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The long-term impact of the Vietnam War on agricultural productivity ☆

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ABSTRACT

We present causal evidence of the long-term effects of the Vietnam War on household agricultural productivity. Using bombing intensity data and data on the intensity of Agent Orange and other chemical agents used during the War, we find that spatial differences in the intensity of the War can help explain differences in long-term household agricultural productivity. Our endogeneity-corrected estimates suggest that, in the long-term, a 10% increase in bombing intensity decreases rice productivity by 2.94% and total agricultural productivity by 3.21%. Results from a fuzzy regression discontinuity design suggest that Agent Orange intensity also had a negative effect on rice productivity. We find that economic production is a channel through which the intensity of bombing and Agent Orange have adversely affected long-term agricultural productivity, while social capital is a channel through which Agent Orange is linked to lower long-term agricultural productivity.

1. Introduction

In this paper we ask the question: What is the long-term effect of aerial bombing and spraying herbicides in the Vietnam War on agricultural productivity? The Vietnam War, which was fought between North Vietnam, with support from the Soviet Union and China, and South Vietnam, with the support of the United States (US) and other anti-communist allies, lasted almost two decades and is regarded as one of the most intense conflicts since World War II. The War featured extensive aerial bombing, with the US dropping bombs equivalent to about three times those dropped in World War II, more than double those dropped in both World War II and the Korean War combined and about 15 times the quantity dropped during the Korean War (Clodfelter, 1995; Miguel & Roland, 2011). Additionally, about 72 million liters of different forms of herbicides were sprayed to defoliate over 25,000 square kilometers of land, to remove foliage used to provide the Viet Cong with cover and eliminate crop supplies used to feed them. Agent Orange, a dioxin and environmental pollutant, accounted for about 65% of the herbicides sprayed (Allukian & Atwood, 2000; Stellman et al., 2003b).

To answer our research question, we combine data on bombing intensity from Miguel and Roland (2011) and herbicides sprayed from Stellman et al. (2003b) with household agricultural productivity data from the *1997/1998 Vietnam Living Standard Survey* (VLSS), the *2004–2016 Vietnam Household Living Standards Survey* (VHLSS) and five waves of data spanning 2008 to 2016 from the *Vietnam Access to Resources Household Survey* (VARHS). Given that rice production in Vietnam is a major component of agriculture that accounts for about 90% of all agricultural production (Kompas, Che, Nguyen, & Nguyen, 2012), in addition to total agricultural productivity, we pay particular attention to the long-term impact of the War on rice productivity.

Because bombing during the Vietnam War was not random, we instrument for the intensity of bombing using the distance from the district in which the bombing occurred to the 17th parallel north latitude. This identification strategy was proposed by Miguel and Roland (2011), in their seminal study of the long-term economic effects of the Vietnam War, and has been widely used to instrument for bombing intensity in the Vietnam War (see, e.g., Awaworyi Churchill, Smyth, & Trinh, 2020; Palmer, Nguyen, Mitra, Mont, & Groce, 2019; Singhal, 2019). The intuition behind this instrument is that bombing intensity was greatest at the 17th parallel north latitude, which was the border established as part of the 1954 Geneva Accords and decided without consultation with the Vietnamese. Given that Agent Orange was mainly

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used in South Vietnam during the War, and was only used on a much smaller scale in North Vietnam, we take advantage of the boundary delineation in the application of Agent Orange and apply a fuzzy regression discontinuity design (RDD) to examine the impact of Agent Orange on agricultural productivity.

We find that bombing intensity and the intensity with which Agent Orange was sprayed decreases agricultural productivity. Our instrumental variable results suggest that about two decades after the War, a 10% increase in bombing intensity decreased rice productivity by 2.94% and total agricultural productivity by 3.21%. However, we also find that the effect of bombing intensity on agricultural productivity dissipates over time and using alternative datasets we show that the magnitude of the effect is much smaller three to four decades after the War. The RDD results suggest that Agent Orange intensity had a negative effect on rice productivity. Specifically, we find that households living close to 17th parallel north latitude in the South have 0.282 kg per square meters lower rice productivity than those living in the North. We find that economic production and social capital are channels through which the Vietnam War has had an adverse effect on long-term agricultural productivity.

We contribute to the literature on the determinants of agricultural productivity, which has thus far focused on determinants, such as technology, land distribution, government expenditure, government policies, education, and infrastructure, among others (see, e.g., Campi, 2017; Fulginiti, Perrin, & Yu, 2004; Lio & Liu, 2006; Loureiro, 2009; Reimers & Klasen, 2013; Thirtle, Lin Lin, Holding, Jenkins, & Piesse, 2004; Vollrath, 2007). Our study is most closely related to the small number of studies that examine the effect of conflict on contemporary agricultural productivity (Arias, Ibáñez, & Zambrano, 2019; Eklund, Degerald, Brandt, Prishchepov, & Pilesjö, 2017; Jaafar, Zurayk, King, Ahmad, & Al-Outa, 2015). Arias et al. (2019) examine the impact of violent shocks and the presence of non-state armed actors on agricultural production preferences in Colombia. They find that prolonged presence of armed actors is associated with a shift to less productive farming activities with short-term yields as opposed to activities that require high investment with potentially better yields. Jaafar et al. (2015) examine the effects of the Syrian War on irrigated agricultural production and find that the War is responsible for a 15% to 30% decline in agricultural water use and productivity in selected Syrian regions. Eklund et al. (2017), somewhat surprisingly, find that the presence of the Islamic State in Syria and Iraq is associated with an expansion in cropland cultivation. Our study also relates to George, Adelaja, and Weatherspoon (2019), who examine the impact of Boko Haram terrorist attacks on food insecurity in Nigeria. Measuring conflict intensity as the number of fatalities, they find that Boko Haram attacks are associated with greater food insecurity in three out of four categories. Specifically, conflict intensity is associated with increased reliance on less preferred foods, reduced variety of foods consumed and reduced meal portions, but has no significant effect on the number of days that households went without eating any food. We differ from each of these studies in that we seek to examine the long-term impact of war on agricultural productivity.

Our study also contributes to a growing literature that examines the long-term effects of violent conflict on economic development more generally (see, e.g, Akresh, Bhalotra, Leone, & Osili, 2017; Awaworyi Churchill et al., 2020; Dell & Querubin, 2018; Islam, Ouch, Smyth, & Wang, 2016; Merrouche, 2011; Miguel & Roland, 2011; Palmer et al., 2019; Singhal, 2019; Teerawichitchainan & Korinek, 2012; Waugh, Robbins, Davies, & Feigenbaum, 2007). This literature has focused on outcomes such as fertility, education, health, child labor and poverty, among others, but not on agricultural productivity. The focus on agricultural productivity is important given that agriculture remains a significant instrument for sustainable development (World Bank, 2008). While many developing countries that have endured violent conflict rely on agriculture as a mainstay of their economy, the long-term impact of these conflicts on agricultural productivity is not well understood. Our study, which is for an economy that is heavily reliant on agriculture, is an important first step to providing estimates of the effects and examining the channels through which these effects occur.

