# How War Changes Land: Soil Fertility, Unexploded Bombs, and the Underdevelopment of Cambodia

**Article** *in* American Journal of Political Science · December 2020

DOI: 10.1111/ajps.12577



Erin Lin
The Ohio State University

# How War Changes Land: Soil Fertility, Unexploded Bombs, and the Underdevelopment of Cambodia

**Erin Lin** Ohio State University

**Abstract:** *How does past political violence impact subsequent development and practices, long beyond the life of the regime that perpetrated violence? Prior research focuses on physical destruction without much attention to weapons left behind in conflict zones. I contend that unexploded ordnance create direct and imminent threats to rural livelihoods. Individuals respond by shortening time horizons and avoiding investment in activities for which there is an immediate security cost but a distant return. Short-term adjustments in agricultural methods accumulate to long-term underdevelopment and poverty. In Cambodia, I find that the historic bombing of high-fertility land, where impact fuses hit soft ground and were more likely to fail, reduces contemporary household production and welfare. Counterintuitively, the most fertile land becomes the least productive. This reversal of fortune qualifies the presumption that post-war economies will eventually converge back to steady-state growth.*

**Verification Materials:** The materials required to verify the computational reproducibility of the results, procedures, and analyses in this article are available on the *American Journal of Political Science* Dataverse within the Harvard Dataverse Network, at: https://doi.org/10.7910/DVN/TUSXIG.

For many analysts of the developing world, war is understood as a defining historical experience. Like colonialism and communism, war brings about a fundamental reordering of previous political, economic, and legal systems that leads to the creation of new post-war regimes (Doyle and Sambanis 2006; Fortna 2008; Matanock 2017; Walter 2004) while it also produces new identities that have proven difficult to change (Balcells 2012; Fouka 2019; Lupu and Peisakhin 2017; Rozenas, Schutte, and Zhukov 2017). Moreover, these experiences can profoundly restrict economic growth (Collier et al. 2003), even though in certain countries the effects are short-lived (see Brakman, Garretsen, and Schramm 2004; Davis and Weinstein 2002; Miguel and Roland 2011). Where, when, and how war leads to long-run underdevelopment are still important open questions.

Scholars have recently examined the role of wartime physical damage as a determinant of long-term economic productivity. War's destruction of assets, capital, and human life creates immediate poverty (Collier et al. 2003), but with time the lost infrastructure and population can be reproduced and redistributed, as in agrarian economies like Vietnam (Miguel and Roland 2011) and more industrialized cases like Japan and Germany (Brakman, Garretsen, and Schramm 2004; Davis and Weinstein 2002). However, more refined measurements of destruction suggest that macroeconomic stability may belie microeconomic inequalities, as victimized populations experience more difficulty in re-accumulating wealth. Jewish sections of Russian cities and oblasts that were targeted during the Holocaust, for example, still have lower wages and declining populations today (Acemoglu, Hassan, and Robinson 2011). Because local

Erin Lin is Assistant Professor, Department of Political Science, Ohio State University, 154 North Oval Mall, Columbus, OH 43210 (lin.2657@osu.edu).

I would like to thank Amaney Jamal, Deborah Yashar, Amanda Robinson, Sarah Brooks, Sara Watson, Asya Magazinnik, Yang-Yang Zhou, Mark Beissinger, Jan Pierskalla, Alex Thompson, Jake Shapiro, Chris Gelpi, Marcus Kurtz, Leonard Wantchekon, John Kastellac, Kris Ramsay, Tom Scherer, Jared Edgerton, participants in the Empirical Studies of Conflict Workshop, Rochester Fieldwork Conference, Southeast Asia Research Group, MPSA 2018 Conference, and Princeton Comparative Politics Research Seminar, and the three anonymous reviewers for very helpful comments. For the spatiotemporal dataset construction, I am indebted to useful discussions with Wangyal Shawa. This research was supported by the Mershon Center, the Initiative for Food and Agriculture Transformation, the Bobst Center, and the Princeton Institute for International and Regional Studies.

*American Journal of Political Science*, Vol. 00, No. 00, XXXX 2020, Pp. 1–16

 DOI: 10.1111/ajps.12577

perpetrators acquired their victims' valuables, Nazi violence in Poland gave villages near killing sites an advantage in acquiring present-day housing (Charnysh and Finkel 2017). These works have made impressive inroads in exploring whether the wartime collapse of family wealth, population, and infrastructure persists through time. But might war leave destructive impacts in other ways?

I argue that military technology can have unintended long-term consequences. Undetonated or leftover weapons often remain behind in conflict zones, and their physical presence has hangover effects on the civilian population. For instance, near the end of their nine-year war with Afghanistan, Soviets laid roughly 10 million landmines as a protective barrier during their 1988–89 withdrawal. The landmines, combined with leftover artillery, missiles, and bombs from subsequent factional fighting and war with the United States, have left more than 1,000 square miles of unexploded munitions. According to 2018 Afghan government data, the leftover ordnance injure or kill 118 civilians a month. In addition, when the Islamic State retreated from the Iraqi city of Mosul, it planted thousands of improvised explosive devices in order to complicate reconstruction. Across the globe, unexploded ordnance from past combat continue to maim about 10 people each day in places like Ukraine, Yemen, Syria, Laos, and Vietnam (Haberman 2016). Might these explosive remnants of war change the behavior of individuals in former conflict zones? If so, how do responses to heightened risk of injury or death impact household welfare and recovery in the long-term?

