timeline of Events

The Interstate 35W Mississippi River Bridge was the third busiest bridge in the Minneapolis city as well as in the state of Minnesota, carrying 140,000 cars daily with 4,760 commercial vehicles

(Xie and Levinson, 2011). Before the collapse of the bridge, though it was rated as "structurally deficient" by the national bridge inspection standards, it was declared safe for cars, truck loading, and even overweight trucks. Given an average life span of 50 years, it was scheduled for reconstruction in 2020-25 (National Transportation Safety Board, 2008).

The bridge collapsed at 6:05 p.m. on August 1, 2007, during the peak of rush hour, killing 13 people and injuring 145 others. 1000 feet out of 1907 feet bridge fell into the river where 111 cars were involved (Hao, 2010). National Transportation Safety Board (2008) attributed the collapse to factors like design errors, increased bridge weight from past modifications, construction load placement, inadequate federal review, deficient design firm procedures, and overlooked inspection issues. The bridge collapse was unforeseen, and the swift replacement construction within a year at the same site offered scant justification for local residents, businesses, and offices to permanently relocate; adjusting travel patterns seemed more reasonable. Similarly, parents lacked motivation to switch their children's school districts. This is evident from enrollment data before and after the bridge incident (see more in section VIII). The construction of the replacement bridge at the same location began on November 1, 2007, finished in less than 14 months, and opened on September 18, 2008 (Zhu et al., 2010). The MCA test of 2008 was held between the collapse and re-opening of the bridge—an important information for the research design.

B. Changes in Traffic Due to Bridge Collapse and Reopening

The bridge collapse not only caused fatalities and injuries but also significantly disrupted the traffic network, reshaping travel patterns in the Minneapolis metro area. Minnesota's Department of Transportation promptly turned Mn 280 into a freeway after the collapse, along with designating I-94 as an alternate route. Mn 280's daily traffic increased from 25,000 to 64,000 in three months, and I-94's Mississippi River bridge saw a 26.36% rise in traffic (Zhu et al., 2010). Drivers also exhibited an "avoidance phenomenon" to evade the affected area, driven by higher perceived travel costs due to unexpected network disruption (Danczyk et al., 2017).

Investigating the impact of the I-35W bridge collapse on traffic patterns, Shanjiang Zhu and David Levinson (2010) proposed a network topological design with five cordons based on freeway availability and alternative routes (refer to Figure 1). The cordons range from the smallest, Cordon 1, encompassing about a half-mile radius around the bridge, to the largest, Cordon 5, with an approximately 15-mile radius. Cordons 2, 3, and 4 have radii of roughly 2.5, 5.5, and 8.5 miles, respectively. Traffic counts remained stable during peak hours before August 1, but exhibited significant changes post-collapse. Notably, Cordon 1 experienced a 67% decrease in traffic demand within a week after the collapse, while Cordon 2 and Cordon 3 experienced shocks of 25% and

6.5%, respectively. Cordons 4 and 5 saw minimal changes in traffic demand. Although Cordon 1's traffic demand didn't recover to pre-collapse levels for months, Cordon 2 and Cordon 3 regained their levels by September 28 and August 24, respectively.

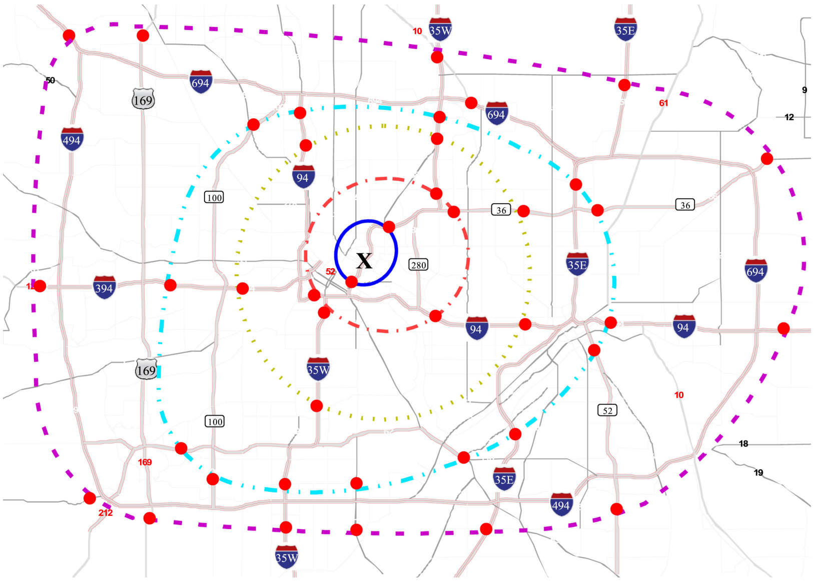

FIGURE 1. ADAPTED WITH PERMISSION (LICENCE NUMBER: 5501610078697) FROM (DANCZYK ET AL., 2017). FIVE CORDON CIRCLES AROUND THE TWIN CITIES FOR THE I-35W BRIDGE, WHERE THE CLOSED BRIDGE IS MARKED WITH AN 'X'. CORDON 1 IS THE INNERMOST CORDON LINE, INCREASING TO CORDON 5 AS THE OUTERMOST CORDON LINE.

Zhu et al. (2010) analyzed 2006 and 2007 on-ramp traffic counts and concluded that the bridge collapse did not significantly alter overall traffic demand. This was attributed to available detour routes and the majority of trips occurring beyond the affected area. They also studied transportation mode preference by examining Metro Transit's monthly bus ridership, Minneapolis' primary public transport provider. The collapse prompted a 6.6 percent rise in monthly ridership.

Beyond traffic demand on various roads and highways, the I-35W bridge collapse heightened congestion on all other bridges over the Mississippi River, as highlighted by (Xie and Levinson, 2011). Notably, nearby bridges such as Plymouth St, Hennepin Ave, 3rd Ave, Washington St, Franklin Ave, Ford Bridge, I-694, and I-94 recorded percentage increases of 23.30, 36.88, 25.94, 54.21, 33.28, 5.84, 5.12, and 26.36, respectively (Zhu et al., 2010). After the I-35W Bridge's reopening, Mn 280 continued as a freeway for a few months, restoring the pre-collapse traffic network. Expectedly, specific cordons exhibited significant traffic demand changes post-reopening. According to Shanjiang Zhu and David Levinson (2010)- "However, immediately after opening, the demand at some cordons experiences a sudden, drastic change. At Cordon 1, it doubles in value. At Cordon 2 and Cordon 3, it increases by 12 percent and 2 percent, respectively. At

Cordon 4 and Cordon 5, there is no notable change."

III. Data

For this paper, my sample consists of yearly average test scores data for the each K-12 educational institutions located at Minneapolis Twin City from 2000 to 2010. The main education data source of this paper is the Minnesota Department of Education which provides a summary of student performance in the Minnesota Comprehensive Assessments (MCA) —an annual statewide test that assesses student academic performance relative to Minnesota Academic Standards. MCA measures students' knowledge of mathematics, reading and science where all students studying in grade 3 to 8 in public schools must take reading and mathematics tests. Science tests are required only for students in grade 5 and 8. Key variables include average test scores, the number of enrolled students, the number of students who appeared on the exams, and the number of absent students on the exam day. As the assessment scales are different across the grades and years, I calculate the Z-scores by each grade-subject-year combinations so that they become comparable during analysis. Information like race of the students, number of eligible students for free or reduced foods are available, however, not for every years. Table 1 provides the summary statistics for the sample I use in my main specifications. I provide the summary statistics of average scores by subject and grade in table A1. I also include a summary statistics table of the full data set (meaning data of all the schools and air quality monitors of Minnesota) in table A2.

Variable Description	Observations	Mean	Standard Deviation	Minimum	Maximum
Grade Enrollment	18,249	101.098	106.907	1	871
Test Takers	18,374	95.519	101.746	10	819
Average Scores	18,374	902.486	455.744	318.7	1912
Absent Students on Exam Day	14,725	0.489	1.737	0	77
Distance of Schools to I-35W Bridge (meters)	18,374	17267.97	12193.21	598.501	59438.02
Distance of Schools to Highways (meters)	18,374	459.449	252.902	0.015	1126.658
Daily PM2.5 concentrations($\mu g/m^3$)	12,221	10.191	6.724	0	59.5
Daily Air Quality Index	12,221	39.015	20.225	0	153
Distance of Monitors to I-35W Bridge (meters)	12,221	14881.51	8873.65	3002.32	37538.41

TABLE 1—SUMMARY STATISTICS

Note: This table presents summary statistics based on the sample used in the main specifications, comprising all the schools in the Minneapolis metro area from 2000 to 2010 and air quality monitors from 2006 to 2009. The first column of the table reports descriptions of the variables used in the analysis. Columns two, three, and four present the number of observations, mean, and standard deviation of each variable, respectively. Additionally, columns five and six display the minimum and maximum values for each variable used in the estimation. The average score encompasses all grades and subjects to provide a comprehensive assessment of academic performance.

The Environmental Protection Agency (EPA) has collected outdoor air quality monitor data for pollutants such as $PM_{2.5}$, PM_{10}, CO, Ozone, and SO_2 over the past two decades. Figure 3 illustrates the distribution of these air quality monitors situated around the I-35W bridge. Additionally, the EPA provides the Air Quality Index, ranging from 0 to 500. The higher the AQI value, the greater the level of air pollution and the greater the health concern. For example, an AQI value of 50 or below represents good air quality, while an AQI value over 300 represents hazardous air quality. These daily pollutant concentration data for all the available monitor sites in Minnesota are extracted from EPA's publicly avaiable "Outdoor Air Quality Data" website for the year 2006 to 2009. Key variables in these data sets include daily measurements of pollutants and location of monitors.

The surface $PM_{2.5}$ data utilized in this study were obtained from the Atmospheric Composition Analysis Group of Washington University in St. Louis. This dataset encompasses annual and monthly ground-level fine particulate matter ($PM_{2.5}$) readings spanning the years 1998 to 2021. The data compilation process involved merging Aerosol Optical Depth (AOD) retrievals from NASA MODIS, MISR, and SeaWIFS instruments with the GEOS-Chem chemical transport model. Subsequently, a Geographically Weighted Regression (GWR) was applied to calibrate the data to global ground-based observations (van Donkelaar et al., 2021). For this research, I focused solely on the monthly $PM_{2.5}$ data ranging from January 2006 to December 2008 over North America. Further details regarding the data cleaning process are elaborated in the appendix section.

The weather data utilized in this study are sourced from the freely accessible National Climatic Data Center's (NCDC) archive of global historical weather and climate data. These datasets consist of quality-controlled daily, monthly, seasonal, and yearly measurements, including temperature, precipitation, and wind speed and direction. Given the limited availability of wind speed and wind direction data within my study period, I focus on utilizing daily precipitation, mean temperature, minimum temperature, and maximum temperature data from Minnesota, spanning from January 2006 to December 2008.

IV. Research Design

This paper exploits the natural experiment of the I-35W bridge collapse where traffic patterns and volume vary exogenously. The bridge collapse reduced the number of daily vehicle crossings from 140,000 to 0 for 14 months, diverting traffic from I-35W to alternate routes through Minneapolis. The unexpected collapse exogenously reduced traffic volume within 2.5 miles of the bridge, allowing me to estimate the causal relationship between the bridge collapse and academic performance. Based on the changes in traffic networks discussed in the background section II after the collapse of the bridge, I define two treatment groups to estimate the impact of bridge collapse on student test scores. Treatment I includes all the schools located within a 2.5-mile radius and

Treatment II consists of schools located from 2.5 to 8.5 miles radius of the bridge. Here, I include this second treatment group to prevent the violation of Stable Unit Treatment Value (SUTVA) assumption which implies that the potential test scores of one school was not affected by the treatment status of other schools-meaning no unmodeled spillover (Rubin, 1977). The common control group is defined as the schools located within 900 meters of the highway in Minneapolis. Figure 2 shows the schools in Treatment I, Treatment II and Control groups. Only schools located in the Minneapolis metro area are shown in this figure (refer to Figure A1 for a detailed view).

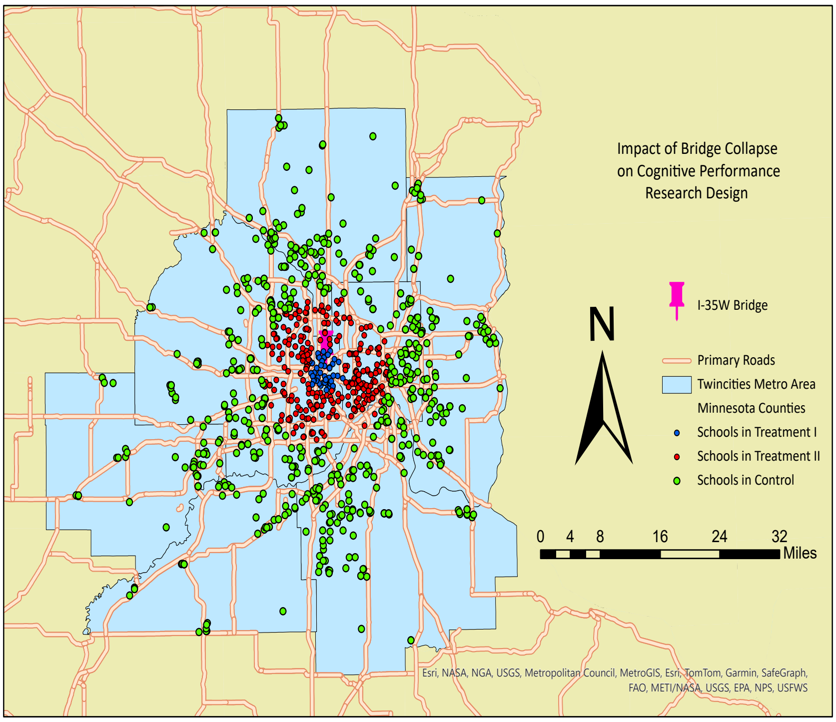

FIGURE 2. RESEARCH DESIGN: TREATED AND CONTROL SCHOOLS AROUND THE BRIDGE

The identification assumption of this research design is that the academic performances of schools near the bridge (treatment group) and those located more than 8.5 miles from the collapse site yet within 900 meters of a highway in Minneapolis (control group) will evolve according to parallel trends. Based on the existing literature, I hypothesize that first, test scores for schools within 2.5 miles of the bridge collapse (Treatment 1) fell substantially due to traffic disruption, inconvenience, and psychological trauma. Secondly, I anticipate no or a less significant adverse effect on the test scores for schools located 2.5 to 8.5 miles from the bridge collapse (Treatment 2), due to their greater distance from and thus lesser direct experience of the disaster's effects.

V. Empirical strategy

A. *Difference-in-Differences Two-way Fixed Effects (TWFE) model*

To estimate the impact of the bridge collapse on student test scores, I use the following Two-way Fixed Effects (TWFE) model:

(1) $$Test_{i,t} = \alpha_i + \beta_1 X_{i,t} + \theta D_{i,t} + \lambda_t + \varepsilon_{i,t}$$

Here $Test_{i,t}$ is the standardized test scores (as Z-scores) of school i and year t. I estimate the model separately for reading and mathematics tests for each grade. α_i controls for school fixed effects and λ_t stands for year fixed effects. This model is estimated using hetreoskedasticity-robust standard errors clustered at the school district level. $D_{i,t}$ is the dummy variable equals to 1 if the schools are within the treatment group after the bridge collapse and 0 otherwise. And $X_{i,t}$ is a vector of school characteristics which includes number of enrolled students, number of test takers and number of absent students on the exam day. [1] [2]

B. *Synthetic Difference-in-Differences Model*

A critical assumption of the Two-Way Fixed Effects (TWFE) estimation strategy is the parallel trends assumption. To graphically demonstrate that the identification assumption holds, and to address potential violations of the parallel trends assumption, I implement the Synthetic Difference-in-Differences method proposed by Arkhangelsky et al. (2021).This method estimates the average causal effect (denoted by τ) by solving the following two-way fixed effects regression:

(2) $$(\hat{\tau}_{sdid}, \hat{\mu}, \hat{\alpha}, \hat{\beta}) = argmin_{\tau,\mu,\alpha,\beta} \left\{ \sum_{i=1}^{N} \sum_{i=1}^{T} (Test_{it} - \mu - \alpha_i - \beta_t - D_{it}\tau)^2 \hat{\omega}_i \hat{\lambda}_t \right\}$$

Here $Test_{i,t}$ is the standardized test score of school 'i' in year 't'. $\lambda_t^{\hat{sdid}}$ is the time weights to compare test scores of the treatment year with similar time periods. $\omega_i^{\hat{sdid}}$ stands for unit weights which makes control schools more comparable with treatment schools. $D_{i,t}$ is a dummy variable 'Treated' which equals to 1 for schools in treatment group post 2007 and 0 otherwise. α_i and β_t are the time and school fixed effect, respectively. Using these two weights, the SDiD estimator

[1] While absences might be viewed as an outcome variable and thus bad control, I control for them in this regression to block backdoor effects and focus on the direct channel (Cinelli, Forney and Pearl, 2022). Additionally, replication of the main results without any control variables shows minimal differences compared to the primary findings. Detailed results from these specifications are available upon request.

[2] I also incorporate lagged test scores as an additional control variable in Equation 1 to increase precision. This adjustment accounts for the potential confounding effects of previous test scores on subsequent results and acknowledges the cumulative nature of cognitive development. Despite these modifications, the main results remained unchanged. Detailed results from these specifications are available upon request.

provides more weights to the control schools that had similar academic performances on average as the treated schools before the bridge collapse and put more weights to the years that are similar to treated periods. After estimating the weights, synthetic DID estimates a TWFE model on the weighted data. Use of unit weights to create parallel trend and use of time weights balance pre and post treatment levels are the ways SDiD differ from traditional DiD method.

After weighting, it can be visually seen that parallel trend is achieved as depicted in figure A2 where I plot the standardized math and reading scores of grade 3 and 5 against the years for Treatment I and the weighted control group. Similar graphs are plotted in figure A3 for Treatment II which also provides a cleaner parallel trends. Moreover, the trend for treatment schools shows little change after 2007, supporting my second hypothesis of minimal or no significant impact on test scores for schools 2.5 to 8.5 miles from the bridge collapse (Treatment 2), attributed to their reduced exposure to the disaster.

C. Event Study

To estimate the dynamic treatment effect of bridge collapse on the MCA test scores near the collapse cite, I use the following event study model:

$$(3) \quad Test_{i,t} = \alpha + X'_{i,t}\beta_1 + \sum_{\omega=2000}^{2005} D_i.1(t=\omega)\tau_{\omega}^{Pre} + D_i.1(t=\omega)\sum_{\omega=2007}^{2010} D_i\tau_{\omega}^{Post} + \phi_i + \lambda_t + \varepsilon_{i,t}$$

where D_i is a binary variable equal to one for schools located within 2.5 miles of the bridge and zero otherwise. ϕ and λ are school and year fixed effects.And $X'_{i,t}$ is a vector of school characteristics. Estimation is performed with standard errors clustered at the school district level.

