



Centre for Globalisation Research

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CGR Working Paper 120

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Keywords: Agent Orange; education; labour outcomes; Vietnam

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January 5, 2026

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Statements and Declarations: The authors declare no competing interests.

*We also acknowledge Duong Trung Le and Thanh Pham for sharing the Agent Orange dataset. For constructive comments that substantially improved the paper, we also thank the participants from the Asian Economic Development Conference 2025 (Peking, China), 2025 World Congress of the Econometrics Society (Seoul, South Korea), German Development Economics Conference 2025 (Frankfurt, Germany), and 30th Annual Conference of the European Association of Environmental and Resource Economists (Bergen, Norway). We thank Viet Cuong Nguyen and Guido Friebel for helpful comments and suggestions. We are also grateful for Long (Tom) Hoang, Hoang Duy Khanh Dang, Thu Luu, and Nguyen Khoi Nguyen for providing excellent research assistance. The usual disclaimer applies.

1 Introduction

The dampening effects of civil conflicts and wars on economic growth are increasingly recognized (Bellows and Miguel, 2006; Blattman and Miguel, 2010; Grobar and Gnanaselvam, 1993; Miguel and Roland, 2011). Beyond the immediate destruction caused by combat, wars often involve environmental and chemical exposures that may persist long after hostilities end, with potentially severe consequences for human capital and economic outcomes. These concerns remain salient in the contemporary world, as illustrated by ongoing conflicts such as the Russia–Ukraine war and the Israel– Hamas conflict, which not only devastate individual well-being, but also heighten and prolong global economic uncertainty (Huynh and Ongena, 2025). A growing literature documents that wartime exposures can generate long-lasting damage to wealth, human capital, health, and labor market outcomes (Akbulut-Yuksel, 2014; Blattman and Miguel, 2010; Halbmeier and Schröder, 2024; Waldinger, 2016). However, much of the existing empirical evidence focuses on physical destruction from bombing, while far less is known about the long-run socioeconomic effects of chemical warfare and toxic environmental contamination (Le et al., 2022). This gap is particularly striking in the context of the Vietnam War, during which the United States conducted the most extensive herbicide spraying campaign in history (Le et al., 2022; Stelman et al., 2003a; Stelman and Stelman, 2004).

While district-level evidence suggests that intensive bombing during the Vietnam War did not lead to persistent negative effects on poverty, infrastructure, or population density in the long run (Miguel and Roland, 2011), these findings do not speak to the consequences of herbicide exposure, which operates through fundamentally different biological and environmental channels. Unlike physical capital destruction, herbicides such as Agent Orange introduced highly toxic dioxins into soil, water, and food systems, creating the potential for long-lasting and intergenerational impacts on health and human capital (Le et al., 2022; Ngo et al., 2006). Despite widespread concerns about the health consequences of Agent Orange exposure, little is known about its long-run effects on individual-level socioeconomic outcomes. Understanding these effects is crucial for assessing the full legacy of the Vietnam War and for informing policies aimed at remediation, compensation, and post-conflict recovery. This paper contributes to the literature by examining the long-term impacts of Agent Orange exposure on socioeconomic outcomes using individual-level data, thereby shedding

new light on an understudied channel through which war can shape economic development.

In this paper, we examine the causal effects of early-life exposure to Agent Orange on labor market outcomes. To our knowledge, this study is among the first to address this question using individual-level data, which allows us to compare outcomes for individuals who remain in their birth locations with those who subsequently relocate. We combine spatially detailed data on herbicide spraying intensity, constructed from historical military records, with individual-level information from the Vietnamese Household Living Standards Survey. Our baseline sample consists of individuals born between 1960 and 1975, who were exposed in utero or during early childhood, up to age four, during the period of Agent Orange spraying from 1962 to 1971. To address potential endogeneity in exposure arising from strategic military operations, we follow the literature by using proximity to Viet Cong military bases as an instrumental variable for local Agent Orange intensity.

Our main result is that early-life exposure to Agent Orange leads to persistent reductions in labor supply among affected cohorts. On average, exposed individuals work 1.7 fewer days per month and 0.4 fewer hours per day, translating into labor income losses ranging from 14 to 27%, depending on migration patterns. We show that a key mechanism underlying these effects is reduced human capital accumulation: individuals from high-exposure areas are more likely to have no formal education and less likely to attain schooling beyond the secondary level. We also present evidence of intergenerational transmission, particularly in educational attainment and labor market integration, among the children of exposed individuals born decades after the war.

We investigate the mechanisms underlying these effects and find that early exposure to Agent Orange reduces the attachment to the labor market through both health impairments and broader reductions in human capital accumulation. Using data from the 2019 population census, we show that increased exposure increases the likelihood of long-term cognitive difficulties. However, educational attainment and employment outcomes remain substantially lower even among individuals who do not report disabilities, suggesting that exposure operates through channels beyond health. Together, these findings demonstrate that the legacy of Agent Orange extends far beyond immediate health consequences, generating durable losses in human capital and the attachment to the labor market that are transmitted over generations.

Our identification strategy exploits variation in herbicide exposure driven by proximity to North Vietnamese military bases, but distance may affect outcomes through channels beyond Agent Or-

ange, such as differential wartime disruption or post-war development. Consistent with this concern, naive estimates reveal strong positive selection in more exposed areas, implying substantial upward bias. However, sensitivity and partial-identification analyses show that our main results are robust to meaningful violations of the exclusion restriction, suggesting that our estimates likely represent conservative lower bounds on the true long-run effects of early-life exposure.

Our study makes two contributions. First, our focus on labor market outcomes complements the literature examining the impact of Agent Orange on health. American and Australian veterans who were directly exposed to the chemical have been reported to experience significant health problems (Donovan, 1983). Empirical evidence using Vietnamese data also links Agent Orange to poor health outcomes, particularly blood pressure problems and mobility disabilities, through polluted food, water and other natural resources (Le et al., 2022; Yamada and Yamada, 2021; Yamashita and Trinh, 2022). The most severe impacts occur among those exposed in-utero, during early childhood, and among ethnic minority women in areas of high-exposure. Building on this extensive body of research, our findings demonstrate that in addition to health, affected individuals have a lower accumulation of human capital and weaker attachment to the labor market. These negative impacts consequently extend to and affect the next generation.

Second, our analysis contributes to studies investigating the long-run economic outcomes of the Vietnam War. At the macroeconomic level, Miguel and Roland (2011, 2023) demonstrate that the intensity of the bombing did not create a poverty trap in Vietnam, partly due to the reconstruction efforts of the government after the war. However, higher levels of bombing and Agent Orange intensity significantly reduced rice and overall agricultural yields (Appau et al., 2021). Using data from 60 households in Quang Tri Province, Palmer (2005) is one of a few studies that uses micro-level data to show that affected families experience lower incomes, higher medical expenses, and diminished educational and social opportunities compared to unaffected households. Our analysis use nationally representative data on individuals to shed light on the long-run effects of exposure on human capital accumulation and labor market outcomes for multiple cohorts, which in turn have intergenerational consequences.

Importantly, our findings highlight different policy implications from similar research on the attachment to the labor market. By examining a programme that provided disability benefits to Vietnam War veterans, Autor et al. (2016) demonstrate that increased financial support led to a

18 percentage point reduction in labor force participation, likely due to disincentives to work and compensation for income lost from significant disabilities, while [Wang et al. \(2025\)](#) also complements the existing literature by using draft lotteries as an instrumental variable to estimate both point-identified effects for compliers and sharp nonparametric bounds for volunteers, who constitute more than 70% of veterans, showing no consistent detrimental health effects for compliers but statistically significant long-term adverse health impacts for volunteers and veterans in general, emerging about a decade after the war and persisting up to 38 years later. Building on these insights, our results shed light on the long-term consequences of war, revealing that individuals exposed to Agent Orange in-utero or as young children also experience a weaker labor market attachment as adults. Our analysis underscores the possibility of underestimating the impacts of conflicts, as the adverse economic outcomes for those who experienced it as children may become visible only when they became adults.

The paper proceeds as follows. Section 2 provides an overview of the Vietnam War and the prevalence of Agent Orange. Section 3 describes the data and explains how the historical data was merged with current data using geographical identifiers in Vietnam. Additionally, we present descriptive statistics comparing exposed and non-exposed regions across various economic outcomes. Section 4 outlines our identification strategy and model specifications. Section 5 presents the main results. To explore potential mechanisms, Section 6 examines how Agent Orange exposure influenced educational and labor outcomes, focusing on disparities in educational attainment and intergenerational effects with the further analyses of health effects. Finally, Section 7 concludes.

2 The Vietnam War and Agent Orange

2.1 Background

The Vietnam War was a long and devastating conflict that lasted from 1961 to 1975. As noted in [Miguel and Roland \(2011, 2023\)](#), the destructive scale of the war was immense, involving at least three times the combined weight of munitions used in World War II and the European theatre. Furthermore, the total tonnage of the munitions deployed in the Vietnam War was not less than fifteen times that used in the Korean War. In fact, the Vietnam war is one of the most brutal wars in human history. The Vietnam War began in the aftermath of the First Indochina War, following the

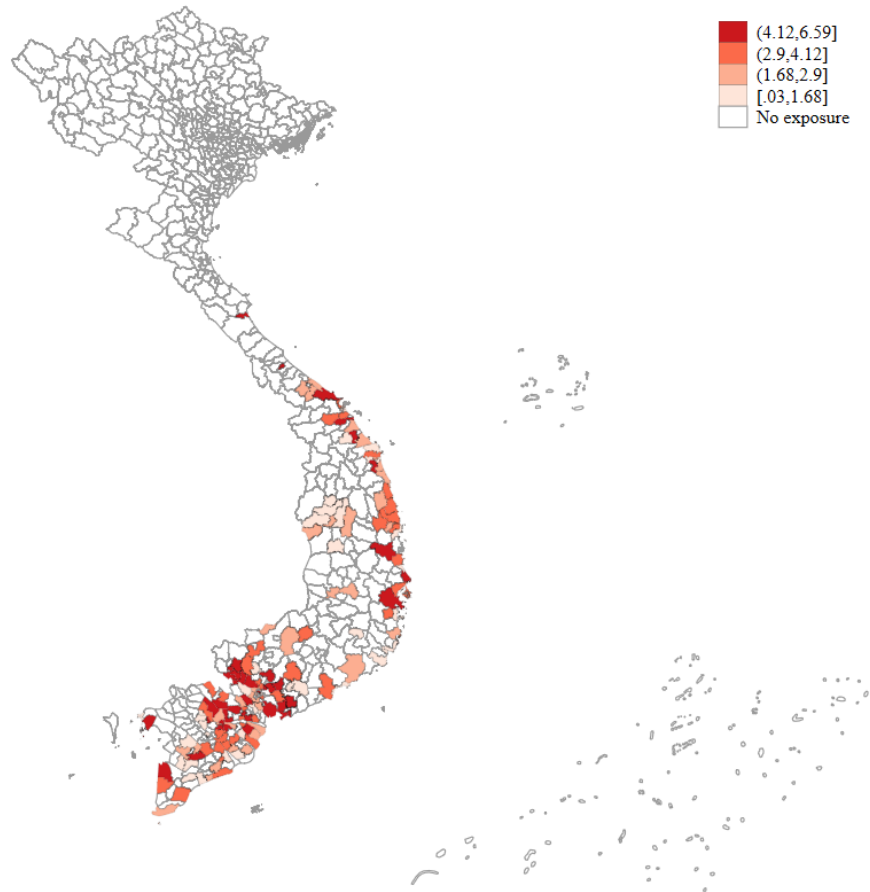
French's unconditional surrender at the Battle of Dien Bien Phu in 1954. This pivotal event led to the Geneva Conference, which resulted in an agreement to divide Vietnam into two parts along the 17th parallel (17th north latitude). North of this line, the Democratic Republic of Vietnam (North Vietnam) was established as a sovereign state, officially recognised at the conference. Meanwhile, the Republic of Vietnam, supported by the United States, was formed in the south.

During the Vietnam War, the American military aimed to locate the hiding spots of the guerrilla forces by spraying herbicides from both the ground and air (Stone, 2007). The operation, known as Operation Ranch Hand (1962–1971), involved monitoring the spraying process over areas at least 14 kilometers wide in a time frame of 45 minutes using cargo planes. One might wonder about the scale of the spraying area in this mission. Stelman et al. (2003a) reported that approximately 24% of the land was exposed to these chemicals. Figure 1 illustrates the distribution of the Agent Orange concentrations in Vietnam during the 1962-1971 period (Data are available from Le et al. (2022)). The distribution of herbicide spraying in Vietnam is concentrated predominantly in the southern regions, particularly in areas such as the Mekong Delta, where darker shades of red signify higher intensity. In contrast, the northern and central regions show lighter shades or white, indicating lower intensity or no recorded data. This spatial variation highlights significant regional differences in herbicide application, with the south bearing the brunt of exposure.