In this article, I present a new theoretical perspective, tied to one consequential way in which war impacts land. My interviews with farmers, paired with policy reports, reveal that bombs can fail to detonate when they hit soft ground, leaving a potentially lethal weapon in the soil for decades after the payload drop. Fertile surfaces, in particular, may fail to trip the trigger's impact fuse that detonates the TNT and other explosive material (Moyes 2002). I contend that unexploded ordnance create direct and imminent threats to farmer livelihoods, counterintuitively making the most fertile land the least productive because it is so dangerous to farm. Drawing upon economic theories of risk and insecurity, I argue that individuals respond by shortening time horizons and lowering their willingness to invest in activities that require an immediate outlay in personal security with a distant and uncertain payoff. Over the span of fifty years, the short-term adjustments in agricultural methods accumulate to long-term underproduction and poverty.

Estimating the causal relationship between violence and long-term development poses notable empirical challenges. For instance, there are concerns about endogeneity since the deployment of weapons—the treatment variable—may have been driven by a location's pre-war security, political, and economic characteristics. This makes it difficult to identify whether the distinctive local patterns of development are caused by the violent event, the leftover weapons, or pre-treatment factors like terrain or pre-war economic capacity. In addition, when weapons are deployed, they ostensibly create two distinct violent events: immediate detonations and long-term exposure to violence through the remaining ordnance. As a result, it could be difficult to distinguish the effects of the wartime destruction from the lingering effects of leftover weapons.

This paper addresses these challenges by examining the US bombing of Cambodia during the Vietnam War and the present-day agricultural output and economic responses of Cambodian farmers. Between 1965 and 1973, Cambodia saw 1.8 million tons of US Air Force ordnance dropped onto its rice fields, villages, and people in an effort to root out Vietnamese Communists from the Cambodian countryside. Payloads of carpet bombs, cluster munitions, and other gravity bombs were dropped in an indiscriminate aerial campaign that covered the majority of the country. While all Cambodians in the target zones suffered the violence of bombing, some have had to endure the added effect of undetonated bombs left in the soil. By 2001, 64,000 people had been killed or injured by unexploded ordnance, and almost half of all Cambodian villages reported areas still riddled with hidden explosives (Collier et al. 2003, 31). This study leverages variation in unexploded ordnance density, which is shown to be an unintentional consequence of the bombing and not politically targeted.

My empirical strategy involves narrative evidence from personal interviews with Cambodian farmers, a unique, spatiotemporal dataset, and a causal inference design that relies on the quasi-random failure rate of bombs and pre-treatment controls. The interviews provide proof-of-concept that farmers find unexploded ordnance in more fertile areas and bomb craters on less fertile land. The qualitative data also probe the mechanisms by which the effects of unexploded ordnance persist through time, providing evidence of farmers using less efficient agricultural methods in order to farm more safely.[1] I test the theory quantitatively using a

[1]Risk is largely privatized, as Cambodian government efforts to remove unexploded ordnance are lacking. A recent UN-commissioned report has criticized the national clearance agency

historical dataset of 115,000 payload drops from US Air Force sorties flown over Cambodia from 1965 to 1973. I identify the location and amount of ordnance dropped, and compare them to the agricultural output and household economic activities from the 2012 Cambodia Socioeconomic Survey. Controlling for pre-war economic and geographic conditions, I find that across historically bombed areas with fertile land, today's farmers respond by limiting their agricultural practices and, in the end, experience higher levels of poverty and seasonal migration, due to the risk of encountering unexploded ordnance. This mechanism does not apply to less fertile land: since it tends to be harder and drier, bombs were much more likely to explode upon impact. In a reversal of fortune, the very best land is held hostage by war.

These results build upon previous studies. While prior studies rely on measures of individual behavior aggregated at the village or district level (Dell and Querubin 2017; Miguel and Roland 2011), this design provides a measure for each household and agricultural field—the unit of production. This article suggests that we should measure the legacy of bombing on a wider range of outcomes, including agricultural productivity variables that are central to economic growth models, particularly in the developing world, as well as variables that are related to quality of life and human health, such as food insecurity. This state of poverty has important theoretical implications for political development. Scholars of democratization, from Lipset to Boix and Stokes, have regarded economic growth as a prerequisite of strong and stable democracies. Moreover, the Weberian state loses its monopoly on violence when it is unable to control latent bomb explosions, decreasing its capacity to enact and enforce policies and respond to constituent demands.

These findings also extend the long-term effects of war beyond intergenerational legacies on political attitudes (Balcells 2012; Lupu and Peisakhin 2017; Rozenas, Schutte, and Zhukov 2017), resource distribution (Charnysh and Finkel 2017), ethnic categorization (Fouka 2019; Voigtländer and Voth 2012), and state engagement (Charnysh 2019). By highlighting how violent political action can elicit environmental change, this paper challenges the conventional treatment of the physical environment as an exogenous driver of human behavior (Diamond 1999; Dunning 2008; Herbst 2000; Ross 2013; Sachs and Warner 2001), and instead shows how war can mediate natural processes by turning favorable geography into something undesirable. Building off new work that shows how foreign actors can transform domestic resources (Christensen 2019), I provide an alternative example of an outside actor's ability to change the value of local endowments: through foreign military technology that is left behind.

for presenting a picture of rapid progress by focusing on areas at minimal or no risk of unexploded ordnance. "There are too many cleared minefields with no/small number of mines," recommending a shift in focus to "priority areas" where dense contamination poses a "high threat to local communities" (Nut and Simon 2016, 9).