The closest studies in the literature to ours are those that have specifically examined the long-term effects of the Vietnam War on economic outcomes (Awaworyi Churchill, Munyanyi, Smyth, & Trinh, 2021; Awaworyi Churchill et al., 2020; Do, 2009; Miguel & Roland, 2011; Palmer et al., 2019; Singhal, 2019; Vu & Lo Bue, 2019). The evidence is mixed. Awaworyi Churchill et al. (2020) find that an increase in bombing intensity during the Vietnam War is associated with a higher prevalence of child labor, while Awaworyi Churchill et al. (2021) find that an increase in bombing intensity is associated with an increase in the probability of being self-employed. The Vietnam War has also had long-term negative effects on the level of disability (Palmer et al., 2019) and mental health (Singhal, 2019). However, Do (2009) finds no significant effect of Agent Orange on the prevalence of cancer three decades after the War, and Vu and Lo Bue (2019) find no evidence of the long-term effects of bombings during the War on schooling outcomes. At the macro level, Miguel and Roland (2011) find no evidence of the long-term effects of bombing intensity on consumption levels, poverty and other development outcomes.

2. The conceptual link between war and agricultural productivity

We expect war to have long-term effects on economic production and social institutions in the form of social capital and that these effects can have important implications for agricultural productivity. Hence, we examine economic production and social capital as potential mechanisms through which the Vietnam War affected agricultural productivity in the long-run.

2.1. Economic production and household consumption

We expect that economic production and household consumption, proxied by night-time light, will mediate the impact of war on agricultural productivity. At the aggregate level, household consumption contributes to the demand for agricultural produce and, hence, an increase in household consumption tends to be positively correlated with an increase in agricultural production (Ayerakwa, 2017; Gallaher, Kerr, Njenga, Karanja, & WinklerPrins, 2013; Tibesigwa, Visser, Collinson, & Twine, 2016). The positive relationship between household consumption and agricultural productivity is particularly evident among households in developing countries, such as Vietnam, that largely rely on agriculture for food security, nutrition and income (Dzanku, 2015; Gollin, 2010; Poulsen, McNab, Clayton, & Neff, 2015; Sibhatu & Qaim, 2017; Venugopal, Gau, Appau, Sample, & Pereira, 2019). War, however, has a negative effect on household consumption and production as it affects household earnings, which support household purchases, savings and investment (Verpoorten & Berlage, 2007). War also displaces households, which can lead to loss of property and economic assets, disrupt labour supply and reduce households' ability to engage in economic production (Arias, Ibáñez, & Zambrano, 2014; Aysa-Lastra, 2011; Bozzoli, Brueck, & Muhumuza, 2016; Ibáñez & Moya, 2010).

Given that economic production is often fuelled by household consumption, there is also a clear link in the literature between economic production and agricultural productivity (Ayerakwa, 2017; Ayerst, Brandt, & Restuccia, 2020; Dzanku, 2015; Gollin, 2010). War negatively affects economic production by diverting capital and labor toward the war effort. Moreover, war has a negative effect on trade, infrastructure, productive assets and foreign direct investment, as well as government spending on education and health care, each of which supports economic production (Collier, 1999; Easterly & Levine, 1997; Gates, 1965).

2.2. Social capital

Social capital refers to the size and quality of a person's trusted social relations, which enables the sharing of resources, knowledge, and human capital in realizing individual and collective goals. Social capital is considered to be a positive good that promotes collective action and interdependency, in addition to nurturing physical and emotional wellbeing (Appau, Churchill, Smyth, & Zhang, 2020; Jennings & Sanchez-Pages, 2017; Putnam, Leonardi, & Nanetti, 1994).

The long-term effect of war on social capital is ambiguous. On the one hand, wars can undermine social capital through causing the death of family, friends, colleagues and other trusted relations during the conflict (Cox, 2008). Wars may also force families to flee their homes and farms, and some may never return to their communities (Collier & Sambanis, 2002; De Luca & Verpoorten, 2015b). In the case of civil wars, atrocities among households within the community can erase trust and friendly ties among neighbours and households, which can discourage collective action and collaboration (Deng, 2010; Goodhand, Hulme, & Lewer, 2000). On the other hand, war can also increase social capital in the long term (Bellows & Miguel, 2009; De Luca & Verpoorten, 2015a; Voors et al., 2012). In particular, it has been shown that individuals and communities that have suffered violence from conflict tend to develop coping strategies that involve increased community participation and altruism that can, in turn, increase levels of social capital (Bellows & Miguel, 2009; Voors et al., 2012).

Social capital is important for agricultural productivity (Brehm & Eisenhauer, 2008; Chloupková & Bjornskov, 2002; Robison & Schmid, 1994). In many rural communities, farming is conducted in groups of families, friends, neighbours and other community collectives, and this contributes to higher agricultural productivity (Getz, 2008). For example, shared social capital among island communities in Australia has been shown to facilitate the sharing of information and knowledge among individual farmers, which improves agricultural yields (Kilpatrick & Falk, 2003). In Kenya, urban farmers have used their social collective to pool resources for their sack gardening, which, in turn, improved their food security (Gallaher et al., 2013). We, therefore, expect that agricultural productivity in the post-war period will be mediated by the level of social capital that is recovered or rebuilt after the war.

3. Data and variables

To examine the impact of the Vietnam War on household agricultural productivity, we use data from multiple sources. Our first measure of war intensity is bombing intensity for each district, measured as the total quantity of bombs, rockets and missiles dropped by the US military per square kilometer during the Vietnam War. The source is Miguel and Roland (2011).[1] Our second measure of war intensity is data on herbicides sprayed during the Vietnam War, from Stellman, Stellman, Christian, Weber, and Tomasallo (2003a), which is categorised into two groups: dioxin-contaminated Agent Orange and other chemical herbicides including Agents White, Blue, Pink and Purple.

