Aerial Bombardment and Educational Attainment

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Abstract

This paper provides evidence that the Allied bombing of Vietnam, the longest and heaviest aerial bombardment in the history, imposed detrimental effects on educational attainment of school-age individuals. By exploiting the plausibly exogenous district-by-cohort variation in bomb destruction under a difference-in-differences framework, we find that an increase in bomb intensity leads to significantly fewer educational years completed by school-age children exposed to the bombardment. A series of robustness checks, falsification tests, and the instrumental-variable strategy further support our results. The findings underline the importance of policies targeting children after wartime.

JEL codes: I20, I21, J24.

Keywords: Vietnam War, large-scale destruction, aerial bombardment, human capital

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1 Introduction

The dread of war and its disruptive consequences, ranging from the destruction of capital and infrastructure to health and environment disasters, are widely known. From a macro perspective, armed conflicts can hinder long-term economic development by inducing poverty traps (Azariadis and Drazen, 1990; Sachs, 2008) or discouraging capital accumulation (Guidolin and La Ferrara, 2007). From a micro viewpoint, wars could potentially lead to severe disruptions to people's lives such as worsened health conditions, shortened schooling accumulation and distorted labor market outcomes (Bundervoet et al., 2009; Akbulut-Yuksel, 2014). Other dreadful consequences of armed conflicts include diverting resources from production, direct destruction of infrastructure, and increased mortality rates (Collier, 2009).

This paper contributes to the literature by investigating the impacts of aerial bombardment, a prevalent practice in modern warfare, on educational attainment and labor market outcomes of children. To draw causal inferences, we restrict our study to the context of the Allied bombing of Vietnam. We are particularly interested in the bombing of Vietnam for two reasons. First, this is by far the longest and heaviest aerial bombardment in history. Throughout the Vietnam War, more than 7.5 million tons of explosives were dropped by the U.S. and its allies. The total weight of bomb delivered was three times as much as that dropped during the European and Pacific Theater in World War II. Second, unlike other countries that were studied previously (e.g. Germany and Austria in the works of Ichino and Winter-Ebmer (2004) and Akbulut-Yuksel (2014)), Vietnam was much poorer at the time of the bombardment period. Consequently, school-aged children during the bombing period were more likely to be affected by shocks arising from such large-scale destruction. Given the substantial horrors of war worldwide nowadays, understanding the long-run impacts of the Vietnam tragedy on children's educational accumulation is of considerable importance to devise policies to reverse the negative effects.

To examine the impacts of wartime bombardment on educational accumulation, we employ the difference-in-differences approach by exploiting the district-by-cohort variation in bombing devastation. This identification strategy rests on the assumption which is had the bombardment not occurred, the difference in schooling between the affected and unaffected cohorts would have been the same. The parallel assumption ensuring internal validity of the difference-in-differences model could potentially be violated due to the heterogeneity in the reconstruction efforts after the war.[1] To this end, we propose a novel instrument, the *"frequency of aerial reconnaissance"*. The availability of military intelligence, as measured by the frequency of aerial reconnaissance, can strongly predict the actual bomb delivered onto a given district. Intuitively, the higher the scouting frequency over an area, the higher the chance of *'suspicious activities'* and *'potential threats'* being captured. Consequently, districts that are scouted more often tend to be bombed more heavily. More importantly, aerial reconnaissance on its own does not leave any physical destruction or disruption, thus, affecting schooling accumulation of children through the only channel of actual bombing.

An additional contribution of this paper is the precise measure of aerial bombardment drawn from the Theater History of Operation. Unlike previous studies which either have limited or no information on the intensity of armed conflicts (Ichino and Winter-Ebmer, 2004; Bundervoet et al., 2009), or rely on unadjusted measures of destruction such as the quantity of bombs (Miguel and Roland, 2011), our measure of bombing devastation is the bomb density - defined as the total weight of all weapons (in tons) dropped onto a district, divided by its area (in square kilometer).[2,3] The incorporation of weapon weight, which adjusts for the destructive power of different classes of weapons, can provide a more accurate measure for the bombardment havoc.

[1] It is possible that the Vietnamese government allocated resources unevenly across districts with different growth prospects in the postwar reconstruction period.

[2] Ichino and Winter-Ebmer (2004) uses "being born in Austria and Germany" and "being born between 1930-1939" as an exposure to the World War II. Bundervoet et al. (2009) relies on the timing and location of the civil war.

[3] Weapons include different classes of bombs, missiles, rockets, and ammunition. See Section 2.1 for details.

This paper can be related to the literature of investigating the impacts of wars/armed conflicts on human capital. For example, Ichino and Winter-Ebmer (2004) along with Akbulut-Yuksel (2014) analyze the educational and earnings loss in Austria and Germany due to World War II. Shemyakina (2011), Chamarbagwala and Moran (2011), and Leon (2012) detect substantial negative effects of civil war on human capital accumulation in central Asia and South America. Shemyakina (2011) points out the gender differential effects of armed conflict with more adverse consequences falling on adolescent girls.

Our study reaches the following findings. First, a 10% increase in bomb density causes school-age individuals who were exposed to the aerial barrage for at least five years to complete from 0.01 to 0.02 fewer years of education. To put these numbers to perspective, the gap in educational attainment between an individual in an average bombed district and an individual in the most heavily bombed district was about 0.3 to 0.7 years. Second, we explore the nonlinearity effects of aerial bombardment. Third, differential impacts of bomb destruction across gender are detected with larger repercussions on females. Finally, we document a negative relationship between aerial bombardment and individual earnings.

The paper proceeds as follows. The next section describes the data and our analysis sample. Section 3 presents the empirical methodology. Section 4 provides the estimation results, falsification test, and robustness check. Section 5 concludes our paper.