VI. Results

Table 2 displays coefficient estimates for the impact of being "treated" on standardized reading and math scores (grades 3 to 8), as defined in equation 1. Being "treated" refers to schools within 2.5 miles of the bridge post-2007. Most estimates are statistically significant, except for grade 4 math and reading, and grade 6 reading. Notably, all 12 coefficient estimates are consistent with the first hypothesis, indicating a negative effect of being in the "treated" group of schools. The magnitude varies from 0.088 (grade 6 reading) to 0.812 (grade 7 math). This implies, for instance, that being labeled a "Treated" school reduces the standardized math score of grade 5 by 0.520 standard deviations. Detailed exploration of the mechanisms behind this consistency with hypothesis 1 is provided in the mechanism section. These coefficient estimates for the 'Treated' variable, as per equation 1, are visualized in figure A13, with 'Treated' on the y-axis and z-scores for math and reading on the x-axis. Besides "Treated", enrollment significantly impacts grade 5 reading and grade 4 math scores, with negative coefficients indicating that higher enrollment corresponds to lower test scores. Absenteeism mostly lacks significance except for grade 5 and grade 7 reading scores, where it has mixed effects. The number of students taking the test significantly influences grade 5 reading and grade 4 math scores, with mostly positive coefficients suggesting that more test-takers can boost scores.

Table 3 contains coefficient estimates for the impact of "being treated" (Treatment II), which in this context refers to schools located between 2.5 and 8.5 miles from the bridge after 2007, on standardized reading and math scores from grade 3 to grade 8, as calculated using equation 1. Statistically significant coefficient estimates are found only for grade 3, 5, and 7 reading and math scores. For grade 4, 6, and 8, 'Treated' remains statistically insignificant. These results align with hypothesis 2, which posits that schools within 2.5 to 8.5 miles of the bridge collapse site experience no significant or less significant adverse effects on test scores. Among these coefficient estimates, 'Treated' exhibits negative effects for grades 3, 5, and 7, with magnitudes ranging from 0.204 for grade 7 reading to 0.421 for grade 5 reading. For example, being a 'Treated' school reduces the standardized reading score of grade 5 by 0.421. Compared to Table 2, most estimates in Table 4 have smaller magnitudes. Enrollment is mostly statistically insignificant, except for grade 4 and 6 math scores, where they have a smaller positive impact. Out of the 12 coefficients, the number of absent students significantly impacts only grade 4 math scores, with a negative effect, indicating that more absent students lead to lower scores. The total number of examinees is significant for grade 4, 6, and 8 math scores, showing a negative relationship between the number of test-takers and MCA test Z-scores. To visually present the results of estimating equation 1 with different dependent variables based on grades and subjects, I plot the coefficient estimates for Treatment II in figure A14.

Table 4 presents synthetic DiD results by estimating equation 2 for reading and math Z-scores of grade 3 and 5. Additional findings for Treatment Group II are available in Appendix Table A3. It's crucial to note that synthetic DiD analysis requires balanced panel data. However, due to numerous missing values, I had to drop several observations, resulting in a model estimated with just one independent variable, 'Treated.' Despite these limitations, similar to the TWFE approach, most coefficient estimates are statistically significant. Similarly, all of them exhibit negative signs, indicating that the bridge collapse lowered the test scores below the mean.

Figure A4 depicts the event-study estimates of the effect of bridge collapse on test scores for grade 3 with confidence intervals on the y-axis and months across the x-axis. The effects are estimated using equation 3. All the pre-event effects are not zero, however, the deviations are

TABLE 2—IMPACT OF THE BRIDGE COLLAPSE (TREATMENT I: ALL THE SCHOOLS LOCATED WITHIN A 2.5-MILE RADIUS OF THE BRIDGE) ON STANDARDIZED READING AND MATH TEST SCORES FOR GRADE 3 TO 8

	(1) Grade 3 Reading	(2) Grade 3 Math	(3) Grade 4 Reading	(4) Grade 4 Math	(5) Grade 5 Reading	(6) Grade 5 Math	(7) Grade 6 Reading	(8) Grade 6 Math	(9) Grade 7 Reading	(10) Grade 7 Math	(11) Grade 8 Reading	(12) Grade 8 Math
Treated	-0.603**	-0.301	-0.249	-0.270	-0.655**	-0.520**	-0.088	-0.381	-0.697***	-0.812***	-0.218	-0.118*
	(0.187)	(0.200)	(0.249)	(0.153)	(0.209)	(0.178)	(0.172)	(0.194)	(0.102)	(0.114)	(0.118)	(0.058)
Grade Enrollment	-0.001	-0.021	0.007	0.013***	-0.037*	-0.022	0.004	0.001	0.003	0.002	0.000	0.001
	(0.003)	(0.015)	(0.005)	(0.004)	(0.017)	(0.016)	(0.004)	(0.004)	(0.003)	(0.002)	(0.002)	(0.001)
Absent Students on Exam Day	-0.004	-0.005	-0.047	-0.094	0.042*	0.015	-0.039	-0.008	-0.048**	-0.042	-0.009	-0.016
	(0.010)	(0.014)	(0.098)	(0.058)	(0.017)	(0.014)	(0.055)	(0.035)	(0.017)	(0.028)	(0.022)	(0.022)
Test Takers	0.001	0.022	-0.008	-0.016***	0.038*	0.024	-0.004	-0.002	-0.000	0.001	0.002	-0.001
	(0.003)	(0.016)	(0.006)	(0.004)	(0.017)	(0.018)	(0.004)	(0.004)	(0.003)	(0.002)	(0.003)	(0.001)
Constant	-0.043	-0.008	0.000	0.189	0.001	0.027	-0.066	0.057	-0.548*	-0.376	-0.271	-0.007
	(0.050)	(0.105)	(0.115)	(0.140)	(0.061)	(0.080)	(0.126)	(0.117)	(0.265)	(0.287)	(0.194)	(0.152)
N	1284	1272	581	569	1255	1246	395	386	340	332	281	276
R-sq	0.850	0.739	0.914	0.909	0.818	0.785	0.929	0.882	0.883	0.856	0.937	0.941

Cluster-robust standard errors, indicated in parentheses, are calculated at the school district level for TWFE.
* p<0.05, ** p<0.01, *** p<0.001

Note: The unit of analysis is school-year where schools only in the metro area are considered ('Restricted Sample'). Column (1) to column (12) shows θ coefficients estimated from equation 1 for different grade-subjects dependent variables with year and school fixed effects. The key predicting/independent variable is Treated which is a dummy variable equal to 1 if the schools are located within 2.5 miles of I-35W bridge after 2007 and 0 otherwise. As controls, student enrollment, number of test takers and number of absent students on the exam days are used. Robust standard errors clustered at the school districts level.

TABLE 3—IMPACT OF THE BRIDGE COLLAPSE (TREATMENT II: ALL THE SCHOOLS LOCATED FROM 2.5 TO 8.5 MILES RADIUS OF THE BRIDGE) ON STANDARDIZED READING AND MATH TEST SCORES FOR GRADE 3 TO 8

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Grade 3 Reading	Grade 3 Math	Grade 4 Reading	Grade 4 Math	Grade 5 Reading	Grade 5 Math	Grade 6 Reading	Grade 6 Math	Grade 7 Reading	Grade 7 Math	Grade 8 Reading	Grade 8 Math
Treated	-0.317***	-0.331***	0.024	-0.092	-0.421***	-0.392***	0.026	-0.001	-0.204*	-0.321**	0.189	0.019
	(0.078)	(0.072)	(0.084)	(0.093)	(0.077)	(0.060)	(0.057)	(0.086)	(0.088)	(0.117)	(0.150)	(0.077)
Grade Enrollment	0.006	-0.014	0.008	0.011***	-0.030	-0.015	0.005	0.005**	0.000	0.000	0.001	0.001
	(0.003)	(0.011)	(0.005)	(0.003)	(0.018)	(0.013)	(0.003)	(0.002)	(0.003)	(0.001)	(0.003)	(0.001)
Absent Students on Exam Day	-0.013	-0.006	0.001	-0.130*	0.024	0.010	-0.063	0.007	-0.024	-0.023	-0.016	-0.026
	(0.009)	(0.010)	(0.062)	(0.060)	(0.016)	(0.014)	(0.039)	(0.029)	(0.020)	(0.023)	(0.020)	(0.022)
Test Takers	-0.004	0.016	-0.008	-0.013***	0.032	0.018	-0.005	-0.007***	0.002	0.002*	-0.001	-0.002**
	(0.003)	(0.012)	(0.005)	(0.002)	(0.018)	(0.014)	(0.003)	(0.002)	(0.003)	(0.001)	(0.002)	(0.001)
Constant	-0.294***	-0.161	-0.257	-0.064	-0.192	-0.169	-0.207*	-0.051	-0.327	-0.287	-0.123	0.162
	(0.085)	(0.132)	(0.138)	(0.145)	(0.102)	(0.096)	(0.092)	(0.112)	(0.256)	(0.308)	(0.190)	(0.216)
N	1887	1872	851	836	1854	1843	629	614	465	457	383	374
R-sq	0.836	0.747	0.915	0.882	0.823	0.782	0.932	0.882	0.900	0.876	0.930	0.946

Cluster-robust standard errors, indicated in parentheses, are calculated at the school district level for TWFE.
* p<0.05, ** p<0.01, *** p<0.001

Note: The unit of analysis is school-year where schools only in the metro area are considered ('Restricted Sample'). Column (1) to column (12) shows θ coefficients estimated from equation 1 for different grade-subjects dependent variables with year and school fixed effects. The key predicting/independent variable is Treated which is a dummy variable equal to 1 if the schools are located within 2.5 to 8.5 miles of I-35W bridge after 2007 and 0 otherwise. As controls, student enrollment, number of test takers and number of absent students on the exam days are used. Robust standard errors clustered at the school districts level.

TABLE 4—SYNTHETIC DID: IMPACT OF THE BRIDGE COLLAPSE (TREATMENT I: ALL THE SCHOOLS LOCATED WITHIN A 2.5-MILE RADIUS OF THE BRIDGE) ON STANDARDIZED READING AND MATH TEST SCORES FOR GRADES 3 AND 5

	(1) Grade 3 Reading	(2) Grade 3 Math	(3) Grade 5 Reading	(4) Grade 5 Math
Treated	-0.576***	-0.520**	-0.653***	-0.818***
	(0.119)	(0.199)	(0.126)	(0.158)
N	6490	6468	5841	5841

Cluster-robust standard errors, indicated in parentheses, are calculated at the school district level for SDID.
* p<0.05, ** p<0.01, *** p<0.001

Note: The unit of analysis is the school year, during which all schools in the state of Minnesota are considered ('Full Sample'). The estimates are from 2. Column (1) to column (4) shows θ coefficients estimated from equation 2 for different grade-subjects dependent variables with year and school fixed effects. The key predicting/independent variable is Treated which is a dummy variable equal to 1 if the schools are located within 2.5 miles of I-35W bridge after 2007 and 0 otherwise. Robust standard errors clustered at the school districts level.

fairly small and it's for only one pre-event period. I find negative but barely significant effects in test scores relative to the 2006 comparison period, after treatment went into effect in 2007. However, I find significant negative effects in figure A5 for grade 5. So, I find that test scores were lower for schools located within 2.5 miles radius of the bridge for the year 2008 and 2009.

VII. Robustness Checks

In the core analysis, I employ two distinct treatment groups: Treatment I comprises schools within a 2.5-mile radius of the bridge, while Treatment II encompasses schools located between 2.5 and 8.5 miles from the bridge. In the primary Two-Way Fixed Effects (TWFE) model, both treatment groups are compared to a common control group consisting of schools within 900 meters of the highways in the Minneapolis metro area. The results show that standardized test scores for schools in Treatment I are significantly lower than the levels observed before the bridge collapse. This aligns with my first hypothesis, which anticipated a substantial decline in test scores for schools within 2.5 miles of the collapse (Treatment 1) due to traffic disruption, inconvenience, and psychological trauma. Similarly, the findings for schools in Treatment II support the second hypothesis, which posited a negligible or less significant adverse effect on test scores for schools located 2.5 to 8.5 miles from the bridge collapse (Treatment 2). This effect is attributed to their greater distance from the disaster site, resulting in a lesser direct experience of the disaster's impact on cognitive performance. In this section, I assess the robustness of these findings to check whether they represent genuine effects or are merely spurious correlations.

To address potential SUTVA violations, I utilize two treatment groups. I start by investigating whether concentrating solely on Treatment I yields consistent outcomes. Table A6 displays coefficient estimates from Two-Way Fixed Effects (TWFE) models involving a single treatment group, with Treatment II (schools within 2.5 to 8.5 miles) included in the control group. Similar to Table 2, estimating Equation 1 yields statistically significant negative coefficient estimates. Next, I need to assess the robustness of the results obtained in Equation 1 when using the 2.5-mile and 8.5-mile treatment boundaries. To do this, I modify Treatment I to extend to 5.5 miles from the bridge, covering cordons 1, 2, and 3 (Shanjiang Zhu and David Levinson, 2010). Similarly, Treatment II is adjusted to range from 5.5 to 8.5 miles from the bridge, focusing solely on cordon 4 instead of both 3 and 4. The control group remains unchanged. Table A7 presents θ coefficients estimated from Equation 2 for various grade-subject dependent variables, accounting for year and school fixed effects. The results align with the main analysis, with statistically significant negative estimates observed for 'Treated.' Additionally, enrollment, the number of test takers, and absenteeism variables exhibit similar signs and significance as in the primary results. Comparable outcomes are found in Table A8, employing this newly defined Treatment II as the key predicting variable.

All prior analyses rely on the 'Restricted Sample', where both treatment and control schools are situated within the Minneapolis metro area. This selection is based on the premise that metro area schools differ from those in other parts of Minnesota, rendering them incomparable. To reinforce the main results from equation 1, I employ the 'full sample', eliminating restrictions. While the treatment groups—Treatment I and Treatment II—remain unchanged, the control group expands to include any school within 900m of Minnesota highways. This inclusion alters sample sizes, shifting them from 1343 to 4544 across models. With the exception of grade 4, 'Treated' remains statistically significant and consistently negative across all grades and subjects in table A9 (see table A10 for Treatment II), mirroring the main results. Thus, the finding persists that test scores at schools in close proximity to the bridge collapse experienced a substantial decline. Enrollment, examinee count, and absent students on exam day also exhibit consistent signs and significance. The analysis using Treatment II as the treatment group, encompassing more schools, substantially increases the sample size, yet the outcomes, including signs, significance, and coefficient estimates, remain robust. Next, I employ Treatment II schools as a control group for Treatment I schools. Given the proximity of schools in Treatment II and their lower test scores, they serve as a potentially suitable control. The outcomes are detailed in Table A11; however, the results persist unchanged, showing adverse effects in test scores.

Considering the dynamic nature of treatment effects, it is possible that MCA test takers in 2008 experienced a brief yet highly intense shock due to the disaster. In contrast, those in 2009 might have encountered months of adjusted normal traffic flow, lower media exposure, and possibly a reduced intensity of psychological trauma and stress leading up to their April 2009 exam. Consequently, I estimate Equation 1 using a sample where the outcomes of interest are the test scores for 2008 and 2009. The results for Treatment I are provided in Table A12 and A13 for 2008 and 2009, respectively. Among the 12 coefficient estimates, none exhibit statistical significance in a positive direction. Tables A16 and A17 display the results for Treatment II in 2008 and 2009, mirroring the core analysis by revealing no statistically significant positive estimates. This suggests that the "treated" status predominantly resulted in lower test scores for the schools in question, even 20 months following the bridge collapse. In order to account for potential spillover effects and address any violations of the Stable Unit Treatment Value Assumption (SUTVA), I conduct a comprehensive joint treatment Two-Way Fixed Effects (TWFE) specification for the test scores. The detailed results of this analysis are presented in table A5. The results reaffirm the detrimental effects of the bridge collapse on test scores within both Treatment I and Treatment II groups. For visual clarity, the coefficient plots corresponding to these results are provided in figure A15.

In addition to using cordons around the bridge to define treatment groups, I also employ continuous distances to the bridge as another method to define treatment. The results, presented in Table A15, show that I interact the distance to the bridge (in miles) with the post-bridge collapse period. Most of the coefficients are positive, indicating that schools farther from the bridge collapse site tend to have better test scores, which aligns with the main finding that test scores of schools located nearer to the bridge are negatively impacted. Specifically, the positive coefficients range from 0.038 to 0.145. This suggests that schools near the bridge experience a decrease in test scores by 0.095 to 0.363 standard deviations compared to those more than 2.5 miles (Treatment I) away. When compared to schools 8.5 miles (Treatment II) away, the decrease ranges from 0.323 to 1.233 standard deviations.

Due to its designation as the alternative route with Mn 280 by the Minnesota Department of Transportation, I-94 bridge demands a separate experiment. Furthermore, following the collapse of the I-35W bridge, the I-94 bridge experienced a notable 26.36% increase in traffic volume (Zhu et al., 2010). Leveraging this exogenous shift in average daily traffic around the I-94 bridge, I examine the potential impact on test scores of schools located in close proximity to the I-94, compared to those situated farther away. Only schools located in the Minneapolis metro area are considered for this analysis. Similar to the I-35W bridge experiment, I've excluded schools within a 2.5-mile radius of the I-35W bridge to uphold the Stable Unit Treatment Value (SUTVA) assumption. The effect I am estimating here primarily concerns increased traffic and potentially higher pollution levels, rather than a psychological effect of the disaster. Using the same model as equation 1, I present estimation results in table A14. Most coefficient estimates are statistically insignificant, except for math scores in grades 4 and 5. Figure A10 plots the 'Treated' variable's coefficient estimates from Equation 2 against z-scores for math and reading.

Threats to Identification

One possible threat to identification can be the changed student body of the schools located near the bridge collapse who either did not appear on the exam on April 14, 2008 or appeared on the exam, but from a different school (a part of control schools or not a part of either of the three groups: Treatment I, Treatment II, Control). To test this possibility, I check the enrollment number of each year for both treated and control as enrollment is counted in the October of each year which is more than two months after the bridge collapse. I plot the annual average number of enrolled student by their treatment status (Treatment I) against years on the x-axis in figure A17. It can be seen that the enrollment number didn't change from 2007 to 2008 for both groups. In a similar manner, I plot by the Treatment II status and found the same trend.

Now, though there was no significance change in the average number of enrolled students by the treatment status between 2007 and 2008, however, it is very much possible that the number if students who appeared on the exams in 2008 were different from previous years. To check this possibility, I plot the annual average number of test takers on the y-axis and years on the x-axis in figure A18. It can be seen that there was a lot of volatility in the number of examinee since 2000 to 2006, however, the numbers are mostly stable over 2007, 2008 and 2009 for both Treatment I and control groups. Similar pattern can be seen when I plot by Treatment II status.

From the above-mentioned discussions, it is clear that the number of enrolled students and the number of test takers were stable before and after the bridge collapse for both treatment and control groups. One last possibility can be whether there were more absent students for treatment schools in 2008. To test this, I plot the average number of absent students against years by the treatment status. Usually, the average number of absent students is quite low which is also exhibited in figure A19. Neither of the treatment (both treatment I and Treatment II) or control groups show that the number of absent students raised from 2007 to 2008 and subsequent years.

VIII. Mechanisms

I find, using TWFE and SDID estimation, that the bridge collapse negatively affected MCA test scores. Moreover, these findings are robust across a variety of specifications and definitions of treatment and control groups. Now, I seek to uncover the mechanisms behind this reduction in test scores.