To measure the long-term effect on agricultural productivity we use several datasets. In the bombing intensity analysis, we use data from the 1997/1998 VLSS. In addition to the VLSS, we also use the 2004–2016 VHLSS, which succeeded the VLSS.[2] As a further check, we also use five waves of data over the period 2008 to 2016 from the VARHS, which focuses on rural households.[3] The 1997/1998 VLSS and VAHRS have the advantage of providing information on the place of birth of respondents and, thus, enable us to accurately control for migration. Specifically, information on place of birth enables us to restrict our sample to those who have not moved from their district of birth, thus ensuring that we isolate the shock associated with bombings. VHLSS does not provide information on location of birth, which is a limitation compared with the other datasets; however, it does ask respondents if their household is registered in the district in which they are living. To have one's household registered in Vietnam, one has to be a long-term resident of the district. To control for migration in the VHLSS, we exclude households that are not registered in the district.[4]

We restrict our sample to households with heads born between 1955 and 1975. The lower bound of 1955 is employed to distinguish the Vietnam War from the first Indochina War, which ended in 1955, while the upper bound of 1975 denotes the end of the Vietnam War. To measure agricultural productivity, we use information on household agricultural production (in kilograms) per size of land (in meters squared). Our first measure of agricultural productivity is household rice production per rice land, given that rice represents the majority of agricultural production in Vietnam (Kompas et al., 2012). Our second measure captures all agricultural production and is measured as total household agricultural production per unit of agricultural land. Similar indicators are routinely used to measure agricultural productivity (see, e.g., Reimers & Klasen, 2013; Rozelle, Taylor, & deBrauw, 1999; Vollrath, 2007).

We include a set of covariates that are likely to influence household agricultural productivity (see, e.g., Appleton & Balihuta, 1996; Kalirajan & Shand, 1985; Oseni, Corral, Goldstein, & Winters, 2014; Reimers & Klasen, 2013; Udry, 1996). Our control variables include household-level agricultural inputs (land, labor supply and value of capital), household head ethnicity, gender, and demographic and geographic characteristics. Land is measured using household arable land size. Labor supply is measured using number of farm employees and capital is measured as the total value (in log) of farm equipment, machinery and tools that the household had in the past 12 months.[5]

We consider economic production and social capital as potential mechanisms through which bombing intensity could influence agricultural productivity. Consistent with the existing literature, we measure social capital using trust (Appau et al., 2020; Awaworyi Churchill & Mishra, 2017; Leigh, 2006; Putnam, 2000). The question on trust in VARHS is consistent with the generalized trust question used in most surveys that usually takes the form: "Generally speaking, would you say that most people can be trusted or that you can't be too careful in dealing with people?"

[1] See Miguel and Roland (2011) for details on how the bombing intensity variable is constructed.

[2] The first wave of the VHLSS survey was in 2002, but we do not use it because it was based on a different questionnaire that does not capture some of the relevant information needed in our analysis. The VLSS and VHLSS report information on different administrative units, which prevents us from merging them. All households included in our analysis are involved in agriculture.

[3] The VARHS is a longitudinal dataset and, thus, we pool the waves. See Markussen, Tarp, and Newman (2013) for details on the VARHS survey.

[4] In robustness checks, reported below, we find that our results are robust to the inclusion of migrants.

[5] In the VHLSS, value of capital is proxied by cost of fuel and depreciation of fixed assets used in farming activities of the household.

The VARHS survey asked respondents whether they "agree" or "disagree" with the following statement: "In this commune one has to be careful, there are people you cannot trust". We measure trust as a binary value equal to one when respondents agree that "one has to be careful, there are people you cannot trust".

We employ satellite data on night-time activity from Hodler and Raschky (2014) to measure economic production at the district level. This approach is consistent with studies that have used night-time light to measure economic production (see, e.g., Awaworyi Churchill et al., 2021, 2020; Henderson, Storeygard, & Weil, 2012; Sutton & Costanza, 2002).

Table A1 presents summary statistics for all variables used in the main analysis. Among some of the key variables, average rice productivity of households in our sample is 0.376 kg per square meter, while average total productivity is 0.402 kg per square meter. The average age of household heads is 35 years, with most being male and of the *Kinh* ethnic group. In terms of agricultural inputs, more than half of the households in our sample have seed investment, and the average number of farm employees per household is 2.54.

4. Empirical strategy

4.1. Bombing intensity

To examine the impact of bombing intensity on agricultural productivity, we use an instrumental variable technique, which is based on the following model:

$$P_{i,j} = \alpha_0 + \alpha_1 B_j + \alpha_2 HH_{i,j} + \alpha_3 Z_j + \pi_C + v_{i,j} \tag{1}$$

where P denotes agricultural outcomes for household i in district j. B_j represents bombing intensity and $HH_{i,j}$ represents household characteristics, which include household-level agricultural inputs (land, labor supply and value of capital) and a set of characteristics of the head of household i residing in district j, which are likely to influence agricultural productivity. Z_j is a vector of district-level factors including average precipitation and temperature during the Vietnam War, pre-war population density, latitude and the share of land at different latitudes. π_C is a cohort fixed effects term that controls for the year of birth of the household head. $v_{i,j}$ is a random error term that allows for correlation at the district level. We cluster standard errors at the district level, but in robustness checks we check the sensitivity of our results to clustering at other levels. α_1 captures the effect of bombing intensity on agricultural productivity, which may be biased given that bombing was not random. To address endogeneity bias, we use distance from the centroid of each district to the 17th parallel north latitude as an instrument. Given that 17th parallel north latitude was exogenously established as the border under the 1954 Geneva Accords without consultation with the Vietnamese, proximity to the border represents a natural experiment that can be used to draw causal inference about the effect of bombing intensity on long-term economic outcomes.

Distance to 17th parallel north latitude, D_j, is measured as the absolute value of the distance between the centroid of district j and the 17th parallel north latitude.

Using this instrument, we estimate the following first stage equation:

$$B_j = \alpha + \gamma D_j + \varphi Z_j + \varepsilon_j \tag{2}$$

where the sign on γ is expected to be negative.

4.2. Agent Orange and other chemical agents

To examine the impact of Agent Orange, we take advantage of the fact that Agent Orange was mostly sprayed in South Vietnam during the War (Palmer, 2005; Stellman & Stellman, 2018; Stellman et al., 2003a, 2003b). As Stellman et al. (2003a) and Stellman and Stellman (2018) note, the reason for spraying Agent Orange was to remove vegetation cover used by North Vietnamese forces, make bombing sites more visible and to destroy 'unfriendly' crops as a tactic for decreasing food supplies available to the North Vietnamese forces in the South. Agent Orange, however, was only used on a small scale in the North. While it is estimated that about 17 million people living in the South were directly exposed to the dioxin, the corresponding number in the North was about 1 million (Nham Tuyet & Johansson, 2001).

