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The Unseen Pain of the Vietnam War: Long Term Effects of Agent Orange on Labor Market Outcomes

CGR Working Paper 120

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Keywords: Agent Orange; education; labour outcomes; Vietnam

JEL Classification: N45; J21; O15; I21

CGR WORKING PAPER SERIES

The Unseen Pain of the Vietnam War: Long Term Effects of Agent Orange on Labor Market Outcomes*

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April 6, 2025

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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. We thank Viet Cuong Nguyen for helpful comments and suggestions. We are also grateful for Long (Tom) Hoang, Hoang Duy Khanh Dang to provide 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). To make matters worse, many of these wars persist for extended periods of time in the contemporary world, as exemplified by the Russia-Ukraine war and the Israel-Hamas conflict. These events not only devastate the well being of individuals affected, but also heighten and prolong global economic uncertainty. Historically, bombing and other war shocks in Germany have been shown to cause persistent declines in wealth (Halbmeier and Schröder, 2024), reductions in human and physical capital (Waldinger, 2016), adverse health effects, and worsening of labor market outcomes (Akbulut-Yuksel, 2014). In contrast, empirical evidence is mixed on the effects of the war in Vietnam, which endured the most intense aerial bombing campaign in human history.

District-level data on local poverty rates, infrastructure development, literacy levels, and population density through 2002 were used to show that the Vietnam War did not have negative impacts in the long run (Miguel and Roland, 2011). A possible explanation lies in the rebuilding efforts of the Vietnamese government to neutralize the damages from bombing on infrastructure and the natural landscape. However, little is known about the long-run effects of Agent Orange on socioeconomic outcomes at the individual level, which has important policy implications.

In this paper, we examine the causal effects of early childhood exposure to Agent Orange on labor market outcomes. To our knowledge, our study is one of the first to investigate this question using individual level data, allowing us to compare the impact of Agent Orange on households who chose to stay in their birth places or relocate to other areas. We combine spatial data of herbicide spraying based on historical records with individual level data from the national household living standard survey. To address endogeneity concerns of the exposure locations due to strategic military operations, we follow the literature in using the proximity of Vietnamese communes in the South to the Viet Cong military bases in the North as an instrumental variable for Agent Orange intensity.

Our main result is that Agent Orange negatively affects labor market participation among the affected cohorts. On average, affected individuals work 1.7 days fewer per month and 0.4 hours less per day, translating into a reduction of 25% lower labor income. We show that a key channel underlying these results is the reduction in human capital accumulation. Specifically,

affected individuals in high exposure areas are more likely to have no education or less likely to have higher education. We also present evidence of intergenerational transmission of these effects, particularly on educational outcomes and the labor market integration among the children of exposed individuals, who were born decades after the War.

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 issues (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 who were exposed in-utero, during early childhood, and among ethnic minority women in high-exposure areas. Building on this extensive body of research, our findings demonstrate that in addition to health, affected individuals have lower human capital accumulation and weaker labor market attachment. 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 rebuilding 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 using micro-level data to show that affected families experience lower incomes, higher medical expenses, and diminished educational and social opportunities relative 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 to similar research on labor market attachment. By examining a program that provided disability benefits to Vietnam War veterans, Autor et al. (2016) demonstrate that increased financial support led to an 18 percentage point reduction in labor force participation, likely due to the disincentives to work and compensation

for income lost from significant disabilities. 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 weaker labor market attachment as adults. Our analysis underscore the possibility of underestimating 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 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 before presenting the main results. To explore potential mechanisms, Section 5 examines how Agent Orange exposure influenced educational and labor outcomes, focusing on disparities in educational attainment and intergenerational effects. Finally, Section 6 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 17^{th} 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. Stellman 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.