## Technology, Armed Force, and Society

In the past century, weapons have grown in size and sophistication, adding to their deadliness and destructive range. One prime example is aerial weaponry, which advocates laud as a more efficient and rapid projection of force compared to land or naval alternatives (Schelling 2008). The world's first payload drop occurred in 1911 when Lieutenant Giulio Gavotti released four grenades, by hand, over the side of his plane during the Italian-Turkish War (De Groot 2005). A half-century later, a formation of six B-52s, dropping their bombs from 30,000 feet, could obliterate almost everything within a box about five-eighths of a mile wide by two miles long, destroying military infrastructure faster than any battalion (Sheehan 1998). The 500-pound MK-82 warhead, used in the US carpet bombing of Vietnam, Cambodia, and Laos, and more recently in the 2016 Saudi bombing of Yemen, is such an effective weapon of destruction that it annihilates its victims beyond recognition: "the shell fractures into several thousand pieces, becoming a jigsaw puzzle of steel shards flying through the air at up to eight times the speed of sound.... It removes appendages from torsos; it disassembles bodies and redistributes their parts" (Stern 2018).

Political scientists and economists have begun to document the extent to which this overwhelming form of firepower has political and economic impacts on subsequent society. The immediate loss in human life and belongings from indiscriminate aerial violence has increased the resolve of insurgents and swayed civilians to their side (Dell and Querubin 2017; Kocher, Pepinsky, and Kalyvas 2011; see Lyall 2009 for an opposing view). In the long run, these political attitudes against perpetrators of bombing are sometimes transmitted to the next generation (Balcells 2012). Economists have noted that these traumatic experiences do not seem to maintain long-lasting impacts on development, though; the cities of Hiroshima and Nagasaki experienced a population boom soon after World War II that reinvigorated the depleted workforce, and their economies quickly rebounded (Davis and Weinstein 2002). Miguel and Roland (2011) find Vietnam War-era bombing has little significant impact on the poverty rates of South Vietnamese villages today. However, few studies link an individual's early-life bombing experiences to later-life economic behavior. Whether violence alters the economic risk preferences central to decisionmaking is an open question; if it does, it could help explain why certain countries fall into cycles of conflict and poverty (Collier et al. 2003).

Most research on the *individual-level* legacies of war focuses exclusively on cultural attitudes. Bombing and mass deportation, respectively, reduced long-term political support for the perpetrators in Spain and Ukraine (Balcells 2012; Rozenas, Schutte, and Zhukov 2017). The death of a family member during the deportation of Crimean Tatars increased the strength of ethnic identification and hostile attitudes towards perpetrators in the minds of victims and their children (Lupu and Peisakhin 2017). This intergenerational mechanism has applied to arguments about perpetrators as well. Black Plague pogroms, in which Jews were blamed for spreading the disease, are highly predictive of anti-Jewish discrimination prior to World War II (Voigtländer and Voth 2012). Though this body of work covers multiple forms of violence, each case relies on a similar explanation: family socialization, in which attitudes are passed down from parent to child, and it is assumed that parents desire to make children more like themselves and have the resources, individual ability, and institutional capacity to control their children's beliefs (Bisin and Verdier 2001).

In order to show that war has long-term impacts on political and social outcomes, the state-of-the-art scholarship has focused its efforts on overcoming methodological challenges of coarse measurement and nonrandom assignment through impressively detailed quantitative datasets and historical knowledge of policies that randomly ascribe treatment status. But perhaps the important question is not whether legacies of war exist, but rather where, in what manner, and why they do or do not manifest themselves. Largely missing from this debate are substantial elaborations of the causal mechanism that accounts for why elements of practice exist beyond the life of the violent experience that gave birth to them. Why would children choose to side with their parent's political ideology, given an array of other parties that may cater to youth issues? How does an individual's wartime loss of wealth compromise her ability to regain income when the market stabilizes? By shifting the research question to describe the causal mechanism, we create a new, second-generation set of inquiries on why the legacy of war persists through time.

## Environmental Legacies of War

In addition, the bulk of research on war's legacy in development focuses on the factors of production, particularly population and capital (discussed in Blattman and Miguel 2010, 8). However, labor and capital are not the only factors of production that can be destroyed by violence, particularly as modern technological warfare from Agent Orange to carpet bombing can make possible the physical destruction of land. War's impact on land and the natural environment, in fact, is among the least understood areas of research on violence. Very few studies examine the long-term effects of political violence on the environment and the surrounding human activity. In Africa, civil war had the unintended effect of preserving populations of large animal species, as rebel fighting keeps poachers away from grassland reserves (Daskin and Pringle 2018). In Vietnam, the extent and distribution of Agent Orange spraying has been documented in *Nature* (Stellman et al. 2003), but due to strained Vietnam-US relations, the dataset has not yet been linked to environmental or human health outcomes (Butler 2008).

Yet, there are good reasons to expect that destructive weapons like bombs can change land—particularly through their failure to detonate, which leaves behind unexploded ordnance that increase the risk of using land. Indeed, American military bomb disposal technicians estimate that as many as one out of every five cluster munitions have failed to detonate upon impact (Ismay 2017). According to the United Nations, unexploded ordnance kills an average of 55 people each day, restricts farmers' access to fields, and disrupts daily routines in schools, markets, and neighboring villages. One-third of countries in the world report a need to clear areas of unexploded ordnance and other explosive remnants of war (Borrie 2003), but proper removal is costly. The US Department of Defense has spent $10.3 billion to clean up more than 900 American military sites contaminated with unexploded ordnance from weapons testing and training, and estimates that it will take $31 billion more to complete the task (US Congressional Report 1995).