As seen in Fig. 1, similar to the bombing, the areas closer to the 17th parallel north latitude were sprayed the most and, thus, have highest exposure to Agent Orange. Because the border was established in 1954, a decade before the Vietnam War, it provides an exogenous cut-off. While the chemical was sprayed on a much smaller scale in the North than in the South, given some districts in the North were exposed to Agent Orange, there is a fuzzy discontinuity in the treatment assignment. To account for the non-zero probability of being sprayed with the chemical in these districts in the North, we employ a fuzzy RDD approach.

As a robustness check on the results of the fuzzy RDD approach for Agent Orange, we employ two-stage Least squares (2SLS) We follow previous studies (see, e.g., Meng, 2013; Samarakoon & Parinduri, 2015) to estimate the following equations:

$$L_{it} = \alpha I_{it} + \beta X_i + g(d_{it}) + \mu_p + \delta_c + \pi_t + \varepsilon_{it} \tag{3}$$

$$P_{it} = \alpha L_{it} + \beta X_i + h(d_{it}) + \mu_p + \delta_c + \pi_t + \varepsilon_{it} \tag{4}$$

P_{it} is agricultural productivity of household i at time t. L_{it} (actual treatment variable) is a dummy equal to one if household i lives in areas exposed to Agent Orange and zero otherwise, and α is the parameter of interest. $g(d_{it})$ and $h(d_{it})$ denote functions of running variable d (distance from the 17th parallel north latitude), μ_p, δ_c andπ_t respectively denote province, cohort and time fixed effects, and ε_{it} denotes the error term. The instrument I_{it} is a dummy equal to one if the household i lives in the South (below the 17th parallel north latitude), and zero otherwise. We select households within +/− 2 latitudes from the cut-off as the main bandwidth. In sensitivity checks, we examine the robustness of our results to other bandwidths.

Our identification strategy for Agent Orange intensity is similar to that used in the case of bombing intensity, but with an important modification. Given that the intensity of Agent Orange sprayed in the North was much smaller than in the South, to include districts in the North in the sample for the Agent Orange analysis would violate the assumption that proximity to the 17th parallel north latitude is associated with higher Agent Orange intensity. Thus, we focus on the South sample and use distance to the 17th parallel north latitude as the instrument for Agent Orange in our 2SLS framework. Removing the northern districts means that the 2SLS strategy is not as clean when applied to Agent Orange as in the bombing intensity case; hence, we use it as a robustness check only. The exclusion of the North from the Agent Orange analysis significantly reduces the sample size in the VLSS. Thus, we use the VHLSS and, as with the VLSS, we only focus on household heads born between 1955 and 1975.

4.3. Channels

To examine economic production and social capital as potential channels, we use a model similar to equation (1) except with the different outcome variables replacing agricultural productivity. Specifically, using the VARHS data, we estimate the following model:

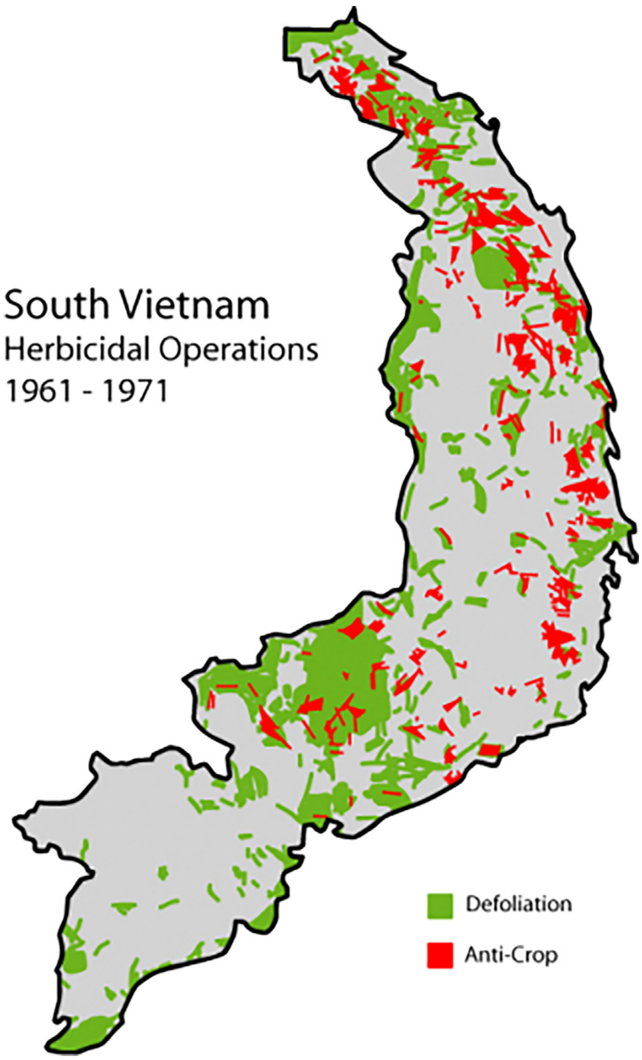

Fig. 1. Agent Orange distribution (Source: Association for Diplomatic Studies & Training).

$$M_{i,j} = \alpha_0 + \alpha_1 B_j + \alpha_2 HH_{i,j} + \alpha_3 Z_j + \pi_C + v_{i,j} \quad (5)$$

where the definition of each variable remains as before except for $M_{i,j}$ which in alternating specifications, denotes economic production or social capital (of the household head) for household i in district j. For a variable to qualify as a channel through which war intensity influences agricultural productivity, the coefficient on bombing intensity or intensity with which Agent Orange was sprayed in equation (5) should be significant. In addition, the inclusion of the mechanism variable into the model that links war intensity to agricultural productivity should reduce the magnitude of the coefficient on war intensity or render it statistically insignificant. Finally, the coefficient on the channel variable should also be significantly related with agricultural productivity (see e.g., Awaworyi Churchill et al., 2021).

5. Results

5.1. Bombing intensity

In this section, we present the results for the effects of bombing intensity on agricultural productivity, drawing on the evidence from each of the three survey datasets available to us.

Table 1 presents results for the effect of bombing intensity on rice and total agricultural production using VLSS. Columns 1 and 2 present OLS estimates for the effects of bombing intensity on rice and total productivity, respectively. The coefficients on bombing intensity are statistically insignificant in both columns suggesting downward bias from endogeneity.

The 2SLS results, using distance to the 17th parallel north latitude as an instrument, are reported in Columns 3 and 4 of Table 1. Consistent with Miguel and Roland (2011) and Singhal (2019), the first stage results show that distance from the 17th parallel north latitude is negatively associated with bombing intensity. The Kleibergen-Paap test results in both columns also show that our instrument is not weak (Stock & Yogo, 2005).

