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The Long-Term Impact of Chemical Warfare on
Educational Attainment: Evidence
from 50 years after the Vietnam War

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Abstract

Between 1962 and 1971, the U.S. sprayed more than 19.5 million gallons of Agent Orange (AO) over Vietnam. Due to the stability of the compound, traces of AO can still be found to this day. By using stacked cross-section and instrumental variable estimate models with decadal age-cohorts, I found that, consistent throughout the decades, individuals in areas with high levels of AO received 0.566 to 1.575 fewer years of education compared to low intensity areas. This is likely due to AO's negative impact on health and agricultural productivity, which are both associated with lower levels of education.

Key Words: Agent Orange, Education, Warfare, Vietnam, Conflict

1. Introduction

War is incredibly destructive and far reaching, with tremendous losses to land, infrastructure, and human life. While there has been much literature dedicated to the immediate destruction caused by war, far less has been devoted to studying the long-term impacts of conflict on economic development. Some studies have found no long-term impact of bombings in Japan, Germany, and Vietnam (Davis and Weinstein, 2002; Brackman et al., 2004; Miguel and Roland, 2011), supporting the idea of the Phoenix Factor which proposes that countries heavily damaged by conflict will undergo rapid post-war recovery to eventually “resume antebellum status” (Organski and Kugler, 1977). Likewise, other papers have found lingering negative impacts of war several decades after the conclusion of the conflict, specifically in Laos, Vietnam, and Cambodia (Guo, 2020; Appau et al., 2021; Riano and Caicedo, 2024; Merrouche, 2010), likely due to landmines and unexploded ordinances, which are remnants of the Vietnam War and other civil conflicts that occurred throughout the mid to late twentieth century. Similar to unexploded ordinances, traces of Agent Orange, a chemical herbicide used by the U.S. Air Force can still be found in the soil today (Olson and Morton, 2019). This paper seeks to not only determine the long-term impacts of chemical warfare on education, but also determine when and if areas most heavily targeted by chemicals converge with less targeted areas. Eventual convergence supports the Phoenix Factor theory whereas a lack of convergence indicates that chemical warfare creates a poverty trap for the afflicted areas that can last even half a century after the conflict.

For this paper, I will be using the Vietnam War as a case study as it is one of the most prominent and well documented examples of chemical warfare. During the war between 1962 and 1971, in what is known as Operation Ranch Hand, the U.S. Air Force dropped approximately 19.5 million gallons of chemical defoliants over Vietnam, with Agent Orange¹ being the most common (Trung Le et. al., 2022). Even five decades after the conclusion of the Vietnam War, the impact of Agent Orange is still persistent to this day (Banout et al., 2014; Tuyet-Hanh, 2010; Schecter et al., 2001). While there has been limited research on the long-term effects of Agent Orange on health and agriculture (Appau et al., 2021; Trung Le, 2022), there has yet to be any research on the long-term impacts of Agent Orange on educational attainment; this paper aims to fill this gap in the literature.

Through a combination of various health surveys and the online Agent Orange Data Warehouse, I use a stacked cross-section with decadal age-cohorts to determine when and if Vietnamese districts exposed to high levels of Agent Orange converge with their counterfactuals. To address endogeneity concerns from the non-random targeting of the pesticide, I am mimicking the empirical strategy devised by Trung Le, Minh Pham, and Polachek, and am using the North Vietnamese Army (NVA) bases as an instrument for herbicide intensity. As identified by Trung Le et al., the purpose of the chemicals was to “defoliate inland forests, coastal mangrove forests, and cultivation land around suspected NVA areas to improve visibility and destroy the enemy food crop supply” (Trung Le et al., 2022, p. 2). My results indicate that exposure to high levels of Agent Orange leads to

¹ While Agent Orange is the most well-known chemical defoliant used by the US Operation Ranch Hand which used “Rainbow Herbicides” consisting of Agent Orange, Purple, Blue, Pink, White, Dinoxol, Trinoxol, and unknown. For the sake of this paper, all of the rainbow herbicides will just be referred to as Agent Orange as it was the most commonly used and well known.

approximately half a year less of formal education, but with each decadal cohort completing more education than the one previous. This is likely due to the longevity and stability of Agent Orange, which is still present in the soil and water and negatively impacting health and agriculture.

This paper proceeds as follows: Section 2 provides a brief review of literature concerning the impact of warfare on education as well as background information on the Vietnam War and Agent Orange. Section 3 then describes the data and identification strategy. Section 4 is where I show the baseline results with section 5 detailing the robustness check and limitations. Section 6 explores possible mechanisms before finally concluding with section 7.

2. Background

2.1 War and Education

Throughout history and across the globe, war has consistently led to a reduction in educational attainment, especially for those directly affected by the conflict. Many regimes systematically targeted education by forcefully shutting down schools and persecuting the highly educated. The Cultural Revolution in China (1966-1976) resulted in the persecution of the intellectual elite, the burning of books, and even the shutdown of colleges and universities for a ten-year period (Huang, 2020). During the Cambodian Civil War and the Khmer Rouge, which lasted from 1975 to 1979, the regime specifically targeted academics, including students and teachers. It is estimated that 90% of the country's schools were destroyed and that only 87 out of every 1,000 academics survived (Harper, 2023). More recently, the Yugoslav Wars (1991-1999) resulted in the purposeful targeting of educational and cultural institutions as a means of ethnic cleansing (Radovic, 2014). Even in 2024, education is still being deliberately targeted, as is the case with the Boko Haram in Nigeria (Bertoni et al., 2019), the Taliban in Afghanistan (Amiri and Jackson, 2021), and in the Syrian Civil War (Haidostian, 2024).

Each of the above examples resulted in severe short and long-run economic and social consequences. Bai and Wu (2023) found that during China's Cultural Revolution, for every one percent increase in revolutionary intensity, there is a 0.82% decrease in industrialization a decade later and a 6.9% decrease in an individual's likelihood of being a college graduate. They also found that these effects dissipated over time, suggesting the impact of the revolution was not permanent. Islam et al. (2014), when analyzing the Khmer Rouge, found similar results. For each additional year of exposure to the conflict during primary school, men and women experienced a 2.9-3.9 and 2.2-3.5 month reduction in schooling and an overall 0.9-1.1 and 0.6-0.9 year reduction in educational attainment over the course of the war, respectively (Islam, et al., 2014). For the Bosnian Civil War, Swee (2015) found that a one standard deviation increase in war intensity, measured by casualties, is associated with a 4-percentage point decrease in the likelihood of completing secondary school. This resulted in a poverty trap for the afflicted individuals, in which lower levels of education were linked to reduced earnings and fewer opportunities in the labor market. As for the educational consequences of the Boko Haram, Bertoni et al. (2019) found that for every one standard deviation increase in the number of fatalities within a 5km radius, there is an associated 0.6 year decrease in schooling, an 11% drop relative to the national average.

It is well established that war and conflict lead to a decrease in educational attainment for those directly impacted and even subsequent generations, but there is little to no literature on the compounded effect of both chemical warfare and conflict, much less its impact on schooling. At this time, there does not seem to be any studies dedicated to chemical warfare and education, and of the few that do analyze the long-term implications of chemical warfare, they largely focus on health or environmental effects. Looking at the Iran-Iraq War, Khateri et al. (2003) found that of the 34,000 individuals exposed to mustard gas, more than 50% currently suffer from chronic respiratory issues and 30% experience persistent skin conditions. Hashemian et al. (2006) found that nearly 60% of Iranian survivors experience symptoms of Post-Traumatic Stress Disorder, anxiety, and depression. In a separate study, Sullivan (2020) analyzes the health challenges of exposure to sodium dichromate (Operation Iraqi Freedom) and Agent Orange (Vietnam War) on U.S. Veterans. The study found that approximately 830 U.S. service members were potentially exposed to sodium dichromate, a highly toxic and carcinogenic substance, which can cause severe respiratory issues, cancer and other health problems. In addition, veterans exposed to Agent Orange have a 9% higher mortality rate compared to those who were not deployed.