The herbicides contained dioxin, a highly toxic substance that exposes up to 4.8 million civilians to levels far exceeding the tolerable daily intake of the World Health Organisation (Le et al., 2022). According to the Ministry of National Defence of the Socialist Republic of Vietnam, an estimated 4.8 million Vietnamese have been exposed to dioxin, including approximately 3 million Agent Orange victims, many of whom are children. It is worth mentioning that Agent Orange not only affects the natural landscape (soil, land, forests, etc.) but also affects the genetic makeup of Vietnamese individuals across generations. The persistence of the chemical varies by location, such as farmland or river sediments, and remains in Vietnamese soils (Olson and Morton, 2019). Its longevity is due to its hydrophobic nature and factors such as spray patterns, bioavailability, ecosystem recycling, and decomposition rates. Given this fact, we hypothesise that the effects of Agent Orange on human lives can be evaluated based on the duration of residence in affected areas across different generations (Bertazzi et al., 2001; Ngo et al., 2006; Vandenberg, 2021).

The US Department of Veterans Affairs links direct exposure to military herbicides during

Figure 1: Distribution of herbicide spraying in Vietnam



Notes: The map illustrates the distribution of herbicide spraying across districts in Vietnam. The darker shades of red represent areas with higher intensity of herbicide exposure, while lighter shades indicate lower intensity. The color gradient follows the range scale on the legend, with values indicating the level of herbicide intensity. Districts without recorded exposure data are represented in white. The exposure score from [Le et al. \(2022\)](#) has no time variation, as it is based on aggregated data covering the entire spray period (1962–1971).

the war to diseases like prostate cancer, respiratory cancers, chronic B-cell leukemia, diabetes, Parkinson’s disease, and peripheral neuropathy¹. Exposure to Agent Orange has also been linked to transgenerational health effects, including birth defects such as spina bifida, which causes nerve damage, paralysis, and psychological disabilities, with reports of problems extending to the second and third generations (Le et al., 2022; Palmer, 2005; Yamashita and Trinh, 2022).

2.2 Related studies

In this section, we expand the literature review to synthesise studies on psychological trauma and its long-term socio-economic implications, which are recognised in the provided sources as key outcomes of violent conflict. One source notes that many children who survive in war zones suffer damage to their physical or mental well-being that is carried on into adulthood (Akbulut-Yuksel, 2014; Blattman and Miguel, 2010; Coutts, 2024). In addition, Singhal (2019) shows that there exist long-term effects on mental health due to the Vietnam war. The effects of the primary exposure to chemical warfare, dioxin, are linked to mental and cognitive health. Exposure to dioxin has been shown to damage brain tissues and potentially cause brain atrophy and declining cognitive functions (Hassoun et al., 2000; Lee et al., 2022; Vandenberg, 2021). Then, Akbulut-Yuksel and Yuksel (2017); Bertazzi et al. (2001) advocate that the effects of war on long term health are very heterogeneous between countries and contexts. Exposure to dioxin or health consequences is also associated with persistent effects on socio-economic outcomes (Aizer et al., 2018; Le et al., 2022; Nguyen, 2009; Palmer, 2005). Exposure is associated with birth defects, even in cohorts born after the war (Ngo et al., 2006). In addition, Do (2009) also shows the relationship between exposure to orange agents and the prevalence of cancer. Research on the hypothesis of foetal origin has expanded to include early childhood, revealing that mild early life shocks can have lasting, heterogeneous impacts, with interventions showing promise, although much remains unknown about the potential for intervening between early life and adulthood (Almond et al., 2018). Having fetal origin could link adult health problems with early in utero nutrition, with economic studies expanding this to show significant long-term effects on education, income and health (Almond and Currie, 2011). Therefore, wartime could have first- and second- generation impacts (Akresh et al., 2023).

¹See more at <https://www.va.gov/disability/eligibility/hazardous-materials-exposure/agent-orange/>, accessed on 25th November 2024.

3 Data

The primary data for our analysis is the spatial variation in herbicide exposure from (Le et al., 2022; Stellman et al., 2003b; Stellman and Stellman, 2004). The U.S. Military Assistance Command Vietnam (MACV) documented all herbicide spraying operations during the Vietnam War through its Herbicide Report System (HERBS). Using these data, the previous literature developed a GIS framework that calculates a log-scale exposure opportunity index for civilian communes in South Vietnam. This model accounts for herbicide type, quantity, proximity to spray sites, and timing, as well as direct and indirect exposure, using a conservative model of environmental disappearance. To create an exposure score for a commune, Le et al. (2022) first took the coordinates of all communes from the historical database of the commune evaluation system and compared them with the current boundaries of the commune. The constructed database also provides the population of each commune during the Vietnam war. The authors then calculate the exposure score for each commune by combining the scores of its communes, with each commune’s score weighted by its population.

In addition, we merge the Agent Orange data with the Vietnam Household Living Standard Survey (VHLSS), conducted by General Statistics Office (2019). This dataset enables us to analyse individual survey responses based on their socioeconomic determinants, such as age, gender, education, number of working hours (or working days), and more. The VHLSS data set has been widely used in numerous previous studies (Dell et al., 2018; McCaig and Pavcnik, 2018). The survey spans multiple waves from 2010 to 2020. Using “district” identifiers, we merged respondents in different waves to capture the dynamics of labor outcomes over the decade (2010–2020). To account for additional determinants related to natural geography and weather, we utilised data from Le et al. (2022); Miguel and Roland (2011), which provides information on variables such as area, poverty rate, number of households, level of urbanisation, and intensity of bombing, among others. Our control variables are from Le et al. (2022), collecting data on socioeconomic factors from the 2002 Vietnamese National Health Survey (VNHS)².

²In Appendix A7, we show that there is no correlation between our control variables and Agent Orange data to ensure that including these controls should not be considered as a “bad control”.

Figure 2: Distribution of income and working days by districts



Notes: The figure presents the distribution of economic outcomes (average income and average working days) across districts in Vietnam over all survey waves (2010, 2012, 2014, 2016, 2018, and 2020). The first and second maps depict average income and average working days, respectively. Darker colours indicate higher levels for each variable. These figures highlight regional disparities in income and labor productivity.

The first map in Figure 2 shows the intensity of herbicide spraying in Vietnam districts, with the highest exposure concentrated in southern regions, particularly around the Mekong Delta, as indicated by the darker red districts. The second map shows the average income levels by different district, with higher incomes generally concentrated in urban and industrial districts in the north and south, while rural central regions have lower incomes, as shown by lighter shades of blue. The third map illustrates the distribution of average working days, with districts in agricultural regions, particularly in the south, displaying higher working days, represented by darker green shades.

In defining the analysis sample, we restricted our attention to districts located in the southern regions of Vietnam, where Agent Orange spraying took place. Districts in the North are excluded from the sample, as none of them were exposed to Agent Orange. Within the South, the intensity of the exposure varied between districts, some areas being directly sprayed and others not affected. This spatial variation in exposure, which is plausibly exogenous to local socioeconomic conditions, provides the source of identification for our empirical analysis. The final sample includes both exposed and non-exposed districts in the South, with the latter serving as the comparison group.

Table 1 presents descriptive statistics for the main variables of interest, comparing individuals living in districts with lower and higher Agent Orange exposure in southern Vietnam. District-level characteristics are constructed by averaging commune-level variables within each district; details on variable source and construction are provided in Appendix A1. On average, individuals residing in more exposed districts work slightly more days per month than those in less exposed districts (22.96 vs. 22.51 days). However, they work marginally fewer hours per day on average (7.03 vs. 7.11 hours).

In terms of education, individuals in more exposed districts exhibit higher educational attainment in these raw comparisons. The share of individuals attaining high school or university education is higher in more exposed districts, and average years of schooling are also slightly greater (7.32 vs. 7.10 years). These patterns are consistent with positive selection: districts closer to military bases—and thus more heavily exposed to Agent Orange—appear to have been systematically more advantaged along dimensions associated with higher human capital. This selection underscores the need for an instrumental variables approach, as discussed in Section 4.2.

At the district level, more exposed areas tend to have smaller average land area (21.65 vs. 28.74 km²), higher population density, and closer proximity to North Vietnamese Army bases. Historical

data from the pre-spraying period indicate that these districts also had higher population density (184.56 vs. 162.79) and lower development scores (Hamla 1967: 44.52 vs. 56.60), reflecting their strategic importance during the war. Average poverty rates are lower in more exposed districts (0.12 vs. 0.14), while bombing intensity is slightly higher (0.52 vs. 0.56 bombs per km^2).

While many of these differences are statistically significant, their magnitudes are relatively modest. Moreover, the fact that more exposed districts appear more advantaged in raw comparisons—exhibiting higher education and lower poverty—yet our IV estimates reveal substantial negative effects of Agent Orange exposure highlights the importance of addressing endogeneity. Balance tests reported in Appendix A8.2 show that our instrument—distance to military bases—is uncorrelated with pre-war district characteristics, lending support to the validity of our identification strategy despite observable differences between more and less exposed districts.

4 Empirical Strategy and Results

4.1 Estimation

We begin with the OLS specification to examine the effects of herbicide exposure on labor outcomes:

$$Y_{idt} = \alpha + \beta_1 \text{Exposure score}_d + \theta \mathbb{X}_{it} + \gamma \Gamma_d + \xi \Xi + \lambda \Lambda + \varepsilon_{idt}, \quad (1)$$

In which, Y_{idt} represents the dependent variable of interest for individual i resident in district d at time t (across six survey waves spanning from 2010 to 2020). The variable Exposure score_d , derived from Le et al. (2022); Stelman et al. (2003b); Stelman and Stelman (2004), captures the herbicide exposure index in district d , reflecting the cumulative exposure an individual has experienced over their lifetime. The vector \mathbb{X}_{idt} includes individual characteristics for i , such as age and gender, for each survey wave. Furthermore, Γ_d represents the vector of control variables at the district level, including the total area of the district (km^2), the poverty rate, the number of households (per commune), the population and the intensity of the attacks (measured by the total number of US bombs, missiles and rockets per km^2). The OLS specification also incorporates two terms, Ξ and Λ , representing fixed effects of the cohort and province, respectively. The standard errors in all regressions are clustered at the village (*diaban*) level to account for potential correlations in the

Table 1: Descriptive Statistics

	South		
	No exposure (1)	Some exposure (2)	<i>p-value</i> (3)
<i>Individual characteristics</i>			
Age	44.20	44.38	0.041
Male	0.48	0.48	0.198
Days worked per month	22.51	22.96	<0.001
Hours worked per day	7.11	7.03	<0.001
No education	0.17	0.16	<0.001
Up to secondary school	0.42	0.43	<0.001
High school	0.16	0.17	<0.001
University	0.07	0.08	<0.001
Years of schooling	7.10	7.32	<0.001
<i>Historical characteristics (1960s)</i>			
Hamla 1967	56.60	44.52	<0.001
Paddy area 1959	12,715	11,224	<0.001
Population density 1959	162.79	184.56	<0.001
Male height 1956	162.96	162.92	<0.001
Female height 1956	152.56	152.29	<0.001
<i>Commune characteristics (VHLSS)</i>			
Area acreage (squared kilometer)	28.74	21.65	<0.001
Poverty rate	0.14	0.12	<0.001
Number of households	2,846	2,892	<0.001
Population	13,949	14,005	0.090
Urban	0.39	0.35	<0.001
Bombs per km^2	0.56	0.52	<0.001
Proximity to North army base (km)			
Maximum	24.56	20.62	<0.001
Average	22.68	17.25	<0.001
Number of individuals	35,862	109,065	-
Number of districts	66	166	-

Notes: This table reports the average characteristics of individuals, provinces, and districts in Southern Vietnam. Commune characteristics are averaged at the district level, except for distance to the North army base, for which we report both the maximum and the average. Column (1) reports means for those without exposure scores. Column (2) reports means for Southern communes with exposure scores. Column (3) reports the *p*-values of the hypothesis that the mean characteristic in column (1) is equal to the mean in column (2).

individual error terms within each commune. ε_{icdt} is an error term.

Our analysis is restricted to Southern Vietnam, where Agent Orange spraying occurred. Dis-

districts in Northern Vietnam, which received no herbicide exposure, are excluded from the estimation sample. This restriction ensures that identification relies solely on within-South variation in exposure intensity, avoiding potential confounding from systematic North-South differences in wartime experiences, political institutions, or post-war development.

One could argue that herbicide spraying locations were not randomly assigned due to the strategic choices made by U.S. forces during deforestation operations aimed at uncovering North Vietnamese military bases (Viet Cong base). As a result, the equation (1) may be subject to location bias. Additionally, concerns may arise regarding the presence of omitted variables when estimating key dependent variables such as educational choices, number of working hours, and number of working days. To address these potential issues, we adopted the identification strategy used by [Le et al. \(2022\)](#), employing a two-stage least squares (2SLS) approach in the form of an instrumental variable (IV) method. Accordingly, the instrumental variable is the maximum proximity of the identified commune to a Northern Vietnamese Army base in the district.