2 Data and Analysis Sample

2.1 Data Overview

The data for this study is drawn from two sources: the Theater History of Operations (THOR) and the Vietnam Household Living Standards Survey 2010-2014 (VHLSS). We first use the THOR database released by the U.S. Department of Defense in late 2016 to measure bombing intensity at the district level.[4] The raw data were recorded at the flight-mission level

[4] The THOR dataset can be accessed at the website of the Air Force Research Institute (www.au.af.mil).

that was drawn from the Combat Activities File 1965-1970 (CACTA), the Southeast Asia Aerial Bombing Database 1970-1975 (SEADAB), and the Strategic Air Command's Combat Activities 1965-1973 (SACCOACT). The publicly available information includes a description of each mission (e.g. mission code, date, operation supported, source of mission logs), a description of aircrafts carrying out the mission (e.g. Air Force Groups, type and quantity of aircrafts, takeoff location, fly hours, time on target), a description of weapons delivered (e.g. ordnance type, quantity, weight, purpose category, and time off target), and a description of mission targets (e.g. latitude-longitude coordinates of targets, target description, weather condition, and bomb damage assessment).

In the THOR database, there are approximately 4.84 million flight missions carried out by 104 types of aircraft during the period of 1965 - 1975. The mainly used type of aircraft is the fighter-bomber McDonnell Douglas F-4 Phantom II, carrying out approximately 957,427 missions. There are 239 main classes of weapons delivered during the Vietnam War including 173 classes of bombs, 25 classes of missiles, 28 classes of rockets, and 13 classes of ammunition. To capture the district-level intensity of bombs delivered from 1965 to 1975, we construct the bomb density measure (in tons per square-kilometer, t/km^2), by dividing the total weight of all weapons (in *tons*) dropped within a district boundary by its area (in km^2).

By special permission, we obtain access to three waves (2010, 2012, and 2014) of the VHLSS from the General Statistics Office (GSO) of Vietnam, which provides the information for individuals in our analysis.[5] The VHLSS is an ongoing longitudinal survey of the Vietnamese population that has been conducted since 1992 by the GSO. The VHLSS allows us to identify the province and district of residence of each individual as well as a wide range of demographic information such as birth year, years of education, gender, marital status, parental education background, among others.

[5] The VHLSS can be obtained from the official website of GSO (www.gso.gov.vn).

2.2 Analysis Sample

To examine the impacts of the immense devastation on educational accumulation, we rely on the difference-in-differences strategy, which requires one affected (treated) group and one unaffected (control) group.[6] In our main setup, we choose the cohorts of 1953 - 1963 as the affected group and the cohorts of 1985 - 1996 as the unaffected group. Specifically, war (affected) cohorts are defined as individuals who spent at least five years of schooling during the bombing period of 1965 - 1975. We believe that the five years of exposure is long enough for the effects of bombing to be realized. We then proceed to drop cohorts of 1948 - 1952 and 1964 - 1969 because they were exposed to the aerial bombardment for fewer than five school years. We do, however, include these individuals in the affected (war) cohorts in a robustness check. Categorizing them into the war cohorts does not substantially change our result. Table A1 in the Appendix provides the number of school years exposed to aerial bombardment. We also remove individuals born between 1970 and 1984 since this group attended school during the Reconstruction period and might partially suffer from adverse effects of the large-scale bombing destruction.

On the other hand, individuals born during 1985 - 1996 constitute the unaffected (non-war) cohorts since they attained their education after the *"Doi Moi"* marking an end to the postwar reconstruction period. We further restrict our sample to those at least 18 years old, i.e. those supposed to already finish high school, when being surveyed. Moreover, macro-level studies suggest that economies quickly return to their steady state within 20 years after wars, (see, for example, Davis and Weinstein, 2002, Brakman et al., 2004, and Miguel and Roland, 2011), lending additional support to our choice of the 1985 - 1996 cohorts as an unaffected group. Although the main analysis sample includes the war cohorts of 1953 - 1963 and the unaffected non-war cohorts of 1985 - 1996, we also try different categorizations of the two groups in various robustness checks as well as the inclusion of all individuals (born between

[6] Details of this method are provided in Section 3.1.

1909 - 1996) in the generalized specification.

Summary statistics for individual-level and district-level variables are respectively presented in Panel A and B of Table A2. An issue with the VHLSS is that they only provide the number of school grades completed. In other words, the number of years of education is top-coded at 12. Therefore, in our main specification, we use this raw top-coded measure of education as our primary outcome. We also attempt to deal with this issue by imputing the total number of educational years based on the reported grade completed and educational level in a different specification. Particularly, individuals with college, university, master, and PhD degrees are assigned with 14, 16, 18, and 20 educational years respectively. The conceptual framework of how aerial bombardment could impact schooling accumulation is presented in Appendix B. As shown in Panel A of Table A2, the war cohorts completed 7.5 years of education on average while the non-war cohorts finished 9.75 years of education. We also empirically investigate the effects of bombing devastation on labor market outcomes, using personal annual earnings. The mean annual earnings of the war cohorts is roughly 35 million VND (around 1,500 USD) whereas that of the non-war cohorts is 29 million VND (1,300 USD).[7] Turing to district-level variables, as visible from Panel B, the average bomb dropped onto a district is 11.42 tons per km^2 and the maximum bomb density is 279.38 tons per km^2. The average frequency of aerial reconnaissance in a district is 185.71 times, with the maximum of 7,578 times (further discussion is provided in Section 3.2). In total, we have information on approximately 32,000 individuals across 625 districts of 63 provinces.

3 Empirical Methodology

3.1 Difference-in-Differences Approach

To evaluate the effects of aerial bombardment on schooling accumulation and labor market outcomes, we rely on the exogenous district-by-cohort variation in bomb destruction intensity,

[7] It is worth noting that all monetary values in the paper are in 2010 constant price.

and employ a difference-in-differences framework given in the following equation:

$$Y_{idt} = \beta_0 + \beta_1 WarCohort_{ic} \times BombIntensity_d + X'_{idc}\gamma + \delta_d + \lambda_t + \epsilon_{idc} \quad (1)$$

where Y_{idt} is the outcomes of interest for individual i residing in district d and born in year t, including the number of educational years and the log of annual earnings. The $WarCohort_c$ term is a dummy variable taking a value of 1 if an individual was exposed to the Allied bombing for at least five schooling years (born between 1953 and 1963), and zero otherwise.[8],[9] The $BombIntensity_d$ term is the log of bomb density measure where bomb density is defined as the total weight of all weapons (in tons) dropped onto district d divided by the district area (in square kilometers).