A bomb's failure rate is commonly thought to be influenced by the surface conditions at the target. Since the majority of explosive ordnance used in aerial attacks is designed to detonate upon impact, soft ground and dense vegetation can cushion the fall and prevent an impact fuse from sparking. Clearance professionals observe that "[s]ub-surface UXO [unexploded ordnance] is more likely to be found in soft ground. Soft ground also makes items less likely to detonate and therefore increases the proportion that remains unexploded.... Dense vegetation, like soft ground, also means that items of ordnance are more likely to remain unexploded" (Moyes 2002). Several types of soft surfaces, such as mud, snow, sand, and surface water, are all found to produce substantial numbers of duds, and these unexploded bombs tend to penetrate ground cover, going 10 to 20 centimeters below the surface at the time of impact (McGrath and Lloyd 2000, 26). Given that soft surfaces can be found in almost all ecosystems, unexploded ordnance is a common occurrence all over the world, from "the mud and jungles of Southeast Asia, the soft peat of the Falklands, the sand desert of the Gulf, and farmland in the Balkans" (King 2000, 39).[2]

This particular mechanism—a bomb's tendency to fail on good soil—is what turns the gift of favorable geography into something more treacherous. In regions where the primary food is produced in paddies, such soft land is the most productive (Nesbitt 1997). Bombings on fertile land are thus expected to have more problems with unexploded ordnance than bombings on less fertile areas. In other words, the best agricultural soils become the most dangerous because farmers face increased risk and uncertainty surrounding their likelihood of injury or death when accessing their land. For this reason, the US State Department describes unexploded ordnance as especially problematic in the developing world: "[m]ost of these countries' economies depend heavily on agriculture," making them particularly vulnerable because these explosive remnants of war can "deny farmers large sections of land" (US Congressional Report 1995).

## Livelihood Risk and Poverty

Economic theories of risk and precautionary behavior predict that when individuals confront a situation with risk, they can take active measures to reduce the probability of a bad event. In situations of financial risk, where insurance markets are incomplete or unavailable, individuals can self-protect by choosing alternative means of production that involve lower risk and typically lower yield (Ehrlich and Becker 1972) or by accumulating precautionary savings (Fafchamps 1992; Jalan and Ravallion 1999). In situations of violent risk, daily operations cause an immediate outlay of personal safety. Victimized individuals self-protect by opting out of situations with high uncertainty (Callen et al. 2014). In some cases, exposure to violence actually changes risk preferences, as individuals become more risk averse (Brown et al. 2019; Jakiela and Ozier 2019; Kim and Lee 2014; see Voors et al. 2012 for contrary evidence). Both lines of work predict a similar behavioral response: farmers develop alternative agricultural practices that lower risk exposure. Yet how do these risk-adjusted behaviors impact economic efficiency?

A premise of this research is that owning assets that provide a comparative advantage (like fertile land) is not sufficient to explain patterns of unit productivity. Rather, the risk environment should affect an individual's time horizon over which the utility of a particular economic activity is being evaluated and thus her willingness to invest in activities which impose an immediate burden on her safety for an uncertain, future return (Brooks 2014, 974). In order to self-protect, individuals would farm less efficiently: limiting themselves to small amounts of land or vetted safe areas, avoiding investments in heavy machinery that leave large footprints on the land, tilling by hand rather than by tractor. These risk-averse strategies may be the most viable means of securing personal safety, but they come at the cost of unit productivity and growth. Over time, short time horizons can have long-term economic impacts. As insecure individuals try to procure stable income in the short term, they avoid risky investments or accumulate excessive precautionary savings, which prevent them from accessing opportunities to leave poverty in the long term (Dercon 2002; Wood 2003). In this view, farmers, by taking measures to protect themselves from physical risks, exclude themselves from development opportunities with future dividends. For example, adoption of more intensive agricultural technologies would require increased exposure to unexploded ordnance (e.g., driving tractors or applying extra fertilizer and water needed for high-yield rice), as would diversifying into other land-based sources of revenue (e.g., rearing livestock or fishing, which would involve traversing swathes of land to chase cattle or access rivers). By opting out of development opportunities and limiting their portfolio of productive assets, farmers are more likely to remain in a state of arrested development.

My principal hypothesis is that when households face threats of violence in their land, they farm less efficiently in order to minimize risk of injury or death. Specifically, on bombed, high fertility soils—where there are more unexploded ordnance—farmers respond to the danger by cultivating less of their land and investing less in agricultural capital, which reduces their overall crop production and profit margin. These self-protection strategies may also result in higher rates of poverty, as

[2] In the Falkands, 80% of the 25,000 mines are hidden in sandy beaches, which shifts the weapon's position, making detection difficult (Ruan and Macheme 2001). In the Balkans, 150,000 pieces of unexploded ordnance remain in rural landscapes, like the forests around Sarajevo and Trebevic mountainsides. The fertile Doboj region is the most heavily mined area in Bosnia and Herzegovina. Demining operations cost an average of 1,000 euro per UXO, and financial cutbacks have delayed removal efforts (Neives 2018).

households cannot safely engage in other land-based livelihoods to supplement their income and are forced to migrate for seasonal work or to rely on children for supplementary income. Crucially, individuals with assets that typically ensure a high rate of return are not the ones supporting local economies. Rather, economic activity occurs in places with resources that have lower capacity, but are safer to use. This theory reveals a new sphere of marginality among individuals who may seem asset-rich, when in fact their assets expose them to violent harm and reduce their economic viability.