The complete data, disclosed by the U.S. Intelligence Agency after the Vietnam War, allows for the estimation of the distance from each commune to the nearest military base. A shorter distance implies higher herbicide exposure intensity due to the strategic choices made by the U.S. to uncover these bases. Following [Le et al. \(2022\)](#), we examine the distance between the commune’s centroid and the nearest base. The use of distance to political or historical locations is common in the economics literature, such as the distance to the 17th parallel ([Miguel and Roland, 2023](#)), the nearest Viet Cong base ([Le et al., 2022](#)), or the distance from village-level centroids to heavily bombed targets, like the Ho Chi Minh Trail in southern Laos or Xieng Khouang Province in northern Laos ([Yamada and Yamada, 2021](#)). Therefore, we expect that the closer proximity to a Viet Cong base correlates with greater herbicide exposure. The first stage of the estimation can thus be written as:

$$Exposure\ score_d = \beta_0 + \beta_1 Nearest\ distance\ to\ military\ base_d + \gamma \Gamma_d + \xi \Xi + \lambda \Lambda + \varepsilon_{idt}, \quad (2)$$

In our empirical setting, we control for the characteristics of the commune, which include the total area of district land (km²), the poverty rate, the number of households (per commune), the population, and the bombing intensity, in the first stage of the equation (2). The variable

Nearest distance to military base _{d} represents the maximum proximity of all communes c to the closest North Vietnamese military base in the district d .³ The validity of this excluded instrument, while untestable, is entirely based on the assumption that this is the only channel through which exposure scores impact labor outcomes, conditional on geographical variation, economic disparities, population density and bombing intensity (Le et al., 2022).

4.2 Our Instrument: Distance to Northern Vietnamese Army Bases

To isolate a plausibly-exogenous source of variation in Agent Orange intensity, we draw on the U.S. military’s herbicide-spraying strategy and the locations of North Vietnamese military bases. The U.S. military campaign was strategically aimed at countering North Vietnamese guerrilla forces. Historical accounts indicate that North Vietnamese Army infiltrators primarily used guerrilla tactics during the War, maintaining bases that were highly mobile and typically short-lived. A typical base remained active for less than two years (median: 21 months) before being abandoned or destroyed (Le et al., 2022; Young, 2009). In the early phase, North Vietnamese Army bases were concentrated in inland forests; accordingly, U.S. forces prioritized the herbicide Agent White for defoliation missions. Because full defoliation generally required several months after application, Agent White was well suited to inland-forest areas where immediate canopy removal was not essential (Young, 1980).

Precisely locating bases was difficult: Northern troops concealed themselves in mangrove forests and sometimes blended into non-military households to avoid detection. Therefore, the campaign also deployed Agent Orange to destroy broadleaf crops (e.g., beans, peanuts, ramie, and root or tuber crops). Unsurprisingly, this approach did little to reveal base locations, as troops and their logistical networks quickly re-embedded within civilian communities. As a result, the spraying strategies were largely concentrated on the base perimeters, cache sites, waterways, and communication lines. Given this history, Northern Vietnamese Army (NVA) base locations provide a plausibly-exogenous source of variation in Agent Orange exposure.

³We also re-estimate our main results using an alternative instrumental variable, the average distance of all communes within district d . The results remain robust, as reported in Appendix A9.

4.3 Threats to Identification

Our identification strategy relies on two key assumptions: instrument relevance (distance to military bases affects Agent Orange exposure) and the exclusion restriction (distance affects outcomes only through exposure). While the first stage (Table A8) demonstrates strong instrument relevance (F-statistic > 18), the exclusion restriction is untestable in the standard sense.

4.3.1 Instrument Exogeneity

If bases were systematically located in remote, underdeveloped areas characterized by difficult terrain and limited infrastructure, then long-run outcomes could reflect these pre-existing disadvantages rather than herbicide exposure. While base placement was determined by military strategy rather than economic considerations, we empirically assess this concern by examining whether distance to bases correlates with pre-war characteristics.

Table A9 in Appendix A8.2 presents detailed results testing whether distance to bases predicts pre-spraying economic and geographic conditions, including population density, cultivated land, infrastructure, and the HAML A/HES development score—a composite measure of wartime governance and modernization widely used in research on the Vietnam War (Kalyvas and Kocher, 2009; Miguel and Roland, 2011).⁴ Across all pre-existing characteristics, we find no significant correlations with distance to bases, suggesting that base location was not driven by economic or demographic conditions. We also find no evidence that bases were systematically placed in areas with challenging terrain (elevation, ruggedness) or restricted cultivable land. These results support the view that our instrument captures exogenous variation in herbicide exposure rather than differences in baseline conditions that would independently affect long-run outcomes.

4.3.2 Sensitivity and Partial Identification Analysis

While the balance tests support the plausibility of the exclusion restriction, we cannot definitively rule out that distance affects outcomes through channels other than Agent Orange exposure. For instance, proximity to bases might be associated with wartime destruction, post-war development

⁴The Hamlet Evaluation System (HES) was an administrative tool used by US and South Vietnamese authorities between 1967 and 1973 to assess progress in pacification and rural development, incorporating security conditions, infrastructure, economic activity, and government control into a composite index.

programs, or migration patterns. To assess robustness to such potential violations, we implement two complementary sensitivity analysis frameworks: [Conley et al. \(2012\)](#), which examines how treatment effect estimates change when allowing the instrument to have direct effects, and [Ban and Kedagni \(2022\)](#), which constructs partial identification bounds under varying violation assumptions.

Table [A10](#) presents results from both approaches. Both parameterize violations using Γ , representing the maximum direct effect of the instrument as a percentage of the reduced form effect. For example, $\Gamma = 0.30$ allows distance to have direct effects up to 30% as large as the total reduced form effect, while $\Gamma = 0$ corresponds to standard IV assumptions.

The Conley analysis shows that our point estimates remain statistically significant at the 5% level when allowing for violations up to 20–40% of the reduced form effect, depending on the outcome. Education effects are robust to violations up to 30%, days worked to 40%, and hours worked per day to 20%. These violation magnitudes represent substantial departures from perfect exclusion—for instance, a 30% violation implies that one-third of the distance-outcome relationship operates through channels other than Agent Orange exposure.

The Ban-Kedagni bounds provide complementary evidence under even weaker assumptions, accounting for both partial identification and sampling uncertainty through confidence regions. For education, the 95% confidence region excludes zero even when allowing violations up to 50% of the reduced form, with an identified set of $[-0.635, -0.212]$ and confidence region of $[-1.214, -0.116]$ at this violation level. For labor market outcomes, confidence regions exclude zero up to violations of 30% for days worked (identified set: $[-2.119, -1.141]$, confidence region: $[-3.805, -0.662]$) and 40% for hours worked per day (identified set: $[-0.624, -0.267]$, confidence region: $[-1.226, -0.118]$).

These thresholds represent scenarios where distance could have direct effects that are 30–50% as large as the total reduced form effect. Such violations would require alternative mechanisms—economic development, infrastructure, or migration around military bases—to have effects nearly one-third as large as the long-term health and productivity impacts of Agent Orange exposure. We view violations of this magnitude as implausibly large. Military bases were established for strategic wartime purposes rather than peacetime development, and while they may have had some local economic effects, these are unlikely to rival the documented impacts of dioxin exposure on human health and productivity.

4.3.3 Summary

Taken together, these analyses provide a broad assessment of our identification strategy. Balance tests indicate that distance to bases is not systematically related to observable pre-war economic and geographic characteristics, lending support to the plausibility of the exclusion restriction. While this assumption cannot be tested directly (Angrist and Pischke, 2009), sensitivity analyses suggest that the main results are reasonably robust to alternative assumptions. The Conley et al. and Ban-Kedagni approaches indicate that the estimated effects we present below remain informative under moderate violations of the exclusion restriction.

5 Results

Our main objective is to examine the long-term human capital and labor market outcomes of early childhood exposure to Agent Orange. We focus on individuals born between 1960 and 1975, who would have been exposed in-utero and during their early childhood years—critical periods for physical and cognitive development. Table 2 presents our main estimates for this baseline cohort.

5.1 OLS vs. IV: Evidence of Selection Bias

Before discussing the magnitude and interpretation of our IV estimates, we first demonstrate the severity of endogeneity in this setting by comparing ordinary least squares (OLS) and instrumental variables (IV) estimates. Table 2, odd columns, reports OLS coefficients from regressing outcomes directly on Agent Orange exposure, while even columns present our IV estimates instrumenting exposure with distance to military bases.

The OLS estimates, which regress outcomes directly on Agent Orange exposure without addressing endogeneity, are severely biased. For education, the OLS estimate is small, positive, and statistically insignificant ($\beta = 0.006, SE = 0.009$), suggesting no adverse effect. For labor outcomes, OLS estimates are negative but severely attenuated: days worked shows a coefficient of -0.065 ($SE = 0.033$), while hours worked per day shows -0.016 ($SE = 0.012$). In contrast, the IV estimates are large, negative, and highly significant: education ($\beta = -0.427, SE = 0.135$), days worked ($\beta = -1.711, SE = 0.493$), and hours worked per day ($\beta = -0.398, SE = 0.161$). For education, the IV estimate represents a complete sign reversal and is 71 times larger in magnitude

than OLS. For labor outcomes, IV estimates are 25-26 times larger than their OLS counterparts.

Our IV estimates likely represent conservative lower bounds on the true adverse effects of Agent Orange exposure. The comparison between OLS and IV estimates reveals substantial positive selection: communes with higher exposure were systematically more advantaged, creating severe upward bias in OLS (with the education coefficient even showing the wrong sign). Even after conditioning on extensive controls and district fixed effects, residual positive selection likely continues to bias our IV estimates toward zero. Additionally, measurement error in our instrument (as distance imperfectly predicts actual spraying) suggests caution against treating our estimates as upper bounds. The large negative effects we document on education and labor supply should thus be interpreted as credible causal estimates that likely understate the true magnitude of harm from early-life herbicide exposure.

5.2 Robustness

Across all specifications, the coefficients of bombing intensity, defined as the total number of US bombs, missiles and rockets per km^2 are statistically zero or of a much smaller magnitude compared to that of exposure score, emphasizing that it is exposure to Agent Orange, rather than bombing, that contributes to lower education attainment and weaker labor market attachments of the baseline cohorts.

We conduct a series of robustness checks to assess the stability of our baseline estimates. First, we augment the baseline specification by controlling for household income, adding survey-year fixed effects, and accounting for nonlinearities in age. The estimated coefficients remain stable in magnitude and precisely estimated; results are reported in Appendix [A2](#).

Second, we address potential exposure misclassification arising from internal migration. Because Agent Orange exposure is measured using an individual's current district of residence, migration may generate discrepancies between measured and true historical exposure. Given that the estimated effects of exposure on schooling and employment outcomes are negative, such misclassification induces attenuation bias. Individuals who moved from more-exposed to less-exposed districts will appear to have outcomes that are too poor relative to their measured exposure, while those who moved in the opposite direction will appear too well-off. In both cases, the association between exposure and outcomes is weakened, biasing estimates toward zero. Our estimates should

Table 2: Impact of Agent Orange Exposure on Education and Labor Market Participation

Sample Dep. Var.	Individuals born between 1960 to 1975					
	Edu		Days worked		Hours worked	
	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
Exposure score	0.00649 (0.00856)	-0.427*** (0.135)	-0.0654* (0.0334)	-1.711*** (0.493)	-0.0162 (0.0122)	-0.398** (0.161)
Age	-0.00481 (0.00325)	-0.00437 (0.00425)	0.0738*** (0.0141)	0.0759*** (0.0177)	-0.0144*** (0.00481)	-0.0143*** (0.00535)
Male	0.292*** (0.0104)	0.295*** (0.0113)	-0.960*** (0.0612)	-0.958*** (0.0640)	0.491*** (0.0220)	0.492*** (0.0224)
Bombs per km^2	0.0404** (0.0175)	0.0404 (0.0275)	0.0532 (0.0663)	0.0374 (0.114)	-0.0666** (0.0277)	-0.0703* (0.0381)
<i>IV: Maximum distance</i>						
Kleibergen-Paap F stat	-	18.19	-	18.46	-	18.84
Mean of dep. var.	1.57	1.57	23.2	23.2	6.96	6.96
Observations	47,987	47,987	42,877	42,877	42,970	42,970

Notes: Table reports the estimated impact of the exposure score (measured at the district level) on education (columns 1 and 2), number of days worked in the past 30 days (columns 3 and 4), and hours worked per day (columns 5 and 6). Odd-numbered columns report OLS estimates, while even-numbered columns report two-stage least squares (2SLS) estimates. The 2SLS specification instruments the district-level exposure score with the maximum distance to the nearest North Vietnamese army base among communes within the district. The estimation sample includes individuals born between 1960 to 1975, those who are in-utero or very young at the time Agent Orange was sprayed. All regressions include controls for commune-level characteristics (including geographic size, population density, number of households and poverty rate), as well as province and birth year fixed effects. The Kleibergen-Paap F-statistic tests for weak instruments; values above 10 indicate strong instruments. Standard errors are clustered at the village (*diaban*) level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

therefore be interpreted as conservative lower bounds.

To further assess the role of mobility, we include province fixed effects and estimate specifications separately for stayers and inter-provincial migrants. The results are similar across these groups, limiting the scope for internal migration to account for our findings. These supplementary results are reported in Appendix [A5](#).

Finally, we conduct a placebo test to assess whether our results could arise spuriously. We randomly reassign Agent Orange exposure intensity across districts and re-estimate equation (1) 500 times. Figure [A2](#) plots the distribution of coefficients from these placebo regressions. In none of the simulations are the coefficients precisely estimated, indicating that our main findings are unlikely to be driven by random variation in exposure intensity.

5.3 Heterogeneity

We examine heterogeneity in the Agent Orange effects across cohorts and by migration status. Columns 1-3 of Table [3](#) present estimates for individuals born before 1960, who ranged from infants to young adults during the spraying period (1961-1971). The effects are similar in magnitude to our baseline cohort: education (-0.444 vs. -0.427), days worked (-1.477 vs. -1.711), and hours worked (-0.485 vs. -0.398). This suggests that cumulative exposure over the decade of spraying operations had substantial impacts even on individuals past early childhood, through direct health effects during childhood, adolescence, and young adulthood. This interpretation is consistent with the negative health effects finding in [Le et al. \(2022\)](#) among those who were 5 to 18 at the time Agent Orange spraying started.