2.2.1 Agent Orange and Agricultural Productivity

There is extensive literature finding that conflict and warfare can have a negative impact on agricultural productivity (Bucala-Hrabia, 2017; Appau et al., 2021; Guo, 2020). Guo (2020) found that bombing can disrupt agricultural infrastructure and fields, leading to decreased productivity. The study uses Laos, the most bombed country in the world, as a case study and looks at how bombing during the Vietnam War was still negatively impacting the country in 2005. The paper found that a one standard deviation increase in unexploded ordinances density resulted in 0.6-0.9 fewer years of education, highlighting the persistent negative impact of unexploded ordinances (Guo, 2020). The study provides evidence that in villages with higher unexploded ordinances density, farmers worked longer hours, and more labor was employed in agriculture to compensate for the reduced efficiency. Additionally, the farmers in these villages tended to be younger, indicating that children were likely being pulled into the agricultural labor force.

As for Agent Orange, the presence of toxic chemical compounds, or dioxin, led to long-lasting soil degradation, making it difficult to cultivate crops effectively even decades after the war (Stellman et al., 2003; Appau et al., 2021). Agent Orange's widespread use also resulted in the destruction of vegetation coverage, which further reduced the land's agricultural potential. Appau et al. (2021) found that a 10% increase in bombing intensity led to a 2.94% decrease in rice productivity and a 3.21% decrease in overall agricultural productivity. Also, by using a regression discontinuity design along the 17th parallel, they found that high levels of exposure to Agent Orange led to 0.282 kg per square meter decrease in rice productivity, indicating that the decrease in agricultural production can be attributed to Agent Orange.

2.2.2 Agent Orange and Health

There is also strong evidence linking Agent Orange exposure to various health defects, even among generations born after the war. Dioxin is known to cause epigenetic and genetic mutations which can be

inherited and contribute to long-term health implications in descendants. Trung Le et al. (2022) found that Vietnamese civilians located in communes that were a one standard deviation more exposed to herbicides during the war are 19.75% more likely to suffer from health diseases medically linked to Agent Orange three decades later. Some of the specific health conditions include blood-pressure related diseases, mobility disabilities, congenital disabilities, diabetes, liver disorders, and cancer. The prevalence of birth defects in more exposed areas is significantly higher compared to regions with little or no exposure to Agent Orange. Children born to exposed parents are 1.5 to 2 times more likely to suffer from congenital disabilities, such as neural tube defects or cleft palate, compared to the national average, and they are 30% more likely to have any sort of birth defect (Trung Le et al., 2022; Yamashita and Trinh, 2022). Even children two generations removed from the war experience persistent health problems, such as various learning disabilities and developmental delays.

Yamashita and Trinh (2021) found four key disabilities that are directly related to Agent Orange that could have a negative impact on education: hearing, mobility, memory, and vision. They found that there is a 0.33% increase in hearing disabilities and a 0.37% increase in mobility disabilities for afflicted individuals (Yamashita and Trinh, 2021). They also found a positive relationship between Agent Orange and vision and memory disabilities, though these were not significant.

2.2 The Vietnam War

Vietnam had been a French colony since the mid-19th century, as part of French Indochina. However, during the Second World War, Japan occupied Vietnam, weakening French control. This period saw the rise of a nationalist movement, led by Ho Chi Minh, who sought independence from both French and Japanese control (Smithsonian, 2023). At the end of the war, Ho Chi Minh declared Vietnamese independence despite French assertion to the land. This led to the First Indochina War between the French and the Viet Minh, which lasted from 1946 to 1954 (Smithsonian, 2023).

Following the war, Vietnam was partitioned along the 17th parallel at the 1954 Geneva Convention, with the North's Democratic Republic of Vietnam being heavily supported by the Soviet Union and China and the South's Republic of Vietnam being supported by the United States, France, and the United Kingdom (Smithsonian, 2023). The partition was intended to only last two years before unification elections, but it was extended due to fears over a communist victory. The South's leader, Ngo Dinh Diem, was deeply unpopular among the south Vietnamese, leading to a civil war in the late 1950's, with the North sending Viet Minh fighters to aid the Viet Cong and the United States sending military advisors to aid the South (Smithsonian, 2023). By the mid 1960's the Vietnam War was in full swing.

It is estimated that between one and 3.5 million people died in total, with many civilian deaths caused by the extensive aerial bombardment in North and South Vietnam. During the war, the United States and their allies dropped more than 7.5 million tons of bombs on Southeast Asia, more than all the bombs dropped during World War Two and the Korean War combined (Clodfelter, 1995; Miguel and Roland, 2011). In addition, during Operation Ranch Hand, the U.S. Air Force also dropped 19.5 million gallons of Agent Orange across more than 31,000 square kilometers of Vietnamese land, affecting millions of people (Trung Le et al., 2022; Stellman et al., 2003).

2.3 Post-War Reconstruction

In 1975, the last of the American troops withdrew from Saigon, leaving the South to surrender and for the north and south to reunify into one country. After centuries of external influence and colonization, there was finally an independent Vietnamese state: the Socialist Republic of Vietnam. However, unifying the communist north and the capitalist south was a daunting task, as many individuals had not interacted with the others in years. Tran Tri Vu, who endured 4.5 years in various re-education camps, said this:

Our generation in the South was suddenly charged with wrongdoing because we had not lived in the North, had not been used to the way of reasoning of the Northern people, had not accepted their ideology. Our skin was the same color, we spoke the same language, our ethnic origin and geographic location were the same, and yet we were completely different from them. When Northern soldiers poured into the South, they had appeared to our eyes as country folks who had strayed into a big town...Living in their company, observing their way of life and thinking, and especially experiencing our treatment in the camp, we had come to realize that between us and them was a barrier that could never be overcome. (APF Canada, 2016)

The North took many harsh steps to consolidate power in the south and to integrate them into their socialist way of life. Following the Fall of Saigon, 140,000 south Vietnamese who were associated with the south's military fled the country, with hundreds of thousands more emigrating in the subsequent years (APF Canada, 2016). The people who fled south Vietnam were among the wealthiest and most highly educated, who had to sell their valuables in order to be smuggled out of the country and escape the communist regime. This led to a loss of human capital and a massive refugee crisis with an estimated 10% to 70% dying at sea, resulting in approximately 300,000 deaths (APF Canada, 2016).

2.3.1 Central Planning Period

For those who stayed, life may not have been much easier. One million Vietnamese who were thought to have been associated with the South's military were sent to re-education camps, which used coercive techniques such as torture, brainwashing, and hard labor to preach the fundamentals of a new communist society (APF Canada, 2016). Some of these individuals were never seen again. The north Vietnamese government also created a personal dossier of "bad elements" in which these people were denied a *ho khan*, a residence permit necessary for attending school, seeking employment, and owning any sort of property or business (Dasgupta, 2011, p.6). It is estimated that 33% of the south's population were included on the dossier of "bad elements" (APF Canada, 2016).

The country was heavily reliant on its communist allies, namely the Soviet Union and China, to uphold the socialist system, with aid contributing approximately 1.11% of its GDP (CIA, 1961). This aid came in the form of economic and military aid, which was part of the broader Soviet strategy to support socialist allies during the Cold War. They also provided technical assistance for industrial projects, infrastructure development, and education. The Soviet Union also engaged in favorable trade terms with Vietnam, providing critical resources such as machinery, oil, and consumer goods.