## US Bombing of Cambodia

During the Vietnam War, the National Liberation Front, more commonly known as the Viet Cong, and North Vietnam built supply routes and mobile bases in parts of Cambodia bordering South Vietnam. Although the Cambodian government, under the leadership of Prince Norodom Sihanouk, did not formally approve of the Vietnamese communists' territorial intrusion, the regime also did not allow American or allied forces to enter the country. The Johnson administration hotly debated whether to respect Cambodian sovereignty while allowing an enemy safe haven or to take military action against an enemy on neutral soil and risk public backlash. While President Lyndon Johnson ended up authorizing limited bomb drops, he ultimately decided against sustained military intervention. However, his successor took a different approach. President Richard Nixon expanded the B-52 strikes into full-fledged carpet bombing starting in March 1969. The bombing escalated to the point that he told Secretary of State Henry Kissinger, "I want everything that can fly to go in there and crack the hell out of them. There is no limitation on mileage and no limitation on budget. Is that clear?"

In total, the US Air Force flew eight years of interdiction missions against enemy efforts to move supplies. Unlike the strategic bombing raids in North Vietnam, where the US targeted military infrastructure, plants, and storage depots, the interdiction missions were intended to support ground troop movements that sought to break up enemy supply lines. However, Secretary of Defense Melvin Laird later acknowledged that aircraft sometimes placed bombs near population centers. His admission suggested that bombs were dropped indiscriminately despite Nixon's public assurance that "we have scrupulously observed the 21-mile limit [the uninhabited jungle perimeter] on penetration of our ground combat forces into Cambodian territory." By 1975, the American bombing campaign in Cambodia dropped over three times the tonnage dropped on Japan during World War II (Chandler 1991, 225).

Today, Cambodia has some of the highest contamination rates in the world of unexploded ordnance. Life after bombing is particularly harsh for civilians in Cambodia, where rice cultivation employs nearly four-fifths of the working population, and an estimated four to six million stray explosives have yet to be located. With an average of more than two civilians killed or injured by unexploded bombs and munitions each day (and 28% of the casualties being children), the bombing continues to have latent, unintended impacts in a predominantly rural country (Collier et al. 2003, 31).

## Narrative Evidence

Recent interviews with Cambodian residents of Ratanakiri province, which borders Vietnam, support the correlation between bomb failure and local ground conditions.[3] A Khmer farmer describes the soil conditions in her home province of Prey Veng, near the capital Phnom Penh and the dry, pebbly plains near the Tonle river. She says, "[o]ver in Prey Veng, we needed fertilizer....The soil was harder in Prey Veng. My hometown soil was the rockiest." She recalls her hometown having bomb craters ("they looked like man-made holes"), but she had never seen an unexploded bomb as a child. She eventually married a man from Ratanakiri province, and moved to his hometown near the Vietnam border. She observes, "[h]ere, the soil is more fruitful. When it's time for me to grow beans in the garden, I have a bountiful harvest. The same is true for our rice crop. We don't need to use fertilizer." But the problem lies with unexploded bombs, as locals have warned her to be careful while farming. Her neighbors even taught her how to differentiate rusted cluster munitions from rocks and scrap metal (Interview 26, May 12, 2018). A large landowner from a nearby district remembers the aerial attacks, particularly how "the cluster bombs didn't really explode—just a few did....They also dropped the B-52s [locals nicknamed the MK-82 general purpose bomb after the B-52 bombers], and a lot of them are still around." After the bombing, he became a Khmer Rouge soldier, and was relocated west to Banteay Meanchey province, where the soil was different. He explains,"in Banteay Meanchey, the land is not black and is dry. In the dry season, it gets cracked....Over there, it was harder."

[3]Interview protocol is provided in the supporting information (pp. A1–A2).

By comparison, "[m]y land here is black and doesn't crack" (Interview 37, May 15, 2018).

Land fertility varies dramatically, not only between provinces but also between neighboring villages in the same province. During the US bombing, one male farmer lived on the main river, where he recalls the land being rocky and relatively difficult to plant. One advantage, though, was that "there were not many kinds of this bomb [pointing to a cluster bomb] but there were a lot of big fragments. They all exploded." After he married, he moved near his parents-in-law's house in a neighboring district. He notes that the soil here is better;"it's black, and it has nutrients. It's dark like charcoal." But "they [the US] dropped bombs over here…so, yes, there are also a lot of cluster bombs here" (Interview 14, May 8, 2018). His comment reveals how he observes the connection between good soil and unexploded ordnance. A married couple also suspects their land is dangerous. It was previously a military base for General Lon Nol, who built "a hospital, barracks, and hiding places" in order to fight the Khmer Rouge and Vietnamese communists (Interview 30, May 13, 2018). "The US dropped a lot of bombs in this area," says the wife, so they avoid that particular area "because [they're] scared of bombs." While these respondents may lack precise measures of location or density of bombs, they still develop an informal coding procedure to identify safe versus dangerous areas. Their coding relies on regional estimates of bombing history and local knowledge of soil fertility. But individuals also seem to understand that if bombing had taken place in the area, they should suspect unexploded ordnance in fertile soil.