Columns 4–6 of Table [3](#) restrict the sample to individuals in baseline cohorts who were residing in their birth provinces at the time of the VHLSS surveys. The estimated effects for this group are smaller in magnitude than those in the baseline results (Table [2](#)), but remain negative and statistically significant across all three outcomes. The attenuation is most pronounced for education, likely reflecting the heterogeneous composition of the stayer sample. It includes both true stayers—individuals who never migrated—and return migrants who left their birth provinces earlier in life but had returned by the time of the survey. These two groups may differ systematically in ways related to both educational attainment and vulnerability to Agent Orange exposure. In particular, education strongly shapes migration decisions: individuals with higher education are more likely

to migrate, while those whose education was more severely affected by early-life exposure may be less likely to do so. Selective out-migration and return migration can therefore attenuate estimated effects within the stayer sample, especially for education.

Nonetheless, the consistently negative and significant effects across both samples—full population and those remaining in birth areas—demonstrate that Agent Orange exposure caused widespread, persistent harm that is not confined to particular subgroups or driven by compositional changes from migration.

Table 3: Impact of Agent Orange Exposure - Robustness

Cohort Dep. var.	Born before 1960			Stayers (born 1960 to 1975)		
	Edu	Days worked	Hours worked	Edu	Days worked	Hours worked
	(1)	(2)	(3)	(4)	(5)	(6)
Exposure Score	-0.444** (0.176)	-1.477* (0.785)	-0.485* (0.266)	-0.164** (0.0677)	-1.097*** (0.315)	-0.364*** (0.122)
Age	-0.00665 (0.00464)	0.0452* (0.0253)	-0.0724*** (0.00864)	-0.00843 (0.00560)	0.113*** (0.0294)	0.00644 (0.00992)
Male	0.558*** (0.0147)	-1.397*** (0.121)	0.428*** (0.0401)	0.287*** (0.0120)	-1.137*** (0.0758)	0.511*** (0.0272)
Bombs per km^2	0.0280 (0.0326)	0.107 (0.140)	-0.0563 (0.0448)	0.0527*** (0.0190)	0.00521 (0.0983)	-0.0518 (0.0403)
<i>IV: Maximum distance</i>						
Kleibergen-Paap F stat	10.07	11.92	11.71	38.65	39.22	39.66
Mean of dep. var.	1.1	21.6	5.62	1.46	23.1	6.81
Observations	31,709	16,790	17,087	32,904	29,252	29,324

Notes: Table reports the 2SLS estimates of the impact of the exposure score (measured at the district level) on education (columns 1 and 4), number of days worked in the past 30 days (columns 2 and 5), and hours worked per day (columns 3 and 6). The distance to the North Vietnamese army base is used as the instrument for the exposure score to Agent Orange at the commune level. The estimation sample in columns 1 to 3 includes individuals born before 1960. The estimation sample includes individuals who are born between 1960 and 1975 and who were still living in the same province as their birth at the time of the VHLSS survey. All regressions include controls for commune-level characteristics (including geographic size, population density, number of households and poverty rate), as well as province and birth year fixed effects. Standard errors are clustered at the village (*diaban*) level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5.4 Income Effects

To assess whether the negative effects of early-life exposure to Agent Orange on labor market participation translate into lower economic returns, we re-estimate equation (1) using income as the outcome of interest. We measure income in two ways. First, we construct household income by aggregating net revenues from agricultural activities, including rice, crops, and fruit trees, after accounting for associated costs and losses from natural disasters. Second, we use individual-level

labor earnings based on wages.

Table 4: Impact of Agent Orange Exposure on Income

Dep. var.	Household Income			Labor Income		
	Before 1960	Born 1960 to 1975		Before 1960	Born 1960 to 1975	
Cohort	All	All	Stayers	All	All	Stayers
	(1)	(2)	(3)	(4)	(5)	(6)
Exposure score	-18661.7** (7584.1)	-16324.2*** (6128.6)	-10849.1*** (3695.7)	-1030.1 (969.9)	-1137.0 (727.7)	-2313.9*** (886.3)
Age	-6073.4*** (355.8)	-3729.4*** (316.8)	4642.5*** (312.9)	303.8*** (62.85)	471.0*** (42.52)	554.6*** (95.98)
Male	6650.7*** (612.8)	3015.5*** (420.6)	1785.7*** (440.8)	2637.7*** (404.6)	2752.8*** (210.5)	3125.6*** (283.9)
Bombs per km^2	-1472.9 (1457.5)	-389.3 (1215.1)	366.7 (1016.1)	-371.8 (239.2)	169.8 (190.0)	298.3 (259.9)
Days worked	No	No	No	Yes	Yes	Yes
Hours worked	No	No	No	Yes	Yes	Yes
<i>IV: Maximum distance</i>						
Kleibergen-Paap F stat	13.89	19.05	40.03	8.27	17.93	19.21
Mean of dep. var.	97,419	111,771	100,585	6,624	8,446	8,672
Observations	36,466	53,700	39,389	748	3,420	2,311

Notes: Table reports the 2SLS estimated impact of the exposure score (measured at the district level) on either household income (columns 1 to 3) or individual labor income (columns 4 to 6). Households that did not move province are "stayer" households. We instrument the district-level exposure score with the maximum distance to the nearest North Vietnamese army base among communes within the district. All regressions include controls for commune-level characteristics (including geographic size, population density, number of households and poverty rate), as well as province and birth year fixed effects. Clustered standard errors at the village (*diaban*) level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4, Columns 1 to 3, presents household income effects. Households in higher-exposure districts experience significantly lower incomes than those in less-exposed areas. Column (1) shows that households with members born before 1960 face income reductions of 19%, likely reflecting broader community-level effects including reduced agricultural productivity and soil contamination from herbicide use.

For the baseline cohort (born 1960–1975), household income falls by 14% in the full sample (column 2) but only 10% among stayers (column 3). This attenuation among stayers mirrors the pattern observed for education and labor supply in Table 3 and likely reflects similar compositional factors: the stayer sample includes both true non-migrants and return migrants who may differ systematically in ways that affect household outcomes.

Labor earnings display a pattern that differs sharply from those observed for education and

labor supply. Relative to the sample mean of 8,446 VND, the full-sample coefficient reported in Column (5) implies a 13.5% reduction in earnings, though it is not statistically significant. Among stayers, however, the coefficient (Column 6) corresponds to a 27.4% reduction—a large and precisely estimated effect. This near-doubling of the effect size suggests that migration to higher-wage locations masks substantial earnings losses in the full population. Absent access to urban wage premia, individuals exposed to Agent Orange in early life experience earnings losses exceeding one-quarter, highlighting the sizable long-run economic cost of exposure that compensatory migration only partially offsets.

From a LATE perspective, the IV estimates capture the effect of Agent Orange exposure on the earnings capacity of individuals whose exposure intensity was influenced by proximity to military bases. For this complier population, migration decisions determine whether reduced earning capacity translates into observed earnings losses. The stayer estimates therefore more closely reflect the local effect of exposure absent access to compensatory migration, while the full-sample estimates incorporate partial offsetting through relocation.

One might argue that income-based labor market measures are vulnerable to sample-selection bias, particularly in contexts like Vietnam, where wages are not observed for many individuals working in informal or agricultural sectors. We address this concern by expanding our analysis in Section 5.6 to include occupation-based outcomes that are less sensitive to these data limitations.

5.5 Effects on Education Levels

To understand how Agent Orange exposure affected the education distribution, we estimate equation (1) using indicators for each completed education level. Table 5 reveals that exposure shifted the entire distribution downward. Individuals in more exposed districts are significantly more likely to have no formal education (column 1) and significantly less likely to complete high school (column 3), university (column 4), or postgraduate education (column 5).

These results are not confined to marginal students near a particular threshold but represent broad-based losses in educational attainment. This pattern suggests that Agent Orange exposure affected fundamental cognitive and health endowments that shape educational capacity throughout the life course. The finding that in-utero herbicide exposure caused long-run human capital deficits carries substantial policy implications. Agent Orange spraying imposed costs beyond immediate

health effects: it created cohorts with systematically lower education, reduced labor market productivity, and diminished earnings capacity. These human capital losses represent a lasting drag on Vietnam’s economic development potential.

Table 5: Impact of Agent Orange Exposure on Education Categories

Dep. var.	No edu (1)	Up to secondary (2)	High sch (3)	University (4)	Postgraduate (5)
Exposure Score	0.0557*** (0.0214)	0.0339 (0.0235)	-0.0582*** (0.0192)	-0.0444*** (0.0141)	-0.00437** (0.00217)
Age	-0.00599*** (0.000850)	-0.0155*** (0.00103)	-0.00306*** (0.000746)	-0.00202*** (0.000583)	-0.000386*** (0.000109)
Male	-0.0503*** (0.00313)	0.0155*** (0.00410)	0.0282*** (0.00276)	0.0240*** (0.00204)	0.00213*** (0.000446)
Bombs per km^2	-0.00960** (0.00402)	-0.00239 (0.00469)	0.0108*** (0.00393)	-0.00224 (0.00333)	0.000545 (0.000657)
<i>IV: Maximum distance</i>					
Kleibergen-Paap F stat	20.16	20.16	20.16	20.16	20.16
Mean of dep. var.	.169	.507	.11	.0575	.00268
Observations	56,761	56,761	56,761	56,761	56,761

Notes: Table reports the 2SLS estimates of the impact of the exposure score (measured at the district level) on education. The distances to the North Vietnamese army base are used as the instrument for exposure to Agent Orange at the commune level. The estimation sample includes individuals who are born between 1960 and 1975. The dependent variable is an indicator for an individual having no education in column 1, up to secondary school in column 2, some high school in column 3, university in column 4, and graduate studies in column 5. All regressions include controls for commune-level characteristics (including geographic size, population density, number of households and poverty rate, as well as province and birth year fixed effects. Standard errors are clustered at the village (*diaban*) level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5.6 Effects on Wage Employment and Sectoral Allocation

Beyond the intensive margins of labor supply (days and hours worked), Agent Orange exposure may affect the type and nature of employment. One might argue that income-based labor market measures are vulnerable to sample-selection bias, particularly in contexts like Vietnam, where wages are not observed for many individuals working in informal or agricultural sectors. We address this concern by examining occupation-based outcomes that are less sensitive to these data limitations. Specifically, we examine employment status, distinguishing wage workers from the self-employed and the unemployed. We then analyze sectoral allocation conditional on wage employment: primary industries (mining, agriculture, and construction), productive industries (manufacturing and

wholesale motor parts), and service or high-skill industries (finance, education, health, and entertainment).

Table 6 shows that higher exposure to Agent Orange is associated with a lower likelihood of wage employment (column 1) and, among wage workers, a higher likelihood of employment in primary industries (column 2). These patterns suggest that individuals with greater exposure face persistent constraints in labor market sorting. In particular, the concentration in sectors characterized by lower skill requirements is consistent with the documented reductions in educational attainment (Table 2). Together, these additional measures provide a more comprehensive picture of labor market impacts and help mitigate concerns related to sample selection in wage data.

Table 6: Impact of Agent Orange Exposure on Employment Type

Cohort	Individuals born between 1960 and 1975			
Dep. Var.	Wage Work	Primary Industries	Productive Industries	Services Industries
	(1)	(2)	(3)	(4)
Exposure score	-0.0807*** (0.0293)	0.0362* (0.0200)	-0.0373 (0.0311)	-0.0000957 (0.0248)
Age	0.0424*** (0.0130)	0.0188* (0.0104)	-0.0524*** (0.0166)	0.0289* (0.0160)
Age squared	-0.000470*** (0.000108)	-0.0000645 (0.0000989)	0.000543*** (0.000147)	-0.000439*** (0.000145)
Male	0.173*** (0.00453)	0.0335*** (0.00426)	0.132*** (0.00894)	-0.130*** (0.00834)
Bombs per km^2	-0.00234 (0.00524)	-0.00394 (0.00488)	0.00497 (0.00594)	-0.00305 (0.00400)
<i>IV: Maximum distance</i>				
Kleibergen-Paap F stat	9.77	9.77	9.77	9.77
Mean of dep. var.	0.451	0.0459	0.433	0.248
Observations	50,713	15,936	15,936	15,936

Notes: This table reports the estimated impact of the exposure score (measured at the district level) on labor market participation as a wage worker and by industry (columns 2 to 4). Each column reports the second stage of 2SLS estimates, using the distance to the North Vietnamese army base as the instrument for the exposure score to Agent Orange. The estimation sample includes individuals born between 1960 to 1975, those who are in-utero or very young at the time Agent Orange was sprayed. All regressions include controls for individual education and commune-level characteristics, as well as province, birth year, and survey year fixed effects. Standard errors are clustered at the village (*diaban*) level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

6 Mechanisms and Intergenerational Effects

6.1 Health effects

Exposure to Agent Orange could result in lower human capital due to its effects on health, which has been documented among Vietnamese civilians and US veterans (Autor et al., 2016; Le et al., 2022; Wang et al., 2025). Consequently, exposure to Agent Orange could also result in less participation in the labor market through its effects on health and through its effects on lower human capital. To explicitly test the health mechanism, we estimate the effects of herbicide exposure on health outcomes using the 2019 Population Census data.⁵

Table 7, Columns 1 and 2 report the effects of Agent Orange exposure to self-reported health difficulties among the baseline cohort (1960 to 1975). Consistent with the literature, we find negative effects of Agent Orange exposure on health. Higher exposure at the district-level significantly increases the likelihood of reporting cognitive difficulties, while the estimated effect on physical difficulties is positive but imprecisely estimated. Beyond health outcomes, Columns 3 to 10 show that exposure is strongly associated with lower educational attainment and a reduced probability of working in the last 30 days. These negative effects are observed not only among individuals reporting cognitive difficulties (Columns 4 and 8), physical difficulties (Columns 5 and 9), or both (Columns 6 and 10), but also among those without reported disabilities (Column 3 and 7), indicating that exposure affects human capital accumulation and labor market attachment through channels beyond health. One potential explanation is household income; however, income information is not available in the population census. To address this limitation, we draw on the evidence from Table 4, which shows that Agent Orange exposure is associated with lower household income. This suggests that the adverse effects of exposure on educational outcomes may operate through both health-related mechanisms and negative income shocks. While the magnitude of the estimates remains broadly stable across subsamples, statistical precision declines sharply in groups with smaller sample sizes, particularly among individuals reporting cognitive difficulties.