A. Long term air quality improvements

As discussed in the background section II, demand for traffic was dropped substantially for areas within 2.5 miles radius of the collapse bridge, creating a possible exogenous change in air quality. To find out or rule out the possibility of air quality changes as a mechanism driving the low test scores, first, I estimate the impact of bridge collapse on the level of pollution within 2.5 miles of the bridge where the treatment group is defined as all the air quality monitors located within 2.5 miles radius of the bridge. A second treatment group is defined as the monitors located in Cordon 3 and 4 (2.5 to 8.5 miles) of the bridge to prevent the violation of SUTVA assumption. To compare with each of these treatment groups, I define a common control group of monitors located in Minneapolis. Here, I use EPA monthly monitor level data for the year 2006-2009 because the bridge collapsed on August 2007 and reopened on October 2008. Figure 3 shows the locations of EPA air quality monitors and the bridge in addition to which monitors are in Treatment I, Treatment II and Control. The key identifying assumption here is that trends of air quality within 2.5 miles (or from 2.5 to 8.5 miles) radius of the bridge would be the same for all of Minneapolis in the absence of a bridge collapse.

In order to find whether there was any change in pollution level due to the bridge collapse, I use the following Two-way Fixed Effects (TWFE) model where standard error is clustered at the county level:

$$Pollution_{i,t} = \alpha_i + \lambda_t + \theta D_{i,t} + \varepsilon_{i,t} \tag{4}$$

In this equation, $Pollution_{i,t}$ is the monthly AQI (and $PM_{2.5}$) value for monitor 'i' at month 't', $D_{i,t}$ is a dummy variable equal to 1 if monitors located either within 0 to 2.5 miles or monitors within 2.5 to 8.5 miles post August 1, 2007, α_i is a monitor fixed-effect, λ_t is a time fixed effect, and $\varepsilon_{i,t}$ is an error term. Table 5 provides the coefficient estimates of equation 4 where AQI is the dependent variable and the only independent variable is the treatment. Here Treatment I reduces the AQI value and $PM_{2.5}$ by 5.938 and 1.665, respectively meaning air quality improves by these amount as lower the AQI and $PM_{2.5}$ better the quality. Similarly, Treatment II also reduces the AQI score and $PM_{2.5}$, however, it is not statistically significant. So, it can be concluded that only Treatment I shows improvement in the air quality.

To estimate the dynamic treatment effect of bridge collapse on the pollution level near the collapse

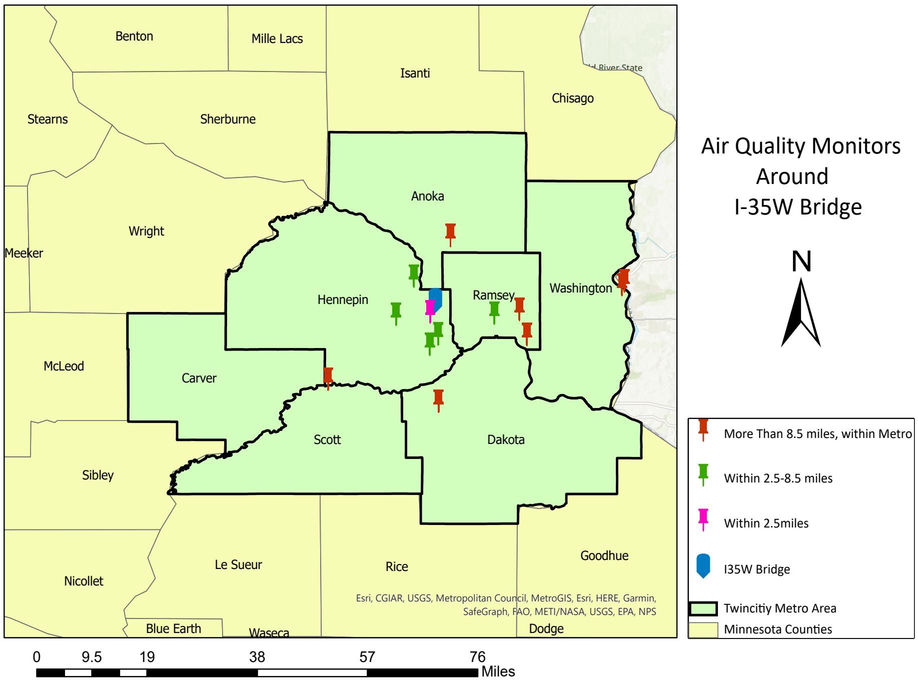

FIGURE 3. AIR QUALITY MONITORS AROUND I-35W BRIDGE BY THE TREATMENT STATUS

site, I use the following event study:

(5)

$$Pollution_{i,t} = \alpha + \sum_{\omega=January2006}^{June2007} D_i.1(t=\omega)\tau_{\omega}^{Pre} + D_i.1(t=\omega) \sum_{\omega=August2007}^{December2009} D_i\tau_{\omega}^{Post} + \phi_i + \lambda_t + \varepsilon_{i,t}$$

where D_i is a binary variable equal to one for monitors located within 2.5 miles of the bridge and zero otherwise. ϕ and λ are county and month fixed effects. Estimation is performed with standard errors clustered at the county level. Figure A6 depicts the event-study estimates of the effect of bridge collapse on monthly air quality index (AQI). The figure shows air quality for each month from 2006 to 2009 relative to July 2007, one month prior to the bridge collapse. There was no significant air quality improvement immediately after the collapse. However, since April 2008, the area within 2.5 miles radius of the bridge had better air quality relative to July 2007 for the rest of Minneapolis and it continued to have much better air quality till January 2009. On the other hand, the statewide exam, MCA, was held in April for both 2008 and 2009. This means though there was very low air quality improvement for the test takers of 2008, examinees were exposed to better air quality for more than nine months. Figure A7 replicates the event study for Treatment II from equation 5 where no significant changes in air quality are noticed relative to July 2007. I also estimate the same event study for $PM_{2.5}$ as a dependent variable (see figure A8 and A9).

TABLE 5—THE IMPACT OF TREATMENT STATUS (MONITORS LOCATED WITHIN 2.5 MILES FOR TREATMENT I OR 2.5 TO 8.5 MILES FOR TREATMENT II) ON AIR POLLUTION

	(1) Monthly AQI	(2) Monthly PM2.5	(3) Monthly AQI	(4) Monthly PM2.5
Treatment I	-5.938***	-1.665***		
	(0.177)	(0.054)		
Treatment II			-0.381	-0.114
			(0.213)	(0.053)
Constant	39.236***	10.121***	39.083***	10.095***
	(0.010)	(0.003)	(0.041)	(0.010)
N	2962	2962	3464	3464
R-sq	0.917	0.936	0.928	0.942

Cluster-robust standard errors, indicated in parentheses, are calculated at the county level using TWFE.
* p<0.05, ** p<0.01, *** p<0.001

Note: The unit of analysis is monitor-month where monitors only in the metro area are considered ('Restricted Sample'). The estimates are from 4. Column (1) to column (4) shows θ coefficients estimated from equation 4 for two different pollutants as dependent variables with time and monitor fixed effects. The key predicting/independent variable is Treated which is a dummy variable equal to 1 if the monitors are located within 2.5 miles (or 2.5 to 8.5 miles for Treatment II) of I-35W bridge after 2007 and 0 otherwise. Robust standard errors clustered at the county level.

Up to this point, to assess the impact of the bridge collapse on pollution levels, I employ EPA monthly monitor level data in equation 4. Additionally, as a robustness check, I conduct an analysis using monthly global $PM_{2.5}$ data from surface and satellite-based sources for the years 2006-2008. Similar to the main analysis, Treatment I comprises census tract area within a 2.5-mile radius of the bridge, Treatment II includes census tract area between 2.5 and 8.5 miles from the bridge, and Control encompasses other census tracts within the state of Minnesota. Figure A11 visually presents the census tracts with a background of global $PM_{2.5}$ raster data, along with the two buffers around the bridge, designated as Treatment I and Treatment II. For a more detailed view of this graph, refer to A12.

To demonstrate the surface-level or Global $PM_{2.5}$ improvement in Cordon 1 and 2, I re-estimate equation 4 with cluster-robust standard errors at the census tract level. Table A18 presents the coefficient estimates, with Global $PM_{2.5}$ as the dependent variable and the treatment as the only independent variable. To explore the impact on the dependent variable, I have estimated this equation separately for Treatment I and II, using mean, minimum, and maximum values of Global $PM_{2.5}$ in three different columns. For Treatment I, the results indicate a reduction in the mean, maximum, and minimum Global $PM_{2.5}$ values by 0.427, 0.415, and 0.435, respectively. This reduction signifies an improvement in air quality, as lower Global $PM_{2.5}$ values indicate better air quality. Notably, when comparing these results to the main analysis (equation 4), the magnitude of the reduction is lower than 1.665. Similarly, Treatment II also exhibits a reduction in Global

$PM_{2.5}$ scores, and this time, it is statistically significant, unlike the main analysis. Consequently, it can be inferred that both Treatment I and II contribute to improvements in air quality. These findings underscore the positive impact of the treatments on air quality, supporting the notion that the bridge collapse led to better overall air quality conditions.

To ensure the robustness of the analysis, I conducted a joint treatment two-way fixed effects (TWFE) specification for the air quality monitors, explicitly addressing spillover effects and addressing any potential violations of SUTVA. The results of this analysis are presented in Table A4. Regarding pollution, the main analysis's conclusion remains consistent: Treatment I leads to a statistically significant reduction in air pollution, decreasing the monthly AQI value by 5.96 and $PM_{2.5}$ by 1.67. Conversely, Treatment II does not have a significant effect on air pollution, aligning with the findings of the main analysis. Additionally, I have included the results of equation 4 with clustering at the air quality monitors instead of the county level, yet the outcomes remain unchanged as shown in table A4. To account for heteroskedasticity, cross-sectional, and temporal correlation, I also estimate equation 4 with Driscoll-Kraay standard errors (Hoechle, 2007).[3] The results are given in table A20, which is similar to the core results. This further confirms the robustness of the findings and underscores the validity of the research design.

To account for potential confounding factors and ensure the robustness of the analysis, I introduce three weather variables—namely, precipitation, minimum temperature, and maximum temperature—into equation 4. These variables are crucial in controlling for time-varying factors that could influence the monitor readings and lead to spurious results. The treatment and control variables are defined in the same manner as presented in equation 4. In Table A19, I present the coefficient estimates, where the dependent variable is AQI (and $PM_{2.5}$), and the independent variables include treatment, along with the weather controls. In this analysis, both Treatment I and Treatment II are found to be statistically insignificant. Moreover, the magnitude of their effects is lower compared to the results of equation 1 in the main analysis.The substantial number of missing weather values could potentially impact the results.

The absence of a negative impact from air pollution can be attributed to several factors. These include the possibility of psychological shocks mitigating the effects due to excessive media coverage of the bridge collapse, the longer commute times students faced when using alternative routes, the relatively smaller magnitude of air quality improvement, and the potential absence of 'exam day effects'.The air quality index (AQI) improvement I calculate amounts to roughly 6. It's im-

[3] The lag length, up to which the residuals may be autocorrelated and denoted as m(T), is calculated based on the first step of Newey and West (1994)'s plug-in procedure as follows: $m(T) = floor[4(T/100)^{2/9}]$ (Hoechle, 2007)

portant to note that the AQI can span the full range from 0 to 500, with an average AQI score of over 38 near the bridge site. Since a lower AQI signifies better air quality, a negative relationship between treated status and AQI suggests that the bridge collapse led to a decrease in AQI of approximately 6. However, this relatively modest improvement in air quality near the bridge may not have been substantial enough to significantly impact the test scores of students eight months later during the April 2008 MCA exams. While traffic in cordon 1 and 2, which are within a 2.5-mile radius around the bridge, didn't fully rebound to pre-collapse levels, this didn't result in significantly improved air quality that would noticeably affect nearby schools' cognitive performance. One plausible explanation is the pollution generated by bridge reconstruction efforts, potentially offsetting the positive effects of reduced traffic volumes.

B. *Exam-day air quality*

It is necessary to check whether the pollution level on the exam days were different from other usual days before the exams meaning whether there was any 'exam day effect' or contemporaneous effects of air pollution. As mentioned in the introduction section I that many papers show short-term effects of pollution and some paper show long-term effects. There is no consensus yet on which effect has the most impact on cognitive outcomes. It could be possible that the level air pollution on the exam day was actually worse on the exam day than before the disaster, even though the average air quality improved. Analyzing EPA's AQI and particulate matters measurements, I find that the mean AQI near bridge (within 2.5 miles) on exam month was 43.5 comparing to mean AQI score of 41.990 in Minneapolis which is higher than the annual air quality index. Similarly, the mean $PM_{2.5}$ near the bridge was 11.04 whereas the $PM_{2.5}$ concentration was 10.64 in the Minneapolis metro area. In figure A16, I plot the pollution measurement on days of exam month in 2008. It can be seen that these pollution measurement were volatile and on April 14, the AQI and $PM_{2.5}$ concentration was not lower than the average of the month. However, there not enough evidences to say that lack of improvements in the exam scores can be explained by these lack of short-term improvement in air quality.

C. *Psychological trauma and commuting costs*

Among the potential reasons for the support of hypothesis 1, the psychological impacts of the bridge collapse stand out as significant, albeit challenging to quantify. The bridge collapse garnered extensive media coverage, notably including a school bus filled with students falling with the bridge, an image with the potential to induce 'secondary traumatization' (McCann and Pearlman, 1990; Spence, Nelson and Lachlan, 2010). Furthermore, Ahern et al. (2004) reported the possibility of post-traumatic stress disorder symptoms. In a study on the psychological impacts of the I-35W bridge, Lachlan, Spence and Nelson (2010) explored how residents sought mediated information and how gender influenced emotional responses and information-seeking behaviors. They surveyed 166 residents living within a block of the bridge, measuring emotional reactions on Likert scales. Their findings indicated that higher media consumption was associated with increased levels of sorrow and sadness, as well as reduced calmness.

In background section II, I referenced Zhu et al. (2010) to highlight the longer travel times as an indication of an 'avoidance phenomenon'. These extended commutes to reach schools not only disrupted daily routines but potentially imposed significant inconvenience costs on students, affecting their overall well-being and possibly their academic performance. Despite potential improvements in the immediate environment around the collapsed bridge and nearby schools, the indirect consequences of altered travel routes—increased commuting times and the associated stress and inconvenience—may have negated any positive effects. However, it's essential to note that I lack data on individual students' home locations, the specific alternative routes school buses or family cars took after the bridge collapse, and the traffic volumes on these alternative routes before and after school hours. Consequently, testing this possibility is challenging.

Based on findings by Carneiro, Cole and Strobl (2021), Lavy, Ebenstein and Roth (2014), Gilraine and Zheng (2022), and Persico and Venator (2021), a $1\,\mu g/m^3$ increase in particulate pollution reduces test scores by between 0.0045 and 0.08 standard deviations. In contrast, my findings indicate an overall disaster impact of between -0.118 and -0.821 standard deviations on test scores, which accounts for both the positive effects of pollution reduction and other negative effects, including psychological trauma, stress, increased commuting times, and other inconveniences. This suggests that the back-of-the-envelope impact of psychological trauma and increased commuting costs alone might reduce test scores by between -0.123 and -0.859 standard deviations.

IX. Conclusion

This paper examines the impact of an infrastructure failure—the collapse of the I-35W Mississippi River Bridge in Minneapolis, Minnesota—on statewide comprehensive exam test scores, using it as a natural experiment. Employing a two-way fixed effects difference-in-differences (TWFE DiD) model, I observe statistically significant declines in test scores for schools near the bridge, with decreases ranging from 0.118 standard deviations in 8th grade math scores to 0.821 standard deviations in 7th grade math scores. Additionally, employing a synthetic difference-in-differences model reveals reductions of 0.576 and 0.520 standard deviations in 3rd grade reading and math scores, respectively, and 0.653 and 0.818 standard deviations in 5th grade reading and math scores. These findings are robust across various estimation methods, assumptions adjustments, treatment and control group re-definitions, and sample variations.

To explore a potential mechanism behind this adverse effect on students' exam performance, I also investigate exogenous changes in pollution levels near the collapse site. Despite improved air quality within a 2.5-mile radius of the bridge, this did not positively impact the test scores of students in schools exposed to reduced pollution. This absence of significant positive effects may be due to increased travel times leading to more pollution exposure and the lack of an 'exam day effect'. Moreover, I find that exposure during test week was about equal, even though exposure during the year changed, so it seems that only short-term air pollution exposures matter, though it requires further investigation to come to this conclusion. Additionally, the psychological impact of the disaster, heightened by media coverage, especially images of a school bus involved in the collapse, extended commute times, and other inconveniences, are also considered. Using a back-of-the-envelope approach, I conclude that psychological trauma and increased commuting costs may alone account for a reduction in test scores ranging from -0.123 to -0.859 standard deviations. I also examine several threats to the identification strategy, such as compositional effects from student attrition, but find no evidence of these impacting the results. Evidence includes stable enrollment numbers, test participation, and absenteeism before and after the collapse across treatment and control groups.

The observed negative impact of the bridge collapse on student test scores underscores the need for policymakers and educators to address both immediate and long-term effects on educational outcomes following an infrastructure failure. This includes allocating additional funds for mental health resources, such as free counseling in schools, to help students cope with psychological stress and trauma. Moreover, investing in stronger, disaster-resilient infrastructure can reduce the likelihood of such catastrophic events and mitigate their impact on education. Additionally, improving transportation options is important to minimize disruptions to educational access in the aftermath of infrastructure failures.

X. Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, Emtiaz Hossain Hritan used ChatGPT-3.5 in order to improve sentence structures. After using this tool/service, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

XI. Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

XII. Declaration of interest

None

XIII. Data Accessibility

The data that support the findings of this study are openly available in Mendeley Data at [DOI: 10.17632/mj9zhb9vxj.1]

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APPENDIX: ADDITIONAL AND ALTERNATIVE ANALYSIS

Subject	Grade	Observations	Mean	Standard Deviation	Minimum	Maximum
Reading	3	2,589	957.2472	557.4046	318.7	1773.14
	4	1,177	454.5468	8.917383	419.8	481.6
	5	2,544	1071.24	487.8501	529.8	1912
	6	876	652.4601	7.98629	625.6	671.9
	7	773	928.8422	304.6517	718.2	1563.5
	8	578	851.144	8.448802	816.79	873.6
Math	3	2,567	965.9733	563.6353	333.8	1850
	4	1,162	453.9881	7.845866	424	480.2
	5	2,531	1055.914	473.4191	516.9	1784.76
	6	859	650.2279	8.913382	612.1	673.3
	7	759	932.0979	307.9132	719.6	1548.06
	8	571	847.6213	9.508917	814.4	871.4

TABLE A1—SUMMARY STATISTICS: AVERAGE SCORES BY SUBJECT AND GRADE

Note: This table presents summary statistics of the average test scores by grades and subjects based on the sample used in the main specifications, comprising all the schools in the Minneapolis metro area from 2000 to 2010. The first and second columns of the table report the subjects and grades of the test scores used in the main analysis. Columns three to seven present the number of observations, mean, standard deviation, minimum and maximum values for each subject-grade combination used in the estimation.