In order to minimize risk, many residents end up farming less efficiently. One common strategy is to farm a fraction of total holdings. To protect themselves, the married couple only plant the "five or six meters outside of the cluster bomb area." Another farmer in a nearby district describes similar changes; he says, "I only work this one strip of land. If an NGO doesn't come to take all the bombs out, I won't move anywhere else" (Interview 11, May 7, 2018). A village chief describes a similar pattern of behavior in his constituency. Because the villagers worry about cluster bombs, "we don't dare work on a large scale" (Interview 24, May 11, 2018). Concerned farmers also rely on safer but lower-yield farming methods. For instance, one young farmer uses hand tools instead of machines. She says, "I cut grass with a machete. Lightly…" She uses this method so she can "keep [her] eyes peeled" (Interview 26, May 12, 2018). A retired bureaucrat from the Office of Economic Development also plows and seeds his field by hand—in large part because "my neighbors tell me to farm carefully and to stay safe." (Interview 12, May 8, 2018). In this view, the distant returns of using heavy machinery do not justify the immediate outlay of personal security.

The interviews lend *prima facie* plausibility to the behavioral mechanisms that illustrate why unexploded ordnance would lead to a long-term reduction in agricultural output. But do these one-off cases represent larger inequalities in Cambodian development? The quantitative empirical analysis proceeds in two parts. I first collect data from historical and contemporary sources to estimate the density of unexploded bombs and present-day household responses. These estimates are also used to test the hypotheses, as I seek to ascertain whether changes in local production and economic welfare are due to latent risk posed by leftover bombs.

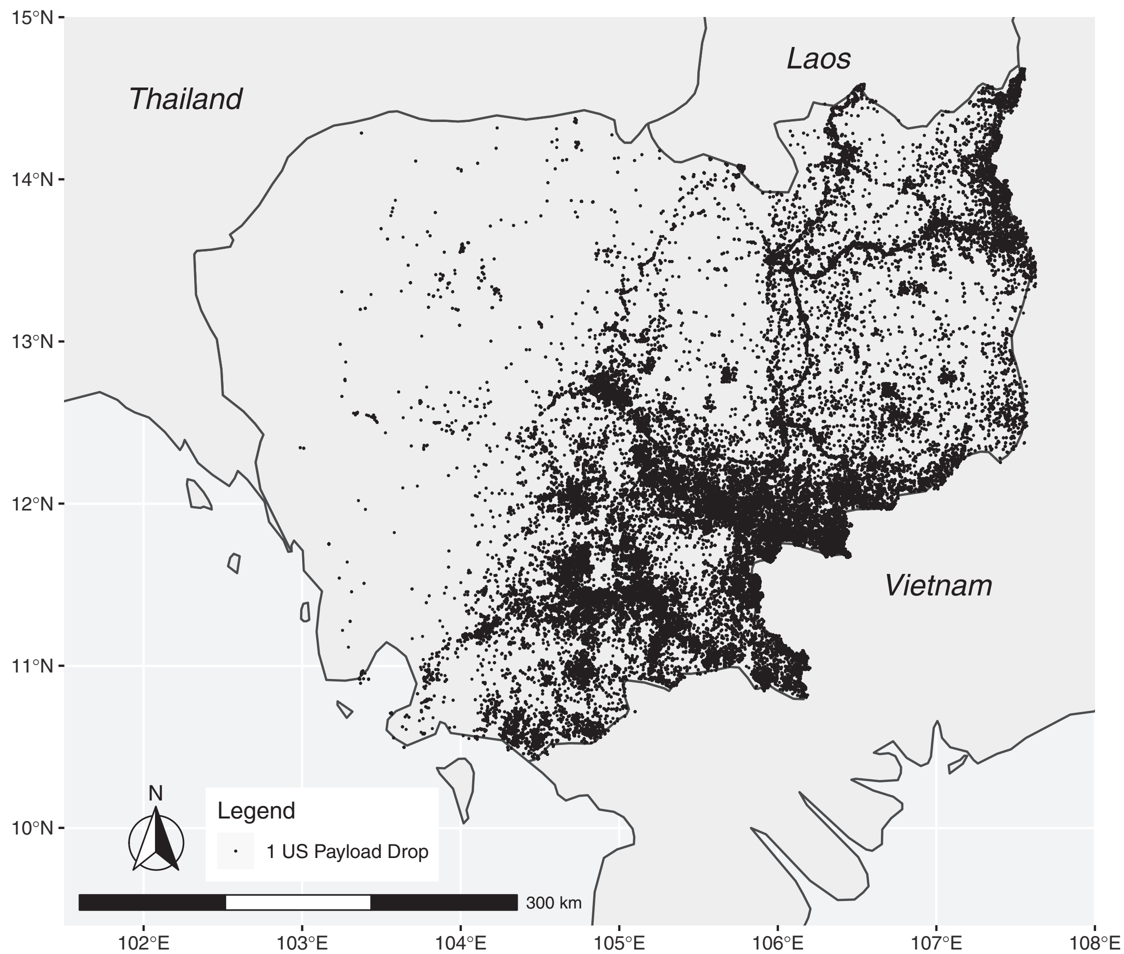
## Empirical Analysis

### Data and Estimation

**Unexploded Ordnance and Their "Sphere of Fear."** I first collected data on US Air Force payloads. I use airstrike placement, conditional on soil fertility, as a proxy for bomb failure. This approach is not a perfect solution, as not everyone within the target zone is equally susceptible to encountering bombs, given that fields within the same drop zone will likely vary in the density and placement of ordnance. However, the insecurity associated with the risk of detonation is not the same as the realization of risk—that is, the lethality and injury rate from leftover ordnance. Gruesome events are easily recalled from memory, leading large segments of the population to exaggerate their likelihood (Thaler 1983) and engage in precautionary behavior in excess of the actual hazard (Fafchamps 1992; Jalan and Ravallion 1999). Expanding far beyond the explosion radius of each bomb, the "sphere of fear" (Perlman 2006) transcends the immediate vicinity, formidably restricting economic activity even for those not directly in harm's way.