⁵We also implemented our analysis using health outcomes from the VHLSS, including measures of illness incidence, clinical visits, and health-related expenditures; results are available upon request. The estimates are imprecise, in part because the number of observations drops substantially after log transformation due to extensive missing data and the prevalence of zero values. More fundamentally, this likely reflects limitations of the VHLSS health module, which records illnesses and health utilization only over the previous 12 months and therefore primarily captures short-term or seasonal conditions rather than long-term health outcomes plausibly affected by Agent Orange exposure. For this reason, we rely instead on population census data that measure chronic health conditions.

Table 7: Impact of Agent Orange Exposure on Health - Population Census

Cohort	Individuals born between 1960 to 1975									
	Cognitive Difficulties		Physical Difficulties		Education			Job last 30 days		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Exposure Score	0.00481*	0.00510	-0.328***	-0.0655	-0.264***	-0.176***	-0.0288**	-0.0343	-0.0388*	-0.0359**
	(0.00269)	(0.00432)	(0.0512)	(0.141)	(0.0710)	(0.0616)	(0.0117)	(0.0333)	(0.0209)	(0.0146)
Age	-0.0251***	-0.0222***	-0.180***	0.652	0.305	-0.204	-0.0615***	0.143	0.0400	-0.0351
	(0.00576)	(0.00800)	(0.0562)	(0.483)	(0.250)	(0.280)	(0.0153)	(0.130)	(0.0639)	(0.0392)
Age squared	0.000317***	0.000250***	-0.00202***	-0.00912*	-0.00675***	-0.00108	0.000582***	-0.00146	-0.000400	0.000343
	(0.0000589)	(0.0000821)	(0.000562)	(0.00475)	(0.00238)	(0.00265)	(0.000144)	(0.00121)	(0.000586)	(0.000367)
Male	0.000735	0.00418***	0.347***	0.264***	0.347***	0.281***	0.0770***	0.0103	0.0437***	0.00454
	(0.000447)	(0.000618)	(0.00414)	(0.0437)	(0.0193)	(0.0214)	(0.00244)	(0.00978)	(0.00520)	(0.00307)
Cognitive difficulty	-	-	No	Yes	No	Yes	No	Yes	No	Yes
Physical difficulty	-	-	No	No	Yes	Yes	No	No	Yes	Yes
Mean of y	0.0359	0.0747	2.77	2.16	2.63	2.21	0.0562	0.0426	0.0496	0.0234
Observations	623,422	623,422	552,133	3,724	27,441	14,879	140,333	2,041	10,673	11,116

Notes: This table reports the estimated impact of the exposure score (measured at the district level) on health and other outcomes using population census data. Columns (1) and (2) report 2SLS estimates of the effect of the exposure score on self-reported health outcomes related to cognitive and physical difficulties. Columns (3)–(6) report the effects of Agent Orange exposure scores on educational outcomes, conditional on whether respondents report any cognitive or physical difficulties. Columns (7)–(10) report the effects of Agent Orange exposure scores on labour market outcomes, conditional on whether respondents report any cognitive or physical difficulties. All regressions include controls for individual education and commune-level characteristics, as well as province, birth-year, and survey-year fixed effects. Standard errors are clustered at the village (*diaban*) level. *** p<0.01, ** p<0.05, * p<0.1.

6.2 Persistence: Effects on the Next Generation

To examine intergenerational transmission, we use VHLSS household roster data to identify children of the baseline cohort. We restrict the sample to post-war children born after 1980 who can be linked to at least one parent born between 1960 and 1975.⁶ To ensure meaningful measurement of outcomes, analyses of educational attainment are limited to post-war cohorts who were aged 25 and above at the time of the survey, while labor market outcomes are examined for individuals aged 15 and above.

Table 8 presents evidence of heterogeneous transmission across generations. In the full sample, we find no statistically significant effect of parental exposure on children’s educational attainment (column 1). However, among children whose parents remained in their birth provinces, educational attainment is lower and marginally significant (column 4). This pattern suggests that intergenerational educational transmission may be mediated by location, with migration potentially enabling access to improved schooling or economic opportunities that attenuate inherited disadvantage.

Labor supply effects are more consistent across samples. For post-war cohorts, a one-unit increase in parental exposure to Agent Orange is associated with reductions of between 1.3 and 1.7 days worked per month (columns 2 and 5), corresponding to declines of approximately 5 and 7% of the mean. We do not find statistically significant effects on hours worked per day (columns 3 and 6), although the point estimates are negative and imprecisely estimated. Overall, these findings indicate that the consequences of Agent Orange exposure extend into the second generation, though transmission is incomplete and heterogeneous.

To explore health as a potential transmission channel, we use data from the 2019 Population Census and focus on individuals born after 1980 who co-resided with a parent from the baseline cohort. Table 9 examines whether parental health disabilities help explain heterogeneity in intergenerational effects. The results point to an important role for parental health in shaping children’s educational outcomes. Among children whose resident parent from the baseline cohort reports physical difficulties—either alone or in combination with cognitive impairments—higher district-level exposure is associated with significantly lower educational attainment (columns 1–4). Point estimates are negative across most specifications, with the exception of the smaller subsample

⁶Our results are robust to restricting the sample to younger cohorts born after 1990, as shown in Table A3.

Table 8: Impact of Agent Orange Exposure on Younger Generation

Cohort	Individuals Born After 1980 with Parents Born 1960-1975					
	All			Stayers		
	Edu	Days worked	Hours worked	Edu	Days worked	Hours worked
Dep. var.	(1)	(2)	(3)	(4)	(5)	(6)
Exposure Score	-0.177 (0.113)	-1.330** (0.526)	-0.172 (0.173)	-0.231* (0.126)	-1.701** (0.672)	-0.209 (0.212)
Age	-0.0204** (0.00906)	0.194*** (0.0248)	0.0496*** (0.00712)	-0.0272** (0.0110)	0.236*** (0.0400)	0.0547*** (0.00999)
Male	-0.303*** (0.0259)	-0.558*** (0.0938)	0.177*** (0.0307)	-0.329*** (0.0282)	-0.577*** (0.102)	0.182*** (0.0328)
Bombs per km^2	0.0101 (0.0335)	0.0914 (0.117)	-0.0505* (0.0306)	0.0120 (0.0368)	0.128 (0.142)	-0.0474 (0.0330)
<i>IV: Maximum distance</i>						
Kleibergen-Paap F stat	16.85	11.95	12.25	15.38	10.02	10.31
Mean of dep. var.	2.53	23.5	7.61	2.52	23.5	7.61
Observations	9,933	17,226	17,276	8,667	14,582	14,623

Notes: Table reports 2SLS estimates of the effect of district-level Agent Orange exposure on education (columns 1, 4), days worked in the past 30 days (columns 2, 5), and hours worked per day (columns 3, 6). Distance to the nearest North Vietnamese army base instruments for commune-level exposure. The sample includes individuals born after 1980 who are children of the baseline cohort (born 1960-1975), restricted to those aged 25+ for education outcomes and 15+ for labor market outcomes. Columns 4-6 further restrict to stayers (individuals in their birth province at survey). All regressions control for commune characteristics (geographic size, population density, number of households, poverty rate) and include province and birth year fixed effects. When using labor market outcomes, we also control for education. Standard errors are clustered at the village (*diaban*) level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

in which parents report cognitive difficulties only. Overall, these findings suggest that intergenerational effects of Agent Orange exposure are more pronounced in families where the exposed parent experienced lasting health impairments, which may have constrained their ability to invest in their children's education.

In contrast, we find no statistically significant effects on children's probability of having worked in the past 30 days across any specification (columns 5–8). Taken together with the stronger educational effects observed conditional on parental disability, these results are consistent with intergenerational transmission operating more strongly through educational outcomes, with weaker or less precisely estimated effects on labor market participation. This pattern aligns with broader evidence that parental health and human capital constraints can transmit disadvantage across generations (Currie and Moretti, 2003).

Table 9: Intergenerational Effects of Agent Orange - Population Census

Cohort Dep. Var.	Born after 1980 with a resident parent born between 1960 to 1975							
	Education				Job past 30 days			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exposure Score	-0.140*** (0.0302)	0.165 (0.176)	-0.279*** (0.0829)	-0.190** (0.0863)	-0.00284 (0.00598)	-0.0877 (0.0758)	-0.00132 (0.0143)	-0.0332 (0.0578)
Age	-0.100*** (0.00663)	-0.138** (0.0596)	-0.0993*** (0.0203)	-0.0613 (0.0381)	-0.00263** (0.00131)	-0.000141 (0.0242)	0.00542 (0.00552)	0.0131 (0.00916)
Male	-0.369*** (0.00414)	-0.347*** (0.0596)	-0.446*** (0.0273)	-0.449*** (0.0260)	0.0203*** (0.00146)	0.0465*** (0.0168)	0.0266*** (0.00497)	0.0273*** (0.00713)
Parent has cognitive difficulty	No	Yes	No	Yes	No	Yes	No	Yes
Parent has physical difficulty	No	No	Yes	Yes	No	No	Yes	Yes
Mean of y	3.16	2.93	3.41	3.22	0.029	0.055	0.0415	0.0586
Observations	415,367	3,434	25,341	14,248	131,682	1,037	7,633	4,166

Notes: This table reports the estimated impact of the exposure score (measured at the district level) on education and health outcomes using population census data for the next generation (individuals born after 1980). The sample is restricted to individuals whose parents (living in the same household) have cognitive or physical disabilities. Columns (1)–(4) report estimates for educational outcomes, while columns (5)–(8) report estimates for labour outcomes. All regressions include controls for individual education and commune-level characteristics, as well as province, birth-year, and survey-year fixed effects. Standard errors are clustered at the village (*diaban*) level. *** p<0.01, ** p<0.05, * p<0.1.

7 Conclusion

This paper shows that exposure to Agent Orange during the Vietnam War had substantial and long-lasting consequences for human capital and economic welfare. Exploiting variation in herbicide exposure driven by proximity to Viet Cong bases, we find that individuals exposed in utero and during early childhood completed fewer years of schooling, supplied less labor, and earned lower incomes decades later. The estimated effects are economically meaningful: affected individuals work fewer days and hours, attain lower levels of education across the distribution, and—absent compensatory migration—experience earnings losses of approximately 27%. These individual-level impacts translate into sizable household income reductions of 10 to 19%, depending on cohort and migration status.

Beyond these direct effects, our findings highlight the persistence and intergenerational transmission of wartime chemical exposure. Individuals from highly exposed areas are significantly less likely to complete secondary education or to receive formal schooling, indicating enduring deficits in human capital formation. Importantly, these disadvantages extend to the next generation. Children of exposed parents work fewer days per month and, particularly in families where parents experience lasting health impairments, attain lower levels of education. Together, these results demonstrate that the economic consequences of herbicide spraying extended well beyond the period of direct exposure and imposed costs across multiple generations of Vietnamese families.

By documenting persistent effects on education, labor supply, earnings, and intergenerational outcomes, this study contributes to the development and labor economics literature on the long-run economic consequences of war. Our findings provide new evidence that wartime chemical exposure reduced human capital accumulation across generations in Vietnam, highlighting a legacy of herbicide use that extends well beyond the period of active conflict. These results stand in contrast to legal and institutional assessments that have historically classified Agent Orange as posing limited harm to humans.⁷

Our findings also have implications for policies aimed at addressing the long-term consequences of wartime chemical exposure in Vietnam. Interventions that expand access to education and healthcare in affected regions may help mitigate the persistence of human capital deficits across

⁷See more at <https://www.vava.org.vn/on-the-lawsuits-against-us-chemical-companies>

generations. In addition, policies that support labor market integration and provide targeted economic assistance to households in exposed areas could reduce the enduring economic disadvantages documented in this study. More broadly, efforts to increase awareness of the lasting effects of Agent Orange and to promote international cooperation for remediation may contribute to narrowing the socio-economic disparities associated with wartime exposure and support long-run economic development.