The vector X'_{idc} includes: (i) individuals' observable characteristics (e.g. gender, mother education, indicator for living in the north) and survey year fixed effects, (ii) a set of interactions between the observables and birth year dummies to account for differential return of these demographic characteristics by cohorts (Acemoglu et al., 2004), and (iii) another set of interactions between district-level geographic controls and birth year indicators to account for the factors determining local economic conditions and strategic bombing decisions during wartime. Geographic variables proxying for local development include districts' centroid longitude, latitude, distance to coast, average precipitation, temperature, terrain ruggedness, and land suitability. Other geographic factors potentially affecting military strategy during the Vietnam War are also controlled for, such as district average altitude and district centroid distance to Ho Chi Minh Trail (Miguel and Roland, 2011).[10]

The next two terms, δ_d and λ_t, denote district and birth year fixed effects, respectively

[8] Ideally, we should use the individual's district of birth instead of the district of residence. However, the VHLSS does not provide this information. We address the potential issue of migration in Section 4.2.

[9] As a robustness check, we also consider those ever exposed to the bombardment during their schooling time as the war cohort.

[10] For example, Ho Chi Minh trail was the main route through which the Communists supplied their backed insurgents fighting in the South, therefore, was bombed heavily.

and ϵ_{idc} is the error term. We also control for the province-specific time trend, and cluster standard errors at the district-by-birth-year level. Coefficient β_1 captures the effects of aerial bombardment on educational attainment and labor market outcomes of the war cohorts.

In this setup, we exploit the exogenous district-by-cohort variation in the devastation of aerial bombing where treatment is the interaction between War Cohort dummy and the natural log of bomb density in a given district. For β_1 to have a causal interpretation, the fundamental identifying assumption, which is, had the aerial bombardment not occurred, the difference in schooling and earnings between the unaffected and affected (war) cohorts would have been the same across districts with varying bomb intensity levels, must be satisfied. To assess this assumption, we specify the generalized version of equation (1) by estimating the cohort-specific impacts of aerial bombardment:

$$Y_{idt} = \beta_0 + \sum_{g=1}^{11}(Cohort_{ig} \times BombIntensity_d)\beta_{1g} + X'_{idc}\gamma + \delta_d + \lambda_t + \epsilon_{idc} \tag{2}$$

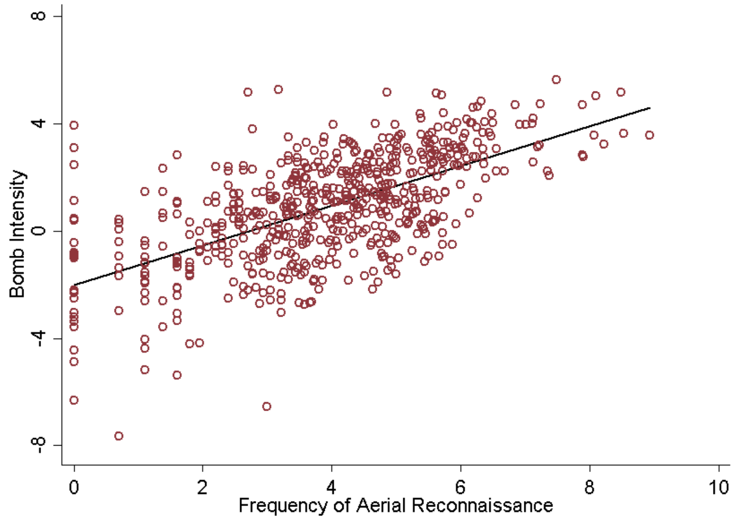
where Y_{idt} is the outcome for individual i residing in district d and born in year t. $Cohort_{ig}$ is an indicator taking the value of 1 if an individual i was born in cohort g. Birth cohorts are grouped into 11 years of birth categories, and the cohorts 1985 - 1996 constitute the comparison group and are omitted from the regression. Each coefficient β_{1g} represents the effects of bombing destruction on a given cohort group. If the "parallel trend" is satisfied then the impact of aerial bombardment should be indistinguishable from zero for cohorts that completed their education before the start of the bombardment period (cohorts born prior to 1948), or for any cohorts who did not spend their schooling years during the devastation time.

3.2 Instrumental Variable Approach

An additional problem that may compromise the integrity of the difference-in-differences estimates is that the Vietnamese government might have put more efforts in reconstructing districts with better growth prospects. This possibility can violate the parallel trend assumption, thus, invalidating our difference-in-differences estimates. To address this concern, we employ the instrumental variable approach where the instrument for the log of bomb density is the availability of military intelligence. According to Chapter 4 of the US Army FM 7-92, reconnaissance is a mission aimed to collect information about the activities and resources of the enemy or geographic characteristics of a particular area. Thus, we use the frequency of the aerial reconnaissance to measure the availability of military intelligence. This instrumental variable is constructed by taking log of the total number of aerial reconnaissance over a district during the period of 1965 - 1975. Data for aerial reconnaissance is also taken from THOR database.

Intuitively, the frequency of the aerial reconnaissance over a particular area strongly predicts the actual amount of bomb dropped onto that area because of the following lines of reasoning. First, the aerial reconnaissance is sent out to collect imagery intelligence, signals intelligence, etc. The higher the scouting frequency over an area, the higher the chance of *'suspicious activities'* and *'potential threats'* being captured. Consequently, districts that are scouted more often tend to be bombed more heavily. For example, the reconnaissance mission was carried out for less than twice in the district of Na Hang (Tuyen Quang Province) and Xi Man (Ha Giang Province), and the total weight of bomb dropped onto these districts was far less than 1 ton per km^2. On the contrary, in the district of Tan Chau (Tay Ninh Province) and Gio Linh (Quang Tri Province), the frequency of reconnaissance was 1397 and 1798 times respectively, and the bomb density in these districts was 114.67 and 1798 ton per km^2. The relationship can also be expressed graphically. Figure 1 provides the association between the log of bomb density and the log of the frequency of aerial reconnaissance. The exclusion restriction condition for the validity of the instrument "frequency of the aerial reconnaissance" is also satisfied in a sense that it is orthogonal on reconstruction efforts. The availability of military reconnaissance can only affect educational attainment and earnings of the war cohorts only through the channel of actual bombing.