However, relations with the outside world, even its communist supporters such as China, soon rapidly deteriorated in this period as Vietnam invaded Cambodia in 1978, ending the Khmer Rouge and setting up a pro-Hanoi regime in Phnom Penh (Dasgupta, 2011). This, combined with several seasons of bad harvest and a failure of “hard reform socialism” and the Three-Plan-System,² led to significant differences between official prices and market prices, leading to hyperinflation (CIA, 1961). Eventually, the Communist Party of Vietnam were forced to abandon “hard reform socialism” and shift towards a more market-oriented economy. This was known as the *Doi Moi*, or renewal, and was intended to dismantle central planning, liberalize trade, and overall generate incentives for people to work harder and more efficiently (Dasgupta, 2011).

2.3.2 State Investment and International Aid

The Vietnamese government focused post-war reconstruction efforts in heavily targeted areas, such as rebuilding damaged infrastructure and demining the countryside. Miguel and Roland (2011) found, by analyzing government yearbook data, that more heavily bombed provinces received significantly more investment than their counterparts. Between 1976 and 1985, during the central planning period, the government would allocate nearly twice as much investment to provinces who received higher than average bombing compared to the less bombed provinces (Miguel and Roland, 2011). Following the end of the border conflict with China and Cambodia, the rate of investment into these areas increased, suggesting that these areas were a priority for the Vietnamese government. Even during the *Doi Moi* period, areas that were above the average level for bombing intensity received 1.5 standard deviations more state investment compared to those below the average (Miguel and Roland, 2011).

The shift to *Doi Moi* was rewarded by renewed international investment, especially from countries such as the United States and Japan. The foreign assistance was primarily aimed at supporting Vietnam’s socioeconomic development, with a significant portion of the aid being allocated towards the country’s education sector (Pham & Fry, 2004). As their economy grew, foreign aid to Vietnam increased, with aid amounts rising from US\$213.43 million in 1991 to US\$1.144 billion by 1994, eventually peaking in 2008 at US\$2.55 billion, which accounted for 3.14% of the country’s GDP (Wang & Balasubramanyam, 2011). Various financial institutions, such as the World Bank and the Asian Development Bank also focused on supporting educational reforms to increase the quality and accessibility of education across Vietnam, especially for those in rural and underserved areas (World Bank, 2022).

These investments, both international aid and foreign direct investment, were instrumental in transforming Vietnam from a war-torn country to one of the fastest growing economies in the region. The improvements in the educational sector were a self-fulfilling prophecy, as a well-educated workforce attracted more foreign investment, resulting in more fundings for schools (Pantelopoulos, 2022). However, even for individuals born

² A system in which a business must adhere to three elements: (1) Input must be provided by the state and all output must go to the state (2) free disposal of products that the factory was established to produce and (3) production of minor products that resulted from the factory’s attempts to diversity were legal

in the 21st century, the average educational attainment is only 7.916,³ indicating that Vietnam must continue investing in education.

3. Identification Strategy

3.1 Regression Specification

The empirical work of this paper will focus primarily on a stacked cross-section regression which will be used to determine when and if areas targeted by Agent Orange converge with their counterparts. To address endogeneity concerns over the non-random targeting of Agent Orange, I will also use an instrumental variable estimate to support my primary regression. As a robustness check, I used different larger, but less precise, datasets to increase the model's statistical power as well as control for potentially confounding factors, such as migration.

3.2.1 Stacked Cross-Section

The primary regression features a stacked cross-section with five decadal age-cohorts. Edu represents the total years of formal education of individual i who lives in district d . Agent Orange represents the number of gallons of herbicide dropped in the individuals' respective district, which has been standardized according to the total area of the district in order to determine the overall herbicide intensity per square kilometer (SQKM).

$$Y_{id} = \beta_0 + \beta_1 AO_{id} + \beta_2 CohortX_i + \beta_3 (AO_{id} \times CohortX_i) + \beta_4 Dist_{id} + B'_i + C'_i + \epsilon_{id}$$

CohortX represents which cohort the individual belongs to, with Cohort 1 having turned 18 between 1962 and 1971; Cohort 1 is also acting as the baseline comparison. The cohorts were formed based on when individuals turned 18, under the assumption that by this age, they would have completed their education or achieved at least 13 years of schooling. Given that the average educational attainment across the entire sample is just under 3 years, it was reasonable to assume that their education would be finished by age 18. Cohorts 2 through Cohort 5 represent individuals who became adults between 1972-1981, 1982-1991, 1992-2001, 2002-2011 respectively. Also, in order to understand the potentially heterogeneous impact of Agent Orange across cohorts, I interacted Agent Orange with each cohort with the expectation that Agent Orange would affect each generation less the further removed they were from the conflict.

3.2.2 Instrumental Variable

Mimicking the empirical strategy devised by Trung Le, Minh Pham, and Polachek, I am using the North Vietnamese Military bases as an instrument for herbicide intensity. This is necessary due to endogeneity concerns because the U.S. military and their allies specifically released Agent Orange on certain areas, meaning that these areas may be inherently different than areas that were not targeted. The model is as follows:

³ Figure from the VARHS dataset

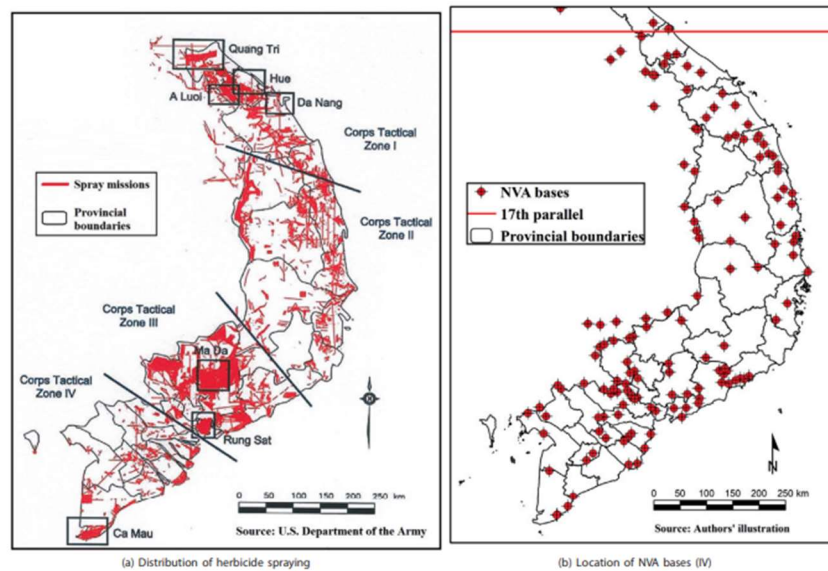
$$\text{First Stage: } Y_{id} = \beta_0 + \beta_1 \text{Dist}_{id} + \beta_2 \text{Cohort}X_i + \beta_3 (AO_{id} \times \text{Cohort}X_i + \beta_4 \text{Dist}_{id} + B'_i + C'_i + \epsilon_{id}$$

$$\text{Second Stage: } Y_{id} = \beta_0 + \beta_1 AO_{id} + \beta_2 \text{Cohort}X_i + \beta_3 (AO_{id} \times \text{Cohort}X_i + \beta_4 \text{Dist}_{id} + B'_i + C'_i + \epsilon_{id}$$

Dist, or distance, represents the distance from the center of the district to the nearest NVA base. The NVA bases are able to act as a viable instrument because the Viet Cong fighters used guerrilla warfare techniques which relied on unpredictability and random attacks. Guerrilla warfare, with its emphasis on mobility, surprise, and local support, allowed the north Vietnamese and Viet Cong to effectively counter the superior firepower and technological advantages of the U.S. forces (Lowe, 2012; Walton, 2004). By employing a variety of tactics, including ambushes, hit-and-run attacks, and extensive use of tunnels, they were able to sustain their operations and achieve strategic goals despite facing a more powerful adversary. The randomness and unpredictability of these attacks were key elements that contributed to their overall effectiveness and allows for the location of the bases to be used as an instrument for herbicide intensity because of how central they were to the guerilla warfare strategy of the NVA.

Just as with the primary regression, I am also stacking the same decadal age cohorts and interacting them with Agent Orange to capture the differential impacts of Agent Orange on further removed generations. This model also features the same set of controls, bombing and demographics, as the primary model.