The second stage results suggest that bombing intensity has a negative effect on agricultural productivity. Column 3 suggests that a 10 per cent increase in bombing intensity generates a 2.94 per cent decrease in rice production per meter square of rice land. Column 4 suggests that a 10 per cent increase in bombing intensity generates a 3.21 per cent decrease in total agricultural production per meter square of agricultural land.

Our main results in Table 1 are based on data from the 1997/1998 VLSS. These represent long-term effects, given this was more than two decades after the Vietnam War. But, given that we are interested in the long-term impacts of the Vietnam War, the VHLSS and VARHS have the advantage of allowing us to examine effects on agricultural productivity up to two decades beyond the VLSS. Table 2 presents 2SLS estimates for the effects of bombing intensity on rice and total productivity using the VHLSS and VARHS. Columns 1 and 2 present results for VHLSS, while Columns 3 and 4 present results for VARHS.

The results here are generally consistent with the finding that bombing intensity is associated with a decline in agricultural productivity. While the effect of bombing intensity is not significant for total productivity in the VHLSS, a 10 per cent increase in bombing intensity generates a 0.56 per cent decrease in rice production per meter square of rice land. Using the VARHS, a 10 per cent increase in bombing intensity generates a 0.94 per cent decrease in rice production per meter square of rice land, and a 0.91 per cent per cent decrease in total agricultural production per meter square of agricultural land.

Compared to the magnitude of the coefficients from Table 1, these results suggest that the effect of bombing on agricultural productivity dissipates over time. Specifically, the results show that about two decades after the war, the effects of bombings reduce productivity by up to 3.21 per cent. However, after a further one to two decades later, the effects of bombing intensity only reduce productivity by 0.91 per cent at most. This finding is consistent with the predictions from Miguel and Roland (2011) theoretical model, and their empirical findings, which suggest that in the long term, the negative effects of war should dissipate.

5.2. Agent Orange and other chemical agents

We apply fuzzy RDD to examine the impact of intensity of Agent Orange (Panel A) and all herbicides (Panel B) in Table 3. Columns 1 and 2 report results for rice productivity and total productivity, respectively. We use the bandwidth of +/−2 latitude and the same set of control variables as in the previous analysis. The results in Panel A show that those living below the 17th parallel north latitude (South) have lower rice productivity than those living above the border (North). Households living close to the 17th parallel in the South have 0.282 kg per square meters lower rice productivity than those living in the North. However, the coefficient in the case of total agricultural productivity is statistically insignificant. The results focusing on all herbicides, as opposed to only Agent Orange, show significant impacts on both rice productivity and total pro-

Table 1
Effect of bombing intensity on agricultural productivity.

	OLS		2SLS	
Dependent variable	Rice productivity (1)	Total productivity (2)	Rice productivity (3)	Total productivity (4)
2SLS results				
Log total bombing per km^2	−0.005	−0.016	−0.294***	−0.321***
	(0.017)	(0.022)	(0.097)	(0.114)
Other controls	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Cohorts FE	Yes	Yes	Yes	Yes
Observations	1,207	1,233	1,207	1,233
First stage of 2SLS				
|Latitude-17 N|			−0.528***	−0.528***
			(0.104)	(0.104)
Kleibergen-Paap test			27.097	27.097

Notes: Robust standard errors in parentheses; standard errors are clustered at the district level; dependent variables are in logs; controls include age of household head, gender, ethnicity, seeding, fertilizer, land size, labor supply, capital value (in log), province pre-war population, latitude, and proportion of district land in different altitude and soil categories. The differences in number of observations for rice and total production is because not all farmers grow rice; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; Full results are available on request.

Table 2
Effect of bombing intensity on agricultural productivity.

	VHLSS		VARHS	
Dependent variable	Rice productivity (1)	Total productivity (2)	Rice productivity (3)	Total productivity (4)
2SLS results				
Log total bombing per km^2	−0.056**	0.074	−0.094***	−0.091***
	(0.025)	(0.049)	(0.010)	(0.011)
Other controls	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Cohorts FE	Yes	Yes	Yes	Yes
Observations	3,994	3,251	3,474	3,534
First stage of 2SLS				
|Latitude-17 N|	−0.902***	−0.902***	−0.732***	−0.732***
	(0.166)	(0.166)	(0.111)	(0.111)
Kleibergen-Paap test	61.54	58.07	48.36	48.36

Notes: see Table 1; controls include age of household head, gender, ethnicity, labor supply, capital value (in log); *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

ductivity. In Tables A2 and A3, we examine the robustness of the RDD estimates to the use of different bandwidths (i.e., +/−3 latitude, +/−4 latitude, and whole sample) to determine the cut-off from the 17th parallel north latitude. Our results remain consistent in all cases. We also conduct a placebo test that assumes that the cut-off latitude is at the 16.5 parallel north latitude. At a parallel latitude anywhere other than the exogenously determined border between North and South, we expect the impact of Agent Orange intensity on rice productivity to be statistically insignificant, as is confirmed in Table A3.

Table 3
Agent Orange and agricultural productivity – RDD.

	(1) Rice productivity	(2) Total productivity
Panel A: Agent Orange		
South region	−0.282***	−0.090
	(0.077)	(0.078)
Observations	1,032	1,032
Controls	Yes	Yes
Province FE	Yes	Yes
Cohorts FE	Yes	Yes
Year FE	Yes	Yes
Panel B: All herbicides		
South region	−0.263***	−0.131**
	(0.072)	(0.057)
Observations	1,032	1,032
Controls	Yes	Yes
Province FE	Yes	Yes
Cohorts FE	Yes	Yes
Year FE	Yes	Yes

Notes: Robust standard errors in parentheses; Results of fuzzy RDD using bandwidth of +/−2 latitude; controls include age of household head, gender, ethnicity, labor supply, capital value (in log); *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

6. Channels and robustness checks

6.1. Channels

An advantage of the VARHS dataset is that, compared to the VLSS and VHLSS, it contains information on social capital, thus allowing us to also examine the effect of bombing intensity on the potential mechanisms discussed in Section 2. In Table 4, we examine the impact of bombing intensity and Agent Orange on economic production and social capital. Panel A presents results for the effect of bombing intensity, while Panel B present estimates for Agent Orange intensity. An increase in bombing intensity is associated with a decline in economic production (Column 2). We also find that an increase in bombing intensity is associated with an increase in the share of people who agree that people cannot be trusted. Thus, bombing intensity is associated with lower levels of social capital. The results in Panel B suggest that that an increase in Agent Orange intensity is associated with an increase

Table 4
Effect of bombing intensity and Agent Orange on mechanisms.