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Appendix

A1 Variable construction

In this section, we explain how our variables were constructed. First, individual characteristics were derived from the Vietnam Household Living Standards Survey (VHLSS) from 2010 to 2020, which is conducted twice a year. This survey enables us to observe individuals in the surveyed areas and trace the year they moved to their current location, allowing intergenerational analysis in our study. In addition, the data set provides detailed information on education and labor outcomes, including educational attainment (levels and the number of schooling years), the number of working days, and the working hours of each household member during the survey period. For our control variables, commune characteristics include “area (square kilometers)”, “poverty rate”, “number of households”, “population”, and “urban/rural status”, following the existing literature (Le et al., 2022). These variables are sourced from the 2002 Vietnam National Health Survey (VNHS 2002), and therefore serve as contemporary control variables. We also merged our constructed data with district-level bombs per km^2 . This variable captures the intensity of bombings to which each district was exposed, under the assumption that the bombing had no economic impact in Vietnam (Miguel and Roland, 2011).

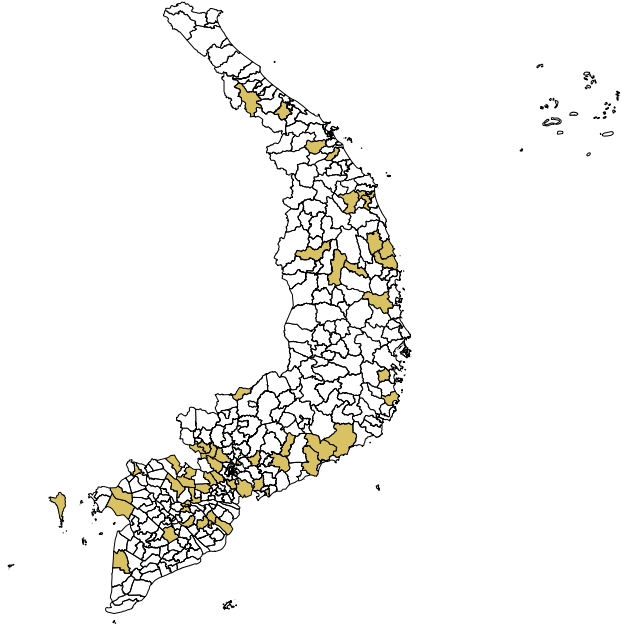
For the exposure score (the main variable), we follow Stellman and Stellman (2004) explanations from the literature. The potential exposure to dioxin at location $A(x_A, y_A)$ from mission i is defined as $\text{Exp Score}_A^i = h_i/d(A, M)$ for *point* releases, where h_i is the spray volume at M and $d(A, M)$ is the distance from A . For *line* releases along a flight path from $M_1(x_1, y_1)$ to $M_2(x_2, y_2)$, the exposure is calculated by integrating the inverse distance along the path, producing a logarithmic expression scaled by $h_i/d(M_1, M_2)$. The total exposure at A is the sum of all missions, $\text{Exp Score}_A = \sum_i \text{Exp Score}_A^i$. To construct exposure at the commune level, Le et al. (2022) aggregate the village-level scores (derived using HES coordinates and wartime populations) within each commune, weighting by village population. In particular, recent studies have matched exposure scores with HAMLET data¹. We retrieved their commune-level exposure index from the study of Le et al. (2022) and aggregated into district level to test the effect of Agent Orange on education and labor outcomes.

To construct the distance to the nearest Viet Cong base, Le et al. (2022) use the locations of NVA bases documented in the Enemy Base Area File (BASFA), 1967–1971, from the U.S. National Archives’ Record Group 330 (declassified). These files compile military reconnaissance data on enemy base areas during the Vietnam and Cambodian Wars and were originally used to support the 1970 U.S.–South Vietnamese invasion of Cambodia². Figure A1 illustrates the distribution of North Vietnamese Army (NVA) bases in the South, which were located in proximity to areas heavily exposed to Agent Orange.

¹A public dataset providing HAMLET names and corresponding exposure scores is available at: <https://www.workerveteranhealth.org/milherbs/new/hes.php>.

²The data is publicly accessible at <https://aad.archives.gov/aad/series-description.jsp?s=4015>.

Figure A1: Distribution of military base



Notes: The map shows the distribution of North Vietnamese Army (NVA) bases, based on the distance to the nearest military installation, adapted from (Le et al., 2022).

To address boundary changes and administrative restructuring, we rely on Le et al. (2022), which provides harmonized commune-level Agent Orange exposure scores. For each VHLSS wave, we follow McCaig and Pavcnik (2015) to build a consistent individual-level panel using revised household and individual identifiers. We correct misclassified matches in the original panel links and harmonize IDs across waves. Individuals are merged across survey rounds based on gender and year of birth to ensure longitudinal consistency within households. Finally, we link individuals to both commune-level and district-level geographic identifiers, allowing us to append external exposure measures and commune characteristics. Furthermore, we use province, district, commune, village, and survey identifiers to merge the VHLSS data with the exposure scores from Le et al. (2022) and the data from Miguel and Roland (2011). As a result, our final sample includes 43,909 individuals from exposed areas, 134,445 individuals from non-exposed areas in the South, and the remaining 266,401 individuals from non-exposed areas in the North.

A2 Additional control variable and fixed effects

In this section, we present a series of exercises to assess the robustness of our main baseline results. An individual’s decision to enter the educational system or the labor market may depend on household income (Mankart and Oikonomou, 2017). Accordingly, Table A1 reports our regression results based on the baseline model, incorporating an additional control for household income and household size. Our main findings remain robust in the instrumented estimates, although the magnitude of the effects is slightly attenuated towards zero. However, we continue to observe that higher levels of exposure scores are associated with a reduction in educational attainment and a lower likelihood of entering the labor market, as reflected in fewer working days and shorter working hours.

Table A1: Robustness of Table 2 (with *household controls*)

Sample	Individuals born between 1960 to 1975					
Dep. Var.	Edu		Days worked		Hours worked	
	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
Exposure score	0.00544 (0.00808)	-0.343*** (0.119)	-0.0630* (0.0338)	-1.610*** (0.491)	-0.0104 (0.0125)	-0.353** (0.159)
Age	0.00734** (0.00360)	0.00826* (0.00442)	0.121*** (0.0164)	0.125*** (0.0201)	-0.00316 (0.00569)	-0.00276 (0.00624)
Male	0.294*** (0.0104)	0.297*** (0.0110)	-0.968*** (0.0633)	-0.965*** (0.0659)	0.501*** (0.0227)	0.502*** (0.0229)
Bombs per km^2	0.0391** (0.0161)	0.0381 (0.0234)	0.0394 (0.0660)	0.0195 (0.112)	-0.0664** (0.0274)	-0.0711* (0.0365)
HH Income	0.00432*** (0.000138)	0.00433*** (0.000148)	0.00846*** (0.000519)	0.00833*** (0.000594)	0.00210*** (0.000185)	0.00207*** (0.000196)
HH Size	-0.118*** (0.00558)	-0.115*** (0.00626)	-0.130*** (0.0267)	-0.115*** (0.0299)	-0.0607*** (0.00906)	-0.0576*** (0.00964)
<i>IV: Maximum distance to base</i>						
Kleibergen-Paap F stat	-	16.93	-	17.05	-	17.41
Mean of dep. var.	1.57	1.57	23.2	23.2	6.96	6.96
Observations	45,126	45,126	40,281	40,281	40,359	40,359

Notes: Table reports the estimated impact of the exposure score (measured at the district level) on education (columns 1 and 2), number of days worked in the past 30 days (columns 3 and 4), and hours worked per day (columns 5 and 6) with additional control variables (household income expressed in thousands and household size). Odd columns report OLS estimates while even columns report the second stage of 2SLS estimates, using the maximum distance to the North Vietnamese army base among all communes at the district level as the instrument for the exposure score to Agent Orange. All regressions include controls for individual education and commune-level characteristics, as well as province and birth year fixed effects. The estimation sample includes individuals born between 1960 to 1975, those who are in-utero or very young at the time Agent Orange was sprayed. Standard errors are clustered at the village (*diaban*) level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

We also conduct an additional robustness test by including (survey) year fixed effects (or province–year fixed effects) in the pooled cross-sectional regressions, as well as incorporating age squared to capture potential nonlinear age effects. The results in Table A2 show the relationship between Agent Orange exposure and labor market outcomes among the 1960–1975 cohort. While the OLS estimates show insignificant association with educational participation, the IV estimates indicate a significant reduction: a one-unit increase in the exposure score lowers completed education by 0.42 units, relative to a mean of 1.57. Individuals from more heavily exposed districts work, on average, 1.71 fewer days per month and roughly 0.39 fewer hours per day, indicating long-term

consequences for both participation and work intensity. Importantly, these findings are robust to the inclusion of age squared and survey year fixed effects, which account for non-linear age patterns and period-specific survey nature. Moreover, the magnitude and significance of the IV coefficients remain unchanged. It confirms the stability of the relationship between exposure and labor market outcomes.

Table A2: Robustness of Table 2 (with *survey-year fixed effects* and *squared term of age*)

Sample	Individuals born between 1960 to 1975					
Dep. Var.	edu		days worked		hrs worked	
	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
Exposure score	0.00630 (0.00962)	-0.422*** (0.134)	-0.0655** (0.0294)	-1.707*** (0.482)	-0.0163 (0.0106)	-0.398** (0.160)
Age	-0.0571* (0.0323)	-0.0541 (0.0355)	0.182 (0.153)	0.208 (0.178)	0.221*** (0.0521)	0.227*** (0.0572)
Age squared	-0.000548** (0.000261)	-0.000649** (0.000259)	-0.00142 (0.00111)	-0.00188 (0.00142)	-0.00244*** (0.000475)	-0.00256*** (0.000479)
Male	0.295*** (0.0113)	0.297*** (0.0119)	-0.960*** (0.0493)	-0.958*** (0.0503)	0.490*** (0.0273)	0.490*** (0.0271)
Bombs per km^2	0.0394** (0.0185)	0.0394* (0.0223)	0.0522 (0.0571)	0.0363 (0.0723)	-0.0675*** (0.0240)	-0.0712** (0.0302)
Mean of dep. var.	1.57	1.57	23.2	23.2	6.96	6.96
Observations	47,987	47,987	42,877	42,877	42,970	42,970

Notes: This paper reports the estimated impact of the exposure score (measured at the district level) on education (columns 1 and 2), number of days worked in the past 30 days (columns 3 and 4), and hours worked per day (columns 5 and 6). Odd columns report OLS estimates while even columns report the second stage of 2SLS estimates, using the distance to the North Vietnamese army base as the instrument for the exposure score to Agent Orange. The estimation sample includes individuals born between 1960 to 1975, those who are in-utero or very young at the time Agent Orange was sprayed. All regressions include controls for commune-level characteristics, as well as province, birth year and VHLSS survey year fixed effects. Standard errors are clustered at the village (*diaban*) level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