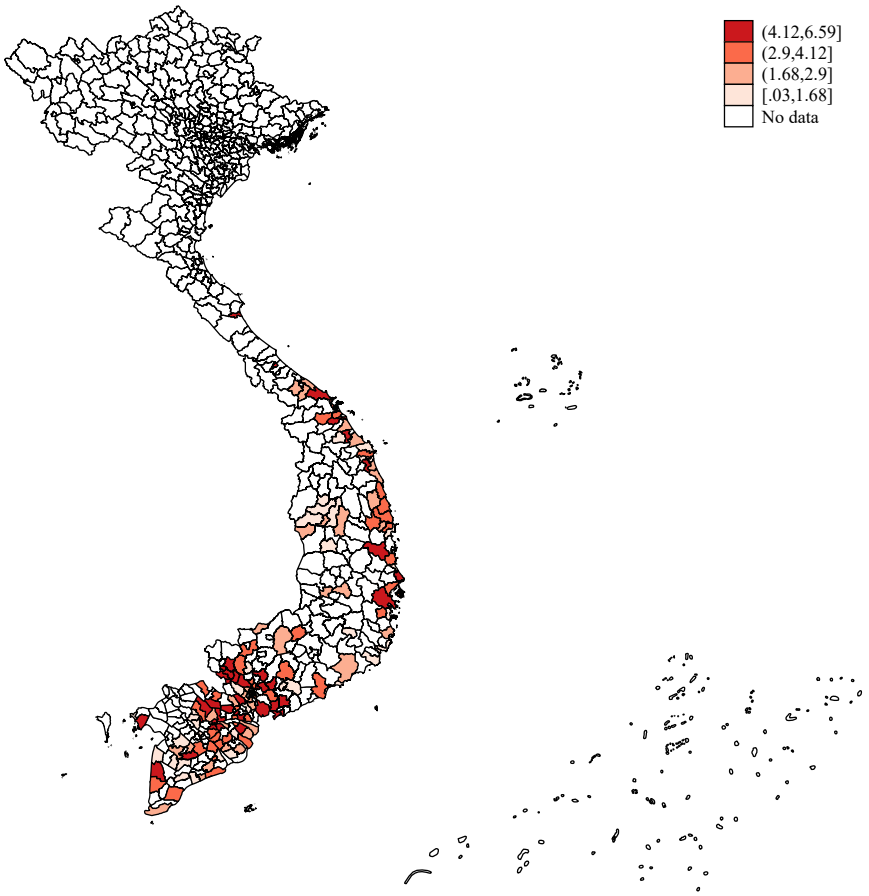
The herbicides contained dioxin, a highly toxic substance that exposes up to 4.8 million civilians to levels far exceeding the tolerable daily intake of the World Health Organisation (Le et al., 2022). According to the Ministry of National Defence of the Socialist Republic of Vietnam [1], an estimated 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 remain 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.

The US Department of Veterans Affairs links direct exposure to military herbicides during the war to diseases like prostate cancer, respiratory cancers, chronic B-cell leukemia, diabetes, Parkinson's disease, and peripheral neuropathy[2]. 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

[1] See more at https://mod.gov.vn/en/intro/sa-en-other/sa-en-other-org/sa-en-other-org-dioxin/sa-en-other-org-dioxin-chemical/9a5f1261-eb8f-4514-89da-dbdf00789416, accessed on 25^{th} November 2024.

[2] See more at https://www.va.gov/disability/eligibility/hazardous-materials-exposure/agent-orange/, accessed on 25^{th} November 2024.

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 with no recorded data are represented in white.

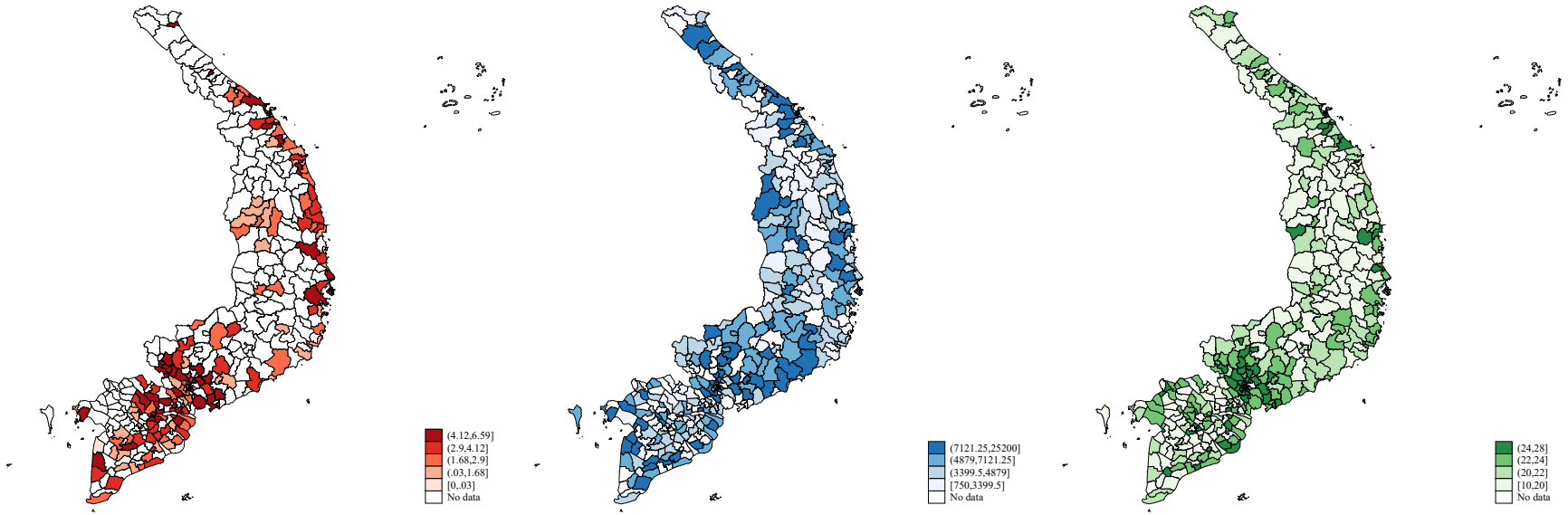
and third generations (Le et al., 2022; Palmer, 2005; Yamashita and Trinh, 2022).