Fig.1: Agent Orange and NVA Bases



Note: Distribution of herbicide spraying & location of North Vietnamese Army (NVA) bases. Map derived from Trung Le, Minh Pham, and Polachek (2002).

3.2 Data

The data on the spatial variation of Agent Orange was borrowed from the online Agent Orange Data Warehouse, compiled by Stellman and Stellman (2004) and Stellman et al. (2003a,b). Using corrected and augmented data from the HERBS files, and archival records from the U.S. National Archives and the U.S. Armed Services Center for Research of Unit Records, they were able to provide a revised estimate of the volume

Table 1: Summary Statistics

Survey Name	Variable	Mean	SD	Min	Max	N
District	Years of Education	2.995	2.101	1	13	948
	Age	40.347	25.519	1	45	838
	Agent Orange Intensity (per SQKM)	232.807	477.657	0	3002.973	73
	Bombing Intensity (per SQKM)	892.010	1069.842	0	4062.022	73
	Male	0.436	0.494	0	1	946
	Vietnamese	0.802	0.398	0	1	948
DHS	Years of Education	7.889	3.880	0	17	24,626
	Age	32.265	9.627	15	49	24,626
	Agent Orange Intensity (per SQKM)	16.072	19.970	0	110.13	66
	Bombing Intensity (per SQKM)	2,582.362	2,735.187	303.947	14,893.77	66
	Residency (Years)	22.154	13.261	0	49	24,626
	Migrated	0.549	0.497	0	1	24,626
VARHS	Years of Education	7.474	3.827	0	12	25,777
	Age	40.778	10.901	18	100	25,783
	Agent Orange Intensity (per SQKM)	10.738	5.026	0.459	22.398	13
	Bombing Intensity (per SQKM)	2,478.4	1,744.459	303.947	4,453.358	13
	Male	0.511	0.499	0	1	25,795
	Married	0.844	0.362	0	1	25,795
	Agriculture	61.371	73.125	0	365	25,795
	(log)Income	7.113	0.836	0	11.034	25,548
	Literate	0.899	0.300	0	1	25,769

Note: Table does not include statistics on health, which is from the District Health Survey

of herbicides sprayed during Operation Ranch Hand. By integrating geographic information system technology, they were able to reconstruct and map flight paths, spray areas, and estimate the populations exposure to the herbicides, revealing an additional 7 million more liters of spray than previously estimated.

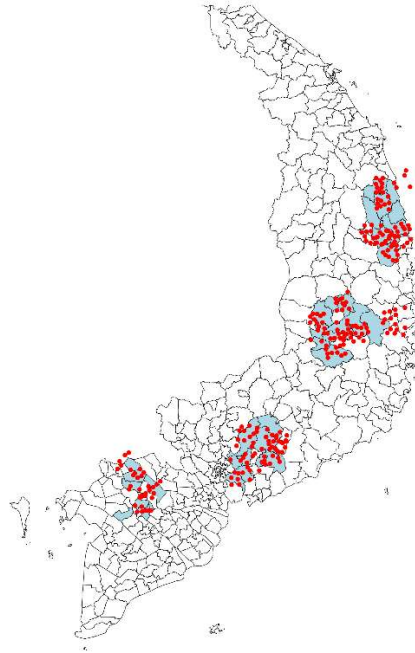
The online GIS provides a detailed description of the model of aircraft used and the amount of each sort of chemical dropped within a 5-kilometer radius of a coordinate pair. To determine the amount of herbicide dropped within a district, I divided the total area of the district by the area covered within the 5km radius (~78.53sqkm). To ensure that the coordinate pairs do not overlap, I mapped the distance between each coordinate pair to ensure they were at least 10 km apart. On average, there were 232.81 gallons per SQKM dropped in each district, with a range of 0 to 3002.97 gallons per SQKM. For my analysis, I am using a binary variable to indicate high or low Agent Orange intensity, with the median, 40.77 gallons, as the threshold.

For the province level analysis, I used similar approach as with the district level analysis covered 10% of the total land area by randomly selecting a proportional number of coordinate points within each province to provide a representative estimate of the amount of Agent Orange dropped within each province. I again standardized this figure according to the total area of each province to determine an estimated proportionate Agent Orange intensity per SQKM. On average, there were 16.07 gallons per SQKM, ranging from 0 to 110.13 gallons per SQKM. As with the district level analysis, I am also using the median value, 9.21 gallons per SQKM, as a benchmark to determine high or low Agent Orange intensity for each province.

The coordinate locations of the NVA bases, used as an instrument for herbicide intensity, were sourced from Trung Le, Minh Pham, and Polachek. They used an ASCII decoder software to process the raw ASCII text from the Department of Defense Enemy Base Area Files from the U.S. National Files Archive, to derive analyzable data. This software was able to determine the coordinate locations for each of the bases, as well as the

number of months the base was active for. I then used STATA to compute the distance between each district and the closest NVA base, in which the shortest distance is acting as an instrument for herbicide intensity.

Fig. 2: Agent Orange Coordinates



Note: Map of only South Vietnam. Light blue highlighted districts are those included in the sample. The red dots represent the coordinate points covered in the analysis, which were randomly selected.

For the primary data on educational attainment, as well as the corresponding demographic controls, I use the District and Commune Health Facility Survey data which was compiled out by the Health Strategy and Policy Institute of the Vietnamese Ministry of Health and in partnership with the World Bank. The survey contained information on 948 individuals hailing from 73 districts and 6 different provinces. However, due to the historical differences between North and South Vietnam, especially during and immediately after the war, the sample size was restricted to just include southern districts, leaving 516 observations. As for educational attainment, the survey asks participants to report the number of years of formal education they had received, ranging from 1 to 13, with the mean being slightly under 3 years of formal education. The survey also has data on basic demographic information such as gender and ethnic background.

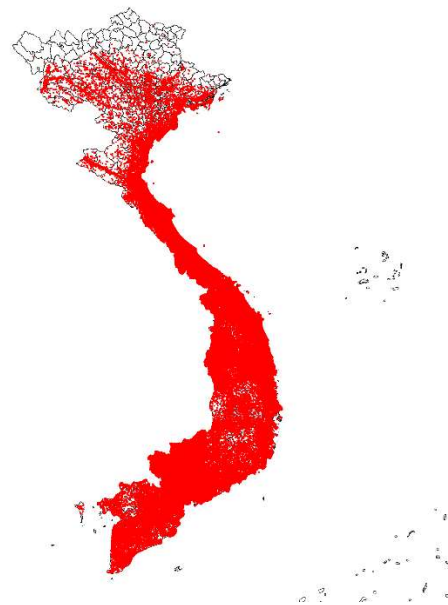
To act as a robustness check, I am incorporating two additional surveys into my analysis. First, I am using the United States Agency for International Development's Demographic Health Survey, which despite its focus on women, offers a significantly larger sample size and information on intra-Vietnamese migration. Due to exogeneity concerns over internal migration, previous papers have either used household permanent residency (Trung Le et al., 2022) or which district the household is registered in (Appau et al., 2021) as a proxy for birthplace; or restricted the data to exclude provinces with high rates of migration (Guo, 2020); or assumed

it away due to overall low levels of permanent internal migration (Miguel and Roland, 2011)⁴. Likewise, the DHS data features information on the number of years at their current place of residency, including an indicator if they had always lived in their respective province. This allows the model to control for migration without having to rely on assumptions like previous papers. The average number of years an individual lived in each province is 22.15 (average age is 32.26), with the median being 21. Further restricting the data to individuals born and raised in their respective provinces reduces the sample size to 5,418 observations, or 55% of the sample.