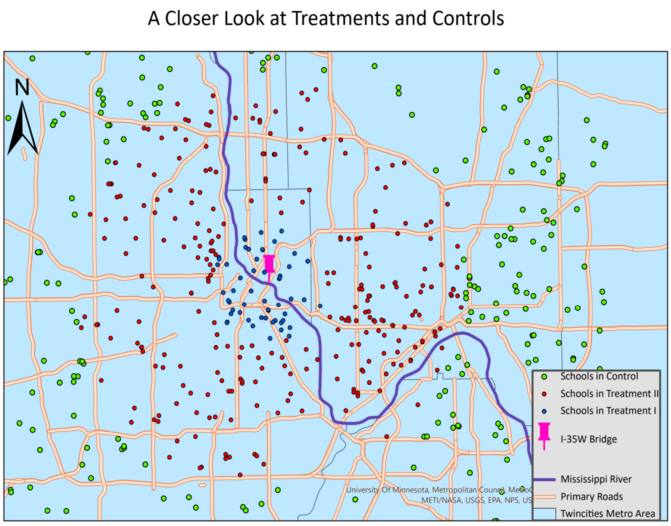


FIGURE A1. CLOSER LOOK OF THE RESEARCH DESIGN: TREATED AND CONTROL SCHOOLS AROUND THE I-35W BRIDGE

Variable Description	Observations	Mean	Standard Deviation	Minimum	Maximum
Grade Enrollment	70,640	88.38134	92.29317	0	871
Test Takers	71,110	84.0929	87.6221	10	841
Average Scores	71,110	929.3883	461.0598	316.20	1918.20
Absent Students on Exam Day	56,043	0.434845	1.494484	0	77
Distance of Schools to I-35W Bridge (meters)	71,110	119470.20	115721.90	598.501	509229.20
Distance of Schools to Highways (meters)	71,110	903.7731	1362.06	0.015	16217.9
Daily PM2.5 concentrations	29,823	8.644	6.400339	0	63.1
Daily Air Quality Index	29,823	33.519	20.36882	0	155
Distance of Monitors to I-35W Bridge (meters)	29,823	132809.20	128555.3	3002.32	430262.6

TABLE A2—SUMMARY STATISTICS FOR THE FULL SAMPLE

Note: This table presents summary statistics based on the full sample, which includes all schools and air quality monitors in Minnesota from 2000 to 2010 and 2006 to 2009, respectively. The first column of the table reports descriptions of the variables used in the analysis. Columns two, three, and four present the number of observations, mean, and standard deviation of each variable, respectively. Additionally, columns five and six display the minimum and maximum values for each variable used in the estimation. The average score encompasses all grades and subjects to provide a comprehensive assessment of academic performance. The grade enrollment of 0 means that no student was enrolled in that particular grade in the month of October of a year.

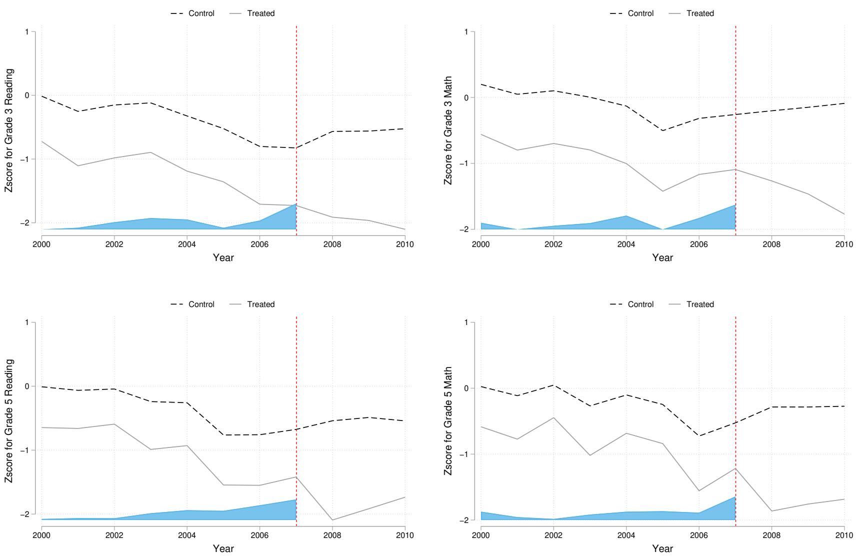


FIGURE A2. SYNTHETIC DID: PARALLEL TRENDS IN READING AND MATH SCORES FOR GRADE 3 AND 5 IN CONTROL AND TREATMENT GROUP I. TREATMENT I INCLUDES ALL THE SCHOOLS LOCATED WITHIN A 2.5-MILE RADIUS OF THE BRIDGE

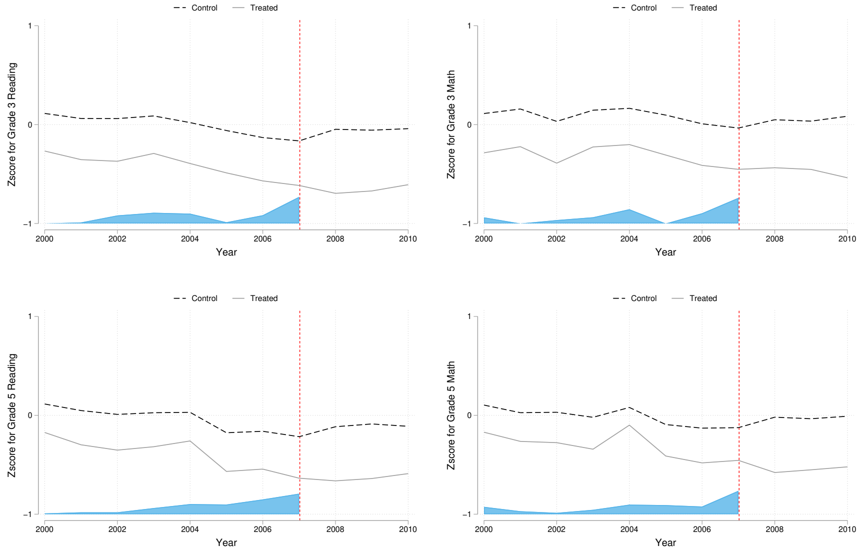


FIGURE A3. SYNTHETIC DID: PARALLEL TRENDS IN READING AND MATH SCORES FOR GRADE 3 AND 5 IN CONTROL AND TREATMENT GROUP II. TREATMENT II CONSISTS OF ALL THE SCHOOLS LOCATED FROM 2.5 TO 8.5 MILES RADIUS OF THE BRIDGE

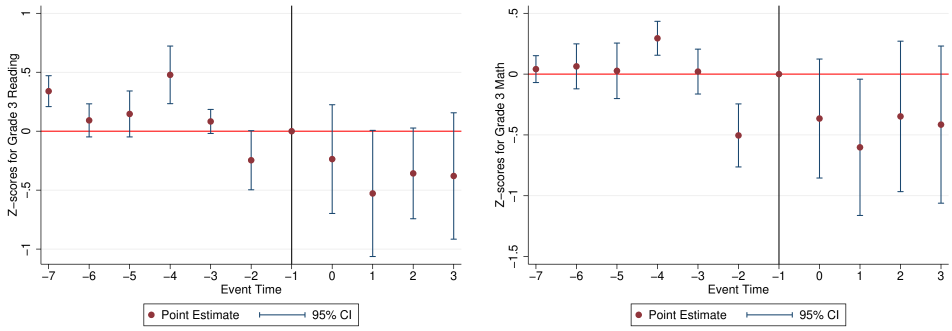


FIGURE A4. EVENT STUDY TO EXPLORE THE EFFECTS OF BRIDGE COLLAPSE (TREATMENT I) ON READING AND MATH SCORES FOR GRADE 3. TREATMENT I INCLUDES ALL THE SCHOOLS LOCATED WITHIN A 2.5-MILE RADIUS OF THE BRIDGE

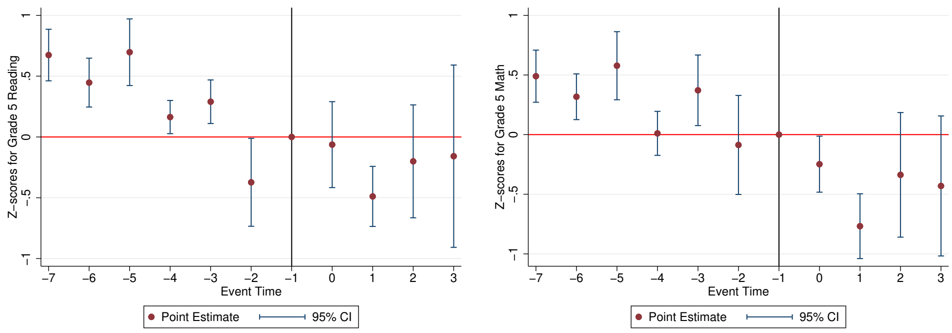


FIGURE A5. EVENT STUDY TO EXPLORE THE EFFECTS OF BRIDGE COLLAPSE (TREATMENT I) ON READING AND MATH SCORES FOR GRADE 5. TREATMENT I INCLUDES ALL THE SCHOOLS LOCATED WITHIN A 2.5-MILE RADIUS OF THE BRIDGE

TABLE A3—SYNTHETIC DID: IMPACT OF THE BRIDGE COLLAPSE (TREATMENT II: ALL THE SCHOOLS LOCATED FROM 2.5 TO 8.5 MILES RADIUS OF THE BRIDGE) ON STANDARDIZED READING AND MATH TEST SCORES FOR GRADES 3 AND 5

	(1) Grade 3 Reading	(2) Grade 3 Math	(3) Grade 5 Reading	(4) Grade 5 Math
Treated	-0.181***	-0.131*	-0.151***	-0.229***
	(0.043)	(0.057)	(0.045)	(0.057)
N	7183	7150	6490	6479

Cluster-robust standard errors, indicated in parentheses, are calculated at the school district level for SDID.
* p<0.05, ** p<0.01, *** p<0.001

Note: The unit of analysis is the school year, during which all schools in the state of Minnesota are considered ('Full Sample').The estimates are from 2 with Treatment II. Column (1) to column (4) shows θ coefficients for different grade-subjects dependent variables with year and school fixed effects. The key predicting/independent variable is Treated which is a dummy variable equal to 1 if the schools are located within 2.5 and 8.5 miles of I-35W bridge after 2007 and 0 otherwise. Robust standard errors clustered at the school districts level.

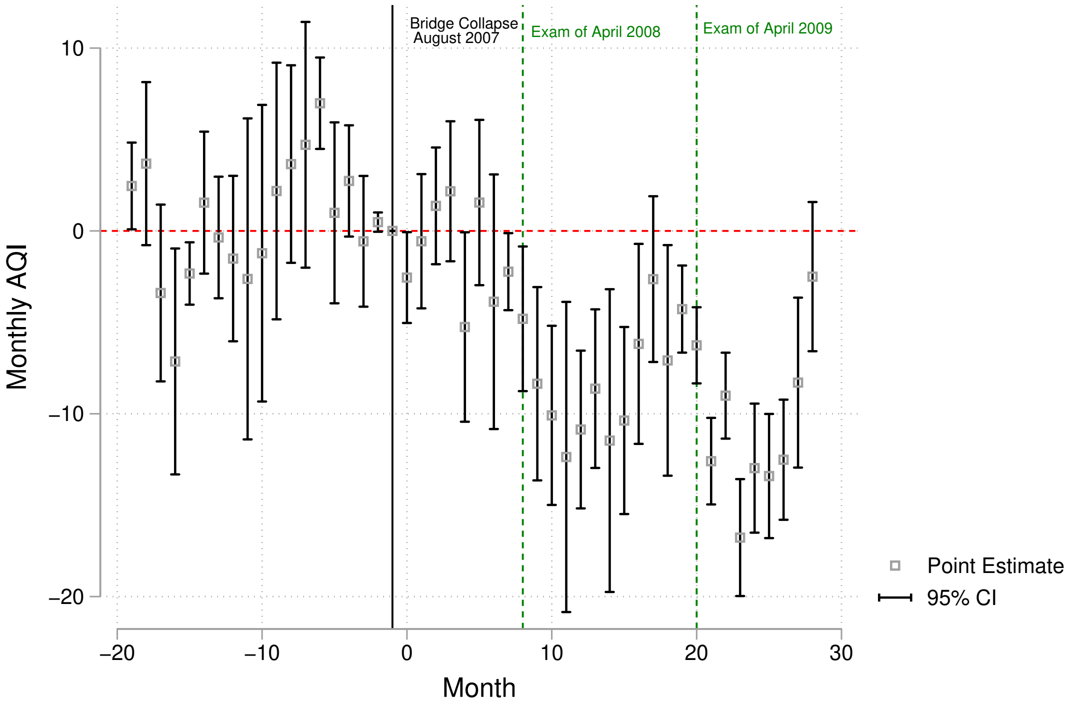


FIGURE A6. EVENT STUDY TO EXPLORE THE EFFECTS OF TREATMENT STATUS ON AIR POLLUTION (AQI). TREATMENT I (MONITORS LOCATED WITHIN A 2.5-MILE RADIUS OF THE BRIDGE) SHOWS THE MONTHLY CHANGES IN POLLUTION LEVEL BEFORE AND AFTER THE BRIDGE COLLAPSE RELATIVE TO JULY 2007

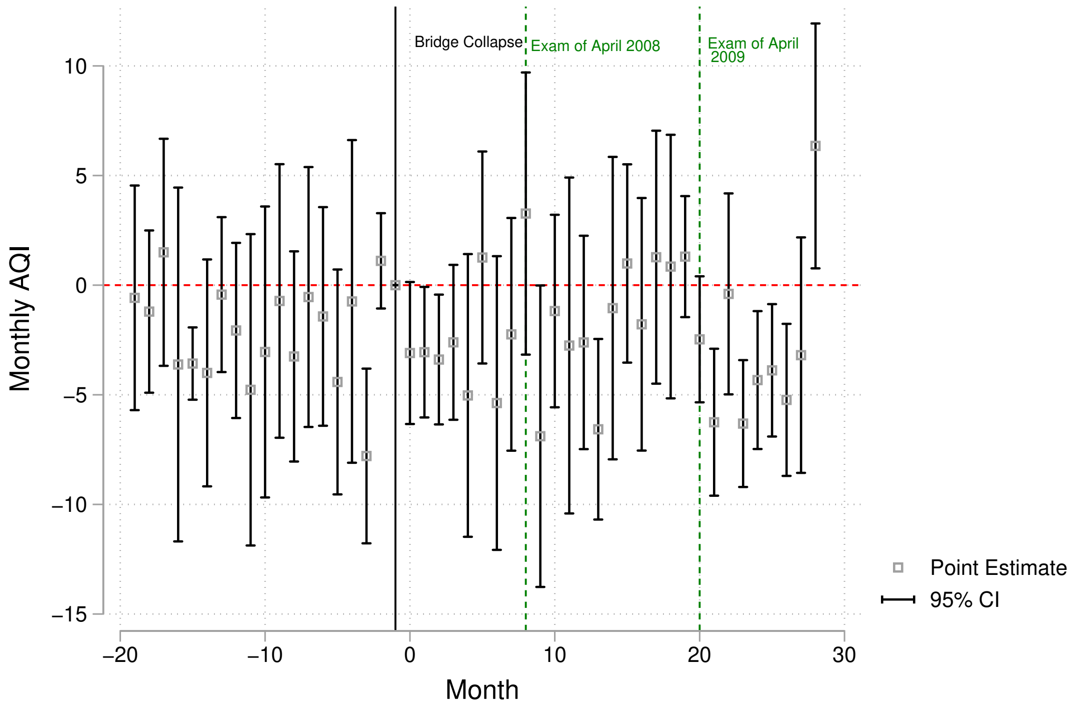


FIGURE A7. EVENT STUDY TO EXPLORE THE EFFECTS OF TREATMENT STATUS ON AIR POLLUTION (AQI). TREATMENT II (MONITORS LOCATED FROM 2.5 TO 8.5 MILES RADIUS OF THE BRIDGE) SHOWS MONTHLY CHANGES IN POLLUTION LEVEL BEFORE AND AFTER THE BRIDGE COLLAPSE RELATIVE TO JULY 2007

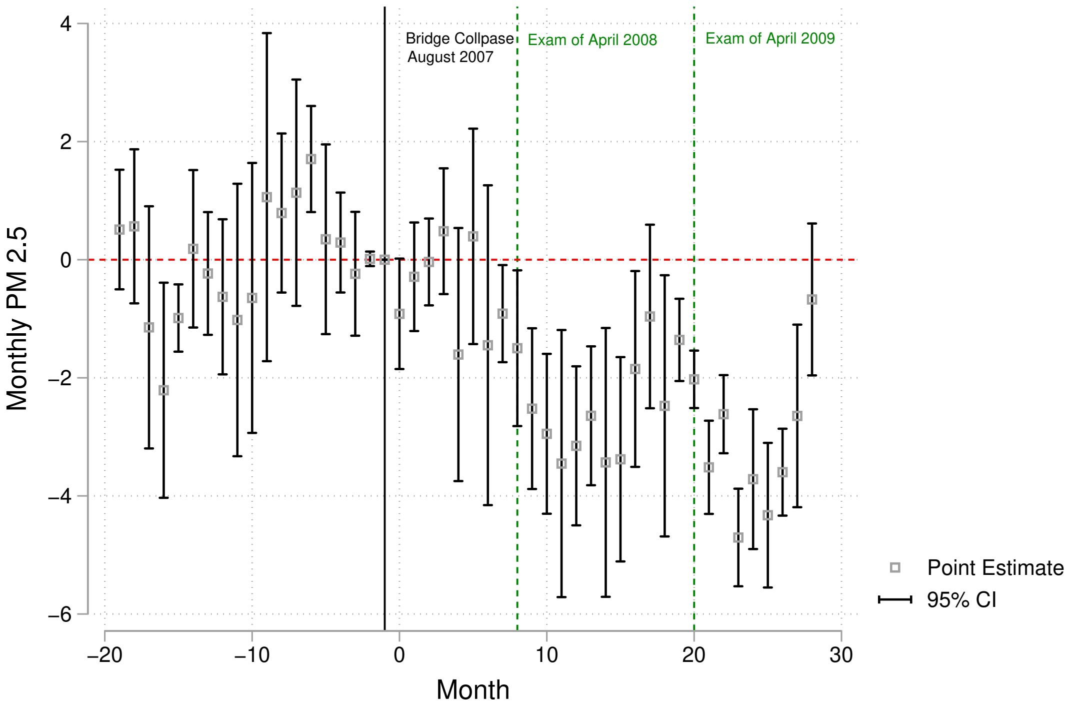


FIGURE A8. EVENT STUDY TO EXPLORE THE EFFECTS OF TREATMENT STATUS ON AIR POLLUTION. TREATMENT I (MONITORS LOCATED WITHIN A 2.5-MILE RADIUS OF THE BRIDGE) SHOWS THE MONTHLY CHANGES IN POLLUTION LEVEL ($PM_{2.5}$) BEFORE AND AFTER THE BRIDGE COLLAPSE RELATIVE TO JULY 2007