The bombing data are derived from the Southeast Asia Air Combat Database, which captured daily air combat information on the Vietnam War. These data detail the coordinates of each released piece of ordnance, date of release, type of ordnance (e.g., 750-lb general purpose bomb, BLU-32 Fire bomb), and number of bombs and weight of the payload. The spatial distribution of the 115,273 payload drops is presented in Figure 1. I mapped the payloads onto village hamlets over the full territory of the country. I drew a circle with a five-kilometer radius around each village center, which provides a reasonable estimate of where households would locate their

**FIGURE 1 Map of Cambodia**




*Note*: 115,273 payloads were dropped by the US Air Force in Cambodia from 1965 to 1973.

fields. Anthropological research indicates that farmers keep their fields within close walking proximity to the hamlet so they can monitor for animals and thieves (Ebihara 1971). I use this procedure to create a variable that counts the tonnage of bombs within the close walking radius of each hamlet. Even though the village centroids do not provide the shape of individual villages, my interviews suggested that farmers select fields based on proximity to hamlet, not the village boundaries, which fluctuate based on local interpretation and are not recorded in the national land register.[4]

The soil fertility indicator is drawn from the Cambodian Agricultural Research and Development Institute's 2008 soil database, which categorized the country's land into three levels of soil productivity (low, medium, and high) based on the main limiting factors for growing rice. Since the key components of soil—minerals, organic content, water, air, and living organisms—are derived from rocks that are physically weathered into smaller pieces, it takes more than 500 years for one inch of topsoil to form. Consequently the 2008 measures of soil fertility are a reasonable reflection of soil fertility decades prior. The land fertility at the village centroid represents a best guess for the soil fertility of each household's fields. While a more accurate indicator would use the boundaries of each field, this information is not recorded by Ministry of Land Management (in charge of maintaining cadastral maps), so coding fertility is tricky without substantial local knowledge.

My ability to identify the effect of unexploded ordnance hinges on the assumption that bomb failure is plausibly exogenous to the prior economic development of villages. The key identifying assumption is that

[4]I also estimated my models using a three-kilometer radius (supporting information, pp. A10–A12). Doing this reduces my precision, but the results are substantively similar.

impact fuse failure is "as good as" random, conditional on soil fertility. As noted earlier, unexploded ordnance stem from flaws in engineering and design, and detonation was largely determined by idiosyncratic characteristics at the target's surface. Ethnographic accounts suggest that this variation in unexploded ordnance density is unrelated to the pre-war behaviors and views of the local population (Uk 2016; Zani 2019) while US government reports underscore how undetonated bombs were malfunctions and largely unrecorded over the course of the war (Martin et al. 2019; US Congressional Report 1995), suggesting that the latent explosions played little role in military strategy.

A second identifying assumption is that households would follow identical trends, absent treatment. This assumption would be violated if contemporary economic patterns are largely driven by damage from the bombs that did explode when dropped, not the unexploded ordnance: for instance, if the destroyed capital and infrastructure created more economic setbacks than unexploded bombs, or if the bomb craters displaced and compacted land to the point that it is impossible to farm. This line of reasoning suggests that detonated bombs have longer legacy effects than undetonated ones, so we would expect areas with more detonations (low-fertility, bombed land) to experience lower productivity than areas with more undetonated bombs (high-fertility, equally-bombed land). This implication is testable with the current dataset, and notably the main hypothesis makes the opposite prediction. In addition, I adjust for this potentially confounding influence by controlling for pre-bombing infrastructure (roads and housing, described later).

To capture contemporary development, I draw on the 2012 Cambodia Socioeconomic Survey, a nationally-representative survey of 3,840 households in 384 villages. The survey was developed to provide a clear picture of development and welfare for the smallest economic units: households, their fields, and their individual members. I geo-locate each respective unit using the Cambodian 2008 census' village coordinates. Given that the census does not describe the shape of individual villages (village boundaries are not even recorded by the Ministry of Planning) or the precise locations of households and their fields, I believe this is a reasonable simplification of a complex reality.

**Agricultural Productivity.** For each household plot, I calculate the amount of rice produced in the past year. Rice functions both as a food crop and a cash crop; rice is a mainstay of the Cambodian diet, providing more than half the daily calories of the poor. Surplus is typically sold at the local market or mill. Since rice quality varies and quantity depends on the size of the paddy, I measure rice production in US dollars per square-meter of paddy. I also collect data on the amount of land that was cultivated for rice compared to the actual size of the field. I use both the absolute measure (in square-meters) and the relative measure (percentage of total field) as indicators of agricultural efficiency.

Other agricultural behaviors operate at the household level. For instance, household members decide whether to buy modern (but heavy) tools that would increase productivity. The survey provides data on the household's capital assets, specifically regarding farm machinery. It records the number of tractors, bulldozers, threshers, semitractors, and water pumps owned by each household. I use a household's total number of farming machines as an indicator of higher investment in agriculture. In addition, household members also pool rice harvest across paddies and decide how much to consume or sell. To measure surplus, I calculate the percentage of the household's rice crop that was sold to market.