Figure 1: Frequency of Aerial Reconnaissance and Bomb Intensity, both in log forms



4 Estimation Results

4.1 Difference-in-Differences Results

We report our baseline results on educational attainment from equation (1) in Table 1. Each cell is the difference-in-differences estimate from a regression that controls for district and birth year fixed effects, survey year fixed effects, and several sets of interactions as discussed in Section 3.1. Column 1 shows the estimated effect for the full sample which is negative (-0.101) and statistically significant at 1%. This implies a 10% increase in bomb density leads to a reduction of 0.01 years of education for individuals who spent at least five years of their schooling during the bombardment time.[11] To get a better understanding of the magnitude of the impact, we compare the educational attainment of an individual in a heavily bombed district, say, Gio Linh (Quang Tri Province) where the bomb density was 279.38 ton/km^2 (the maximal bomb density, Table A2), and an individual in a district with average bomb density (11.42 ton/km^2, Table A2). Individuals of school age during the bombing period in Gio Linh

[11] Because $BombIntensity$ is the log of bomb density, the linear-log specification (1) where the outcome is the number of educational years omits the six districts which were not bombed at all. To this respect, we re-estimate equation (1) where $BombIntensity$ is $log(1 + bombdensity)$. The point estimate is still negative and significant, implying the gap of 0.5 years of education between affected individuals in the most heavily bombed district and affected individuals in the district with average destruction level (Column 1 of Table A3).

completed 0.3 years of education than those in a district with average destruction level. This impact is consonant with the effect of wars or civil conflicts on educational attainment in Akbulut-Yuksel (2014), and Leon (2012).

Table 1: Impacts of Aerial Bombardment on Educational Attainment

	All Individuals	Male Only	Female Only	Mother with higher than primary education	Mother with primary education or less
	(1)	(2)	(3)	(4)	(5)
WarCohort × Bomb Intensity	-0.101*** (0.031)	-0.087** (0.042)	-0.122*** (0.041)	-0.045 (0.062)	-0.373*** (0.126)
Sample size	32,440	15,662	16,778	3,233	2,540

NOTE: Each cell reports coefficient β_1 of equation (1). War cohorts consist of individuals born in 1953-1963. The comparison (unaffected) cohorts include individuals born in 1985-1996. Regressions are conditioned on district, birth year, survey year fixed effects, and province-specific time trend. Individual observable characteristics include gender, mother education, an indicator for living in the north, and the interactions of these characteristics with birth year dummies. Additional controls consist of the interactions between district-level geographic characteristics and birth year indicators. See Section 3.1 for the details on geographic controls. Standard errors are clustered at the district-by-birth year level and provided in the parentheses. ***p<0.01, **p<0.05, *p<0.1.

We present the heterogeneity of the impacts of aerial bombardment in Column 2 through 5 of Table 1 along the lines of gender and mother's education. A female who spent at least five school years during the bombardment finished 0.012 fewer years of schooling in response to a 10% increase in bomb density (Column 3) while the reduction for a male counterpart is roughly 0.008 year (Column 2). This finding is consistent with the work of Shemyakina (2011) where a larger impact of armed conflicts on females is documented. As evident from Column 4 and 5, individuals with higher educated mothers (mothers' education is higher than primary level) were hardly affected by bomb destruction while individuals with a more disadvantaged background (mother with lower educational attainment, primary education or less) were severely impacted. Having said that, due to a large number of missing values for mother's education, we urge some caution in interpreting the heterogeneous effects of bombing in this respect.

4.2 Mobility, Falsification, Nonlinearity, and Generalized Model

Endogenous Mobility - It should be noted that in equation (1) and (2) we measure the bomb density at the district of residence, not the district of birth, level. Endogenous mobility could potentially contaminate our coefficient estimates since people might have reallocated from heavily bombed districts to less destroyed ones for better living conditions or the heavily destroyed districts might have been better in attracting labor and talent during the reconstruction era. We test for this potential contamination by creating a migration indicator that takes the value of 1 if the individual lacks permanent registration in their district of residence.[12] Demombynes and Vu (2016) documented that very few people moved without the sanction before 1990, and those who did move struggled to survive without local *"ho khau"* (permanent registration). Using Household Registration data of Vietnam, Demombynes and Vu (2016) further shows that the population without permanent registration has demographics characteristics that are typical of migrant populations. Therefore, the probability of not holding *"ho khau"* is a good proxy for the probability of migration. We estimate equation (1) using the migration indicator as the outcome variable. Table 2 reports the point estimate. Evident from Column 1, aerial barrage does not appear to be correlated with the probability of migration.

Falsification Test - To lend support to the causal interpretation of the estimated effect of bomb destruction on educational accumulation in Table 1, we conduct a falsification test. Particularly, we run equation (1) with the war cohorts being those born between 1909 and 1940 (who should have completed their education before the bombardment started). The 1985 - 1996 cohorts still serve as a comparison unaffected group. If the effects of aerial bombardment on education are true, we expect to find no impact of bomb destruction on individuals who finished schooling prior to the onset of the bombing of Vietnam. We

[12] This permanent registration system known as *"ho khau"*, which is similar to the *"hukou"* in China, *"hoju"* in Korea and *"koseki"* in Japan. The *"ho khau"* is a remnant of the centrally planned economy that was employed by the States for public security and control of migration. Those moving from one district to another must meet certain requirements in order to transfer their *"ho khau"*.

report the results to this exercise in Column 2 of Table 2. The point estimate is small and highly insignificant (p-value is 0.681), suggesting no spurious relationship between bombing destruction and schooling accumulation.