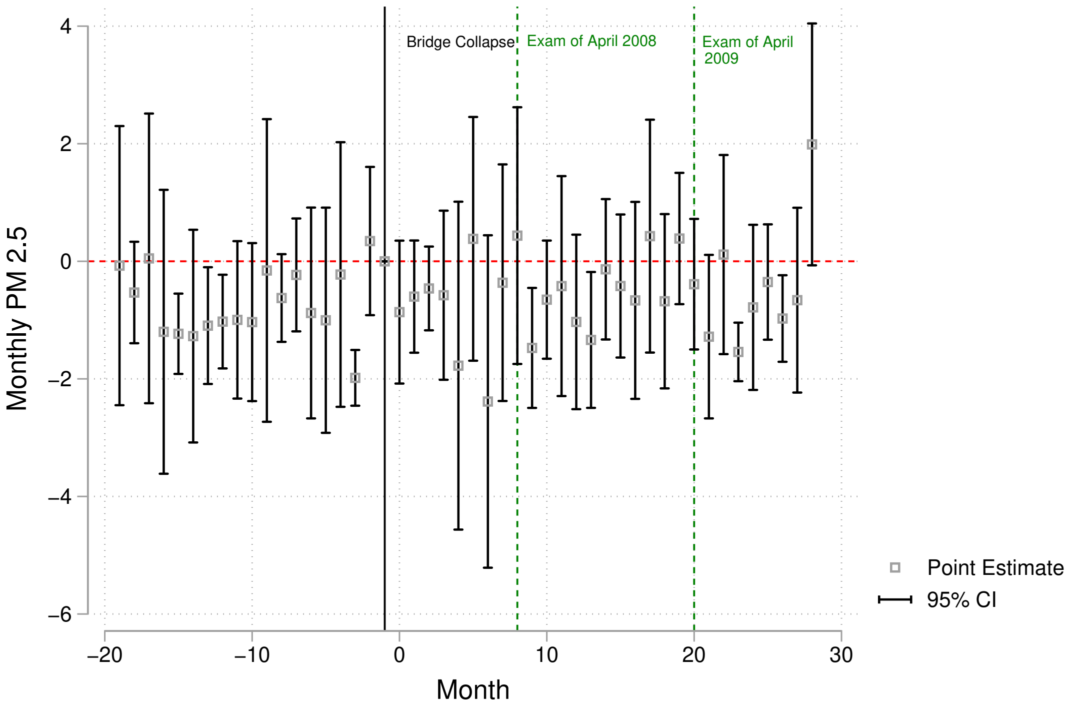


FIGURE A9. EVENT STUDY TO EXPLORE THE EFFECTS OF TREATMENT STATUS ON AIR POLLUTION. TREATMENT II (MONITORS LOCATED FROM 2.5 TO 8.5 MILES RADIUS OF THE BRIDGE) SHOWS MONTHLY CHANGES IN POLLUTION LEVEL($PM_{2.5}$) BEFORE AND AFTER THE BRIDGE COLLAPSE RELATIVE TO JULY 2007

Table A4—Robustness Check (Clustering at the monitor levels and Joint Treatment TWFE): The impact of Treatment Status on Air Pollution. Treatment I consists of all the monitors located within a 2.5-mile radius of the bridge and Treatment II includes all the monitors located from 2.5 to 8.5 miles radius of the bridge

	(1) Monthly AQI	(2) Monthly PM2.5	(3) Monthly AQI	(4) Monthly PM2.5	(5) Monthly AQI	(6) Monthly PM2.5
Treatment I	-5.938***	-1.665***			-5.969***	-1.679***
	(0.159)	(0.048)			(0.162)	(0.053)
Treatment II			-0.381	-0.114*	-0.339	-0.102
			(0.240)	(0.050)	(0.227)	(0.054)
Constant	39.236***	10.121***	39.083***	10.095***	39.406***	10.197***
	(0.009)	(0.003)	(0.047)	(0.010)	(0.046)	(0.012)
N	2962	2962	3464	3464	3633	3633
R-sq	0.917	0.936	0.928	0.942	0.922	0.939

Cluster-robust standard errors, indicated in parentheses, are calculated at the monitor level

* p<0.05, ** p<0.01, *** p<0.001

Note: This is the sample which includes all air quality monitors in Minneapolis metro area. The unit of analysis is monitor-month. Columns (1) to (4) present the coefficients from Equation 4, with standard errors clustered at the air quality monitor level, rather than at the county level. Columns (5) and (6) show the coefficients from a joint treatment Two-Way Fixed Effects (TWFE) specification for the air quality monitors, explicitly addressing spillover effects and any potential violations of the Stable Unit Treatment Value Assumption (SUTVA)

TABLE A5—ROBUSTNESS CHECK (JOINT TREATMENT TWFE): IMPACT OF THE BRIDGE COLLAPSE ON STANDARDIZED READING AND MATH TEST SCORES FOR GRADE 3 TO 8. TREATMENT I CONSISTS OF ALL SCHOOLS LOCATED WITHIN A 2.5-MILE RADIUS OF THE BRIDGE, WHILE TREATMENT II INCLUDES SCHOOLS LOCATED FROM 2.5 TO 8.5 MILES AWAY FROM THE BRIDGE

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Grade 3 Reading	Grade 3 Math	Grade 4 Reading	Grade 4 Math	Grading 5 Reading	Grading 5 Math	Grade 6 Reading	Grade 6 Math	Grade 7 Reading	Grade 7 Math	Grade 8 Reading	Grade 8 Math
Treated I	-0.662***	-0.448**	-0.277	-0.287*	-0.681***	-0.594***	-0.079	-0.424*	-0.774***	-0.829***	-0.174	-0.107
	(0.167)	(0.156)	(0.224)	(0.136)	(0.197)	(0.154)	(0.173)	(0.200)	(0.105)	(0.112)	(0.122)	(0.059)
Treated II	-0.315***	-0.331***	0.046	-0.080	-0.417***	-0.396***	0.025	0.010	-0.191*	-0.318**	0.186	0.019
	(0.080)	(0.072)	(0.081)	(0.090)	(0.077)	(0.060)	(0.057)	(0.082)	(0.081)	(0.117)	(0.150)	(0.077)
Grade Enrollment	0.006	-0.011	0.006	0.012***	-0.027	-0.014	0.005	0.007***	0.000	0.001	0.000	0.002
	(0.003)	(0.010)	(0.005)	(0.002)	(0.018)	(0.012)	(0.003)	(0.002)	(0.003)	(0.001)	(0.003)	(0.001)
Absent students on Exam Day	-0.014	-0.007	0.003	-0.122*	0.024	0.008	-0.060	-0.006	-0.023	-0.015	-0.016	-0.025
	(0.009)	(0.010)	(0.068)	(0.059)	(0.015)	(0.013)	(0.038)	(0.032)	(0.020)	(0.023)	(0.020)	(0.021)
Test Takers	-0.004	0.014	-0.005	-0.014***	0.029	0.017	-0.005	-0.008***	0.002	0.001	0.000	-0.002**
	(0.003)	(0.010)	(0.005)	(0.002)	(0.018)	(0.013)	(0.003)	(0.002)	(0.003)	(0.001)	(0.003)	(0.001)
Constant	-0.388***	-0.278*	-0.406**	-0.198	-0.270**	-0.237*	-0.361***	-0.193	-0.429	-0.323	-0.285	0.020
	(0.080)	(0.131)	(0.128)	(0.132)	(0.094)	(0.092)	(0.095)	(0.112)	(0.232)	(0.267)	(0.190)	(0.189)
N	2081	2057	943	920	2041	2025	692	672	539	524	443	431
R-sq	0.848	0.759	0.909	0.890	0.825	0.796	0.935	0.896	0.900	0.874	0.926	0.940

Cluster-robust standard errors, indicated in parentheses, are calculated at the school district level for TWFE.
* p<0.05, ** p<0.01, *** p<0.001

Note: The unit of analysis is school-year where schools in the Minneapolis metro area are considered. Both Treatment I and II are considered now with a common control group. Column (1) to column (12) shows θ coefficients estimated from the joint treatment TWFE version of equation 2 for different grade-subjects dependent variables with year and school fixed effects. The key predicting/independent variables are Treated I and II which are a dummy variable equal to 1 if the schools are located within 0 to 2.5 miles and 2.5 to 8.5 miles of I-35W bridge after 2007, respectively and 0 otherwise. As controls, student enrollment, number of test takers and number of absent students on the exam days are used. Robust standard errors clustered at the school districts level.

TABLE A6—ROBUSTNESS CHECK (WITH ONLY TREATMENT I, RELAXATION OF SUTVA): IMPACT OF THE BRIDGE COLLAPSE ON STANDARDIZED READING AND MATH TEST SCORES FOR GRADE 3 TO 8. TREATMENT I INCLUDES ALL THE SCHOOLS LOCATED WITHIN A 2.5-MILE RADIUS OF THE BRIDGE

	(1) Grade 3 Reading	(2) Grade 3 Math	(3) Grade 4 Reading	(4) Grade 4 Math	(5) Grade 5 Reading	(6) Grade 5 Math	(7) Grade 6 Reading	(8) Grade 6 Math	(9) Grade 7 Reading	(10) Grade 7 Math	(11) Grade 8 Reading	(12) Grade 8 Math
Treated	-0.519***	-0.293*	-0.298	-0.251	-0.508**	-0.426**	-0.091	-0.429*	-0.690***	-0.703***	-0.252*	-0.115*
	(0.138)	(0.140)	(0.235)	(0.137)	(0.179)	(0.146)	(0.167)	(0.185)	(0.090)	(0.114)	(0.106)	(0.047)
Grade Enrollment	0.007*	-0.013	0.006	0.012***	-0.027	-0.014	0.005	0.007***	0.001	0.002	0.000	0.002
	(0.003)	(0.010)	(0.004)	(0.002)	(0.018)	(0.012)	(0.003)	(0.002)	(0.002)	(0.001)	(0.003)	(0.001)
Absent Students on Exam Day	-0.013	-0.004	0.002	-0.129*	0.024	0.009	-0.060	-0.005	-0.023	-0.018	-0.011	-0.025
	(0.008)	(0.009)	(0.068)	(0.060)	(0.016)	(0.013)	(0.038)	(0.032)	(0.021)	(0.024)	(0.019)	(0.021)
Test Takers	-0.005	0.015	-0.006	-0.014***	0.029	0.017	-0.005	-0.008***	0.001	0.001	0.001	-0.002**
	(0.003)	(0.010)	(0.005)	(0.002)	(0.019)	(0.013)	(0.003)	(0.002)	(0.003)	(0.001)	(0.002)	(0.001)
Constant	-0.392***	-0.284*	-0.395**	-0.217	-0.330**	-0.294**	-0.353***	-0.190	-0.477*	-0.403	-0.238	0.024
	(0.083)	(0.137)	(0.127)	(0.123)	(0.102)	(0.104)	(0.093)	(0.107)	(0.238)	(0.272)	(0.179)	(0.186)
N	2081	2057	943	920	2041	2025	692	672	539	524	443	431
R-sq	0.844	0.754	0.909	0.890	0.818	0.790	0.935	0.896	0.899	0.871	0.925	0.940

Cluster-robust standard errors, indicated in parentheses, are calculated at the school district level for TWFE.
* p<0.05, ** p<0.01, *** p<0.001

Note: The unit of analysis is school-year where schools only in the metro area are considered ('Restricted Sample'). Only Treatment I is considered meaning Treatment II is now considered as the control group. Column (1) to column (12) shows θ coefficients estimated from equation 2 for different grade-subjects dependent variables with year and school fixed effects. The key predicting/independent variable is Treated which is a dummy variable equal to 1 if the schools are located within 2.5 miles of I-35W bridge after 2007 and 0 otherwise. As controls, student enrollment, number of test takers and number of absent students on the exam days are used. Robust standard errors clustered at the school districts level.

TABLE A7—ROBUSTNESS CHECK: TREATMENT I DEFINED FOR SCHOOLS WITHIN 0 TO 5.5 MILES OF THE BRIDGE, AND TREATMENT II FOR SCHOOLS WITHIN 5.5 TO 8.5 MILES

	(1) Grade 3 Reading	(2) Grade 3 Math	(3) Grade 4 Reading	(4) Grade 4 Math	(5) Grade 5 Reading	(6) Grade 5 Math	(7) Grade 6 Reading	(8) Grade 6 Math	(9) Grade 7 Reading	(10) Grade 7 Math	(11) Grade 8 Reading	(12) Grade 8 Math
Treated	-0.391*	-0.374***	-0.043	-0.203	-0.456**	-0.480***	0.020	-0.138	-0.350**	-0.565***	0.042	0.022
	(0.154)	(0.102)	(0.128)	(0.106)	(0.138)	(0.070)	(0.096)	(0.140)	(0.124)	(0.107)	(0.224)	(0.081)
Grade Enrollment	0.005	-0.013	0.006	0.013***	-0.030	-0.016	0.008*	0.010**	0.004	0.003*	0.001	0.002
	(0.003)	(0.013)	(0.004)	(0.003)	(0.018)	(0.015)	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.001)
Absent Students on Exam Day	-0.010	-0.002	-0.024	-0.063	0.028	0.012	-0.027	-0.012	-0.041*	-0.034	-0.015	-0.021
	(0.010)	(0.010)	(0.081)	(0.053)	(0.016)	(0.011)	(0.037)	(0.031)	(0.018)	(0.023)	(0.021)	(0.021)
Test Takers	-0.003	0.017	-0.007	-0.016***	0.032	0.019	-0.007*	-0.009**	0.000	0.000	0.001	-0.002
	(0.003)	(0.013)	(0.005)	(0.003)	(0.018)	(0.016)	(0.004)	(0.003)	(0.004)	(0.002)	(0.003)	(0.001)
Constant	-0.349***	-0.333*	-0.250*	-0.031	-0.237**	-0.199*	-0.431***	-0.402**	-0.855***	-0.673**	-0.492**	-0.245
	(0.072)	(0.154)	(0.095)	(0.114)	(0.076)	(0.086)	(0.120)	(0.152)	(0.173)	(0.206)	(0.181)	(0.126)
N	1795	1772	791	769	1773	1756	566	552	485	470	401	390
R-sq	0.850	0.757	0.916	0.907	0.829	0.792	0.931	0.900	0.897	0.876	0.920	0.946

Cluster-robust standard errors, indicated in parentheses, are calculated at the school district level for TWFE.
* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Note: The unit of analysis is school-year where schools only in the metro area are considered ('Restricted Sample'). Only Treatment I is considered meaning Treatment II is now considered as the control group. Column (1) to column (12) shows θ coefficients estimated from equation 2 for different grade-subjects dependent variables with year and school fixed effects. The key predicting/independent variable is Treated which is a dummy variable equal to 1 if the schools are located within 5.5 miles of I-35W bridge after 2007 and 0 otherwise. As controls, student enrollment, number of test takers and number of absent students on the exam days are used. Robust standard errors clustered at the school districts level.

TABLE A8—ROBUSTNESS CHECK: WITH TREATMENT II DEFINED AS SCHOOLS WITHIN 5.5 TO 8.5 MILES OF THE BRIDGE

	(1) Grade 3 Reading	(2) Grade 3 Math	(3) Grade 4 Reading	(4) Grade 4 Math	(5) Grade 5 Reading	(6) Grade 5 Math	(7) Grade 6 Reading	(8) Grade 6 Math	(9) Grade 7 Reading	(10) Grade 7 Math	(11) Grade 8 Reading	(12) Grade 8 Math
Treated	-0.324***	-0.272**	-0.016	-0.106	-0.435***	-0.317***	-0.004	-0.040	-0.142	-0.165	0.004	-0.020
	(0.068)	(0.101)	(0.101)	(0.136)	(0.078)	(0.076)	(0.063)	(0.100)	(0.082)	(0.146)	(0.103)	(0.089)
Grade Enrollment	0.003	-0.018	0.009	0.010**	-0.033	-0.018	0.004	0.000	0.001	-0.001	0.002	0.001
	(0.004)	(0.013)	(0.005)	(0.003)	(0.018)	(0.015)	(0.003)	(0.002)	(0.003)	(0.001)	(0.002)	(0.001)
Absent Students on Exam Day	-0.012	-0.012	-0.001	-0.134*	0.029	0.010	-0.080	0.018	-0.024	-0.022	-0.017	-0.020
	(0.010)	(0.012)	(0.065)	(0.062)	(0.015)	(0.014)	(0.047)	(0.032)	(0.022)	(0.027)	(0.021)	(0.022)
Test Takers	-0.002	0.019	-0.010*	-0.011***	0.035	0.020	-0.005	-0.002	0.001	0.003	-0.001	-0.001**
	(0.004)	(0.014)	(0.005)	(0.003)	(0.018)	(0.016)	(0.004)	(0.002)	(0.003)	(0.001)	(0.002)	(0.001)
Constant	-0.084	0.068	-0.066	0.102	-0.041	-0.012	0.007	0.193	-0.125	-0.101	0.176	0.442
	(0.074)	(0.120)	(0.152)	(0.156)	(0.098)	(0.090)	(0.090)	(0.106)	(0.275)	(0.340)	(0.174)	(0.241)
N	1552	1543	707	699	1509	1502	517	508	374	371	305	301
R-sq	0.831	0.739	0.922	0.879	0.813	0.767	0.923	0.871	0.873	0.844	0.943	0.933

Cluster-robust standard errors, indicated in parentheses, are calculated at the school district level for TWFE.
* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Note: The unit of analysis is school-year where schools only in the metro area are considered ('Restricted Sample'). Only Treatment I is considered meaning Treatment II is now considered as the control group. Column (1) to column (12) shows θ coefficients estimated from equation 2 for different grade-subjects dependent variables with year and school fixed effects. The key predicting/independent variable is Treated which is a dummy variable equal to 1 if the schools are located within 5.5 to 8.5 miles of I-35W bridge after 2007 and 0 otherwise. As controls, student enrollment, number of test takers and number of absent students on the exam days are used. Robust standard errors clustered at the school districts level.

TABLE A9—ROBUSTNESS CHECK: TREATMENT I WITH CONTROL DEFINED AS SCHOOLS WITHIN 900M OF THE ROAD WITHIN MINNESOTA ('FULL SAMPLE'). TREATMENT I INCLUDES ALL THE SCHOOLS LOCATED WITHIN A 2.5-MILE RADIUS OF THE BRIDGE

	(1) Grade 3 Reading	(2) Grade 3 Math	(3) Grade 4 Reading	(4) Grade 4 Math	(5) Grade 5 Reading	(6) Grade 5 Math	(7) Grade 6 Reading	(8) Grade 6 Math	(9) Grade 7 Reading	(10) Grade 7 Math	(11) Grade 8 Reading	(12) Grade 8 Math
Treated	-0.645***	-0.286	-0.196	-0.168	-0.565**	-0.363*	-0.137	-0.422*	-0.713***	-0.750***	-0.255*	-0.173***
	(0.180)	(0.183)	(0.243)	(0.141)	(0.202)	(0.162)	(0.169)	(0.193)	(0.090)	(0.095)	(0.115)	(0.044)
Grade Enrollment	-0.006	-0.013	0.008*	0.008**	-0.038**	-0.023*	0.005	0.005	0.003	0.002	0.002	0.001
	(0.008)	(0.010)	(0.003)	(0.003)	(0.012)	(0.012)	(0.003)	(0.003)	(0.002)	(0.003)	(0.002)	(0.001)
Absent Students on Exam Day	0.014	-0.000	-0.031	-0.087*	0.035**	0.015	-0.034	0.006	-0.041***	-0.027	-0.020	-0.004
	(0.010)	(0.009)	(0.051)	(0.039)	(0.012)	(0.012)	(0.027)	(0.021)	(0.012)	(0.018)	(0.015)	(0.013)
Test Takers	0.005	0.013	-0.009**	-0.011***	0.040**	0.025*	-0.006*	-0.007*	-0.001	-0.002	-0.002	-0.002*
	(0.008)	(0.011)	(0.004)	(0.003)	(0.012)	(0.012)	(0.003)	(0.003)	(0.002)	(0.003)	(0.002)	(0.001)
Constant	0.121***	0.122*	0.179**	0.239***	0.051	0.028	0.147*	0.243**	-0.068	0.033	0.009	0.153*
	(0.034)	(0.048)	(0.057)	(0.072)	(0.047)	(0.054)	(0.070)	(0.079)	(0.097)	(0.104)	(0.079)	(0.065)
N	4527	4514	1990	1973	4322	4311	1487	1475	1614	1604	1329	1319
R-sq	0.697	0.587	0.833	0.799	0.670	0.621	0.836	0.798	0.747	0.746	0.835	0.854

Cluster-robust standard errors, indicated in parentheses, are calculated at the school district level for TWFE.
* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Note: The unit of analysis is school-year where schools in the Minnesota State are considered ('Full Sample'). This sample only includes public schools. Column (1) to column (12) shows θ coefficients estimated from equation 2 for different grade-subjects dependent variables with year and school fixed effects. The key predicting/independent variable is Treated which is a dummy variable equal to 1 if the schools are located within 2.5 miles of I-35W bridge after 2007 and 0 otherwise. As controls, student enrollment, number of test takers and number of absent students on the exam days are used. Robust standard errors clustered at the school districts level.