Dependent variable	Trust (1)	Economic production (2)
Panel A: 2SLS estimates of bombing intensity		
Log total bombing per km^2	0.061**	−1.345***
	(0.029)	(0.409)
Other controls	Yes	Yes
Province FE	Yes	Yes
Cohorts FE	Yes	No
Observations	2,299	273
Panel B: 2SLS estimates of Agent Orange		
Agent Orange	0.025*	−2.980***
	(0.015)	(0.668)
Other controls	Yes	Yes
Province FE	Yes	Yes
Cohorts FE	Yes	No
Observations	1,094	129

Notes: Clustered robust standard errors in parentheses; controls include age of household head, gender and ethnicity; Economic activity (night time light) regressions are at the district level. Controls in this model include population density, soil quality; first stage results pass the relevant tests; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5
Effects of mechanism on agricultural productivity.

	Bombing intensity		Agent Orange	
Dependent variable	Rice productivity (1)	Total productivity (2)	Rice productivity (3)	Total productivity (4)
Panel A: Unconditional estimates of war intensity				
War intensity	−0.061***	−0.056***	−0.084***	−0.085***
	(0.008)	(0.008)	(0.018)	(0.017)
Observations	3,478	3,538	1,023	1,060
Panel B: Effects of social capital				
War intensity	−0.178***	−0.175***	−0.066**	−0.070***
	(0.018)	(0.017)	(0.026)	(0.026)
Trust	−0.023	−0.020	−0.099***	−0.071**
	(0.019)	(0.020)	(0.033)	(0.033)
Observations	1,748	1,774	513	529
Panel C: Effects of economic growth				
War intensity	−0.094	−0.063	−0.085***	−0.088***
	(0.084)	(0.076)	(0.026)	(0.024)
Economic growth	0.012*	0.014**	0.008*	0.008**
	(0.006)	(0.006)	(0.004)	(0.004)
Observations	2,092	2,129	605	627

Notes: Cluster robust standard errors in parentheses; all regressions include cohort, year and province fixed effects; first stage results pass the relevant tests; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

in the share of people who agree that people cannot be trusted and a decrease in economic production.

In Table 5, we examine the effect of these potential mechanisms on agricultural productivity. In Panel A, we report unconditional estimates of war intensity, which serve as a baseline. The results reinforce that there is a negative relationship between war intensity and agricultural productivity. In Panel B, the coefficient on social capital is only significant in the Agent Orange specification, in which a decrease in social capital is associated with a decline in agricultural productivity. The inclusion of social capital also reduces the coefficient on Agent Orange. In Panel C, economic production is positively associated with agricultural productivity, while its inclusion also renders the coefficients on bombing intensity insignificant and reduces the magnitude of the coefficient on Agent Orange. Based on Tables 4 and 5, we can conclude that social capital is a mechanism through which Agent Orange transmits to agricultural productivity, and economic production is a mechanism through which both bombing intensity and intensity with which Agent Orange was sprayed transmit to agricultural productivity.

We should be cautious about reading too much into the differential result for social capital. Social capital could have been a significant channel for bombing intensity as well if not for the slight loss of statistical significance.[6] That both Agent Orange and bombing intensity transmit via economic production to agricultural productivity is an indication of how economic production can be a primary mechanism that can be linked to most economic outcomes and is particularly susceptible to major shocks such as conflict and wars. Indeed, evidence in other contexts confirm the importance of economic production as a channel, in shaping outcomes such as entrepreneurship in post-war settings (see, e.g., Awaworyi Churchill et al., 2021).

6.2. Robustness checks

In Table A4, we consider the robustness of our results for bombing intensity to alternative measures of bombing. The results reported in Table 1 are based on bombing intensity measured

[6] We cluster the standard errors at the district level, which is quite conservative and, thus, the standard errors are relatively larger compared to clustering at a lower level. If we cluster the standard errors at the household level, social capital would statistically be a channel linking bombing intensity to agricultural productivity.

using the quantity of bombs, missiles, and rockets dropped per square meter. In Panel A of Table A4, we examine the robustness of our results to defining bombing as the quantity of bombs dropped, but excluding missiles and rockets. In Panel B, the measure of bombing does not account for district areas, and thus only captures the quantity of bombs, missiles and rockets. Our main findings are robust to these alternative ways of measuring bombing.

During the Vietnam War, Quang Tri province was the mostly heavily bombed (Miguel & Roland, 2011). More bombs were dropped on Quang Tri province than all of Germany during World War II (Black, 2016). Thus, compared to other provinces, it is generally accepted that the effects of the bombing are more persistent in this province. To ensure that Quang Tri province is not an outlier driving our results, we examine the robustness of our results to excluding this province. Table A5, which reports the results for a sub-sample that excludes Quang Tri province, shows that our findings are not driven by this province.

In Table A6, we examine the robustness of our results to the clustering of our standard errors at different levels. In our main results, standard errors are clustered at the district level. In Panel A of Table A6, we cluster the standard errors at the household level, while in Panel B, we cluster the standard errors at the cohort level. In both cases, we find that our results are robust. By examining the impact of the Vietnam War on contemporary agricultural outcomes, we assume persistence, as is the case for other studies that examine the impact of past events on contemporary outcomes. Standard errors in these cases may be underestimated if they do not account for persistence (Kelly, 2019). To account for this possibility, in Panel C, we employ Conley (1999) standard errors and find that our results remain robust.

It is possible that differences in post-war policies and resources across provinces could be driving our results. To ensure that this is not the case, we interact province dummies with time of birth linear trends, in order to control for differential time trends in agricultural outcomes across provinces. We also control for interview time fixed effects. The results, which are reported in Panels A and B of Table A7, show that our findings are robust.

In another check on the bombing intensity results, we examine the robustness of our results to the inclusion of migrants. Our main results exclude migrants from the sample in order to isolate the effect of the War. In doing so, we lose up to 9% of our sample depending on the survey. Singhal (2019) shows that migration does not bias estimates. In Panels A of Table A8, we find that our results are robust to the inclusion of migrants, except for the results using VLSS.

In our main analysis, we restrict our sample to households with heads born between 1955 and 1975, which is the year that the Vietnam War ended. By focusing on a lower bound of 1955, we are able to distinguish the Vietnam War from the first Indochina War, which ended in 1955. However, given that the channels through which the war influences agricultural outcomes, such as economic production, may not depend on respondents experiencing the War, we also examine the sensitivity of our results with the unrestricted sample. In Panel B of Table A8, our results are robust to the inclusion of respondents who did not directly experience the War.