A3 Robustness of younger generation analysis

Table A3: Impact of Agent Orange Exposure on Younger Generation

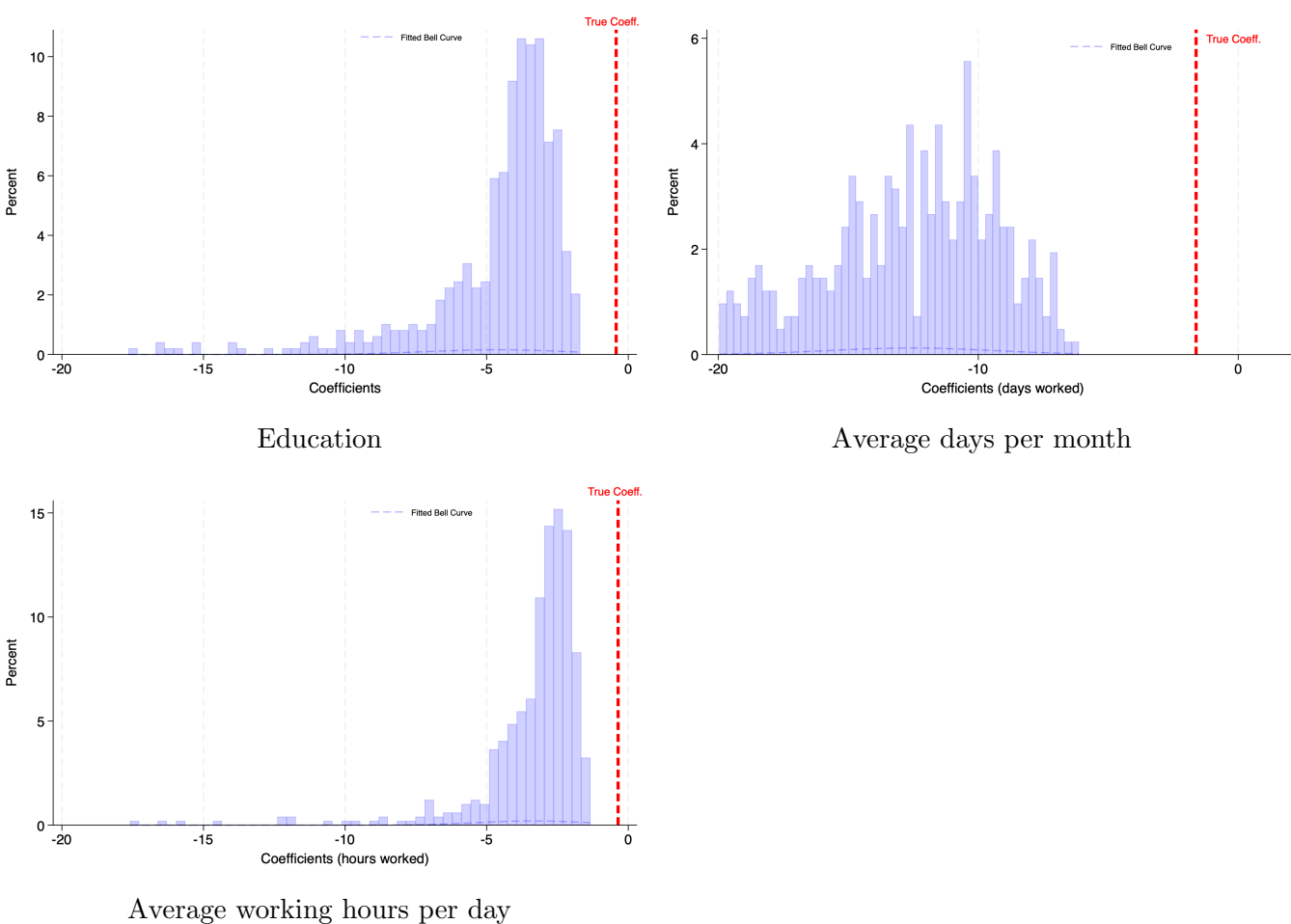
Sample	Children born after 1990s of AO affected Individuals					
	All			Stayers		
Dep. var.	edu	days worked	hrs worked	edu	days worked	hrs worked
Exposure score	-0.213 (0.185)	-1.662** (0.671)	-0.411 (0.252)	-0.268 (0.202)	-1.973** (0.863)	-0.434 (0.325)
Age	-0.0530*** (0.0141)	0.337*** (0.0272)	0.0930*** (0.00900)	-0.0485*** (0.0151)	0.307*** (0.0418)	0.0865*** (0.0116)
Male	-0.380*** (0.0343) (0.0292)	-0.662*** (0.128) (0.130)	0.165*** (0.0440) (0.0422)	-0.399*** (0.0352) (0.0324)	-0.652*** (0.143) (0.149)	0.158*** (0.0517) (0.0438)
Commune controls	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
Birth Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Mean of dep. var.	2.6	23	7.51	2.58	23	7.52
Observations	4,531	15,376	15,420	4,153	13,509	13,548

Notes: Table reports the estimated impact of the exposure score (measured at the district level) on education, number of days worked in the past 30 days, and hours worked per day for the whole sample (the first three columns) and for those who did not move (the last three columns). We report the second stage of 2SLS estimates, using the distance to the North Vietnamese army base as the instrument for the exposure score to Agent Orange. The estimation sample includes individuals born after 1990s of agent orange affected individuals. Standard errors are clustered at the village (*diaban*) level. *** p<0.01, ** p<0.05, * p<0.1.

A4 Placebo test

As a robustness check, we conducted a placebo exercise by randomly redistributing Agent Orange exposure across sprayed areas. We generated 500 placebo exposure variables drawn from a normal distribution using the mean and standard deviation of the observed scores (excluding districts with missing population data), setting values below the 25th percentile to zero and capping those above the 95th percentile. For each iteration, we re-estimated the main regression by replacing the actual exposure score with the placebo variable for education, monthly working days, and daily working hours, while keeping all controls and clustering at the village (*diaban*) level. We then compared the histogram of placebo coefficients with the true coefficient. The true coefficient lies outside the placebo distribution, indicating that the results are unlikely to be driven by chance.

Figure A2: Placebo Treatment Assignment of AO Exposure (50 bins)



A5 Internal migration: adjusted exposure scores

To assess whether migration-induced mismeasurement affects our results, we compare estimates based on exposure at current residence with estimates that adjust exposure for individuals who may have moved after the spraying period. We divided the baseline cohort into two groups using the median exposure score of their current district. For those with below-median exposure, we reassign the maximum provincial exposure; this adjustment mechanically biases the estimate toward zero if current exposure is correct but moves it closer to the true value if individuals migrated. The estimated effect in this group changes from -0.184 (unadjusted) to -0.082 (adjusted). For those with a higher mean exposure, we reassign the minimum provincial exposure; the estimate changes only slightly, from -0.199 to -0.195 , suggesting a limited migration-related error. Using only current residence yields an estimated effect of -0.427 (from our baseline results in Table 2). Taken together, these values bound the plausible true effect on education at roughly -0.139 to -0.44 , with all specifications indicating a negative impact. Our estimated coefficients are reported in Table A4.

Table A4: Impact of Agent Orange Exposure on Education - Migration Adjustment

Sample Dep. Var.	Individuals born between 1960 to 1975			
	Education categories			
	Exposure score < median		Exposure score > median	
	(1)	(2)	(3)	(4)
Adjusted exposure score	-0.0818*** (0.0211)		-0.195*** (0.0502)	
Observed exposure score		-1.847** (0.743)		-0.199*** (0.0531)
Age	-0.104** (0.0486)	-0.145* (0.0847)	-0.0920** (0.0378)	-0.0838** (0.0412)
Age squared	-0.000678** (0.000324)	-0.000636 (0.000589)	-0.000446 (0.000299)	-0.000636** (0.000316)
Male	0.282*** (0.0165)	0.310*** (0.0226)	0.311*** (0.0124)	0.307*** (0.0124)
Bombs per km^2	0.114*** (0.0186)	0.109** (0.0441)	0.0515* (0.0292)	0.0816*** (0.0244)
Commune controls	Yes	Yes	Yes	Yes
Birth Year FE	Yes	Yes	Yes	Yes
VHLSS Year FE	Yes	Yes	Yes	Yes
Mean of dep. var.	1.61	1.61	1.54	1.54
Observations	23,676	23,676	24,311	24,311

Notes: This table reports the estimated impact of Agent Orange exposure on education after adjusting for potential migration-related measurement error. Individuals born between 1960 and 1975 are split into two groups based on whether their current district-level exposure score is below or above the provincial median. For the adjusted specification, individuals below the median are assigned the maximum provincial exposure score, while those above the median are assigned the minimum. Columns 1 and 3 report estimates using the adjusted exposure score; columns 2 and 4 use the observed score from current residence. Standard errors are clustered at the village (*diaban*) level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

A6 Baseline results with 2019 Population Census data

In this section, we re-estimate our baseline results using the 2019 Population Census to examine the effects of Agent Orange on education and labor outcomes, including labor market participation and the skill level of occupations (Table A5). The coefficients are negative and statistically significant at the level of 1%. Consistent with our earlier findings, individuals exposed to Agent Orange are more likely to attain lower levels of education. A potential concern is the validity of our labor outcome measures, such as the number of working days or hours. The Census provides an alternative set of employment indicators, including whether individuals worked in the past 30 days and the sector of employment (high- or low-skill jobs). Using these measures, we again find that those exposed to Agent Orange are less likely to have worked in the last 30 days. In addition, they also exhibit a lower probability of securing employment in high-skill sectors.

Table A5: Population Census - Impact of Agent Orange Exposure

Dep. Var. Cohort	Education		Worked in last 30 days		High Skill Jobs	
	1960-1975	<1960	1960-1975	<1960	1960-1975	<1960
	(1)	(2)	(3)	(4)	(5)	(6)
Exposure score	-0.318*** (0.0426)	-0.307*** (0.0387)	-0.0301*** (0.0109)	-0.000330 (0.00298)	-0.0263*** (0.00481)	-0.0176*** (0.00387)
Age	-0.384*** (0.00553)	-0.327*** (0.00749)	-0.00211 (0.00156)	0.0000559 (0.000402)	-0.0372*** (0.00110)	-0.0170*** (0.00110)
Male	0.344*** (0.00417)	0.595*** (0.00609)	0.0648*** (0.00209)	0.00970*** (0.000502)	0.00748*** (0.000806)	0.0283*** (0.00138)
Bombs per km^2	0.0135* (0.00746)	0.0192*** (0.00584)	0.00337* (0.00189)	0.000902* (0.000527)	-0.00223*** (0.000830)	-0.00106 (0.000841)
Commune controls	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
Birth Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Mean of y	2.74	2.25	0.0533	0.00951	0.0799	0.0393
Observations	598,177	345,736	164,163	253,535	460,469	123,798

Notes: This table reports the estimated impact of the district-level exposure score on education and labour outcomes using the 2019 Population Census, based on 2SLS estimates that instrument exposure with the distance to the nearest North Vietnamese army base. Columns (1) and (2) differ by sub-sample: individuals born between 1960–1975 (who were in utero or very young during the Agent Orange spraying period) and those born before 1965. The same sub-sample structure applies to Columns (3) and (4), as well as Columns (5) and (6). Low-skill sectors include agriculture, basic manufacturing, construction, trade, transport, and personal services. High-skill sectors include high-tech manufacturing, knowledge-intensive services, finance, professional services, and public-sector occupations such as education, health, and science. Standard errors are clustered at the village (*diaban*) level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

In Table A6, we also estimate the effects of exposure to Agent Orange on employment categories. Individuals with higher exposure scores are less likely to participate in the formal labor market as wage earners or business owners. We find no significant effect on self-employment, but those with higher exposure are more likely to engage in unpaid family work. In general, these results complement the findings in Table 6. Taken together, analyses from two independent datasets—the Vietnam Household Living Standards Survey and the 2019 Population Census—converge on the same conclusion: people living in areas more heavily exposed to Agent Orange are more likely to

participate in lower-skill informal labor.

Table A6: Population Census - Impact of Agent Orange Exposure on Employment Type

Sample	Baseline cohort (1960 to 1975)			
	Wage Earner	Owner	Self Employment	Unpaid Family
	(1)	(2)	(3)	(4)
Exposure Score	-0.0384*** (0.00673)	-0.00259* (0.00141)	0.00879 (0.00732)	0.0461*** (0.00746)
Age	-0.0211*** (0.00128)	-0.00340*** (0.000375)	0.000553 (0.00111)	0.00675*** (0.00111)
Male	0.129*** (0.00146)	0.0154*** (0.000435)	0.134*** (0.00299)	-0.0914*** (0.00324)
Bombs per km^2	-0.00311*** (0.00113)	-0.000123 (0.000328)	0.00472*** (0.00131)	0.00310* (0.00165)
Commune controls	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Birth Year FE	Yes	Yes	Yes	Yes
Mean of y	0.2300	0.0183	0.3630	0.1380
Observations	623,422	623,422	623,422	623,422

Notes: This table reports the estimated impact of the district-level exposure score on employment-type outcomes using the 2019 Population Census, based on 2SLS estimates that instrument exposure with the distance to the nearest North Vietnamese army base. The dependent variable in Column (1) is a dummy indicating whether an individual is a wage earner (1) or not (0). Columns (2), (3), and (4) correspond to indicators for being a business owner, self-employed worker, and unpaid family worker, respectively. Standard errors are clustered at the village (*diaban*) level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

A7 Regional characteristics and Agent Orange exposure

Adding these variables as controls may constitute “bad controls,” given the potential correlation between the control variables and the main variable of interest (Agent Orange exposure). In Table A7, we show that the socioeconomic characteristics used as controls have no predictive power for the exposure score, alleviating concerns about bias arising from conditioning on post-treatment or endogenous variables.

Table A7: Regional Characteristics and Agent Orange Exposure

	(1)	(2)	(3)
	Exposure Score	Exposure Score	Exposure Score
Distance to Army Base (km)	-0.0544*** (0.00952)	-0.0545*** (0.0103)	-0.0545*** (0.0103)
Area (km^2)		0.00204 (0.00409)	0.00204 (0.00409)
Poverty rate (VNHS 2002)		-1.641 (1.268)	-1.641 (1.268)
Number of households (VNHS 2002)		0.000525 (0.000593)	0.000525 (0.000593)
Population density (VNHS 2002)		-0.0000952 (0.000120)	-0.0000952 (0.000120)
Total Bombs per (km^2)		-0.00351 (0.168)	-0.00351 (0.168)
Constant	3.276*** (0.258)	3.271*** (0.438)	3.271*** (0.438)
Mean of dep. var.	2.15	2.15	2.15
Observations	232	232	232
R-squared	0.107	0.121	0.121

Notes: The table reports the correlations between Agent Orange exposure scores and socioeconomic characteristics of Vietnamese districts (aggregated from commune levels), including poverty rate, the number of households, the population density, the total of bombs per kilometer squared (in 2002 from [Le et al. \(2022\)](#)). Robust standard errors are in parenthesis level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

A8 Validity of the Instrumental Variables Strategy

A8.1 First Stage Estimations

Table A8: First-Stage Estimates: Distance and Agent Orange Exposure

Dep. Var.	Agent Orange Exposure Score				
	(1)	(2)	(3)	(4)	(5)
Proximity to NVA base (km)	-0.0139*** (0.00396)	-0.0140*** (0.00404)	-0.0175*** (0.00390)	-0.0175*** (0.00408)	-0.0175*** (0.00407)
Commune Bombing Intensity	No	Yes	Yes	Yes	Yes
Commune Controls (District Averages)	No	No	Yes	Yes	Yes
Individual Controls	No	No	No	Yes	Yes
Birth Year FE	No	No	No	No	Yes
Mean of dep. var.	2.24	2.24	2.24	2.26	2.26
Observations	56,761	56,761	56,761	47,987	47,987
R-squared	0.394	0.394	0.416	0.414	0.414

Notes: This table reports first-stage estimates of the effect of distance to the nearest military base on Agent Orange exposure score. The dependent variable is the average Agent Orange exposure intensity across communes at the district level. All columns include province fixed effects. Column (2) adds commune bombing intensity during the war. Column (3) adds commune-level controls measured as district averages. Column (4) adds individual-level controls (age, gender, education). Column (5) adds birth year fixed effects. Standard errors clustered at the village level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

A8.2 Instrument exogeneity: geography and development

One might argue that the location of the bases of the Northern Vietnamese Army was not random but was systematically chosen in rural or mountainous areas characterised by difficult terrain, limited cultivable land, and poor access to transportation. If such areas were inherently less developed or faced structural geographic disadvantages, then long-term economic outcomes could be driven by these preexisting conditions rather than exposure to herbicide spraying. In addition, subsequent government development programmes may have disproportionately targeted regions surrounding former army bases, introducing policy-driven effects distinct from wartime exposure.