TABLE A10—ROBUSTNESS CHECK: TREATMENT II WITH CONTROL DEFINED AS SCHOOLS WITHIN 900M OF THE ROAD WITHIN MINNESOTA ('FULL SAMPLE'). TREATMENT II CONSISTS OF ALL THE SCHOOLS LOCATED FROM 2.5 TO 8.5 MILES RADIUS OF THE BRIDGE

	(1) Grade 3 Reading	(2) Grade 3 Math	(3) Grade 4 Reading	(4) Grade 4 Math	(5) Grade 5 Reading	(6) Grade 5 Math	(7) Grade 6 Reading	(8) Grade 6 Math	(9) Grade 7 Reading	(10) Grade 7 Math	(11) Grade 8 Reading	(12) Grade 8 Math
Treated	-0.359***	-0.237**	0.077	-0.005	-0.331***	-0.233**	-0.028	-0.011	-0.210**	-0.245**	0.106	-0.037
	(0.068)	(0.083)	(0.072)	(0.080)	(0.053)	(0.086)	(0.046)	(0.078)	(0.069)	(0.092)	(0.142)	(0.070)
Grade Enrollment	-0.002	-0.010	0.008*	0.007**	-0.034**	-0.018	0.006*	0.007***	0.001	0.001	0.003	0.002
	(0.007)	(0.008)	(0.003)	(0.002)	(0.012)	(0.010)	(0.003)	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)
Absent Students on Exam Day	0.009	-0.001	-0.018	-0.098*	0.028*	0.012	-0.047	0.013	-0.027*	-0.019	-0.022	-0.008
	(0.009)	(0.007)	(0.043)	(0.038)	(0.012)	(0.011)	(0.024)	(0.020)	(0.013)	(0.016)	(0.015)	(0.013)
Test Takers	0.002	0.011	-0.009**	-0.010***	0.036**	0.021	-0.006*	-0.008***	-0.000	-0.001	-0.003	-0.003***
	(0.007)	(0.008)	(0.003)	(0.002)	(0.012)	(0.011)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
Constant	0.010	0.044	0.057	0.139	-0.052	-0.068	0.063	0.163*	-0.047	-0.004	0.031	0.182*
	(0.048)	(0.063)	(0.064)	(0.073)	(0.063)	(0.058)	(0.057)	(0.071)	(0.099)	(0.111)	(0.076)	(0.077)
N	5131	5115	2260	2240	4921	4908	1721	1703	1739	1729	1431	1417
R-sq	0.727	0.625	0.856	0.806	0.709	0.654	0.868	0.822	0.788	0.774	0.853	0.870

Cluster-robust standard errors, indicated in parentheses, are calculated at the school district level for TWFE.
* p<0.05, ** p<0.01, *** p<0.001

Note: The unit of analysis is school-year where schools in the Minnesota State are considered ('Full Sample'). Only Treatment I is considered meaning Treatment II is now considered as the control group. Column (1) to column (12) shows θ coefficients estimated from equation 2 for different grade-subjects dependent variables with year and school fixed effects. The key predicting/independent variable is Treated which is a dummy variable equal to 1 if the schools are located within 2.5 to 8.5 miles of I-35W bridge after 2007 and 0 otherwise. As controls, student enrollment, number of test takers and number of absent students on the exam days are used. Robust standard errors clustered at the school districts level.

TABLE A11—ROBUSTNESS CHECK (TREATMENT II SCHOOLS AS CONTROLS FOR TREATMENT I): IMPACT OF THE BRIDGE COLLAPSE ON STANDARDIZED READING AND MATH TEST SCORES FOR GRADE 3 TO 8. TREATMENT II CONSISTS OF ALL THE SCHOOLS LOCATED FROM 2.5 TO 8.5 MILES RADIUS OF THE BRIDGE

	(1) Grade 3 Reading	(2) Grade 3 Math	(3) Grade 4 Reading	(4) Grade 4 Math	(5) Grade 5 Reading	(6) Grade 5 Math	(7) Grade 6 Reading	(8) Grade 6 Math	(9) Grade4 7 Reading	(10) Grade 7 Math	(11) Grade 8 Reading	(12) Grade 8 Math
Treated	-0.391***	-0.231	-0.353	-0.215	-0.317	-0.328*	-0.097	-0.458*	-0.633***	-0.547***	-0.362**	-0.132
	(0.109)	(0.131)	(0.235)	(0.152)	(0.165)	(0.129)	(0.165)	(0.180)	(0.097)	(0.136)	(0.126)	(0.065)
Grade Enrollment	0.011**	0.004	0.002	0.015***	0.004	0.003	0.005	0.013***	-0.004	0.002	-0.002	0.002
	(0.004)	(0.004)	(0.006)	(0.003)	(0.005)	(0.002)	(0.005)	(0.003)	(0.004)	(0.002)	(0.005)	(0.002)
Absent Students on Exam day	-0.031*	-0.011	0.088	-0.147	-0.001	-0.013	-0.089	-0.036	0.080*	0.078*	-0.056	-0.078
	(0.012)	(0.012)	(0.120)	(0.113)	(0.013)	(0.015)	(0.062)	(0.063)	(0.038)	(0.032)	(0.051)	(0.054)
Test Takers	-0.005	0.003	0.003	-0.013***	0.001	0.004*	-0.003	-0.014***	0.005	-0.002	0.003	-0.004**
	(0.004)	(0.003)	(0.007)	(0.004)	(0.005)	(0.002)	(0.006)	(0.003)	(0.004)	(0.001)	(0.005)	(0.001)
Constant	-1.177***	-1.029***	-1.224***	-1.083***	-0.972***	-1.017***	-0.909***	-0.701***	-0.561**	-0.467*	-0.517*	-0.285
	(0.090)	(0.154)	(0.254)	(0.249)	(0.068)	(0.086)	(0.141)	(0.139)	(0.195)	(0.186)	(0.242)	(0.231)
N	987	966	451	432	971	956	359	340	271	257	220	210
R-sq	0.838	0.774	0.875	0.857	0.822	0.807	0.934	0.901	0.903	0.880	0.905	0.927

Cluster-robust standard errors, indicated in parentheses, are calculated at the school district level for TWFE.
* p<0.05, ** p<0.01, *** p<0.001

Note: The unit of analysis is school-year where schools only in the metro area are considered ('Restricted Sample'). Treatment II schools are used as controls for treatment I schools. Column (1) to column (12) shows θ coefficients estimated from equation 2 for different grade-subjects dependent variables with year and school fixed effects. The key predicting/independent variable is Treated which is a dummy variable equal to 1 if the schools are located within 2.5 miles of I-35W bridge after 2007 and 0 otherwise. As controls, student enrollment, number of test takers and number of absent students on the exam days are used. Robust standard errors clustered at the school districts level.

TABLE A12—ROBUSTNESS CHECK: USING 2008 AS OUTCOME OF INTEREST FOR TEST SCORES. TREATMENT I INCLUDES ALL THE SCHOOLS LOCATED WITHIN A 2.5-MILE RADIUS OF THE BRIDGE

	(1) Grade 3 Reading	(2) Grade 3 Math	(3) Grade 4 Reading	(4) Grade 4 Math	(5) Grade 5 Reading	(6) Grade 5 Math	(7) Grade 6 Reading	(8) Grade 6 Math	(9) Grade 7 Reading	(10) Grade 7 Math	(11) Grade 8 Reading	(12) Grade 8 Math
Treated	-0.656***	-0.089	-0.464*	-0.294	-0.930***	-0.552*	-0.115	-0.229*	-0.563***	-0.709***	-0.222*	-0.111
	(0.184)	(0.244)	(0.205)	(0.147)	(0.157)	(0.214)	(0.135)	(0.098)	(0.111)	(0.158)	(0.085)	(0.125)
Grade Enrollment	-0.002	-0.031	-0.009	0.012*	-0.040*	-0.027	0.005	-0.001	0.004	-0.000	0.008*	0.005*
	(0.004)	(0.017)	(0.013)	(0.006)	(0.016)	(0.017)	(0.010)	(0.005)	(0.004)	(0.002)	(0.004)	(0.002)
Absent Students on Exam day	-0.007	0.012	-0.161	-0.083	0.041**	0.022	0.011	0.015	-0.072**	-0.061	-0.077**	-0.045
	(0.008)	(0.011)	(0.170)	(0.101)	(0.015)	(0.016)	(0.091)	(0.053)	(0.022)	(0.043)	(0.027)	(0.026)
Test Takers	0.001	0.032	0.008	-0.014***	0.042*	0.030	-0.005	0.007	-0.001	0.002	-0.006	-0.002*
	(0.004)	(0.018)	(0.012)	(0.004)	(0.017)	(0.019)	(0.011)	(0.005)	(0.005)	(0.002)	(0.004)	(0.001)
Constant	0.030	0.021	0.061	0.055	-0.038	-0.024	-0.090	-0.512	-0.568	-0.288	-0.143	-0.455
	(0.058)	(0.125)	(0.254)	(0.314)	(0.065)	(0.098)	(0.376)	(0.454)	(0.474)	(0.502)	(0.322)	(0.412)
N	977	973	274	270	947	947	184	176	181	180	126	122
R-sq	0.840	0.728	0.931	0.932	0.824	0.776	0.953	0.946	0.889	0.824	0.978	0.976

Cluster-robust standard errors, indicated in parentheses, are calculated at the school district level for TWFE.
* p<0.05, ** p<0.01, *** p<0.001

Note: The unit of analysis is school-year where schools only in the metro area are considered ('Restricted Sample'). Column (1) to column (12) shows θ coefficients estimated from equation 2 for different grade-subjects dependent variables with year and school fixed effects. The key predicting/independent variable is Treated which is a dummy variable equal to 1 if the schools are located within 2.5 miles of I-35W bridge after 2007 and 0 otherwise. As controls, student enrollment, number of test takers and number of absent students on the exam days are used. Robust standard errors clustered at the school districts level.

TABLE A13—ROBUSTNESS CHECK: USING 2009 AS OUTCOME OF INTEREST FOR TEST SCORES. TREATMENT I INCLUDES ALL THE SCHOOLS LOCATED WITHIN A 2.5-MILE RADIUS OF THE BRIDGE

	(1) Grade 3 Reading	(2) Grade 3 Math	(3) Grade 4 Reading	(4) Grade 4 Math	(5) Grade 5 Reading	(6) Grade 5 Math	(7) Grade 6 Reading	(8) Grade 6 Math	(9) Grade 7 Reading	(10) Grade 7 Math	(11) Grade 8 Reading	(12) Grade 8 Math
Treated	-0.585**	-0.138	-0.312	-0.186	-0.747***	-0.498*	-0.122	-0.378*	-0.681***	-0.776***	-0.276*	-0.116*
	(0.171)	(0.219)	(0.246)	(0.148)	(0.178)	(0.197)	(0.176)	(0.155)	(0.101)	(0.129)	(0.109)	(0.044)
Grade Enrollment	-0.001	-0.025	0.004	0.010*	-0.039*	-0.025	0.004	-0.000	0.002	0.002	-0.000	0.002*
	(0.003)	(0.017)	(0.008)	(0.004)	(0.016)	(0.017)	(0.006)	(0.003)	(0.003)	(0.002)	(0.003)	(0.001)
Absent Students on Exam day	-0.008	0.002	-0.014	-0.091	0.040*	0.020	-0.038	-0.037	-0.056**	-0.053	-0.008	-0.016
	(0.010)	(0.013)	(0.106)	(0.065)	(0.016)	(0.015)	(0.056)	(0.045)	(0.018)	(0.035)	(0.022)	(0.027)
Test Takers	0.001	0.027	-0.007	-0.015***	0.040*	0.026	-0.004	-0.000	0.001	0.001	0.002	-0.002***
	(0.003)	(0.017)	(0.008)	(0.004)	(0.017)	(0.019)	(0.006)	(0.004)	(0.004)	(0.002)	(0.004)	(0.001)
Constant	-0.069	-0.046	0.128	0.260	-0.011	0.033	-0.039	0.085	-0.601	-0.442	-0.311	0.095
	(0.055)	(0.107)	(0.148)	(0.178)	(0.057)	(0.075)	(0.152)	(0.262)	(0.349)	(0.407)	(0.237)	(0.198)
N	1124	1116	427	419	1097	1090	290	283	259	256	207	203
R-sq	0.850	0.735	0.925	0.917	0.821	0.767	0.947	0.912	0.877	0.848	0.943	0.958

Cluster-robust standard errors, indicated in parentheses, are calculated at the school district level for TWFE.
* p<0.05, ** p<0.01, *** p<0.001

Note: The unit of analysis is school-year where schools only in the metro area are considered ('Restricted Sample'). Column (1) to column (12) shows θ coefficients estimated from equation 2 for different grade-subjects dependent variables with year and school fixed effects. The key predicting/independent variable is Treated which is a dummy variable equal to 1 if the schools are located within 2.5 miles of I-35W bridge after 2007 and 0 otherwise. As controls, student enrollment, number of test takers and number of absent students on the exam days are used. Robust standard errors clustered at the school districts level.

TABLE A14—SECOND EXPERIMENT: IMPACT OF HIGHER TRAFFIC VOLUME AROUND THE I-94 BRIDGE ON STANDARDIZED READING AND MATH TEST SCORES FOR GRADES 3 TO 8. TREATMENT I INCLUDES ALL THE SCHOOLS LOCATED WITHIN A 2.5-MILE RADIUS OF THE BRIDGE

	(1) Grade 3 Reading	(2) Grade 3 Math	(3) Grade 4 Reading	(4) Grade 4 Math	(5) Grade 5 Reading	(6) Grade 5 Math	(7) Grade 6 Reading	(8) Grade 6 Math	(9) Grade 7 Reading	(10) Grade 7 Math	(11) Grade 8 Reading	(12) Grade 8 Math
Treated	0.329	-0.161	-0.035	0.338*	0.092	-0.513**	-0.009	0.288	0.140	0.014	-0.005	0.068
	(0.241)	(0.267)	(0.103)	(0.136)	(0.090)	(0.194)	(0.127)	(0.471)	(0.073)	(0.171)	(0.109)	(0.055)
Grade Enrollment	0.007	-0.015	0.008	0.011***	-0.029	-0.016	0.005	0.005**	0.001	0.001	-0.000	0.001
	(0.004)	(0.012)	(0.005)	(0.003)	(0.018)	(0.013)	(0.003)	(0.002)	(0.003)	(0.001)	(0.003)	(0.001)
Absent Students on Exam Day	-0.013	-0.003	0.002	-0.136*	0.022	0.009	-0.059	0.008	-0.025	-0.027	-0.011	-0.025
	(0.008)	(0.010)	(0.061)	(0.062)	(0.016)	(0.013)	(0.040)	(0.029)	(0.021)	(0.025)	(0.019)	(0.022)
Test Takers	-0.006	0.016	-0.008	-0.013***	0.031	0.019	-0.005	-0.006***	0.001	0.001	0.000	-0.002**
	(0.003)	(0.012)	(0.005)	(0.002)	(0.019)	(0.014)	(0.003)	(0.002)	(0.003)	(0.001)	(0.002)	(0.001)
Constant	-0.297**	-0.164	-0.229	-0.067	-0.248*	-0.211*	-0.215*	-0.074	-0.424	-0.374	-0.022	0.165
	(0.088)	(0.139)	(0.135)	(0.135)	(0.109)	(0.102)	(0.089)	(0.105)	(0.271)	(0.314)	(0.168)	(0.211)
N	1890	1875	848	833	1855	1844	630	614	466	457	384	374
R-sq	0.833	0.744	0.917	0.883	0.816	0.777	0.931	0.882	0.900	0.874	0.935	0.943

Cluster-robust standard errors, indicated in parentheses, are calculated at the school district level for TWFE.
* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Note: The unit of analysis is school-year where schools only in the metro area are considered (‘Restricted Sample’). Column (1) to column (12) shows θ coefficients estimated from equation 2 for different grade-subjects dependent variables with year and school fixed effects. The key predicting/independent variable is Treated which is a dummy variable equal to 1 if the schools are located within 2.5 miles of I-94 bridge after 2007 and 0 otherwise. As controls, student enrollment, number of test takers and number of absent students on the exam days are used. Robust standard errors clustered at the school districts level.

TABLE A15—ROBUSTNESS CHECK: DEFINING TREATMENT BY CONTINUOUS DISTANCE TO THE BRIDGE (IN MILES) FOR SCHOOLS WITHIN THE MINNEAPOLIS METRO AREA

	(1) Grade 3 Reading	(2) Grade 3 Math	(3) Grade 4 Reading	(4) Grade 4 Math	(5) Grade 5 Reading	(6) Grade 5 Math	(7) Grade 6 Reading	(8) Grade 6 Math	(9) Grade 7 Reading	(10) Grade 7 Math	(11) Grade 8 Reading	(12) Grade 8 Math
Distance to Bridge X Post-2007	0.097**	0.128**	0.073	0.061	0.101***	0.096**	0.077	0.058	0.145*	0.038	-0.088*	-0.044
	(0.034)	(0.040)	(0.064)	(0.051)	(0.024)	(0.030)	(0.084)	(0.054)	(0.067)	(0.045)	(0.041)	(0.041)
Grade Enrollment	0.003	-0.007	0.007*	0.010***	-0.022	-0.009	0.007**	0.006***	0.003	0.001	0.000	0.001
	(0.002)	(0.007)	(0.003)	(0.002)	(0.016)	(0.009)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)
Absent Students on Exam Day	-0.007	-0.008	-0.011	-0.106*	0.014	-0.003	-0.043**	-0.015	-0.029	-0.009	-0.025	-0.018
	(0.007)	(0.008)	(0.042)	(0.041)	(0.015)	(0.010)	(0.016)	(0.021)	(0.017)	(0.018)	(0.015)	(0.015)
Test Takers	0.000	0.010	-0.007*	-0.012***	0.025	0.011	-0.008***	-0.007***	-0.001	0.001	0.000	-0.002*
	(0.002)	(0.007)	(0.003)	(0.002)	(0.016)	(0.010)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)
N	3593	3559	1613	1585	3440	3415	1061	1038	829	811	683	665
R-sq	0.833	0.744	0.912	0.887	0.819	0.797	0.937	0.906	0.895	0.869	0.931	0.945

Cluster-robust standard errors, indicated in parentheses, are calculated at the school district level for TWFE.
* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Note: The unit of analysis is school-year where schools only in the metro area are considered ('Restricted Sample'). Column (1) to column (12) shows θ coefficients estimated from equation 2 for different grade-subjects dependent variables with year and school fixed effects. The key independent variable is the interaction between the distance to the bridge (in miles) and 'Post-2007'— a dummy variable that equals 1 for test scores recorded after 2007 and 0 otherwise. As controls, student enrollment, number of test takers and number of absent students on the exam days are used. Robust standard errors clustered at the school districts level.