In Table A9, we split the sample to examine the heterogeneous impact of bombing on agricultural productivity for those from the South and North. Agriculture in Vietnam is more extensive in the South and, thus, any shocks to productivity are likely to be more severe in the South than in the North. Consistent with expectations, we find that the effects of bombing are stronger in the South sub-sample compared to the North, and, thus, the overall effects somewhat reflect the effect of bombing on agricultural productivity in the South.

As a robustness check on the results from the fuzzy RDD, in Table A10 we present the 2SLS estimates for the effects of chemical agents on agricultural productivity. Panel A reports results for the effect of Agent Orange intensity. Panel B reports results for the effects of all herbicides, while Panel C reports results for the effects of the frequency of herbicide spraying. Across all panels, Columns 1 and 2 report results based on the VHLSS, while Columns 3 and 4 report results from the VARHS. The coefficients on the variables measuring the chemical agents are negative and significant across the board. Specifically, the results in Panel A suggest that a 10 per cent increase in Agent Orange intensity generates up to a 0.51 per cent decrease in rice productivity and up to a 1.54 per cent decrease in total agricultural productivity. The results in Panel B suggest that a 10 per cent increase in total herbicide intensity generates up to a 0.59 per cent decrease in rice productivity and up to a 1.59 per cent decrease in total agricultural productivity. From Panel C, a 10 per cent increase in the number of hit counts, or number of times that Agent Orange was sprayed, is associated with up to a 1.85 per cent decrease in rice productivity and up to a 2.87 per cent decrease in total agricultural productivity.

7. Conclusion

We have examined the long-term impact of the Vietnam War on agricultural productivity. During the Vietnam War, the US air force dropped more bombs in Vietnam than any previous war in which the US was engaged (Miguel & Roland, 2011). The US also defoliated over 25,000 square kilometers of land using Agent Orange and other chemical agents (Allukian & Atwood, 2000; Stellman et al., 2003b). Using data on bombing intensity compiled by Miguel and Roland (2011) and data on the intensity with which Agent Orange and other chemical agents were sprayed from Stellman et al. (2003a), we show that an increase in war intensity is associated with a decrease in long-term agricultural productivity. We find that the effect of bombing intensity on agricultural productivity is stronger in the South, where agriculture is more predominant and that the overall effects on productivity decline over time. We find that economic production is a channel through which the intensity of bombing and Agent Orange have adversely affected long-term agricultural productivity, while social capital is a channel through which Agent Orange is linked to lower long-term agricultural productivity.

Agricultural productivity accounted for about half of Vietnam's GDP before the War and this continued to be the case for decades after. Agriculture continues to be the largest employment sector in Vietnam even though labor input and agriculture's contribution to Vietnam's GDP is decreasing (Giang, Xuan, Trung, & Que, 2019). Given that a fall in agricultural productivity can have serious ramifications for economic recovery and growth post-war, especially in economies that largely depend on agriculture, our results suggest that it is important that targeted policies are aimed at post-war recovery for households in agricultural production.

Policies that stimulate economic production and promote social capital in affected districts can benefit such post-war agricultural recovery. This is reflected in the US experience, where initiatives at state and federal levels to stimulate economic production improved aggregate and state-level agricultural productivity after World War II. In the case of Vietnam, policies that liberalized markets for agricultural inputs and outputs since the 1980s have contributed to improved agricultural productivity (Ayerst et al., 2020). Our results also suggest that social capital is a channel through which war influences agricultural productivity. Cox (2008) suggests that policies that are designed to encourage social cohesion and reconciliation, especially in post-civil war contexts, can build social collaboration, which contributes to communal agricultural productivity (Brehm & Eisenhauer, 2008; Deng, 2010).

Conflict of interest declaration

The authors declare no conflict of interest.

CRediT authorship contribution statement

Samuelson Appau: Conceptualization, Writing - original draft, Writing - review & editing. **Sefa Awaworyi Churchill:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **Russell Smyth:** Conceptualization, Writing - original draft, Writing - review & editing. **Trong-Anh Trinh:** Conceptualization, Methodology, Software, Formal analysis.

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Appendix

Table A1 Summary statistics.

Variables	Description	Mean	St. Dev.
Agricultural production			
Rice productivity	Rice production/Rice land (kg/m^2)	0.376	0.127
Total productivity	Total production/Total agricultural land (kg/m^2)	0.402	0.197
Individual characteristics (household head)			
Age	Age in years	35.189	4.884
Female	Gender (Female=1)	0.131	0.338
Non-*Kinh*	Ethnicity (Non-*Kinh*=1)	0.193	0.395
Land property rights	Having rights to use land (Yes=1)	0.800	0.400
Seeding	Seed investment (Yes=1)	0.646	0.478
Fertilizer	Amount of fertilizer used (kg)	5.643	1.012
Land area	Total land area for agriculture (in log)	8.030	0.768
Labor supply	Number of farm employees	2.540	1.156
Capital value	Value of farm equipment, machinery and tools (in log)	4.415	2.987
Province/District-level variables			
Total US bombs, missiles, rockets per km^2	Number of bombs, missiles, rockets per km^2 during the war	43.832	78.295
Total US bombs per km^2	Number of bombs per km^2 during the war	33.553	61.685
Total US bombs, missiles and rockets	Number of bombs, missiles, rockets during the war	17,335.230	37,422.281
Agent Orange	Number of dioxins (gallons)	171,809.1	465,899.2
All herbicides	Number of all herbicides (gallons)	275,237.8	764,411.0
Hit counts	Number of hit count within 5 km from the centre of district	2.970	6.273
Population density, 1960-1961	Population density (thousand people per km^2 – in log)	4.993	1.172
Latitude	Latitude of district centre	17.459	5.214

Notes: Summary statistics for household observations are from VLSS data. Similar statistics are observed for VHLSS and VARHS, and are available on request.

Table A2 RDD – Different bandwidths.

	+/-3 latitude Rice productivity	+/-4 latitude Rice productivity	Whole sample Rice productivity
South region	-0.086***	-0.092***	-0.263***
	(0.030)	(0.017)	(0.016)
Controls	Yes	Yes	Yes
Province FE	Yes	Yes	Yes
Cohorts FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	1,977	3,923	7,640

Notes: Robust standard errors in parentheses; Results of fuzzy RDD; controls include age of household head, gender, ethnicity, labor supply, capital value (in log); *** p<0.01, ** p<0.05, * p<0.1.

Table A3 RDD – Placebo test.