To address this concern, we used district-level data from the pre-spraying period (late 1950s–early 1960s), drawn from Miguel and Roland (2011), covering population density, cultivated land, and other indicators. In particular, the HAMPLA/HES “development score” comes from the Hamlet Evaluation System, an administrative tool used by US and South Vietnamese authorities between 1967 and 1973 to assess progress in pacification and rural development during the Vietnam War³. In the HAMPLA phase (1967–1969), the system calculated and aggregated monthly and quarterly data at the town and village levels, covering factors such as security conditions, infrastructure, economic activity, population loyalty, and government control. These components were then combined into a composite index, often ranging from 0 to 500, intended to measure a town’s level of “revolutionary development” or how effectively it was brought under government influence. In research,

³See more details at <https://www.cia.gov/readingroom/docs/CIA-RDP80R01720R000200120001-2.pdf>

this development score is commonly used as an indicator of wartime governance, modernisation, or pacification, helping scholars to analyse the relationship between conflict intensity, state presence, and long-term socioeconomic outcomes. This index has been widely used in current academic research (Kalyvas and Kocher, 2009; Miguel and Roland, 2011).

In Table A9, we test whether the distance to the nearest army base correlates with these pre-existing characteristics and find no significant associations, suggesting that base placement was not driven by economic or demographic conditions. We also include geographic factors, elevation and district area, to assess whether bases were located in remote or challenging terrain, and again find imprecisely estimated coefficients. In general, the evidence indicates that the base locations were not selected based on underdevelopment or terrain, supporting the view that our instrument reflects exogenous variation in herbicide exposure rather than differences in baseline conditions or subsequent intervention.

Table A9: Pre-War regional characteristics and distance to army base

	Exposure Score		Distance to Army Base (km)	
	(1)	(2)	(3)	(4)
Distance to Army Base (km)	-0.0544*** (0.00952)			
HAMLA Development Score		-0.00311 (0.00562)	-0.00458 (0.00683)	-0.00458 (0.00667)
Population density 1959		-0.0000536 (0.0000445)	0.000591 (0.00310)	-0.000283 (0.00338)
Paddy Area 1959			0.0000633 (0.0000939)	0.0000449 (0.0000987)
Female Height 1956			-0.177 (0.506)	-0.0616 (0.532)
Male Height 1956			-0.381 (0.712)	-0.398 (0.707)
Elevation (m)			0.00740 (0.00551)	0.00706 (0.00561)
Area (km^2)			0.00659 (0.0431)	0.00685 (0.0436)
Total Bombs per km^2				-0.0101 (0.00843)
Mean of dep. var.	2.15	19.8	19.6	19.6
Observations	232	203	191	191
R-squared	0.107	0.001	0.029	0.035

Notes: The table reports the correlations between distance to the nearest army base and several pre-1960 socioeconomic characteristics of Vietnamese provinces, including the share of land under paddy cultivation, average height of females and males, population density, elevation, and the district area (in 1960 from Miguel and Roland (2011)). All variables are measured prior to 1960 to mitigate concerns of endogeneity arising from post-conflict developments. Robust standard errors are in parenthesis (at the village *diaban*) level. *** p<0.01, ** p<0.05, * p<0.1.

A8.3 Sensitivity to violations of the exclusion restriction

While the balance tests support the plausibility of the exclusion restriction, we cannot definitively rule out that distance affects outcomes through channels other than Agent Orange exposure. To assess robustness to such violations, we implement two complementary sensitivity analyses following Conley et al. (2012) and Ban and Kedagni (2022). Both approaches parameterize violations using Γ , representing the maximum direct effect as a percentage of the reduced form effect (e.g., $\Gamma = 0.30$ allows direct effects up to 30% as large as the total reduced form). The Conley et al. approach provides point estimates under violations; the Ban-Kedagni approach constructs identified sets (bounds). Table A10 reports the maximum Γ at which effects remain statistically significant under each approach, with corresponding effect ranges and confidence intervals. For Ban-Kedagni, confidence regions are constructed via clustered bootstrap (1,000 replications at the village level).

Table A10: Robustness to Violations of Exclusion Restriction

Outcome	Baseline IV (95% CI)	Conley et al. (2012)		Ban and Kedagni (2022)	
		Robust to Violation	Range at Max Violation	Robust to Violation	Bounds at Max Violation
Panel A: Education					
	-0.427*** [-0.692, -0.163]	±30%	[-0.551, -0.297] (at 30%)	≥50%	[-0.635, -0.212] CI: [-1.214, -0.116]
Panel B: Days Worked					
	-1.711*** [-2.677, -0.744]	±40%	[-2.282, -0.978] (at 40%)	30%	[-2.119, -1.141] CI: [-3.805, -0.662]
Panel C: Hours Worked					
	-0.398** [-0.714, -0.083]	±20%	[-0.535, -0.357] (at 20%)	40%	[-0.624, -0.267] CI: [-1.226, -0.118]

Notes: This table presents two complementary robustness analyses for violations of the exclusion restriction. Violation levels represent the maximum direct effect of distance to military base as a percentage of the reduced form effect. The Conley et al. (2012) column shows the maximum violation level where point estimates remain statistically significant at the 5% level, with the corresponding effect range at that violation level. The Ban and Kedagni (2022) column shows the maximum violation where the 95% confidence region for the identified set excludes zero, with point bounds and confidence intervals (CI) reported at that violation level. Confidence regions constructed via clustered bootstrap with 1,000 replications at the village level. All specifications include district fixed effects and baseline controls. Standard errors clustered at the village level. ** $p < 0.05$, *** $p < 0.01$.

A9 Alternative IV

One might argue that the previous instrumental variable, constructed using the maximum distance among all communes c in district d , is overly conservative in capturing the effects. In this section, we instead use the average distance across all communes c in district d to examine the impact of Agent Orange on educational and labor outcomes. Table A11 reports the baseline results corresponding to Table 2. The estimated coefficients are precisely estimated and indicate negative effects of Agent Orange exposure on education and on the number of working days (and hours). Tables A12 and A13 also show findings that are consistent with the previously estimated coefficients reported in Tables 4 and 8, respectively.

Table A11: Table 2 Robustness - Alternative Instrument (Average Distance)

Sample Dep. Var.	Individuals born between 1960 to 1975					
	Edu		Days worked		Hours worked	
	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
Exposure score	0.00649 (0.00856)	-0.373*** (0.0872)	-0.0654* (0.0334)	-1.468*** (0.321)	-0.0162 (0.0122)	-0.329*** (0.108)
Age	-0.00481 (0.00325)	-0.00442 (0.00403)	0.0738*** (0.0141)	0.0756*** (0.0168)	-0.0144*** (0.00481)	-0.0143*** (0.00518)
Male	0.292*** (0.0104)	0.294*** (0.0111)	-0.960*** (0.0612)	-0.958*** (0.0632)	0.491*** (0.0220)	0.492*** (0.0222)
Bombs per km^2	0.0404** (0.0175)	0.0404 (0.0251)	0.0532 (0.0663)	0.0398 (0.103)	-0.0666** (0.0277)	-0.0697** (0.0354)
<i>IV: Average distance to base</i>						
Kleibergen-Paap F stat	-	35.47	-	36.32	-	36.74
Mean of dep. var.	1.57	1.57	23.2	23.2	6.96	6.96
Observations	47,987	47,987	42,877	42,877	42,970	42,970

Notes: Table reports the estimated impact of the exposure score (measured at the district level) on education (columns 1 and 2), number of days worked in the past 30 days (columns 3 and 4), and hours worked per day (columns 5 and 6). Odd columns report OLS estimates while even columns report the second stage of 2SLS estimates, using the average distance of communes to the North Vietnamese army base as the instrument for the exposure score to Agent Orange. The estimation sample includes individuals born between 1960 to 1975, those who are in-utero or very young at the time Agent Orange was sprayed. All regressions include controls for commune-level characteristics (including geographic size, population density, number of households and poverty rate), as well as province and birth year fixed effects. Standard errors are clustered at the village (*diaban*) level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A12: Impact of Agent Orange Exposure on Income - Alternative IV (Average Distance)

Dep. var. Cohort	Household Income			Labor Income		
	Before 1960	Born 1960 to 1975		Before 1960	Born 1960 to 1975	
	All (1)	All (2)	Stayers (3)	All (4)	All (5)	Stayers (6)
Exposure score	-15303.6*** (4535.0)	-14321.0*** (4015.4)	-10792.3*** (2704.3)	-756.5 (749.6)	-760.3 (530.8)	-1455.3** (588.0)
Age	-6068.5*** (347.9)	-3735.9*** (310.3)	4642.8*** (312.2)	305.6*** (61.38)	470.6*** (41.27)	526.8*** (84.95)
Male	6604.3*** (592.5) (5.418)	2990.3*** (412.1) (4.710)	1784.9*** (438.9) (4.893)	2604.1*** (388.8) (1.278)	2749.0*** (206.4) (1.187)	3095.3*** (262.7) (1.659)
Bombs per km^2 .	-1314.6 (1282.8)	-384.2 (1142.2)	366.0 (1013.0)	-395.6* (234.5)	146.7 (174.5)	254.8 (210.9)
Days worked	No	No	No	Yes	Yes	Yes
Hours worked	No	No	No	Yes	Yes	Yes
<i>IV: Average distance</i>						
Kleibergen-Paap F stat	33.01	38.31	65.67	14.26	29.09	30.65
Mean of dep. var.	97,419	111,771	100,585	6,624	8,446	8,672
Observations	36,466	53,700	39,389	7,48	3,420	2,311

Notes: Table reports the 2SLS estimated impact of the exposure score (measured at the district level) on either household income (columns 1 to 3) or individual labor income (columns 4 to 6). Households that did not move province are "stayer" households. We instrument the district-level exposure score with the average distance to the nearest North Vietnamese army base among communes within the district. All regressions include controls for commune-level characteristics (including geographic size, population density, number of households and poverty rate), as well as province and birth year fixed effects. Clustered standard errors at the village (*diaban*) level. *** p<0.01, ** p<0.05, * p<0.1.

Table A13: Intergenerational Impacts of Agent Orange - Alternative IV (Average Distance)

Cohort	Individuals Born After 1980 with Parents Born 1960-1975					
	All			Stayers		
Dep. var.	Edu	Days worked	Hours worked	Edu	Days worked	Hours worked
	(1)	(2)	(3)	(4)	(5)	(6)
Exposure Score	-0.252*** (0.0925)	-1.234*** (0.376)	-0.134 (0.130)	-0.297*** (0.103)	-1.548*** (0.454)	-0.131 (0.152)
Age	-0.0205** (0.00933)	0.194*** (0.0244)	0.0498*** (0.00702)	-0.0268** (0.0114)	0.236*** (0.0387)	0.0548*** (0.00970)
Male	-0.302*** (0.0263)	-0.562*** (0.0917)	0.176*** (0.0302)	-0.330*** (0.0286)	-0.581*** (0.0998)	0.179*** (0.0323)
Bombs per km^2	0.0122 (0.0366)	0.0885 (0.112)	-0.0514* (0.0290)	0.0140 (0.0400)	0.123 (0.132)	-0.0498* (0.0295)
<i>IV: Average distance to base</i>						
Kleibergen-Paap F stat	29.49	23.51	23.65	26.53	20.08	20.30
Mean of dep. var.	2.53	23.5	7.61	2.52	23.5	7.61
Observations	9,933	17,226	17,276	8,667	14,582	14,623

Notes: Table reports 2SLS estimates of the effect of district-level Agent Orange exposure on education (columns 1, 4), days worked in the past 30 days (columns 2, 5), and hours worked per day (columns 3, 6). Distance to the nearest North Vietnamese army base instruments for commune-level exposure. The sample includes individuals born after 1980 who are children of the baseline cohort (born 1960-1975), restricted to those aged 25+ for education outcomes and 15+ for labor market outcomes. Columns 4-6 further restrict to stayers (individuals in their birth province at survey). We instrument the district-level exposure score with the average distance to the nearest North Vietnamese army base among communes within the district. All regressions control for commune characteristics (geographic size, population density, number of households, poverty rate) and include province and birth year fixed effects. Standard errors are clustered at the village (*diaban*) level. *** p<0.01, ** p<0.05, * p<0.1.