Table 2: Tests for Endogenous Mobility, Falsification, and Nonlinear Effects

	Migration	Years of Education		Years of Education
	(1)	(2)		(3)
WarCohort × Bomb Intensity	-0.002	-0.018	WarCohort × Middle Third Bomb Intensity	-0.057
	(0.001)	(0.044)		(0.125)
			WarCohort × Top Third Bomb Intensity	-0.350**
				(0.141)
Sample size	32,440	23,452		33,702

NOTE: Column 1 reports the coefficient β_1 in equation (1) but the outcome is the migration indicator (defined as individual lacking permanent registration in their district of residence). In Column 1, the war cohorts consist of individuals born in 1953-1963 and the comparison (i.e. unaffected) cohorts include individuals born in 1985-1996. Column 2 presents the results of a falsification test (using specification (1)) where the "war" cohorts include individuals born prior to 1940 and the unaffected cohorts contain individuals born between 1985 and 1996. Column 3 shows the possible nonlinear impacts of bomb destruction where the single *BombIntensity* measure is replaced with indicators which take the value of 1 if the bomb density in the district lies in the top, middle, and bottom third of the bomb density distribution (with the bottom third dummy being omitted). Standard errors are clustered at the district-by-birth year level and provided in the parentheses. ***p<0.01, **p<0.05, *p<0.1. See the note under Table 1 for details on control variables.

Nonlinear Effects - To explore the possible nonlinear effects of aerial bombardment, we replace the single $BombIntensity_d$ measure in equation (1) with three indicators , each of which takes the value of 1 if the bomb density in the district lies in the top, middle, and bottom third of the bomb density distribution (with the bottom third dummy being omitted). The results are reported in Column 3 of Table 2. The adverse effects are both economically and statistically significant for individuals in districts in the top third of the bomb destruction distribution; however, the point estimate falls short of statistical significance for individuals in districts in the middle third of the bomb distribution.[13]

Generalized Difference-in-Differences - The validity of the results in Table 1 depends

[13] Sample size is larger than that in Column 1 of Table 1 because here we take into account six districts with zero bomb destruction. These districts belong to the omitted bottom third category.

on the identifying assumption that the difference in years of education between the war and non-war cohorts would have remained the same across districts with varying bomb intensity levels if the bombing devastation had never happened. We provide the estimates for the cohort-specific effects of aerial barrage on educational accumulation using equation (2). For the parallel trend assumption to hold, there should be no effect for any cohorts that were not exposed to the bombardment during their school-going years. That is what we find based on the estimating results reported in Table 3.[14]

Table 3: Aerial Bombardment and Individual Outcomes by Cohorts

	Years of Education		Log(Earnings)	
	Coefficients (1)	Std. Errors (2)	Coefficients (3)	Std. Errors (4)
Born before 1936×Bomb Intensity	0.003	(0.048)	-0.061	(0.042)
Born(1937-1941)×Bomb Intensity	-0.029	(0.061)	-0.046	(0.050)
Born(1942-1947)×Bomb Intensity	-0.012	(0.054)	-0.049	(0.048)
Born(1948-1952)×Bomb Intensity	-0.081*	(0.048)	-0.012	(0.054)
Born(1953-1957)×Bomb Intensity	-0.142***	(0.040)	-0.030	(0.051)
Born(1958-1960)×Bomb Intensity	-0.089**	(0.043)	-0.165***	(0.063)
Born(1961-1964)×Bomb Intensity	-0.107***	(0.036)	-0.068	(0.057)
Born(1965-1968)×Bomb Intensity	-0.023	(0.038)	0.015	(0.056)
Born(1969-1974)×Bomb Intensity	0.037	(0.033)	0.062	(0.049)
Born(1975-1984)×Bomb Intensity	0.011	(0.027)	-0.003	(0.040)
Sample size	80,692		80,692	

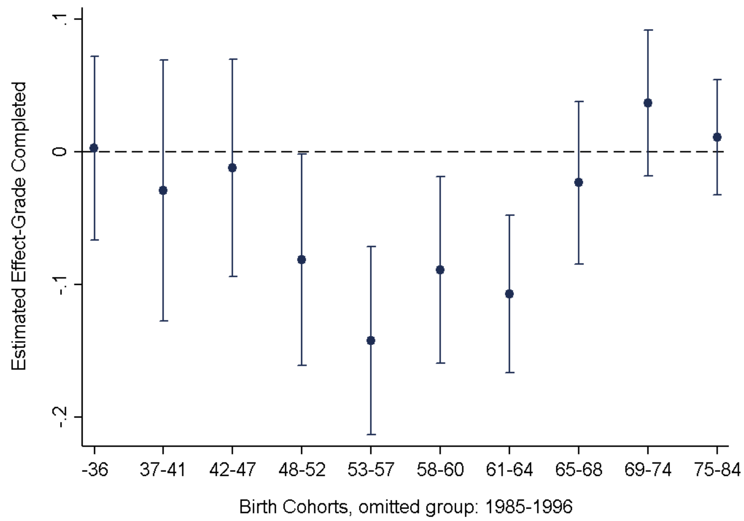
NOTE: Each cell reports coefficient β_{1g} in equation (2). Omitted cohorts are individuals born during 1985-1996. Standard errors are clustered at the district-by-birth year level and provided in the parentheses. ***p<0.01, **p<0.05, *p<0.1. See the note under Table 1 for details on control variables.

For cohorts of 1948 - 1952, 1953 - 1957, 1958 - 1960, and 1961 - 1964 the estimated effects are negative and significant while for other cohorts (who finished schooling prior to the bombardment period, e.g. the 1937 - 1941 cohort, or attained education after the end of the bombing destruction, e.g. the 1975 - 1984 cohort), point estimates are statistically indistinguishable from zero. Individuals born in 1953 - 1957 and 1961 - 1964 respectively

[14] In the generalized difference-in-differences framework, we include all cohorts and group them into different categories. There are 11 groups and cohorts 1985 - 1996 are omitted from the regression.

completed 0.014 and 0.011 fewer years of education in response to a 10% increase in bomb density. In other words, individuals born in 1953 - 1957 in a district with maximal aerial destruction completed 0.45 fewer educational years than those in a district with average destruction level. The reduction in years of education for cohorts 1948 - 1952 and 1958 - 1960 is around 0.008 to 0.009 when bomb density rises by 10%.[15] Figure 2 plots these coefficients and the 90% confidence interval.

Figure 2: Impacts of Aerial Bombardment on Years of Education by Cohorts, 90% CI.