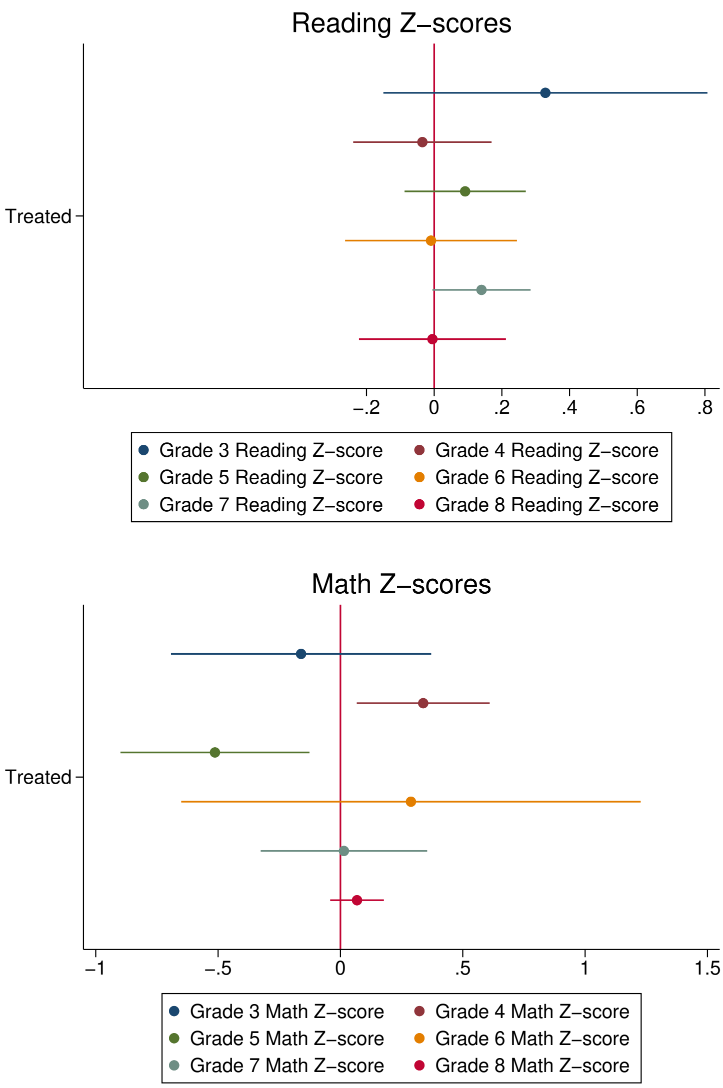


FIGURE A10. COEFFICIENT PLOT: IMPACT OF HIGHER TRAFFIC VOLUME AROUND THE I-94 BRIDGE (TREATMENT I) ON STANDARDIZED READING AND MATH TEST SCORES FOR GRADES 3 TO 8. TREATMENT I INCLUDES ALL THE SCHOOLS LOCATED WITHIN A 2.5-MILE RADIUS OF THE BRIDGE

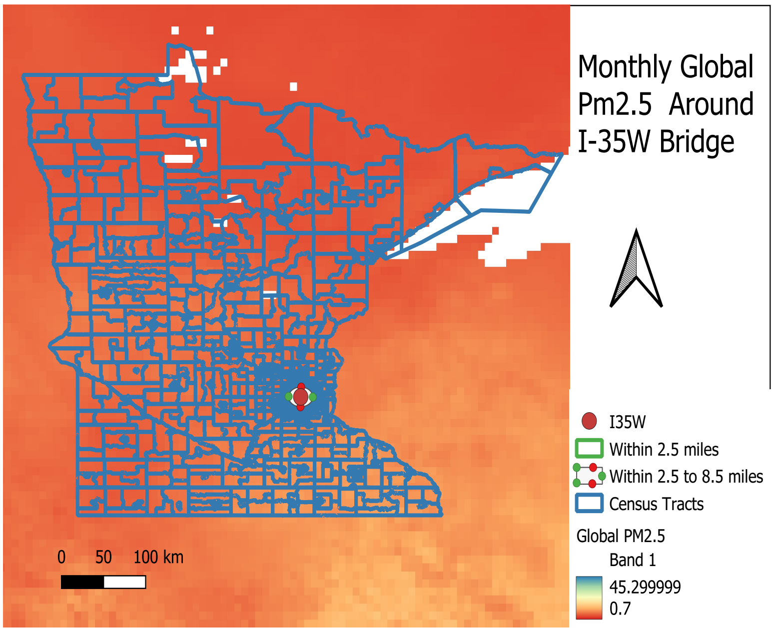


FIGURE A11. TREATMENT CENSUS TRACTS AROUND THE I-35 BRIDGE, OVERLAID WITH GLOBAL $PM_{2.5}$ DATA IN THE BACKGROUND. TREATMENT I COMPRISES CENSUS TRACT AREA WITHIN A 2.5-MILE RADIUS OF THE BRIDGE, TREATMENT II INCLUDES CENSUS TRACT AREA BETWEEN 2.5 AND 8.5 MILES FROM THE BRIDGE, AND CONTROL ENCOMPASSES OTHER CENSUS TRACTS WITHIN THE STATE OF MINNESOTA

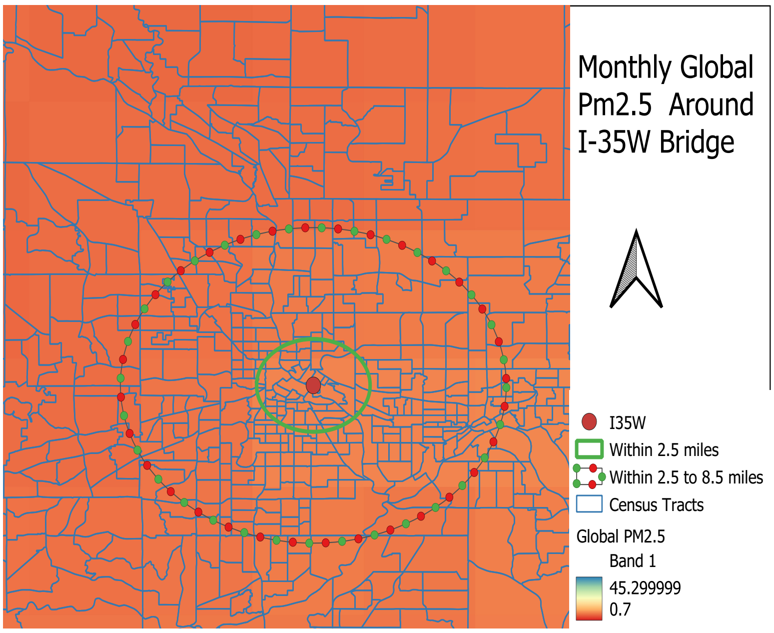


FIGURE A12. CLOSER LOOK OF TREATMENT CENSUS TRACTS AROUND THE I-35 BRIDGE, OVERLAID WITH GLOBAL $PM_{2.5}$ DATA IN THE BACKGROUND. TREATMENT I COMPRISES CENSUS TRACT AREA WITHIN A 2.5-MILE RADIUS OF THE BRIDGE, TREATMENT II INCLUDES CENSUS TRACT AREA BETWEEN 2.5 AND 8.5 MILES FROM THE BRIDGE, AND CONTROL ENCOMPASSES OTHER CENSUS TRACTS WITHIN THE STATE OF MINNESOTA.

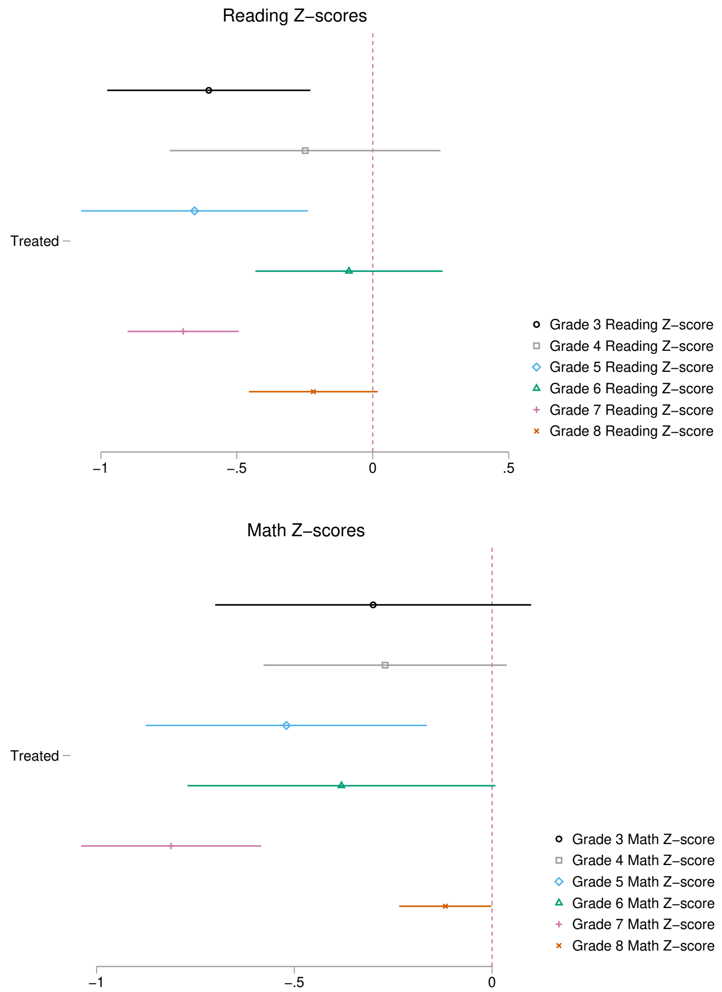


FIGURE A13. COEFFICIENT PLOTS FOR ESTIMATION OF EQUATION 1: IMPACT OF THE BRIDGE COLLAPSE (TREATMENT I) ON STANDARDIZED READING AND MATH TEST SCORES FOR GRADES 3 TO 8. TREATMENT I INCLUDES ALL THE SCHOOLS LOCATED WITHIN A 2.5-MILE RADIUS OF THE BRIDGE

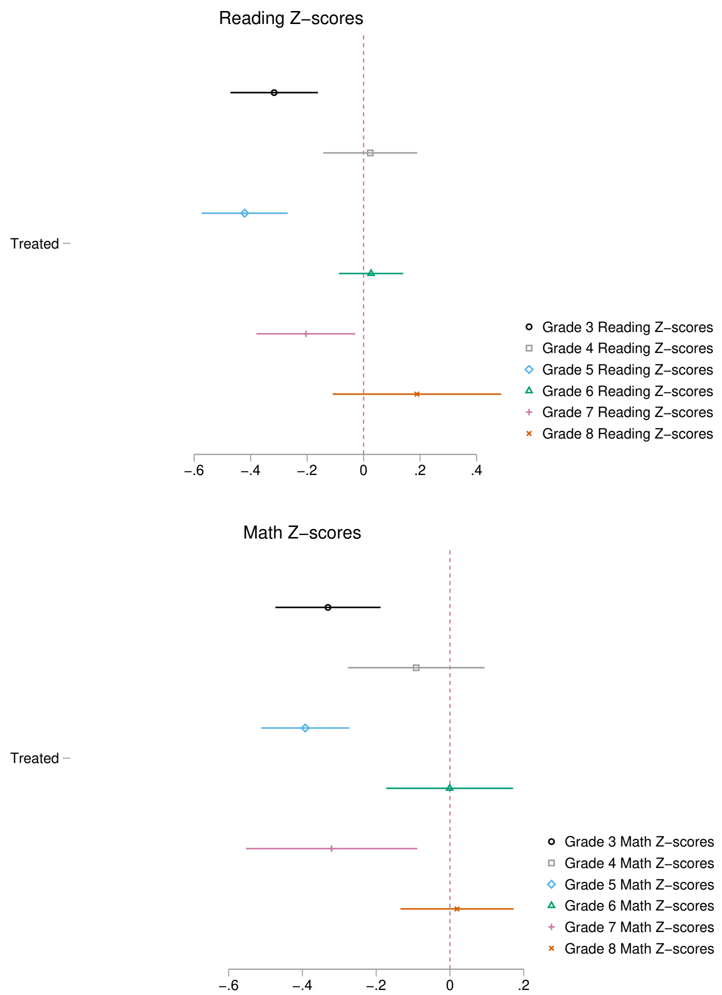


FIGURE A14. COEFFICIENT PLOTS FOR ESTIMATION OF EQUATION 1: IMPACT OF THE BRIDGE COLLAPSE (TREATMENT II) ON STANDARDIZED READING AND MATH TEST SCORES FOR GRADES 3 TO 8. TREATMENT II CONSISTS OF ALL THE SCHOOLS LOCATED FROM 2.5 TO 8.5 MILES RADIUS OF THE BRIDGE

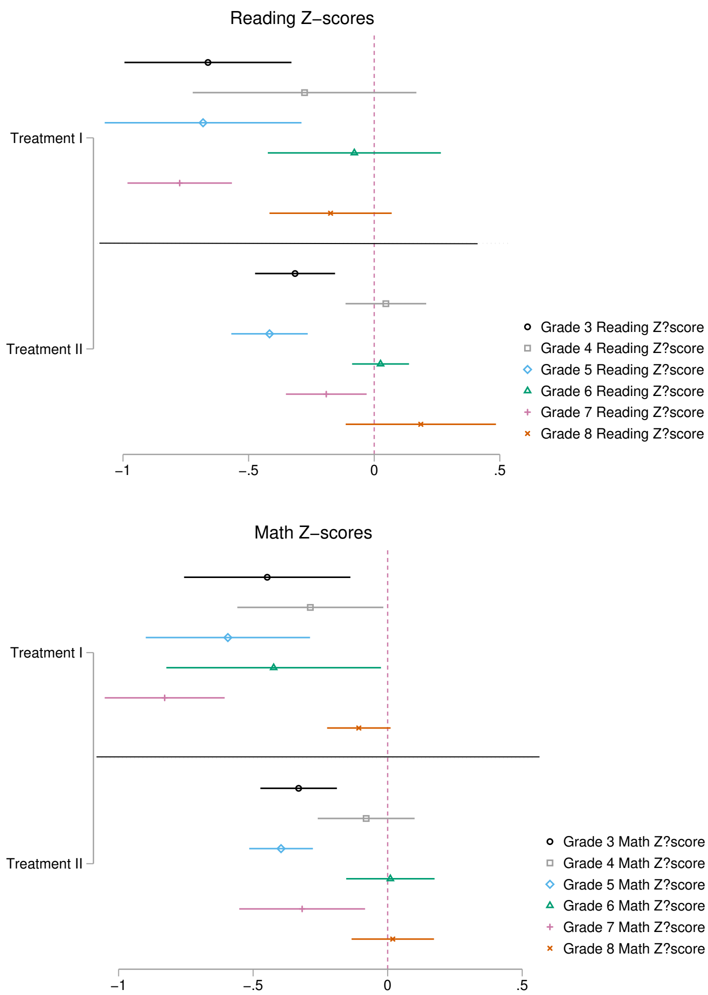


FIGURE A15. COEFFICIENT PLOT (JOINT TREATMENT TWFE): IMPACT OF THE BRIDGE COLLAPSE ON STANDARDIZED READING AND MATH TEST SCORES FOR GRADE 3 TO 8. TREATMENT I CONSISTS OF ALL SCHOOLS LOCATED WITHIN A 2.5-MILE RADIUS OF THE BRIDGE, WHILE TREATMENT II INCLUDES SCHOOLS LOCATED FROM 2.5 TO 8.5 MILES AWAY FROM THE BRIDGE

TABLE A16—ROBUSTNESS CHECK FOR TREATMENT II: USING 2008 AS OUTCOME OF INTEREST FOR TEST SCORES. TREATMENT II CONSISTS OF ALL THE SCHOOLS LOCATED FROM 2.5 TO 8.5 MILES RADIUS OF THE BRIDGE

	(1) Grade 3 Reading	(2) Grade 3 Math	(3) Grade 4 Reading	(4) Grade 4 Math	(5) Grade 5 Reading	(6) Grade 5 Math	(7) Grade 6 Reading	(8) Grade 6 Math	(9) Grade 7 Reading	(10) Grade 7 Math	(11) Grade 8 Reading	(12) Grade 8 Math
Treated	-0.271**	-0.159	0.012	-0.019	-0.414***	-0.348***	0.124	0.077	-0.180	-0.238	0.249	0.157
	(0.089)	(0.116)	(0.100)	(0.099)	(0.114)	(0.074)	(0.080)	(0.095)	(0.111)	(0.168)	(0.166)	(0.094)
Grade Enrollment	0.007	-0.022	0.009	0.012**	-0.033	-0.021	0.010	0.002	0.001	0.000	0.006	0.005*
	(0.003)	(0.014)	(0.008)	(0.004)	(0.017)	(0.015)	(0.008)	(0.005)	(0.004)	(0.002)	(0.006)	(0.002)
Absent Students on Exam Day	-0.016*	0.008	-0.015	-0.110	0.025	0.016	-0.008	0.044	-0.033	-0.031	-0.060*	-0.050*
	(0.007)	(0.008)	(0.075)	(0.075)	(0.015)	(0.015)	(0.071)	(0.048)	(0.024)	(0.030)	(0.026)	(0.021)
Test Takers	-0.006	0.024	-0.009	-0.015***	0.036	0.024	-0.012	-0.003	0.003	0.004***	-0.003	-0.002**
	(0.003)	(0.014)	(0.008)	(0.003)	(0.018)	(0.016)	(0.007)	(0.004)	(0.004)	(0.001)	(0.006)	(0.001)
Constant	-0.248*	-0.157	-0.328	0.006	-0.258*	-0.201*	0.090	0.092	-0.712	-0.539	-0.299	-0.224
	(0.096)	(0.163)	(0.188)	(0.294)	(0.114)	(0.092)	(0.211)	(0.221)	(0.365)	(0.382)	(0.455)	(0.418)
N	1451	1447	412	408	1416	1414	298	292	251	253	178	174
R-sq	0.830	0.741	0.934	0.909	0.813	0.774	0.954	0.924	0.868	0.812	0.928	0.946

Cluster-robust standard errors, indicated in parentheses, are calculated at the school district level for TWFE.
* p<0.05, ** p<0.01, *** p<0.001

Note: The unit of analysis is school-year where schools only in the metro area are considered ('Restricted Sample'). Column (1) to column (12) shows θ coefficients estimated from equation 2 for different grade-subjects dependent variables with year and school fixed effects. The key predicting/independent variable is Treated which is a dummy variable equal to 1 if the schools are located within 2.5 to 8.5 miles of I-35W bridge after 2007 and 0 otherwise. As controls, student enrollment, number of test takers and number of absent students on the exam days are used. Robust standard errors clustered at the school districts level.