I am also using the Vietnam Access to Resources Household Survey (VARHS), which may not have migration data but does include a larger sample size of both men and women, therefore increasing the model's statistical power as well as being more representative of the entire population. There are a total of 25,777 observations, which when restricted to only include southern provinces, reduces down to 10,829 individuals from 6 different provinces. The survey also provides valuable data on literacy, income, and agriculture. Of the southern provinces, 92.7% of the population is considered literate⁵ and 62.24% work in agriculture.⁶ On average, individuals spend 57.66 days working in agriculture, with a median of 30 days. There are 41 individuals who work in agriculture every day, with the 75th percentile spending 90 days or more in agriculture.

Finally, to act as a control, I am using data from the Theater History of Operations (THOR) files on the Vietnam War to account for any long-term impacts brought about by the bombing raids vs Agent Orange. According to the flight logs, there were approximately 4.84 million flight missions (THOR files) which resulted in more than 4.1 million tons of ordnances dropped on Vietnam, approximately 0.101 tons (202 pounds/ 91.6 kilos) per person (Boddington and Chanthavongsa, 2009). These files have information on the date of the flight, which country dropped the bombs, and most importantly, the weapon weight and target coordinates.

Fig.3: Vietnam Bombing



Note: Using the THOR files, this map was generated in R-Studio and the red dots represent the target coordinates of each bombing mission. Bombing missions outside Vietnam were excluded.

⁴ Specifically, Miguel and Roland used the 1997/ 1998 Vietnamese Living Standards Survey and assumed that most individuals who were displaced by the war would return to their home districts/ provinces.

⁵ Able to read and write their own name

⁶ Work in agriculture at least one day a year

4. Results

The results indicate that Agent Orange has a statistically significant negative relationship with educational attainment for both the stacked cross-section and the instrumental variable model. However, once you control for province fixed effects, the impact of Agent Orange becomes insignificant, leaving only the individual age-cohorts, representing time, significant.

4.1.1 Agent Orange

The results of the baseline model (column 1) indicate that Agent Orange has an independent and statistically significant negative relationship with educational attainment. Residing in a district above the median Agent Orange threshold is associated with 0.566 fewer years of schooling, significant at the 99% confidence interval. However, when you include province level fixed effects, the coefficient shrinks to -0.025 and becomes insignificant. This indicates that there was little within province variation, which could potentially be due form of decentralization within the Vietnamese government. The provincial level government is significantly more powerful than the district level, as budgeting and resource allocation is determined at the province level (Forde, 2003). The provincial government has authority over areas such as infrastructure, economic development and education, whereas district level authorities are primarily charged with implementing policies from above. This could potentially explain the lack of variation within provinces, especially if the provincial government prioritized rebuilding the districts that were the most affected by the war.

4.1.2 Decadal Age-Cohorts

Each individual age-cohort (except Cohort 2) is statistically significant at the 99% confidence interval. Individuals who became adults during Operation Ranch Hand, 1962 to 1971, have an average of 2.11 more years of formal education and for each of the following cohorts, education increases at an increasing rate. For the individuals who became adults during the following two decades (1972-1991), they received an approximate 0.97 more years of education, as compared to the baseline cohort, with little difference between the two. It wasn't until the 1990's that educational attainment started to see significant increases, with Cohort 4 (1992-2001) receiving an average of 1.695 more years of education and Cohort 5 (2002-2011) receiving 2.199 more years of education relative to Cohort 1.

Table 2: Effects of Agent Orange on Education (Stacked Cross-Section)

	Educational Attainment	
	(1)	(2)
Agent Orange Intensity (High/ Low)	-0.566*** (0.206)	-0.025 (0.228)
Cohort 2	0.998* (0.587)	1.051* (0.579)
Cohort 3	0.957*** (0.272)	0.965*** (0.281)
Cohort 4	1.695*** (0.288)	1.547*** (0.275)
Cohort 5	2.199*** (0.323)	2.250*** (0.330)
Agent Orange × Cohort 2	0.178 (0.655)	-0.036 (0.638)
Agent Orange × Cohort 3	0.242 (0.501)	0.406 (0.487)
Agent Orange × Cohort 4	0.191 (0.424)	0.072 (0.402)
Agent Orange × Cohort 5	0.149 (0.483)	-0.308 (0.467)
Province FE	No	Yes
Observations	514	514

Note: Standard errors are heteroscedasticity robust. * p < 0.10, ** p < 0.05, *** p < 0.01

This is to be expected because as time goes on, and Vietnam distances itself from the war and modernizes, you would expect to see an increase in formal education for its citizenry. The spike in the 1990's is also consistent with the timeline of Vietnam opening up to the outside world post- *Doi Moi* and when it started receiving significant amounts of foreign aid, especially from the United States and Japan. Even after controlling for province fixed effects, the results remain largely unchanged.

4.1.3 Interaction Terms

To determine if Agent Orange had a differential effect on each of the proceeding cohorts, I interacted each of the decadal age-cohorts with Agent Orange intensity. Individually, each of these variables are all positive and significant, but jointly there is no significance for any of the interaction terms. This suggests that the effect of Agent Orange does not significantly vary across age-cohorts, meaning that even half a century after the conflict, areas with high levels of Agent Orange still have not converged with their counterfactuals.

4.2 Instrumental Variable

4.2.1 IVE First Stage

In the first stage of the IVE, I regressed the endogenous variable, Agent Orange exposure, on the instrument, distance to the nearest NVA base, along with other covariates. The results of the first stage regression confirm the validity of the instrument; the coefficient on distance is negative and statistically significant at the 99% confidence interval. For every one kilometer away a NVA base is from a district, there is an estimated 0.011 decrease in herbicide intensity. In other words, the further away districts are from the NVA bases, the less likely they are to have been targeted by Agent Orange. The F-statistic for the instrument is 61.69, well above the conventional threshold of 10, suggesting that distance is a strong instrument for herbicide intensity. This holds true even when accounting for province fixed effects.

4.2.2 IVE Second Stage

The second stage results indicate that Agent Orange exposure has a statistically significant negative impact on educational attainment. The coefficient on Agent Orange is -1.575 and significant, suggesting that exposure to Agent Orange reduces years of schooling by more than 1.5 years on average across all cohorts. The coefficients for the age-cohorts vary from the stacked cross-section, with cohorts 2 and 3 being statistically insignificant. However, Cohorts 4 and 5 are in line with the previous results, with the estimates being 1.02 and 1.71, respectively.

Contrary to the results from the stacked cross-section, the interaction terms Agent Orange x Cohort 4 and Agent Orange x Cohort 5, are significant in this model. The net effect of Agent Orange for Agent Orange x Cohort 4 and Agent Orange x Cohort 5 is -0.491 and -0.541 respectively, indicating that the influence of Agent Orange varies across select age-cohorts. However, it is noteworthy that, even when considering the insignificant interaction terms, the coefficients of the interaction terms are all within 0.054 years of one another, suggesting that Agent Orange has a relatively uniform effect across time.

Table 2: Effects of Agent Orange on Education (Instrumental Variable Estimates)

	Educational Attainment			
	(1) First Stage	(1) Second Stage	(2) First Stage	(2) Second Stage
First Stage F-Statistic	61.69		72.29	
Distance	-0.011***		-0.010***	
(Instrument)	(0.001)		(0.001)	
Agent Orange Intensity		-1.575***		-0.338
(High/ Low)		(0.542)		(0.633)
Cohort 2		0.507		1.945**
		(0.472)		(0.863)
Cohort 3		0.483		0.863***
		(0.435)		(0.400)
Cohort 4		1.020**		1.439***
		(0.408)		(0.369)
Cohort 5		1.719***		2.144***
		(0.377)		(0.343)
Agent Orange × Cohort 2		1.065		0.182
		(0.701)		(0.665)
Agent Orange × Cohort 3		1.088		0.570
		(0.704)		(0.623)
Agent Orange × Cohort 4		1.084*		0.283
		(0.649)		(0.603)
Agent Orange × Cohort 5		1.034*		-0.061
		(0.606)		(0.618)
Province FE	No	No	Yes	Yes
Observations	514	514	514	514

Note: Standard errors are heteroscedasticity robust. * p < 0.10, ** p < 0.05, *** p < 0.01

5. Robustness Checks and Limitations

As aforementioned, this robustness check will feature the same stacked cross-section model as the primary regression but instead use data from the United States Agency for International Development's Demographic Health Survey (DHS), which will increase the model's statistical power as well as control for migration, as well as the Vietnam Access to Resources Household Survey (VARHS), which will also increase the model's statistical power but also feature both men and women.