	(1) Rice productivity	(2) Total productivity
South region	-0.231 (0.181)	0.065 (0.277)
Controls	Yes	Yes
Province FE	Yes	Yes
Cohorts FE	Yes	Yes
Year FE	Yes	Yes
Observations	1,327	1,258

Notes: Robust standard errors in parentheses; Results of fuzzy RDD; controls include age of household head, gender, ethnicity, labor supply, capital value (in log); *** p<0.01, ** p<0.05, * p<0.1.

Table A4 Alternative measures of bombings.

Dependent variable	Rice productivity (1)	Total productivity (2)
Panel A: Total bombing per km^2 (excluding missiles and rockets)		
Log total bombing per km^2	-0.331*** (0.118)	-0.392*** (0.132)
Other controls	Yes	Yes
Province FE	Yes	Yes
Cohorts FE	Yes	Yes
Observations	1,207	1,233
Panel B: Total bombing, missiles and rockets (not accounting for district areas)		
Log total bombing, missiles and rockets	-0.345*** (0.110)	-0.368*** (0.128)
Other controls	Yes	Yes
Province FE	Yes	Yes
Cohorts FE	Yes	Yes
Observations	1,207	1,233

Notes: See Table 1; first stage results pass the relevant tests; *** p<0.01, ** p<0.05, * p<0.1.

Table A5 Excluding Quang Tri.

Dependent variable	Rice productivity (1)	Total productivity (2)
Log total bombing per km^2	-0.303*** (0.100)	-0.330*** (0.117)
Other controls	Yes	Yes
Province FE	Yes	Yes
Cohorts FE	Yes	Yes
Observations	1,202	1,227

Notes: See Table 1; first stage results pass the relevant tests; *** p<0.01, ** p<0.05, * p<0.1.

Table A6 Different clustering.

Dependent variable	Rice productivity (1)	Total productivity (2)
Panel A: Cluster at household level		
War intensity	-0.294*** (0.074)	-0.321*** (0.102)
Other controls	Yes	Yes
Province FE	Yes	Yes
Cohorts FE	Yes	Yes
Observations	1,207	1,233
Panel B: Cluster at cohort levels		
War intensity	-0.294*** (0.075)	-0.321*** (0.104)

Table A6. (*continued*)

Dependent variable	Rice productivity (1)	Total productivity (2)
Other controls	Yes	Yes
Province FE	Yes	Yes
Cohorts FE	Yes	Yes
Observations	1,207	1,233
Panel C: Conley standard errors		
War intensity	-0.294***	-0.321***
	(0.071)	(0.097)
Other controls	Yes	Yes
Province FE	Yes	Yes
Cohorts FE	Yes	Yes
Observations	1,207	1,233

Notes: See Table 1; first stage results pass the relevant tests; *** p<0.01, ** p<0.05, * p<0.1.

Table A7 Time trends and fixed effects.

Dependent variable	Rice productivity (1)	Total productivity (2)
Panel A: Province-cohort linear time trend		
War intensity	-0.284***	-0.293**
	(0.098)	(0.118)
Other controls	Yes	Yes
Province FE	Yes	Yes
Cohorts FE	Yes	Yes
Province*cohort FE	Yes	Yes
Observations	1,207	1,233
Panel B: Interview time fixed-effects		
War intensity	-0.269**	-0.270**
	(0.105)	(0.126)
Other controls	Yes	Yes
Province FE	Yes	Yes
Cohorts FE	Yes	Yes
Interview time FE	Yes	Yes
Observations	1,207	1,233

Notes: See Table 1; first stage results pass the relevant tests; *** p<0.01, ** p<0.05, * p<0.1.

Table A8 Effect of bombing intensity (including migrants and removing year restrictions.

	VLSS		VHLSS		VARHS	
Dependent variable	Rice productivity (1)	Total productivity (2)	Rice productivity (3)	Total productivity (4)	Rice productivity (5)	Total productivity (6)
Panel A: including migrants (2SLS second stage results)						
Log total bombing per km^2	-0.172	-0.143	-0.056**	0.075	-0.098***	-0.088***
	(0.107)	(0.129)	(0.025)	(0.049)	(0.010)	(0.010)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
Cohorts FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,384	1,432	4,005	3,256	3,844	3,958
Panel B: removing year restrictions (2SLS second stage results)						
Log total bombing per km^2	-0.265**	-0.267***	-0.035*	0.053	-0.114***	-0.112***
	(0.101)	(0.100)	(0.020)	(0.038)	(0.013)	(0.012)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
Cohorts FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,842	2,942	7,154	5,730	6,484	6,707

Notes: see Table 1 and Table 2; first stage results pass the relevant tests; *** p<0.01, ** p<0.05, * p<0.1.

Table A9 Heterogeneous Effect of bombing intensity in the North and South.

Dependent variable	Rice productivity (1)	Total productivity (2)
Panel A: South sub-sample		
Log total bombing per km^2	-0.635***	-0.722***
	(0.232)	(0.249)
Other controls	Yes	Yes
Province FE	Yes	Yes
Cohorts FE	Yes	Yes
Observations	403	413
Panel B: North sub-sample		
Log total bombing per km^2	-0.290*	-0.382
	(0.164)	(0.307)
Other controls	Yes	Yes
Province FE	Yes	Yes
Cohorts FE	Yes	Yes
Observations	804	820

Notes: see Table 1; first stage results pass the relevant tests; *** p<0.01, ** p<0.05, * p<0.1.

Table A10 Effect of chemical agents on agricultural productivity.

	VHLSS		VARHS	
Dependent variable	Rice productivity (1)	Total productivity (2)	Rice productivity (3)	Total productivity (4)
Panel A: Agent Orange				
Agent Orange per km^2	-0.051***	-0.154***	-0.012***	-0.011***
	(0.015)	(0.029)	(0.001)	(0.001)
Other controls	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Cohorts FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	3,994	3,251	3,474	3,534
Panel B: All herbicides				
All herbicides per km^2	-0.059***	-0.159***	-0.011***	-0.011***
	(0.014)	(0.028)	(0.001)	(0.001)
Other controls	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Cohorts FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	3,994	3,251	3,474	3,534
Panel C: Number of hit counts				
Frequency of Agent Orange spraying	-0.185***	-0.287***	-0.032***	-0.031***
	(0.024)	(0.055)	(0.004)	(0.004)
Other controls	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Cohorts FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	3,994	3,251	3,474	3,534

Notes: Clustered robust standard errors in parentheses; dependent variables are in logs; controls include age of household head, gender, ethnicity, labor supply, capital value (in log); first stage results pass the relevant tests; *** p<0.01, ** p<0.05, * p<0.1.

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