Robustness Checks - As a robustness check, we examine the impacts of aerial bombardment on the number of educational years using equation (1) with different definitions of war and non-war cohorts. Results are reported in Table 4. In Column 1 and 2, the 1909 - 1935 and the 1935 - 1947 cohorts (who completed schooling prior to the onset of the Allied bombing) are respectively defined as the comparison group, with the war cohorts being the 1953 - 1963 groups. Point estimates are negative, significant, and close in magnitude to the estimate in Table 1, implying a reduction in schooling for individuals of school age in the bombarded districts during the devastation period.

In Column 3, all cohorts other than the main war cohorts (1953 - 1963) constitute the unaffected group. In Column 4, the affected cohorts consist of those born between 1948 and

[15] Cohorts of 1948 - 1952 were exposed to the bombardment from 0.5 to 4 school years.

1968, who ever spent any time of their schooling years in the bombardment period. The effects are still negative and significant, although the point estimate is smaller than the one in Table 1. Individuals exposed to the aerial bombardment for at least eight school years are considered the war cohorts in Column 5. The estimated impact is somewhat similar to the effect in the main specification.[16, 17]

Table 4: Aerial Bombardment and Education: Different Unaffected and War Cohorts

	Y = Years of Education				
	(1)	(2)	(3)	(4)	(5)
WarCohort×	-0.139**	-0.116**	-0.113***	-0.058**	-0.103***
Bomb Intensity	(0.056)	(0.047)	(0.024)	(0.026)	(0.040)
Sample size	18,784	21,431	80,692	44,924	24,477
War Cohorts	1953-1963	1953-1963	1953-1963	1948-1968	1956-1960
Non-war Cohorts	1909-1935	1935-1947	Others	1985-1996	1985-1996

NOTE: Each cell reports coefficient β_1 of equation (1) with different definitions of war and non-war cohorts. Standard errors are clustered at district-by-birth year level and provided in the parentheses. ***p<0.01, **p<0.05, *p<0.1. See the note under Table 1 for details on control variables.

4.3 Instrumental Variable Results

Another important concern for the parallel trend assumption is the possible endogeneity of the distribution of postwar reconstruction. Put it differently, the reconstruction efforts might have been unevenly allocated across districts with different growth prospects. To address this concern, we employ an instrumental variable method. The bomb density is instrumented by (the log of) the frequency of aerial reconnaissance.

We report the 2SLS estimate for equation (1) in Table 5. The second-stage estimate (Column

[16] We also try employing a different measure of bomb density. Instead of using the total weight of all bombs dropped onto a given district as in the main text, we consider only bombs which were intended to destroy physical capital. The result, which remains close to the main estimate in Table 1, is reported in Column 2 of Table A3.

[17] In a different specification, we impute the total number of educational years based on the reported grade completed and educational level, and re-estimate our main specification (1) using the imputed total years of education as the dependent variable. Particularly, individuals with college, university, master, and PhD degrees are assigned with 14, 16, 18, and 20 educational years respectively. Results to this exercise are similar to the main results and are provided in Column 3 of Table A3.

1) is -0.237 and significant at 1%. A 10% increase in bombing devastation results in a reduction of 0.02 years of education for the war cohorts, implying school-aged individuals in a district with maximal bombing havoc completed 0.76 fewer years of education than those in a district with average damage level. In Column 2, we report the first-stage estimate and statistics. The first-stage estimate is close to unity and highly significant, consistent with the hypothesis that the more likely to be bombed districts are also the ones being scouted more frequently. The statistics in Table 5 indicate the instrument "frequency of aerial reconnaissance" passes the weak instrument and weak-instrument-robust inference tests.[18] Reduced-form estimate, which is negative and significant, is provided in Column 3.

Table 5: Aerial Bombardment and Education: Instrumental Variable Approach

	Second Stage	First Stage	Reduced Form
	Years of Education	Warcohort × Bomb Intensity	Years of Education
	(1)	(2)	(3)
War Cohort×Bomb Intensity	-0.237***		
	(0.059)		
Warcohort × Frequency of Aerial Reconnaissance		0.808***	-0.183***
		(0.019)	(0.047)
Sample size	31,308	31,308	
Kleibergen-Paap Wald rk F statistic		1812.32	
Anderson-Rubin Wald test (Chi-square)		17.10	
Stock-Wright LM S statistic		19.07	

NOTE: This table reports the second, the first stage, and the reduced form coefficients in a 2SLS estimation of equation (1). Bomb Intensity is instrumented by the logarithm of the frequency of aerial reconnaissance. Standard errors are clustered at district-by-birth year level and provided in the parentheses. ***p<0.01, **p<0.05, *p<0.1. See the note under Table 1 for details on control variables.

[18] The Kleibergen-Paap rk Wald F statistic is 1812.32, exceeding the Stock-Yogo critical value for one endogenous variable and instrument at 10% maximal IV size (16.38). The Chi-square statistics for Anderson-Rubin Wald test and the Chi-square statistics for the Stock-Wright LM S statistic are 17.10 and 19.07, respectively. Both numbers are larger than the Chi-square (1) critical value of 3.841 at the 5 percent significance level.