5.1 Demographic Health Survey

Similar to the baseline regression, the coefficient on Agent Orange for the DHS model is also negative and statistically significant; however, the effect is much stronger with a reduction of 1.133 years of education vs 0.566. Likewise, the individual age cohorts are roughly in line with the previous estimates, only being an average of 0.198 higher in the robustness check than the main regression. This is reinforcing the previous results of a steady increase in overall average educational attainment in Vietnam, as well as a lingering and uniform effect of Agent Orange. When including the migration control, Agent Orange loses its statistical significance, but the age-cohorts do not. They also still roughly follow the same pattern, where they are increasing by an average of 0.7315 years each decade. Interestingly, the interaction term Agent Orange x Cohort 3 is statistically significant, indicating the negative effect of Agent Orange on educational attainment is more pronounced for individuals in

Cohort 3 (1982-1991) compared to individuals who became adults during Operation Ranch Hand. The overall net total effect of Agent Orange on educational attainment for Cohort 3 is a reduction of 1.467 years of schooling for individuals exposed to high levels of Agent Orange within Cohort 3.

Table 3: Effects of Agent Orange on Education (Stacked Cross-Section)

	Educational Attainment			Literacy	Income
	(1)	(2)	(3)	(4)	(5)
Agent Orange Intensity (High/ Low)	-1.133*** (0.392)	-0.389 (0.524)	-0.452*** (0.163)	-0.044*** (0.012)	-0.073** (0.032)
Cohort 2	1.116*** (0.349)	1.276*** (0.484)	0.147 (0.344)	-0.005 (0.026)	0.040 (0.068)
Cohort 3	1.728*** (0.342)	2.472*** (0.473)	0.534** (0.243)	-0.003 (0.018)	-0.104** (0.049)
Cohort 4	1.739*** (0.348)	2.231*** (0.479)	1.069*** (0.197)	0.038*** (0.013)	0.043 (0.045)
Cohort 5	2.058*** (0.357)	2.926*** (0.480)	0.091 (0.482)	-0.060 (0.042)	-0.096 (0.115)
Agent Orange × Cohort 2	-0.058 (0.421)	-0.516 (0.564)	-1.047*** (0.380)	-0.018 (0.029)	0.065 (0.076)
Agent Orange × Cohort 3	0.040 (0.413)	-1.078* (0.553)	-0.075 (0.264)	0.031 (0.019)	0.302*** (0.054)
Agent Orange × Cohort 4	-0.184 (0.421)	-0.612 (0.562)	0.037 (0.219)	-0.000 (0.014)	0.059 (0.050)
Agent Orange × Cohort 5	0.479 (0.432)	-0.141 (0.562)	0.109 (0.596)	0.042 (0.052)	0.050 (0.143)
Gender			-0.967*** (0.071)	-0.042*** (0.004)	-0.039** (0.015)
Migration Control	No	Yes	No	No	No
Female Only	Yes	Yes	No	No	No
Observations	9,840	5,350	10,822	10,815	10,715

Note: Columns 1-2 are from the Demographic Health Survey and columns 3-5 are from the Vietnam Access to Resources Household Survey. Standard errors are heteroscedasticity robust. * p < 0.10, ** p < 0.05, *** p < 0.01

5.2 Vietnam Access to Resources Household Survey

As for the VARHS survey, the estimates also largely follow the same pattern and find that high levels of Agent Orange lead to an overall reduction of -0.452 years in educational attainment for the affected areas, which is significant. This estimate is in line with the results from the District Health survey, which estimated a reduction of 0.566 years of education and also significant. This could potentially be due to both genders being included in the sample, as it seems that gender has a significant impact on educational attainment, with a reduction of nearly 0.967 years of schooling for females. When looking at the regressions pertaining to literacy and income, I find that there is a statistically significant negative impact of Agent Orange on both. Individuals in areas with high levels of Agent Orange are 4.4% less likely to be literate and earn on average 7.3% less income as compared to individuals who live in areas with low Agent Orange levels.

5.3 Limitations

The limitations of the research largely center on the lack of open-source data on educational attainment in Vietnam, especially data at the commune or grid level. This study relies on the assumption that there is a uniform distribution of Agent Orange within each district and province, when in reality spraying varied widely both within district and province levels.

6. Potential Mechanisms

The concerns over Agent Orange are due to contamination with dioxin, specifically Tetrachlorodibenzo-p-dioxin (TCDD). TCDD is highly stable and resistant to environmental degradation, which leads to its persistence in the environment which can last for decades. It also binds itself to a protein found in various cells throughout the human body, which can alter the expression of genes involved in cell growth and differentiation, detoxification, and immune responses, leading to a variety of harmful biological effects. (NIH, 1994). By leveraging data from the Vietnam Access to Resources Household Survey, I am able to establish a link between Agent Orange and its detrimental effects on agriculture and health and then how these disruptions can lead to negative educational outcomes, reinforcing the broader socio-economic impacts of TCDD exposure.

6.1 Agent Orange, Agriculture, and Education

Agent Orange was explicitly designed to target the environment; its purpose of Agent Orange was to defoliate forests and reduce enemy agricultural production capabilities. The presence of TCDD in soil has profound implications for soil health and agricultural productivity. Dioxins like TCDD bind strongly to organic matter and clay particles, which not only reduces their bioavailability but also makes them difficult to remove (Safe, 1990). This binding can disrupt the soil microbiome, which is crucial for nutrient cycling and soil fertility. Studies have shown that dioxins can inhibit the activity of soil enzymes and decrease the population of beneficial soil microorganisms, leading to reduced soil fertility and structure (Huang et al., 2003).

By using a basic linear regression model, and still controlling for bombing, I have found that areas with high levels of Agent Orange are correlated with an additional 5.874 days of working in agriculture, as compared to areas with low Agent Orange intensity. Then, in a separate model, I found that Agent Orange is associated with -0.519 years of education and that, for each day an individual works in agriculture, they are likely to receive 0.006 fewer years of education. Combined, this would suggest that individuals who live in areas with high levels of Agent Orange are likely to receive 0.554 fewer years of education as compared to their counterparts. However, the coefficient of the interaction term between Agent Orange and Agriculture is both zero and statistically insignificant, indicating that the presence of Agent Orange does not significantly modify the effect of agriculture on education.

This data complements the previous findings by Appau et al. (2021) that Agent Orange is causally linked to reduced agricultural productivity. High levels of dioxins in the soil necessitate greater time and effort from farmers in areas with intense Agent Orange exposure to cultivate the same amount of produce as those in areas with low Agent Orange intensity. Consequently, as suggested by Guo (2022), this increased agricultural labor

requirement reduces the time children can spend in school, diverting them to work in the fields instead. Specifically, my data indicates that high Agent Orange exposure necessitates nearly six additional days of agricultural work annually, which translates to over half a year less of education for affected children.