3 Data

The primary data for our analysis are 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 commune and 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 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.

Figure 2: Distribution of herbicide exposure scores and economic outcomes by district



Herbicide spraying | Average income | Average working days

Notes: The figure presents the distribution of herbicide exposure and economic outcomes (average income and average working days) across districts in Vietnam. The first map shows the intensity of herbicide spraying, while the second and third maps depict average income and average working days, respectively. Darker colors indicate higher levels for each variable. These figures highlight regional disparities in herbicide exposure, 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 areas. The second map shows the average income levels by district, with higher incomes generally concentrated in urban and industrial areas 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.

Table 1 presents the descriptive statistics for the variables of interest, comparing individuals from non-exposed and exposed areas. On average, people in exposed areas of southern Vietnam work more days per month than those in non-exposed areas. However, while individuals in exposed areas work more days, their average working hours per day are slightly higher compared to their non-exposed counterparts. In terms of education, individuals in exposed areas tend to achieve higher educational levels. To be more specific, the proportion of people who attain university or high school education is higher in exposed areas compared to non-exposed areas. This finding suggests that despite the adverse impacts of Agent Orange, there might be compensatory mechanisms, such as a greater focus on education in affected areas. These differences in educational outcomes are statistically significant at the level 5%. At the commune level, exposed areas tend to have smaller land areas, higher population density, and greater proximity to the bases of the North Army. In addition, the intensity of the bombing is considerably higher in the exposed areas, underscoring the direct historical impact of the conflict in these regions. The poverty rate is also significantly higher in exposed communes, reflecting the long-term socioeconomic consequences of exposure.

4 Empirical Strategy and Results

4.1 Estimation strategies

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

$$Y_{icdt} = \alpha + \beta_1 Exposure\ score_{icdt} + \theta \mathbb{X}_{it} + \gamma \Gamma_c + \xi \Xi + \lambda \Lambda + \varepsilon_{icdt}, \tag{1}$$

In which, Y_{icdt} represents the dependent variable of interest for individual i in commune c, within

Table 1: Descriptive Statistics

	South			North
	No exposure	Some exposure	*p-value*	No exposure
	(1)	(2)	(3)	(4)
Individual characteristics				
Age	44.20	44.38	0.041	44.05
Male	0.48	0.48	0.198	0.48
Days worked per month	22.51	22.96	<0.001	21.43
Hours worked per day	7.11	7.03	<0.001	6.96
No education	0.17	0.16	<0.001	0.10
Up to secondary school	0.42	0.43	<0.001	0.44
High school	0.16	0.17	<0.001	0.21
University	0.07	0.08	<0.001	0.08
Years of schooling	7.10	7.32	<0.001	8.52
Commune characteristics				
Area (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)	24.56	20.62	<0.001	-
Number of individuals	43,909	134,445	-	266,401
Number of communes	66	166	-	

Notes: The table reports the average characteristics of individuals living in Southern communes without exposure scores (column 1), Southern communes with exposure scores (column 2), and Northern communes (column 4). Column 3 reports the p-values of the hypotheses that the mean characteristic of individuals or communes in column 1 is equal to the mean outcome of individuals or communes in column 2.

district d, at time t (across six survey waves spanning from 2010 to 2020). The variable $Exposure\ score_c$, derived from Le et al. (2022); Stellman et al. (2003b); Stellman and Stellman (2004), captures the herbicide exposure index for commune c in district d, reflecting the cumulative exposure an individual has experienced over their lifetime. The vector $\mathbb{X}_{icdt}$ includes individual characteristics for i, such as age and gender, for each survey wave. Furthermore, Γ_c represents the vector of control variables at the commune 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, X_i and Λ, representing fixed effects of the cohort and province, respectively.

The standard errors in all regressions are clustered at the commune level to account for potential correlations in the individual error terms within each commune. ε_{icdt} is an error term.

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. 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 proximity of the identified commune to a Northern Vietnamese Army base. 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 the study by 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:

$$Exposure\ score_{icdt} = \beta_0 + \beta_1 Nearest\ distance\ to\ military\ base_c + \gamma\Gamma_c + \xi\Xi + \lambda\Lambda + \varepsilon_{icdt}, \quad (2)$$

In our empirical setting, we control for the characteristics of the commune, which include the total area of district land (km^2), the poverty rate, the number of households (per commune), the population, and the intensity of the explosions, in the first stage of the equation (2). The variable $Nearest\ distance\ to\ military\ base_c$ represents the proximity of commune c to the closest North Vietnamese military base. 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 Results