TABLE A17—ROBUSTNESS CHECK FOR TREATMENT II: USING 2009 AS OUTCOME OF INTEREST FOR TEST SCORES. TREATMENT II CONSISTS OF ALL THE SCHOOLS LOCATED FROM 2.5 TO 8.5 MILES RADIUS OF THE BRIDGE

	(1) Grade 3 Reading	(2) Grade 3 Math	(3) Grade 4 Reading	(4) Grade 4 Math	(5) Grade 5 Reading	(6) Grade 5 Math	(7) Grade 6 Reading	(8) Grade 6 Math	(9) Grade 7 Reading	(10) Grade 7 Math	(11) Grade 8 Reading	(12) Grade 8 Math
Treated	-0.292**	-0.230**	0.015	-0.024	-0.432***	-0.378***	0.058	0.016	-0.132	-0.259	0.212	0.047
	(0.086)	(0.078)	(0.083)	(0.085)	(0.086)	(0.064)	(0.056)	(0.083)	(0.088)	(0.143)	(0.151)	(0.073)
Grade Enrollment	0.006	-0.017	0.005	0.012***	-0.032	-0.018	0.010	0.005	-0.000	0.002	0.000	0.003*
	(0.003)	(0.013)	(0.006)	(0.003)	(0.017)	(0.014)	(0.005)	(0.003)	(0.003)	(0.001)	(0.003)	(0.001)
Absent Students on Exam Day	-0.015	-0.001	-0.034	-0.125	0.023	0.013	-0.041	0.001	-0.025	-0.025	-0.020	-0.023
	(0.008)	(0.009)	(0.086)	(0.069)	(0.015)	(0.015)	(0.043)	(0.038)	(0.021)	(0.026)	(0.021)	(0.026)
Test Takers	-0.004	0.020	-0.007	-0.016***	0.034	0.021	-0.010*	-0.005	0.004	0.002**	0.002	-0.002***
	(0.003)	(0.013)	(0.007)	(0.002)	(0.018)	(0.015)	(0.005)	(0.002)	(0.004)	(0.001)	(0.003)	(0.001)
Constant	-0.313**	-0.218	-0.172	0.029	-0.200*	-0.156	-0.225	-0.160	-0.633*	-0.617	-0.385	0.045
	(0.091)	(0.147)	(0.192)	(0.204)	(0.097)	(0.082)	(0.186)	(0.296)	(0.273)	(0.337)	(0.224)	(0.205)
N	1658	1650	624	615	1623	1619	462	453	352	348	282	277
R-sq	0.837	0.743	0.926	0.889	0.821	0.778	0.943	0.900	0.895	0.854	0.939	0.956

Cluster-robust standard errors, indicated in parentheses, are calculated at the school district level for TWFE.
* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Note: The unit of analysis is school-year where schools only in the metro area are considered ('Restricted Sample'). Column (1) to column (12) shows θ coefficients estimated from equation 2 for different grade-subjects dependent variables with year and school fixed effects. The key predicting/independent variable is Treated which is a dummy variable equal to 1 if the schools are located within 2.5 miles of I-35W bridge after 2007 and 0 otherwise. As controls, student enrollment, number of test takers and number of absent students on the exam days are used. Robust standard errors clustered at the school districts level.

TABLE A18—THE IMPACT OF TREATMENT STATUS ON GLOBAL $PM_{2.5}$. TREATMENT I COMPRISES CENSUS TRACT AREA WITHIN A 2.5-MILE RADIUS OF THE BRIDGE AND TREATMENT II INCLUDES CENSUS TRACT AREA BETWEEN 2.5 AND 8.5 MILES FROM THE BRIDGE

	(1) Monthly Mean PM2.5	(2) Monthly Min PM2.5	(3) Monthly Max PM2.5	(4) Monthly Mean PM2.5	(5) Monthly MIN PM2.5	(6) Monthly MAX PM 2.5
Treatment I	-0.427*	-0.415*	-0.435*			
	(0.201)	(0.200)	(0.207)			
Treatment II				-0.557***	-0.576***	-0.537***
				(0.086)	(0.089)	(0.083)
Constant	8.472***	8.332***	8.613***	8.485***	8.343***	8.627***
	(0.002)	(0.002)	(0.002)	(0.007)	(0.007)	(0.007)
N	45366	45366	45366	49002	49002	49002
R-sq	0.834	0.836	0.828	0.829	0.832	0.824

Cluster-robust standard errors, indicated in parentheses, are calculated at the Census Tracts level for TWFE.
* p<0.05, ** p<0.01, *** p<0.001

Note: Results for equation 4 where three different dependant variables are used: mean, minimum and maximum Global $PM_{2.5}$. The unit of analysis is Census Tract-month. Treatment I comprises census tract area within a 2.5-mile radius of the bridge, Treatment II includes census tract area between 2.5 and 8.5 miles from the bridge, and Control encompasses other census tracts within the state of Minnesota.

TABLE A19—THE IMPACT OF TREATMENT STATUS ON AIR POLLUTION WITH WEATHER INDICATORS. TREATMENT I CONSISTS OF ALL THE MONITORS LOCATED WITHIN A 2.5-MILE RADIUS OF THE BRIDGE AND TREATMENT II INCLUDES ALL THE MONITORS LOCATED FROM 2.5 TO 8.5 MILES RADIUS OF THE BRIDGE

	(1) Monthly AQI	(2) Monthly PM2.5	(3) Monthly AQI	(4) Monthly PM2.5
Treatment I	-0.086	0.044		
	(0.876)	(0.240)		
Monthly Precipitation	-5.532**	-1.957***	-6.122**	-2.125***
	(1.488)	(0.434)	(1.806)	(0.529)
Monthly Maximum Temperature	-0.452	-0.156	-0.477	-0.169
	(0.411)	(0.124)	(0.411)	(0.124)
Monthly Minimum Temperature	-0.120	-0.045	-0.216	-0.077
	(0.369)	(0.110)	(0.379)	(0.115)
Treatment II			1.878	0.585*
			(0.912)	(0.266)
Constant	59.227**	17.837**	64.405**	19.729**
	(19.645)	(5.775)	(19.433)	(5.747)
N	615	615	666	666
R-sq	0.840	0.829	0.846	0.836

Cluster-robust standard errors, indicated in parentheses, are calculated at the monitor level for TWFE.
* p<0.05, ** p<0.01, *** p<0.001

Note: Results for equation 4 which incorporates weather controls. Temperatures are in Fahrenheit and precipitation is in millimeters. The standard errors are clustered at the air quality monitor level. The sample includes all the AQI monitors in Minnesota. The unit of analysis is a monitor-month.

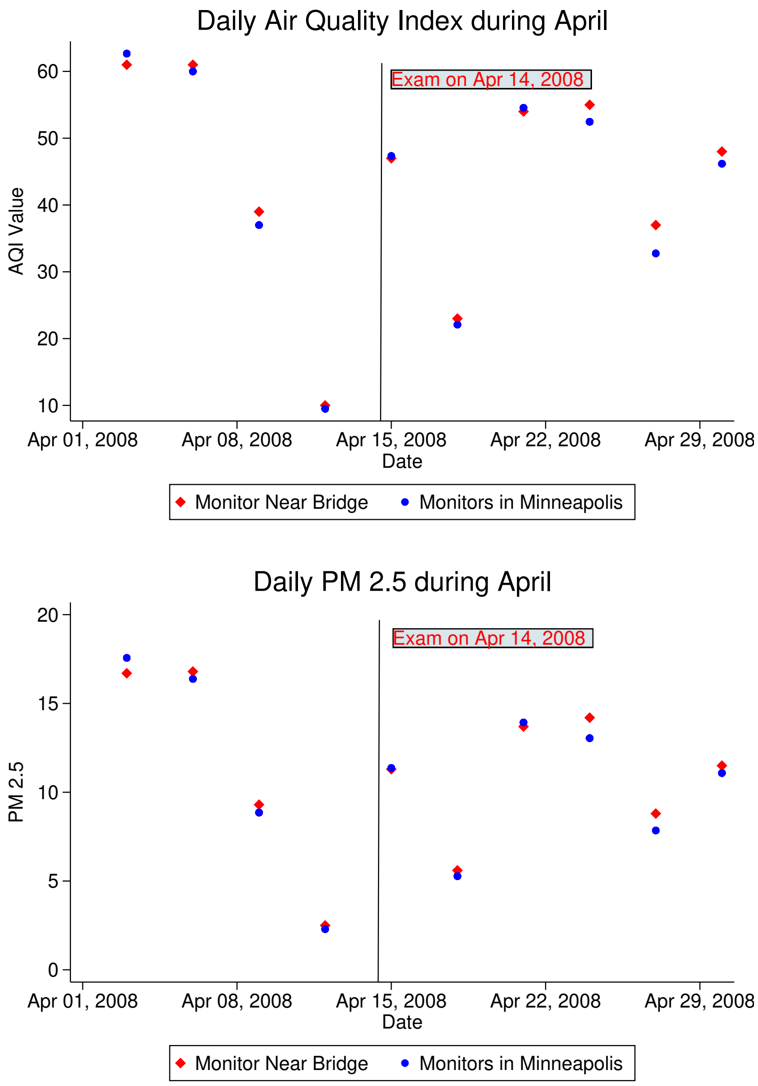
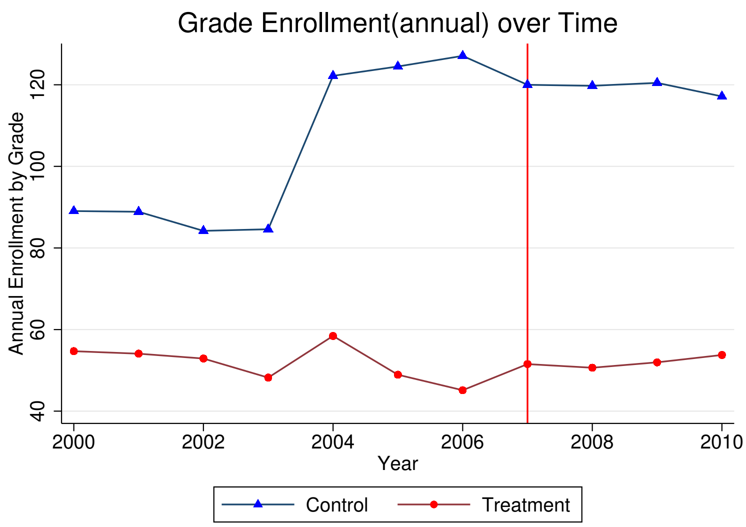


FIGURE A16. FLUCTUATIONS IN AVERAGE POLLUTION LEVELS DURING EXAM MONTH: MONITORED NEAR THE BRIDGE AND ACROSS MINNEAPOLIS CITY. THE UPPER FIGURE ILLUSTRATES THE AVERAGE CHANGES IN AIR QUALITY INDEX, WHILE THE LOWER FIGURE DEPICTS THE CORRESPONDING SHIFTS IN AVERAGE PM2.5 LEVELS



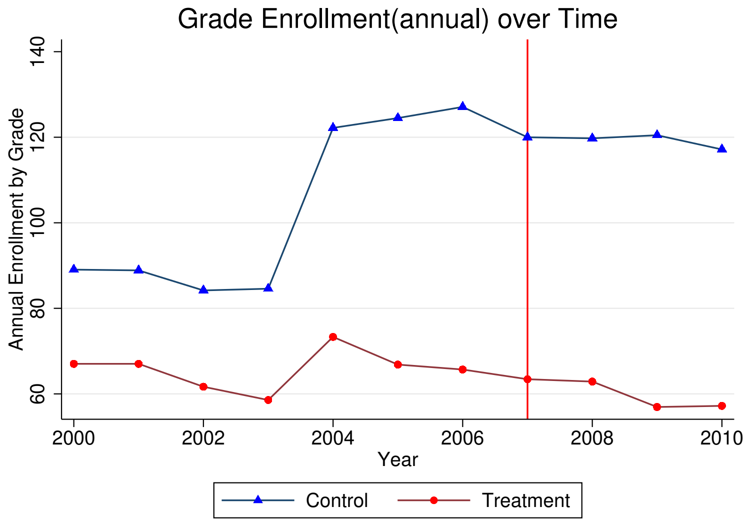


FIGURE A17. EVOLUTION OF AVERAGE ENROLLMENT ACROSS TREATMENT GROUPS. THE FIGURE ABOVE DEPICTS THE AVERAGE ENROLLMENT FOR TREATMENT I, WHILE THE FIGURE BELOW ILLUSTRATES THE AVERAGE ENROLLMENT FOR TREATMENT II. TREATMENT I CONSISTS OF ALL SCHOOLS LOCATED WITHIN A 2.5-MILE RADIUS OF THE BRIDGE, WHILE TREATMENT II INCLUDES SCHOOLS LOCATED FROM 2.5 TO 8.5 MILES AWAY FROM THE BRIDGE

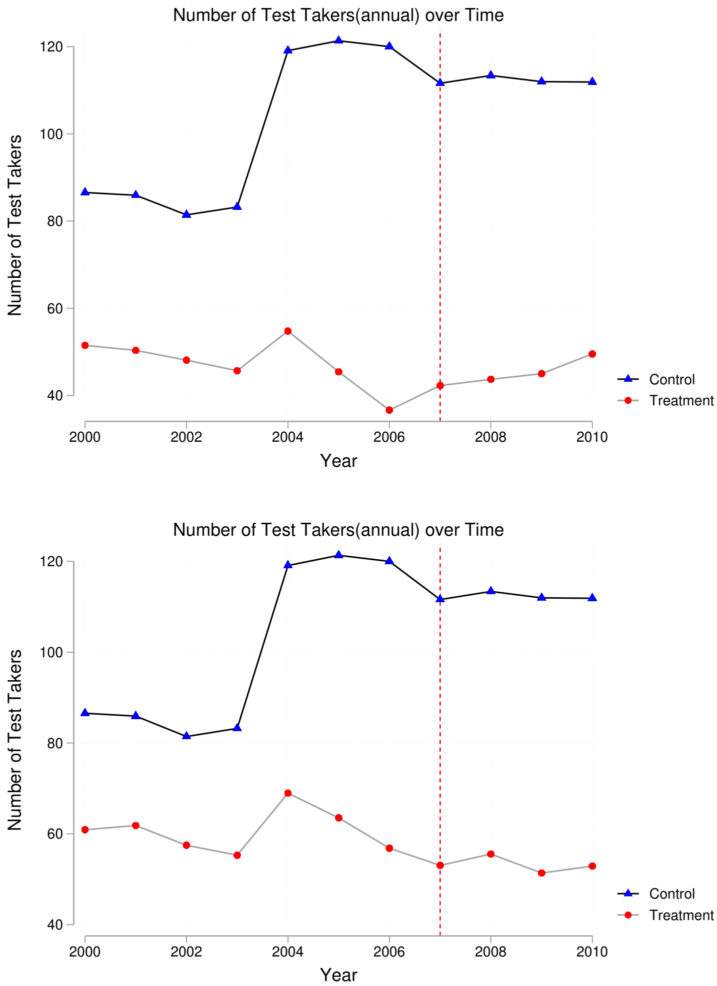


FIGURE A18. DISTRIBUTION OF AVERAGE TEST TAKERS ACROSS TREATMENT GROUPS. THE UPPER PANEL ILLUSTRATES THE AVERAGE NUMBER OF TEST TAKERS UNDER TREATMENT I, WHILE THE LOWER PANEL DISPLAYS THE CORRESPONDING FIGURES FOR TREATMENT II. TREATMENT I CONSISTS OF ALL SCHOOLS LOCATED WITHIN A 2.5-MILE RADIUS OF THE BRIDGE, WHILE TREATMENT II INCLUDES SCHOOLS LOCATED FROM 2.5 TO 8.5 MILES AWAY FROM THE BRIDGE

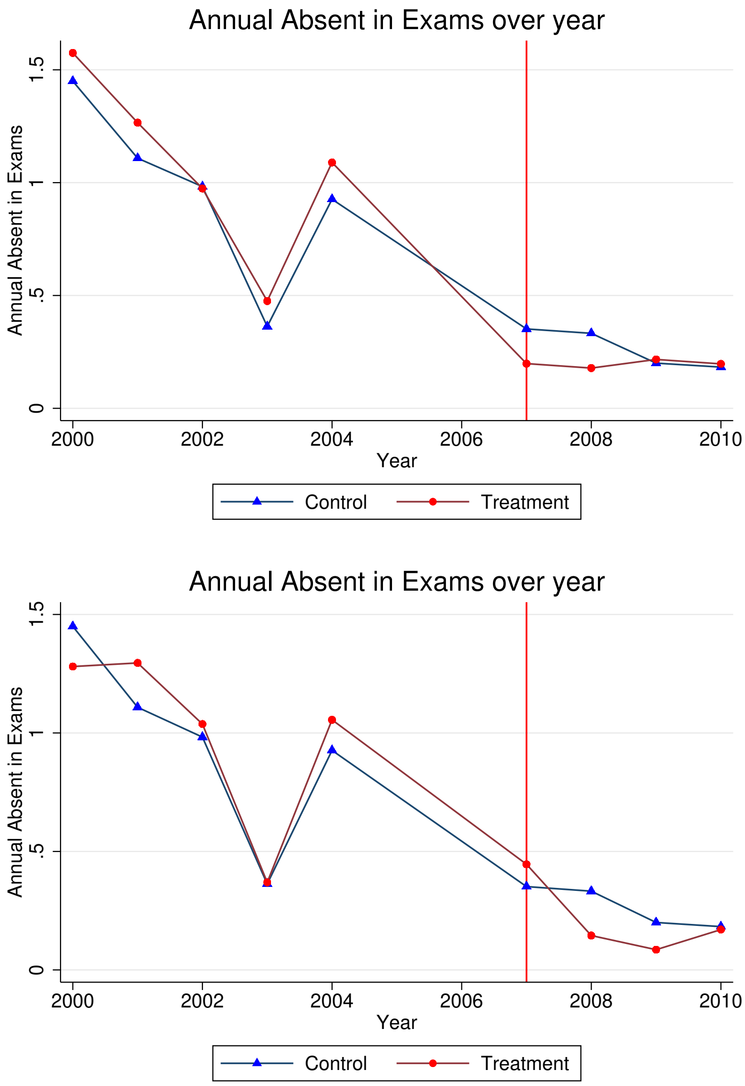


FIGURE A19. EXAM DAY ABSENTEEISM ACROSS TREATMENT GROUPS: THE UPPER FIGURE ILLUSTRATES THE AVERAGE NUMBER OF ABSENT STUDENTS ON EXAM DAY FOR TREATMENT I, WHILE THE LOWER FIGURE DEPICTS THE CORRESPONDING DATA FOR TREATMENT II. TREATMENT I CONSISTS OF ALL SCHOOLS LOCATED WITHIN A 2.5-MILE RADIUS OF THE BRIDGE, WHILE TREATMENT II INCLUDES SCHOOLS LOCATED FROM 2.5 TO 8.5 MILES AWAY FROM THE BRIDGE

TABLE A20—THE IMPACT OF TREATMENT STATUS ON AIR POLLUTION WITH DRISCOLL-KRAAY STANDARD ERRORS. TREATMENT I CONSISTS OF ALL THE MONITORS LOCATED WITHIN A 2.5-MILE RADIUS OF THE BRIDGE AND TREATMENT II INCLUDES ALL THE MONITORS LOCATED FROM 2.5 TO 8.5 MILES RADIUS OF THE BRIDGE

	(1) Monthly AQI	(2) Monthly PM2.5	(3) Monthly AQI	(4) Monthly PM2.5
Treatment I	-6.187**	-1.753**		
	(2.086)	(0.587)		
Treatment II			-0.508	-0.162
			(0.629)	(0.194)
N	289	289	340	340
R-sq	0.107	0.105	0.002	0.002

Driscoll-Kraay standard errors, indicated in parentheses, are calculated at the monitor site level using TWFE.
* p<0.05, ** p<0.01, *** p<0.001