Table X: Agent Orange, Education, and Agriculture

	(1) Agriculture	(2) Education
Agent Orange Intensity (High/ Low)	5.874*** (2.090)	-0.519*** (0.146)
Agriculture (Days Worked)		-0.006*** (0.001)
Agent Orange × Agriculture		0.000 (0.001)
Observations	10,829	10,822

Note: Column 1 represents the effect of Agent Orange on agriculture and Column 2 represents the effect of Agent Orange and agriculture on education. Standard errors are heteroscedasticity robust. * p < 0.10, ** p < 0.05, *** p < 0.01

6.2 Agent Orange, Health, and Education

Due to either direct exposure to Agent Orange during the war, or secondhand exposure through genetics and or environment, TCDD is known to cause several health conditions such as:

- **Carcinogenicity:** TCDD is classified as a Group 1 carcinogen by the International Agency for Research on Cancer and has been linked to various cancers such as lung, liver, and gastrointestinal cancers.
- **Reproductive and Developmental Effects:** TCDD also has been known to negatively impact the reproductive system, leading to reduced fertility, spontaneous abortions, birth defects, and developmental delays.
- **Endocrine Disruptions:** It can also affect hormone regulation, leading to disorders such as hypothyroidism and diabetes - it interferes with the normal functioning of the thyroid gland and insulin regulation.
- **Cardiovascular Effects:** Exposure has been linked to increased risk of cardiovascular disease, including ischemic heart disease and hypertension. (NIH, 1994)

6.2.1 Effect of Agent Orange Related Health Conditions on Educational Attainment

In their paper “The Long-Term Health Impact of Agent Orange: Evidence from the Vietnam War,” Trung Le et al. (2022) found that Agent Orange can be econometrically linked to a range of health conditions, even decades after the Vietnam War. By using commune level health data and the distance between the commune and the nearest NVA base as an instrument for herbicide intensity, they found that individuals residing in communes with a one standard-deviation higher exposure to Agent Orange are found to be 19.75% more likely to suffer from disabilities related to blood pressure, mobility and cancer. These three morbidity indicators have been found by the Veterans and Agent Orange Update to have “sufficient evidence” or “limited suggestive evidence” linked to Agent Orange exposure. I am building on Trung Le et al. (2022) findings and

going one step further by linking several of these health conditions to reduced educational attainment. By using the District Health Survey, I am able to determine if having a respiratory, gastrointestinal, cardiovascular, urologic, musculoskeletal, or endocrine condition leads to a decrease in the number of years of formal schooling.

Of the above six Agent Orange-related conditions, only respiratory diseases have a significant impact on educational attainment; if an individual has a respiratory disease, they are expected to receive 0.844 fewer years of schooling. This is due to TCDD being known to cause severe respiratory conditions, such as Chronic Obstructive Pulmonary Disease, pulmonary fibrosis, respiratory cancers, and exacerbated asthma, all of which can severely impair physical capabilities and overall quality of life (Birnbaum, 1994; Kang et al., 2006; Mandal, 2005; Baan et al., 2009). These health conditions can potentially manifest into educational challenges that can limit the number of years of school an individual receives. They have the potential to lead to cognitive impairments, decreased concentration, and fatigue which can hinder academic performance and lead to higher dropout rates (Taras & Potts-Datema, 2005). This is not to mention the socio-economic burdens faced by families with Agent Orange-related health conditions, such as medical expenses, which can lead to long-term reductions in educational attainment and limited professional opportunities, thus perpetuating the cycle of poverty (Brooks-Gunn & Duncan, 1997; Cutler & Lleras-Muney, 2006).

Table 5: Effect of Health on Education

Education	Educational Attainment					
	(1) Resp.	(2) Gastro.	(3) Cardio.	(4) Urologic	(5) Musculo.	(6) Endocrine
Health Condition	-0.844*** (0.159)	-0.174 (0.169)	-0.245 (0.160)	-0.026 (0.304)	0.103 (0.309)	-0.181 (0.257)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observation	498	498	498	498	498	498

Note: Columns 1-6 represent 6 different models each featuring a different Agent Orange related health condition. The variable Health Condition is a binary indicator if the individual has the associated health condition, and the estimates represent years of schooling. Standard errors are heteroscedasticity robust. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

7. Conclusion

The findings of this study highlight the significant long-term impact of chemical warfare, specifically Agent Orange, on educational attainment. While I do observe continuous improvement in educational attainment, with each subsequent generation finishing more years of formal education than the previous, Agent Orange still has an overall negative effect on educational attainment which is consistent across all age-cohorts. Residing in a high-intensity Agent Orange district results in a 0.566 to 1.575 reduction in years of schooling for the average individual. This is likely due to the persistence of Agent Orange in the environment which continues to pose challenges even half a century after the war. High levels of Agent Orange are associated with 5.874 more days working in agriculture, with each of these days reducing educational attainment by an estimated 0.006 years. It has also been linked to respiratory diseases, which can also result in 0.084 fewer years of schooling for the afflicted individuals. These results highlight the unique characteristics of chemical warfare and post-war recovery that must be addressed with specialized treatment. While there recently have been efforts to

decontaminate the soil (CRS, 2021), more resources must be allocated towards Agent Orange cleanup in order for there to be complete convergence between high and low-intensity Agent Orange areas.

References

- Amiri, R., & Jackson, A. (2021). *Taliban attitudes towards education: Evidence from the ground* (Working paper 601). Overseas Development Institute. https://cdn-odi-production.s3.amazonaws.com/media/documents/taliban_attitudes_towards_education.pdf
- Asia Pacific Foundation of Canada. (n.d.). *Vietnam after the war*. Asia Pacific Curriculum. <https://asiapacificcurriculum.ca/learning-module/vietnam-after-war>
- Baan, R., Grosse, Y., Straif, K., Secretan, B., El Ghissassi, F., Bouvard, V., Altieri, A., Coglian, V., & WHO International Agency for Research on Cancer Monograph Working Group. (2009). A review of human carcinogens—Part F: Chemical agents and related occupations. *The Lancet Oncology*, 10(12), 1143–1144. [https://doi.org/10.1016/S1470-2045\(09\)70358-4](https://doi.org/10.1016/S1470-2045(09)70358-4)
- Banout, J., Urban, O., Musil, V., Száková, J., & Balik, J. (2014). Agent Orange footprint still visible in rural areas of Central Vietnam. *Journal of Environmental and Public Health*, 2014, 528965. <https://doi.org/10.1155/2014/528965>
- Bertoni, G., Li, X., Bigi, F., & Maggi, R. (2019). Copper-catalyzed enantioselective synthesis of indole-based polyheterocycles via C–H functionalization. *Journal of Catalysis*, 371, 105–114. <https://doi.org/10.1016/j.cattod.2018.05.011>
- Birnbaum, L. S. (1994). Evidence for the role of the Ah receptor in response to dioxin. In H. L. Spitzer, T. J. Slaga, W. F. Greenlee, & M. McClain (Eds.), *Receptor-mediated biological processes: Implications for evaluating carcinogenesis* (pp. 139–154). Wiley-Liss.
- Boddington, M. A. B., & Chanthavongsa, B. (2009). *National survey of UXO victims and accidents: Phase 1*. National Regulatory Authority for UXO/Mine Action Sector in Lao PDR. <https://www.nra.gov.la/>
- Brooks-Gunn, J., & Duncan, G. J. (1997). The effects of poverty on children. *The Future of Children*, 7(2), 55–71.
- Bucala-Hrabia, A. (2017). Agricultural land use changes in Polish Carpathians: A case study of Jaszcze and Łapsze Niżne villages. *Land Use Policy*, 67, 255–265. <https://doi.org/10.1016/j.landusepol.2016.12.022>
- Central Intelligence Agency (CIA). (1965). *A comparison of the economies of North and South Vietnam* (Report No. RDP79R01141A002200070001-8). Central Intelligence Agency.
- Clodfelter, M., & Fawcett, J. M. (1995). The RMA and Air Force roles, missions, and doctrine. *Parameters*, 25(1). <https://doi.org/10.55540/0031-1723.1723>
- Cutler, D. M., & Lleras-Muney, A. (2006). Education and health: Evaluating theories and evidence (NBER Working Paper No. 12352). National Bureau of Economic Research. <https://doi.org/10.3386/w12352>
- Dasgupta, A. (2011). *Economics of development in Vietnam since Doi Moi*. Pentagon Press.
- Datamil. (2016). *Vietnam War THOR dataset*. Data.World. <https://data.world/datamil/vietnam-war-thor-data>
- Davis, D. R., & Weinstein, D. E. (2002). Bones, bombs, and break points: The geography of economic activity. *The American Economic Review*, 92(5), 1269–1289. <https://doi.org/10.1257/000282802762024502>
- Demombynes, G., & Hurt, K. (2016). District and commune health facility survey 2015 [Data set]. *World Bank, Development Data Group*. <https://doi.org/10.48529/WKJ8-R109>