Our main objective in the paper is to examine the long-term labor market outcomes of early childhood exposure to Agent Orange. Table 2 presents our estimation on the baseline cohort, individuals born between 1960 and 1975, since they would have been exposed to the spraying of Agent Orange in-utero and during their early childhood years. Table 2 shows that the IV estimates (even columns) are smaller than the OLS coefficients (odd columns), suggesting that there is an upward bias if we use the commune-level exposure score itself as the measure of exposure. Using the closest distance to the northern Vietnam military base as an instrument, we are able to isolate the parts of commune-level exposure to Agent Orange that are plausibly exogenous to commune and individual characteristics. In columns (1) and (2), we show that individuals who are born to mothers living in communes with higher Agent Orange exposure end up with lower levels of completed education.[3]

We also examine whether exposure to Agent Orange as a child has long-term consequences for participation in the labor market. In Table 2, columns (3) and (4) show that individuals work 1.7 fewer days per month for an additional unit increase in the exposure score in the communes where their mother lived. In line with this finding, we also find that these individuals work 0.4 hours less per day for a one-unit higher exposure score. 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 contribute to lower education attainment and weaker labor market attachments of the affected cohorts. In particular, exposure to Agent Orange could result in less education due to its effects on health, which has been documented among Vietnamese and US veteran soldiers (Autor et al., 2016; Le et al., 2022). 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 ensure that our previous results did not occur by chance, leading to significant coefficients,

[3]Our education measure is categorical, with a higher number indicating more years of education.

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

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	0.00649	-0.427***	-0.0654**	-1.711***	-0.0162	-0.398**
	(0.00963)	(0.134)	(0.0294)	(0.485)	(0.0109)	(0.162)
Age	-0.00481	-0.00437	0.0738***	0.0759***	-0.0144***	-0.0143**
	(0.00325)	(0.00319)	(0.00912)	(0.0122)	(0.00537)	(0.00575)
Male	0.292***	0.295***	-0.960***	-0.958***	0.491***	0.492***
	(0.0112)	(0.0117)	(0.0500)	(0.0511)	(0.0274)	(0.0271)
Bombs per km^2	0.0404**	0.0404*	0.0532	0.0374	-0.0666***	-0.0703**
	(0.0186)	(0.0225)	(0.0566)	(0.0721)	(0.0239)	(0.0301)
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.	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
R-squared	0.117		0.076		0.134	

Notes: Table reports the estimated impact of the exposure score (measured at the commune level) on education (columns 1 and 2), number of days worked in the past 30 days (columns 3 and 4), and hours worked per week (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. Standard errors are clustered at the village (*diaban*) level. *** p<0.01, ** p<0.05, * p<0.1.

or an overestimation of the magnitude, we conduct a placebo test by randomly distributing the intensity of exposure to Agent Orange. Subsequently, we re-estimate equation (1) 500 times and plot the resulting coefficients in Figure A1. In summary, in no instance were the coefficients precisely estimated using the randomised Agent Orange levels in this figure. This result suggests that our main findings are unlikely to be driven by a random allocation of Agent Orange intensity.

Next, we show that our findings effects are robust to using other cohorts in Table 3. Focusing on individuals who were born before 1960, we find that exposure to higher amounts of Agent Orange is associated with lower levels of completed education and fewer days worked. The magnitude of the estimated effects are similar to those we find for the baseline cohort, except for hours worked (column 3). Next, we isolate the non-movers in our baseline cohort, that is, individuals who were living in their province of birth at the time of the VHLSS survey. Columns (4) to (6) show that, in all our outcomes of interest, exposure to Agent Orange has negative effects. If anything, the estimated coefficients are slightly higher than those reported in Table 2, suggesting the possibility that if an individual is born to a mother who lived in an affected commune and continued to live in the same province, the long-term effects on the outcomes of the labor market are more pronounced.

To understand whether the negative effects of exposure to Agent Orange on participation in the labor market translate into lower income, we repeat the estimation of equation (1) with income as an outcome of interest. We measure income in two ways. First, we calculate household income as the sum of profits generated from various agricultural activities, including rice, crops, and fruit trees with all related costs associated with these activities, along with additional expenses such as losses incurred from natural disasters subtracted. Second, we use the reported salary to measure labor income at the individual level.

Table 4 shows that in terms of household income, all households living in communes with higher exposure scores do worse than less exposed localities. Controlling for commune characteristics and province fixed effects, our estimated effects are robust to inherent variation in underlying economic circumstances that affect household income across communes. Comparing columns (1) and (2), we show that households with at least one member in the affected cohort (born between 1960 and 1975) perform worse than households without these individuals, pointing to factors beyond lower agricultural productivity and soil contamination through Agent Orange that might be responsible for lower agricultural gains. We conjecture that these factors include medical spending on the