4.4 Results on Labor Market Outcomes

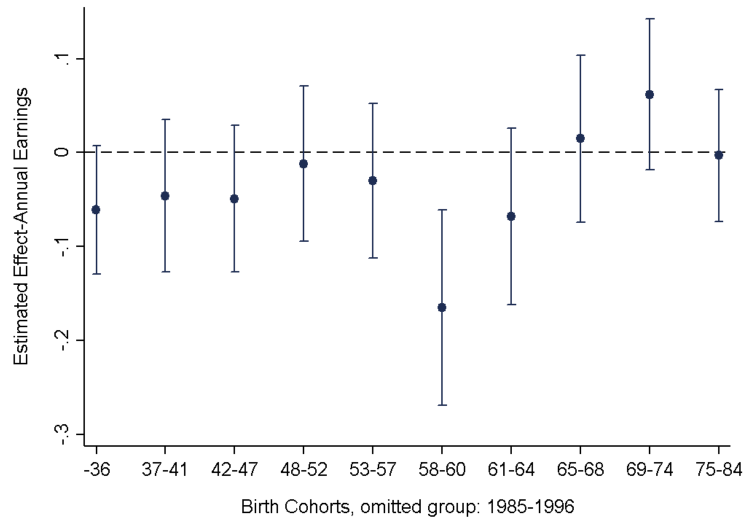
In this subsection, we explore the effects of aerial bombardment on future labor market outcomes. The dependent variable is the log of annual earnings. The main difference-in-differences estimate in Column 1 of Table 6 is negative and marginally significant (p-value is 0.124). Estimates using different categorizations of war and non-war cohorts are reported from Column 2 through 6. There are negative and strongly significant impacts on annual earnings when the comparison group is individuals other than the 1953 - 1963 cohorts. In other words, 1% increase in bomb density leads to 0.086% decrease in annual earnings for individuals exposed to the aerial barrage for at least five school years. Put it differently, the annual earnings of an individual in the most heavily bombed district is around three-fourths of the yearly income of an individual in a district with average destruction level. The cohort-specific impact on annual earnings in the generalized difference-in-differences framework is reported in Column 2 of Table 3. The adverse effects of bombing devastation are only found for individuals born in the period of 1958 - 1960. Figure 3 plots these coefficients and the 90% confidence interval.

Table 6: Aerial Bombardment and Earnings: Different Unaffected and War Cohorts

	Y = Log Individual Annual Earnings					
	(1)	(2)	(3)	(4)	(5)	(6)
WarCohort× Bomb Intensity	-0.073 (0.047)	0.004 (0.048)	-0.001 (0.045)	-0.086*** (0.033)	-0.035 (0.040)	-0.042 (0.060)
Sample size	32440	18784	21431	80692	44924	24477
War Cohorts	1953-1963	1953-1963	1953-1963	1953-1963	1948-1968	1956-1960
Non-war Cohorts	1985-1996	1909-1935	1935-1947	Others	1985-1996	1985-1996

NOTE: Each cell reports coefficient β_1 of equation (1) with different categorizations of war and non-war cohorts. Standard errors are clustered at the district-by-birth year level and provided in the parentheses. ***p<0.01, **p<0.05, *p<0.1. See the note under Table 1 for details on control variables.

Figure 3: Impacts of Aerial Bombardment on Annual Earnings by Cohorts, 90% CI.



5 Discussion and Conclusion

This paper contributes to the literature by providing causal evidence on the ramifications of large-scale physical destruction during the Allied bombing of Vietnam. Notably, we exploit the district-by-cohort variation in bomb intensity in a difference-in-differences framework to quantify the effects of interest. The paper also utilizes the newly released dataset (THOR) to construct a more accurate measure of aerial destruction, the total weight of all weapons dropped onto a district per km^2 area. We further introduce a novel instrument for bomb intensity: the frequency of aerial reconnaissance, which is not only strongly correlated with actual bombing but also exogenous to educational trends. The negative impacts on schooling accumulation detected in this paper highlights the long-term consequences of aerial bombardment. Specifically, we find that a 10% increase in bomb density leads to a reduction from 0.01 year of education (in a difference-in-differences specification) to 0.02 educational years (in the instrumental variable specification) for individuals who spent at least five schooling years during the bombing of Vietnam. To put these numbers into perspective, a school-aged individual in the most destroyed district completed from 0.3 to 0.7 fewer years of education than his/her peer in the district with an average bomb density level. Our results are robust to different robustness checks, falsification test and the test for parallel trends.

The detrimental consequences of aerial bombardment on schooling accumulation among the war cohorts could potentially transmit through both the supply side and the demand side of the education production function. Through the supply side, aerial bombardment could destroy schools, and increase the absence of teachers (see, for example, Glewwe and Jacoby, 1994; Akbulut-Yuksel, 2014). Through the demand side, adverse income shocks to households (Jacoby and Skoufias, 1997; Thomas et al., 2004), sizable damages to both mental and physical health (Hoeffler and Reynal-Querol, 2003; Ghobarah et al., 2003; Annan et al., 2006; Evans and Miguel, 2007) could possibly shrink the number of students. Unfortunately, we are unable to formally analyze these potential mechanisms due to the unavailability of historical data.

We also document adverse effects of aerial bombardment on future labor market outcomes. Given that the returns to education go beyond personal earnings, the reduction in educational attainment among the war cohorts could have affected other aspects of their lives such as health (Silles, 2009; Conti et al., 2010; Kemptner et al., 2011), and the outcomes of their offspring (Currie and Moretti, 2003; McCrary and Royer, 2011; Lundborg et al., 2014). Our findings underline the importance of policies targeting children after wartime.

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Appendix A: Supplementary Tables

Table A1: Number of School Years Affected from Aerial Bombardment

Minimum Exposed Years	Cohorts	Minimum Exposed Years	Cohorts	Minimum Exposed years	Cohorts
1	1949-1967	4	1952-1964	7	1955-1961
2	1950-1966	5	1953-1963	8	1956-1960
3	1951-1965	6	1954-1962	9	1957-1959

Table A2: Summary Statistics

	Affected	Unaffected		All Bombed Districts	
	Mean (1)	Mean (2)		Mean (3)	Max (4)
Panel A: Individual			**Panel B: District**		
Years of Education	7.51	9.75	Bomb Density (t/km^2)	11.42	279.38
	(3.56)	(3.09)		(26.40)	
Annual Earnings	35,614	29,210	Reconnaissance Frequency	185.71	7578
	(41,173)	(24,608)		(540.03)	
Year of Birth	1958	1989	Number of Provinces	63	
	(3.09)	(2.95)			
Sample size	15,113	17,327	Number of Districts	625	

NOTE: Standard deviations are in parentheses. Affected group refer to individuals born in the period of 1953-1963. Unaffected group includes those born in the period of 1985-1996. Monetary values of earnings are in '000 VND, 2010 constant price.