- Fforde, A. (2003). *Decentralisation in Vietnam: Working effectively at provincial and local government level – A comparative analysis of Long An and Quang Ngai provinces*. Australian Agency for International Development (AusAID).
- Guo, S. (2020). The legacy effect of unexploded bombs on educational attainment in Laos. *Journal of Development Economics*, 147, 102527. <https://doi.org/10.1016/j.jdeveco.2020.102527>
- Haidostian, T. (2024). *The impact of the Syrian civil war on its education sector*. *Pepperdine Policy Review*, 16(1), Article 3. <https://digitalcommons.pepperdine.edu/ppr/vol16/iss1/3>
- Harper, M. (2023). Cambodia's tragedy and triumph: The UN's greatest experiment 30 years on. *Harvard International Review*. <https://hir.harvard.edu/cambodias-tragedy-and-triumph-the-uns-greatest-experiment-30-years-on/>
- Huang, Z., Phillips, G. M., Yang, J., & Zhang, Y. (2020). Education and innovation: The long shadow of the Cultural Revolution (Working Paper). *Tsinghua University, Dartmouth College, and Nottingham University*.
- Islam, A., Ouch, C., Smyth, R., & Wang, L. C. (2014). The long-term effects of civil conflicts on education, earnings, and fertility: Evidence from Cambodia (Discussion Paper No. 36/14). *Department of Economics, Monash University*.
- Kang, H. K., Cypel, Y., & Kilbourne, A. M. (2006). Chapter 4: Health outcomes among Veterans. In *Gulf War and Health: Volume 4. Health Effects of Serving in the Gulf War* (pp. 69-110). National Academies Press. <https://www.ncbi.nlm.nih.gov/books/NBK195087/>
- Le, Duong, Pham, Thanh, & Polachek, Solomon. (2022). The long-term health impact of Agent Orange: Evidence from the Vietnam War. *World Development*, 155, 105813. <https://doi.org/10.1016/j.worlddev.2022.105813>
- Lowe, P. (2012). Hybrid war in Vietnam. In *Hybrid Warfare* (pp. 65-89). Cambridge University Press. <https://doi.org/10.1017/CBO9780511790874.004>
- Mandal, P. K. (2005). Dioxin: A review of its environmental effects and its aryl hydrocarbon receptor biology. *Journal of Comparative Physiology B*, 175(4), 221–230. <https://doi.org/10.1007/s00360-005-0483-3>
- Merrouche, O. (2011). The long-term educational cost of war: Evidence from landmine contamination in Cambodia. *The Journal of Development Studies*, 47(3), 399–416. <https://doi.org/10.1080/00220388.2010.485633>
- Miguel, E., & Roland, G. (2011). The long-run impact of bombing Vietnam. *Journal of Development Economics*, 96(1), 1-15. <https://doi.org/10.1016/j.jdeveco.2010.07.004>
- Nguyen, Q. T., Henseler, J., Nguyen, T. T., & Vo, L. C. (2022). Entrepreneurship and innovation in emerging economies: The influence of institutional environments on entrepreneurial activities in Vietnam. *World Development*, 151, 105739. <https://doi.org/10.1016/j.worlddev.2021.105739>
- Olson, J. M., Zanna, M. P., & Fazio, R. H. (2019). Attitude functions: The classification of attitudes and their functional bases. *Psychology*, 10(2), 123-136. <https://doi.org/10.4236/psych.2019.102010>
- Olson, K., & Morton, L. (2019). Long-term fate of Agent Orange and dioxin TCDD contaminated soils and sediments in Vietnam hotspots. *Open Journal of Soil Science*, 9(1), 1-34. <https://doi.org/10.4236/ojss.2019.91001>

- Organski, A. F. K., & Kugler, J. (1977). The costs of major wars: The Phoenix Factor. *American Political Science Review*, 71(4), 1347–1366. <https://doi.org/10.2307/1961484>
- Pantelopoulous, G. (2022). Higher education, gender, and foreign direct investment: Evidence from OECD countries. *Industry and Higher Education*, 36(1), 86–93. <https://doi.org/10.1080/00207179.2022.2088888>
- Pham, H. L., & Fry, G. W. (2004). Education and economic, political, and social change in Vietnam. *Educational Research for Policy and Practice*, 3(3), 199–222. <https://doi.org/10.1007/s10671-005-0678-0>
- Radovic, B. (2014). *Yugoslav wars 1991-1999 and some of their social consequences*. [Translated by Jelena Antonijevic].
- Riaño, J. F., & Caicedo, F. V. (2024). Collateral damage: The legacy of the Secret War in Laos. *The Economic Journal (London)*. <https://doi.org/10.1093/ej/ueae004>
- Safe, S. (1990). Polychlorinated biphenyls (PCBs), dibenzo-p-dioxins (PCDDs), dibenzofurans (PCDFs), and related compounds: Environmental and mechanistic considerations which support the development of toxic equivalency factors (TEFs). *Critical Reviews in Toxicology*, 21(1), 51–88. <https://doi.org/10.3109/10408449009089873>
- Schecter, A., Le Cao Dai, Pöpke, O., Prange, J., Constable, J. D., Matsuda, M., Thao, V. D., & Piskac, A. L. (2001). Recent dioxin contamination from Agent Orange in residents of a southern Vietnam city. *Journal of Occupational and Environmental Medicine*, 43(5), 435–443. <https://doi.org/10.1097/00043764-200105000-00002>
- Stellman, J. M., Stellman, S. D., Christian, R., Weber, T., & Tomasallo, C. (2003). The extent and patterns of usage of Agent Orange and other herbicides in Vietnam. *Nature*, 422(6933), 681–687. <https://doi.org/10.1038/nature01537>
- Smithsonian Channel. (2023, August 3). *Inside the Vietnam War: American's deadly chemical weapon* [Video]. YouTube. <https://youtu.be/cH8A5y10nPU>
- Tuyet-Hanh, T. T., Vu-Anh, L., Ngoc-Bich, N., & Tenkate, T. (2010). Environmental health risk assessment of dioxin exposure through foods in a dioxin hotspot-Bien Hoa City, Vietnam. *International Journal of Environmental Research and Public Health*, 7(5), 2395–2406. <https://doi.org/10.3390/ijerph7052395>
- VARHS. (2019). *Survey data for growth, structural transformation, and rural change in Viet Nam*. United Nations University World Institute for Development Economics Research (UNU-WIDER). <https://www.wider.unu.edu/database/survey-data-growth-structural-transformation-and-rural-change-viet-nam-book>
- Walton, J. (2004). The Tet Offensive: The turning point of the Vietnam War. *OAH Magazine of History*, 18(5), 45–51.
- Wang, C., & Balasubramanyam, V. N. (2011). Aid and foreign direct investment in Vietnam. *Journal of Economic Integration*, 26(4), 644–668. <https://doi.org/10.11130/jei.2011.26.4.644>
- Worker Veteran Health Project. (n.d.). *Military herbicides data warehouse*. Worker Veteran Health. <https://www.workerveteranhealth.org/milherbs/new/index.php>
- World Bank. (2022). Net official development assistance and official aid received - Vietnam.

Yamashita, N., & Trinh, T. (2022). Long-term effects of Vietnam War: Agent Orange and the health of Vietnamese people after 30 years. *Asian Economic Journal*, 36(2), 180–202.
<https://doi.org/10.1111/asej.12265>