Table 3: Impact of Agent Orange Exposure - Robustness

Sample	Old cohorts (Born before 1960)			Non-movers in affected cohort		
Dep. var.	edu	days worked	hrs worked	edu	days worked	hrs worked
	(1)	(2)	(3)	(4)	(5)	(6)
Exposure score	-0.444***	-1.357**	-0.352	-0.164**	-1.097***	-0.398***
	(0.156)	(0.559)	(0.234)	(0.0673)	(0.267)	(0.120)
Age	-0.00665	0.0456*	-0.0739***	-0.00843*	0.118***	0.00547
	(0.00502)	(0.0254)	(0.00732)	(0.00504)	(0.0258)	(0.00933)
Male	0.558***	-1.110***	0.460***	0.287***	-0.934***	0.561***
	(0.0146)	(0.112)	(0.0304)	(0.0125)	(0.0652)	(0.0253)
Bombs per km^2	0.0280	0.152	-0.0628*	0.0527**	0.0581	-0.0480
	(0.0196)	(0.129)	(0.0366)	(0.0215)	(0.0690)	(0.0366)
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.	1.1	21.6	5.59	1.46	23	6.81
Observations	31,709	20,065	20,469	32,904	35,101	35,195

Notes: Table reports the 2SLS estimates of the impact of the exposure score (measured at the commune level) on education (columns 1 and 4), number of days worked in the past 30 days (columns 2 and 5), and hours worked per week (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 esitmation 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. Standard errors are clustered at the village (*diaban*) level. *** p<0.01, ** p<0.05, * p<0.1.

affected household member in place of time and investment spent on agricultural activities. In terms of individual labor income, we find that people living in communes with higher or lower exposure scores but not born during the years when Agent Orange was sprayed do not have systematically different levels of income (column 4). Even among individuals in affected cohorts, the labor incomes of those in more exposed communes are not statistically different. Yet, individuals who stayed in their provinces of birth earn about 25% less (about 2,000 VND) per year than the average if their communes have one unit higher exposure score.

Table 4: Impact of Agent Orange Exposure on Income

Dep. var.	Household Income			Labor Income		
		Affected			Affected	
	Unaffected	All	Stayers	Unaffected	All	Stayers
	(1)	(2)	(3)	(4)	(5)	(6)
Exposure score	-9,571.1**	-19,351.4***	-11,343.1***	-1,030.1	-1,137.0	-2,313.9**
	(4,486.4)	(7,271.2)	(3,414.2)	(1,130.2)	(734.3)	(953.4)
Age	-1,231.2***	-1990.9***	-1,663.2***	303.8***	471.0***	554.6***
	(44.09)	(65.35)	(61.32)	(71.75)	(27.28)	(97.78)
Male	20,906.6***	15,926.2***	13,575.3***	2,637.7***	2,752.8***	3,125.6***
	(1826.6)	(2683.8)	(2510.7)	(353.8)	(186.2)	(214.2)
Commune controls	Yes	Yes	Yes	Yes	Yes	Yes
Days worked	No	No	No	Yes	Yes	Yes
Hours worked	No	No	No	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
Birth Year FE	No	No	No	Yes	Yes	Yes
Mean of dep. var.	88,945	108,527	96,724	6,624	8,446	8,672
Observations	28,001	34,014	24,198	748	3,420	2,311

Notes: Table reports the estimated impact of the exposure score (measured at the commune level) on either household income (columns 1 to 3) or individual labor income (columns 4 to 6). The first 3 columns report household-level analysis while the last 3 columns are individual-level estimations. Households that are unaffected by Agent Orange are those without any individual born between 1960 to 1975. Affected households are those with at least one individual born between 1960 to 1975. Affected households that did not move province are "stayers" households. For individual estimations, unaffected individuals are born before 1960. Affected individuals are those born between 1960 to 1975. are Clustered standard errors at the village (*diaban*) level. *** p<0.01, ** p<0.05, * p<0.1.

5 Mechanism

Our main finding so far is that individuals who are exposed to Agent Orange in-utero have lower levels of education and labor market participation. These long term effects translate directly into sizeable income losses. To gain insight into which part of the education distribution does Agent Orange affect, we repeat the estimation of equation (1) on the indicator variables for each level of completed education. Table 5 shows the results. Individuals in more exposed communes are more likely to have no education (column 1), less likely to have completed high school (column 3), university (column 4) and postgraduate education (column 5). To the best of our knowledge, the finding of exposure to Agent Orange having a negative effect on human capital accumulation is novel and has important policy implications. Spraying of the chemical did not only lead to adverse health effects, but also possibly led to cohorts of individuals ending up with lower human capital, stunting the long-term productivity and economic development of Vietnam.

To check whether these long-term adverse effects are intergenerational, we use the detailed questions in VHLSS and identify the children of the affected cohorts. Table 6 shows that the estimation of Equation (1) in the next generation of the affected cohort reveals statistically zero effects on education (column 1), which is somewhat reassuring. However, we find a marginally significant negative effect on education among the children of affected individuals who continue to live in their provinces of birth (column 4). We also find that children of affected individuals who live in more exposed communes work between 1.3 and 1.6 days fewer per month (columns 2 and 5), or 5.6% less than the average. Although we do not find that the negative effects of exposure to Agent Orange on hours among the affected cohort translate into the working hours of their children (columns 3 and 6), it is important to note that the estimated effects on days worked are similar in magnitude (albeit smaller) to those reported in Table 2. Overall, these results highlight the long-term effects of exposure to Agent Orange on multiple generations of Vietnamese families.