Table A3: Aerial Bombardment and Education: Supplementary Specifications

	Years of Education	Years of Education	Imputed Years of Education
	(1)	(2)	(3)
WarCohort × Log(1+Bomb Density)	-0.163***		
	(0.049)		
WarCohort × Bomb Intensity (with intention to destroy)		-0.083***	
		(0.031)	
WarCohort × Bomb Intensity			-0.103***
			(0.035)
Sample size	33,702	32,112	32,440

NOTE: Each cell reports coefficient β_1 of equation (1). War cohorts consist of individuals born in 1953 - 1963. The comparison (unaffected) cohorts include individuals born in 1985 - 1996. In Column 1, $BombIntensity_d$ is defined as the log of (1+Bomb Density) to account for districts with no bombing destruction. In Column 2, the measure of bomb density is restricted to bombs the mission of which was to destroy physical capital. In Column 3, $BombIntensity_d$ is still the log of Bomb Density, but dependent variable is the imputed years of education (individuals with college, university, master, and PhD degrees are assigned with 14, 16, 18, and 20 educational years respectively). See the note under Table 1 for details on control variables. Standard errors are clustered at the district-by-birth year level and provided in the parentheses. *** p<0.01, ** p<0.05, * p<0.1

Appendix B: Conceptual Framework

While the aerial devastation can affect educational attainment of exposed children through many channels, in this paper, we are interested in the overall effect. We assume that this total effect distorts the efficiency in accumulating human capital, thus, discouraging educational attainment. Based on the *Schooling and Wage Earnings* model in Cahuc et al. (2014), our model is modified to focus entirely on the decision of school-age individuals.[19]

Now, suppose that individuals are expected to live for $T > 0$ years (excluding retiring and pre-schooling years). At year $\tau \leq T$, individuals face two options: (1) leaving school to join the labor market, or (2) staying in school to accumulate human capital. For the sake of simplicity, we assume that individuals cannot go back to school after joining the labor market. Let us denote by $s \geq 0$ the "*additional years of schooling*" expected to attain by an individual at year τ. Her human capital after s additional years of schooling is given by,

$$h_{\tau+s} = h_\tau \exp\left[s\, \Theta(x)\right] \tag{3}$$

[19] Cahuc, P., Carcillo, S., and Zylberberg, A. (2014). *Labor economics*. MIT press.

where $h_\tau = h_0 \exp\left[\tau\ \Theta(x)\right]$ is the level of human capital at year τ, with τ years of schooling and h_0 innate human capital. The value of $\Theta(\cdot)$ represents the local level of efficiency affecting human capital production, and x is the degree of destruction caused by the aerial bombing. We assume that $\partial\Theta(x)/\partial x < 0$, such that the efficiency level is negatively correlated with bombing destruction. Thus, after s years of additional schooling, human capital increases by an amount of $\Delta h_\tau = h_{\tau+s} - h_\tau$, given by,

$$\Delta h_\tau = h_\tau \exp\left[s\ \Theta(x)\right] - h_\tau \tag{4}$$

By staying in school to gain Δh_τ unit of human capital, she produces zero unit of output for s years. However, if she chooses to quit school and go to work, her production function exhibits constant returns to scale technology taking a form of:

$$y_\tau = h_\tau \tag{5}$$

where y_τ is the amount of output produced, and h_τ is the level of human capital accumulated up to year τ. Normalizing output price to one, zero-profit condition implies that individual earning is also her human capital $w_\tau = h_\tau$. The discounted value of lifetime gain from s additional years of schooling ($\Delta\Omega_\tau$) can be expressed as follows,

$$\Delta\Omega_\tau = \int_{\tau+s}^{T} h_{\tau+s} e^{-\rho t} \mathrm{d}t - \int_{\tau}^{T} h_\tau e^{-\rho t} \mathrm{d}t \tag{6}$$

where ρ is the discount factor. Thus, the marginal return of the additional years of schooling evaluated at year τ is given by,

$$\frac{\partial\Delta\Omega_\tau}{\partial s} \triangleq \frac{\Theta(x) - \rho}{e^{\rho(\tau+s)}} - \frac{\Theta(x)}{e^{\rho T}} \tag{7}$$

The symbol $\triangleq$ indicates that common terms are suppressed for simplicity. The first order condition, i.e. setting $\partial\Delta\Omega_\tau/\partial s = 0$, yields the optimal years of schooling,

$$\tau + s = \begin{cases} \tau\ ,\ \text{if } x > \breve{x} \\ T + \dfrac{1}{\rho}\ln\left[\dfrac{\Theta(x) - \rho}{\Theta(x)}\right] > \tau\ ,\ \text{if } x \leq \breve{x} \end{cases} \tag{8}$$

where the value of the threshold $\breve{x}$ is obtained from inverting the equality $\Theta(x) = \rho\big/1 - e^{-T\rho}$.

Put it differently, $\breve{x} = \Theta^{-1}\left(\rho/1 - e^{-T\rho}\right)$. The model generates two important predictions regarding the relationship between bombing destruction x and individuals' educational attainment $\tau + s$.

First, the probability of staying in school $P(\tau + s > \tau)$ is directly linked to the degree of destruction x according to the equality $P(\tau + s > \tau) = P(x \leq \breve{x})$. Therefore, the theory suggests that across geographic units and individuals identical in all respects except for the degree of bombing destruction, the higher the degree of destruction x, the lower the probability of staying in school $P(\tau + s > \tau)$. In other words, when the degree of bombing destruction exceeds a certain threshold $\breve{x}$, individuals will drop out of school. We refer to this relationship as the impact of bombing on education at the extensive margin.

Second, individual's additional years of schooling s, conditional on staying in school $s > 0$, is a decreasing function of bombing destruction x. To see this, we differentiate the second case of equation (8) with respect to the degree of destruction x to obtain the following,

$$\text{sign}\left[\frac{\partial s_i(x|x < \breve{x})}{\partial x}\right] = \text{sign}\left[\frac{\partial \Theta(x)}{\partial x}\right] < 0 \tag{9}$$

Thus, the theory also suggests that an increase in the degree of bombing destruction generates a reduction in individuals' years of schooling, conditional on staying in school. We refer to this relationship as the impact of bombing on education at the intensive margin.

Overall, the model shows that the aerial bombardment decreases educational attainment of school-age individuals during the wartime. At the extensive margin, the devastation forces them to drop out of school while at the intensive margin, shortens the additional years of education for those not dropping out.