6 Conclusion

Drawing on a longitudinal survey of households in Vietnam that spanned nearly a decade from 2010 to 2020, our findings reveal that exposure to Agent Orange significantly reduces years of schooling and participation in the labor market among those affected during the Vietnam War. Our empirical

Table 5: Impact of Agent Orange Exposure and Education Categories

Dep. var. (0/1)	no edu	up to secondary	high sch	university	graduate
	(1)	(2)	(3)	(4)	(5)
Exposure score	0.0557**	0.0339	-0.0582***	-0.0444***	-0.00437*
	(0.0220)	(0.0215)	(0.0205)	(0.0137)	(0.00238)
Age	-0.00599***	-0.0155***	-0.00306***	-0.00202***	-0.000386***
	(0.000673)	(0.00123)	(0.000677)	(0.000436)	(0.000111)
Male	-0.0503***	0.0155***	0.0282***	0.0240***	0.00213***
	(0.00276)	(0.00432)	(0.00321)	(0.00226)	(0.000536)
Bombs per km^2	-0.00960***	-0.00239	0.0108***	-0.00224	0.000545
	(0.00291)	(0.00333)	(0.00318)	(0.00293)	(0.000642)
Commune controls	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes
Birth Year FE	Yes	Yes	Yes	Yes	Yes
Mean of dep. var.	0.1690	0.5070	0.1100	0.0575	0.0026
Observations	56,761	56,761	56761	56,761	56,761

Notes: Table reports the 2SLS estimates of the impact of the exposure score (measured at the commune 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. Standard errors are clustered at the village (*diaban*) level. *** p<0.01, ** p<0.05, * p<0.1.

strategy hinges on the nearest distance to Viet Cong bases as a proxy, as the American military often sprayed this chemical to expose hidden bases. This approach helps isolate the confounding effects of the non-random distribution of Agent Orange and other potential confounders.

Our findings indicate that individuals in exposed areas attain lower levels of education and work approximately 1.7 fewer days per month (and 0.4 fewer hours per day). The effects of Agent Orange are particularly pronounced among those who were born and continued to live in these high-risk areas. Our results remain robust even after controlling for income. Furthermore, we find that the long-term consequences of the war, particularly exposure to Agent Orange, persistently reduce household and labor income by approximately 25%. More notably, our findings highlight the long-term impacts of intergenerational transmission, particularly among individuals born in the 1980s and 1990s. Our results also indicated that people in the exposed areas have lower

Table 6: Impact of Agent Orange Exposure on Younger Generation

Sample	Children born after 1980s of AO affected Individuals					
	All			Non-movers		
Dep. var.	edu	days worked	hrs worked	edu	days worked	hrs worked
	(1)	(2)	(3)	(4)	(5)	(6)
Exposure score	-0.177	-1.305**	-0.281	-0.231*	-1.559**	-0.318
	(0.119)	(0.526)	(0.184)	(0.135)	(0.670)	(0.247)
Age	-0.0204**	0.261***	0.0655***	-0.0272***	0.287***	0.0700***
	(0.00800)	(0.0226)	(0.00786)	(0.00882)	(0.0369)	(0.00952)
Male	-0.303***	-0.617***	0.161***	-0.329***	-0.654***	0.147***
	(0.0248)	(0.102)	(0.0333)	(0.0304)	(0.104)	(0.0377)
Bombs per km^2	0.0101	0.0640	-0.0489*	0.0120	0.103	-0.0359
	(0.0276)	(0.0955)	(0.0283)	(0.0302)	(0.111)	(0.0308)
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.	2.53	23.2	7.55	2.52	23.2	7.56
Observations	9,933	21,511	21,551	8,667	18,280	18,316

Notes: Table reports the estimated impact of the exposure score (measured at the commune level) on education (columns 1 and 4), number of days worked in the past 30 days (columns 2 and 5), and hours worked per week (columns 3 and 6). When using education as the dependent variable, we apply the restriction that individuals must be at lest 25 years of age at the the time of the VHLSS survey to ensure that we observe completed education. When using labor market outcomes as the dependent variables, we apply the restriction that an individual must be at least 15 years of age at the time of the VHLSS survey to ensure eligibility to work. 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 includes individuals who are born after 1980s and are the children of those affected by Agent Orange, defined as those in exposed communes and are born between 1960 and 1975. Columns 4 to 6 further restricts the estimation sample to include individuals who did not move from the province of birth at the time of the VHLSS survey. Standard errors are clustered at the village (*diaban*) level. *** p<0.01, ** p<0.05, * p<0.1.

secondary education or do not receive education. This study extends the contributions in the field of development and labour economics by examining the long-term impacts of war on economic outcomes. We provide empirical evidence that agent orange has visible effects of generations of lower human capital in Vietnam, although the US federal court in New York ruled that Agent Orange, being a herbicide, does not pose any harm to humans[4].

The findings of this study have important policy implications for addressing the long-term con-

[4]See more at https://www.vava.org.vn/on-the-lawsuits-against-us-chemical-companies

sequences of exposure to Agent Orange in Vietnam. Policies should focus on improving access to education and healthcare in affected areas to mitigate the intergenerational impacts of the herbicide. Programmes aimed at improving labour market participation and providing financial support to those in exposed regions could help alleviate the economic disadvantages linked to Agent Orange. Furthermore, initiatives to raise awareness of its persistent effects and secure international cooperation for remediation efforts could contribute to reducing the socio-economic disparities exacerbated by the war. These measures would not only support the recovery of affected communities, but would also foster long-term economic development.

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Appendix

A1 Appendix

A1.1 Additional control variable

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 labour 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. 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 labour market, as reflected in fewer working days and shorter working hours.

Table A1: Robustness of Table 2 (with household income)

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	0.00465	-0.362***	-0.0641**	-1.622***	-0.0109	-0.359**
	(0.00878)	(0.118)	(0.0302)	(0.495)	(0.0111)	(0.164)
Age	0.00964***	0.0106***	0.124***	0.127***	-0.00186	-0.00151
	(0.00359)	(0.00365)	(0.0115)	(0.0140)	(0.00578)	(0.00665)
Male	0.282***	0.285***	-0.992***	-0.986***	0.490***	0.491***
	(0.0110)	(0.0116)	(0.0495)	(0.0503)	(0.0261)	(0.0257)
Household income	Yes	Yes	Yes	Yes	Yes	Yes
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.	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
R-squared	0.161		0.085		0.137	

Notes: Table reports the estimated impact of the exposure score (measured at the commune level) on education (columns 1 and 2), number of days worked in the past 30 days (columns 3 and 4), and hours worked per week (columns 5 and 6) with additional control variable (household income). 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. Standard errors are clustered at the village (*diaban*) level. *** p<0.01, ** p<0.05, * p<0.1.

A1.2 Younger generation analysis

We now examine the impacts of exposure to Agent Orange on the younger generation in Vietnam. Although it can be argued that Agent Orange may not directly affect individuals initially exposed,

these chemicals could have gradual and harmful effects, potentially impacting the second or third generations. This suggests that people directly exposed to Agent Orange may not have immediate disabilities. However, subsequent generations might experience adverse health outcomes, cognitive limitations, or reduced learning and working capabilities. Table A2 presents our main findings, focussing on generations born in the 1990s. This time frame is significant, as individuals exposed to Agent Orange during the 1960s and 1970s would typically have their first children 20 to 30 years later.

Table A2: Impact of Agent Orange Exposure on Younger Generation

Sample	Children born after 1990s of AO affected Individuals					
	All			Non-movers		
Dep. var.	edu	days worked	hrs worked	edu	days worked	hrs worked
Exposure score	-0.213	-1.662**	-0.411	-0.268	-1.973**	-0.434
	(0.185)	(0.671)	(0.252)	(0.202)	(0.863)	(0.325)
Age	-0.0530***	0.337***	0.0930***	-0.0485***	0.307***	0.0865***
	(0.0141)	(0.0272)	(0.00900)	(0.0151)	(0.0418)	(0.0116)
Male	-0.380***	-0.662***	0.165***	-0.399***	-0.652***	0.158***
	(0.0343)	(0.128)	(0.0440)	(0.0352)	(0.143)	(0.0517)
	(0.0292)	(0.130)	(0.0422)	(0.0324)	(0.149)	(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 commune level) on education, number of days worked in the past 30 days , and hours worked per week for the whole sample (the first three columns) and for those who did not move (the first last 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.

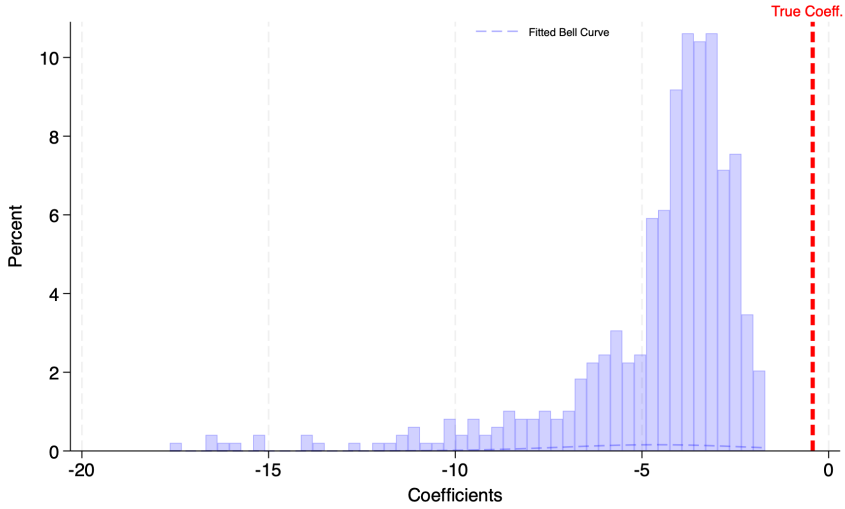
The impacts of Agent Orange on subsequent generations with parents in exposed areas are significant only for the number of working days, while the coefficients for educational attainment and working hours remain insignificant. The magnitude of the *Exposure Score* on *days worked* is higher for nonmovers compared to the full sample. This implies that individuals who persistently reside in exposed areas are more likely to suffer from the negative impacts of Agent Orange on their employment opportunities. Although we found that individuals born in the 1980s are less likely to enrol in educational training, this effect diminishes for the 1990 generation. However, the results with respect to the number of working days remain unchanged. On the one hand, this indicates that people in exposed areas tend to reduce the number of days they participate in the labour market each week. On the other hand, they do not work fewer hours within a single day.

A1.3 Placebo test

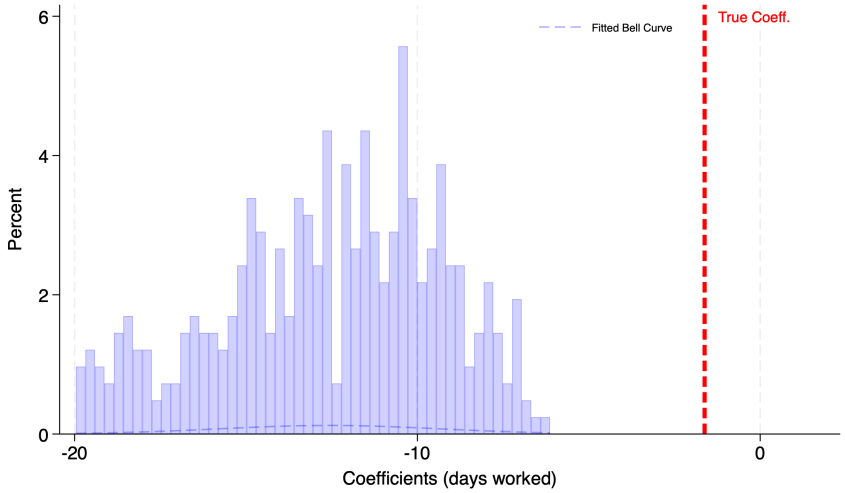
To ensure the robustness of our findings, we conduct a placebo test by randomly distributing the intensity of exposure to Agent Orange to the areas sprayed. Specifically, we generated a placebo

variable, based on a normal distribution using the mean and standard deviation of the observed exposure scores while excluding communes with missing population data. We further adjusted the placebo values by setting them to zero for communes below the 25^{th} percentile and capping them at the 95^{th} percentile to avoid extreme outliers. This procedure was repeated 500 times, each iteration assigning a unique random seed to ensure variability. In each iteration, we re-estimated the main regression equation, focusing on three key variables of interest: education, average working days per month, and average working hours per day. We replace the actual exposure score with the placebo variable while controlling for key covariates and clustering at the commune level. The resulting placebo coefficients were then compiled and plotted as a histogram to compare their distribution with the true coefficient. The robustness check demonstrates that the true coefficient lies outside the range of coefficients generated by randomisation, indicating that our results are unlikely to be driven by chance.

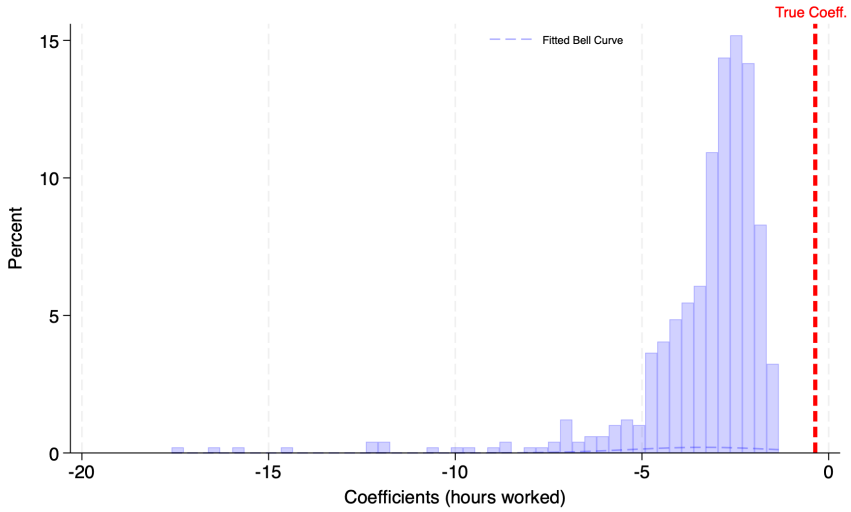
Figure A1: Placebo Treatment Assignment of AO Exposure (50 bins)



Education



Average days per month



Average working hours per day