**Economic Diversification and Welfare.** To examine whether households exposed to unexploded ordnance work in non-farming sectors, I use the survey items on alternative land-based livelihoods. For each household, the survey records the past year's income from fish and from livestock and poultry. If unexploded bombs limit local economic activities, family members may be more likely to explore distant labor markets and leave home for safer jobs. To evaluate local migratory patterns, I collect individual-level survey responses on the number of weeks each household member has been absent from home.

Another possibility is that in these households exposed to unexploded bombs, parents may rely more on children to supplement their income. Given the long treatment window, parents may try to increase the family labor force by having more children. The reduction in farming may provide parents more time to have and care for children. Eventually, income from grown children may offset the losses in the field. For each household, I calculate the number of family members younger than 18 years old. Lastly, I collect the survey data on each household's reported cash income in the past year.

**Additional Relevant Factors: Geography, Wartime Movements, and Agricultural Zones.** I acknowledge that there is possible endogeneity in the treatment assignment because not all parts of the country received similar levels of bombing. Even though the failure rate of bombs was exogenous to local economic characteristics, proximity to Vietnam—where all of the Ho Chi Minh Trails eventually ended—influenced the general level of bombing. Because distance to the border may have also impacted economic activity, I control for kilometers to Vietnam from the center of each village. I also control for the location of pre-bombing transit points, as the decision to drop payloads was influenced by the presence of roads and waterways that were believed to be used by the Vietnamese communists. To do so, I employ a series of military topographic maps of Cambodia (1962–67), developed by US Army Map Service for the purpose of military land navigation. The Army Corps of Engineers had used aerial photographs to tag information on household location, crop boundaries, dirt roads, and river tributaries in order to identify potential targets in a remote setting that lacked friendly support units. An indicator for road density was constructed by calculating the meters of road within five kilometers of the village center. A binary variable for waterways represents whether a river, lake, or tributary is located within the five-kilometer buffer around the village centroid. Because bombings could have been focused on areas with high agricultural production or larger populations, as they might have been seen as providing cover for the National Liberation Front, I adjust for this potentially confounding influence by controlling for pre-bombing village development. Specifically, I estimate the percentage of rice fields and count the number of houses within each five-kilometer village buffer.[5]

In all estimations, I add fixed effects for the five price zones identified by the Cambodia Development Resource Institute (2008) in their survey of the Cambodian rice market. Price zone fixed effects are useful for these purposes because the analysts developed them inductively, based on the four agro-climatic zones and Phnom Penh (which has rice fields in the suburbs of the capital). By including price zone effects, I adjust for the possible confounding influence of unobserved shifts in supply and demand, as well as regional variation in transport and storage costs, wages, and input costs.

## Legacy Effect on Agriculture

I first analyze whether exposure to unexploded ordnance is associated with lower agricultural productivity and investment. In all models, the fertility variable is interacted with the bombing intensity in $\log(x + 1)$ transformed pounds. I set the baseline to *High Fertility Soil*, so the bombing coefficient can be interpreted as the effect of bombing on high fertility soil or, in other words, the effect of unexploded ordnance. A negative coefficient would support the hypothesis. Results are presented in Tables 1 and 2, and the unit of analysis is the agricultural field and the household, respectively. The hypothesis also predicts different marginal effects across fertility. Low-fertility soils, where bombs have detonated and no longer pose a threat, should have insignificant marginal effects of bombing. To facilitate substantive interpretation, I computationally derive the marginal effect of bombing in low- versus high-fertility areas in Figure 2.

To test whether unexploded ordnance impact agricultural efficiency, Models (1)–(2) in Table 1 estimate the conditional effect of bombing on a farmer's likelihood to cultivate the entirety of her field. Model (1) examines the share of land, in proportion to the size of the field, and Model (2) evaluates the absolute amount of land. The coefficient on *Bombing* is negative and statistically significant at $\alpha < 0.01$ in both models. The effects are substantively meaningful: on high-fertility land, moving from no bombing to the sample average reduces the amount of their land that farmers actually use by 4,888m$^2$ (11.4 – 428.8). It also decreases the share of land that is actively farmed by 12%. Figure 2, Row 1 provides the marginal effects graphically. The point estimates for the condition of low-fertility soil are statistically indistinguishable from zero.

The remaining column examines rice production. In Model (3) in Table 1, results support the hypothesis: the bombing coefficient is negative and statistically significant. Figure 2 plots the marginal effects, revealing a clear discontinuity between soil fertility categories. On high-fertility soil, an unbombed plot yields rice valued at 0.30 USD/m$^2$. Moving from no bombing to the sample mean decreases rice production by 0.19 USD/m$^2$, a two-thirds drop in value. Crucially, these households produce rice at the rate of low-fertility farms. An unbombed, low-fertility plot yields rice worth 0.15 USD/m$^2$. Even though moving from no bombing to the sample mean decreases rice production by 0.09 USD/m$^2$, the 95% confidence interval of the low-fertility marginal effect in Figure 2 overlaps with zero. Since a high-fertility field with the sample mean of bombing produces 0.11 USD/m$^2$, it falls within the production range of low-fertility farms. Put another way, unexploded ordnance appear to remove the fertility advantage of high-fertility soils.

Analysis presented in Table 2 suggests that unexploded bombs negatively influence farming decisions made at the household level. The negative coefficient on bombing is statistically significant across the two outcomes: the household's investment in agricultural, for example, a count of the household's heavy agricultural machines (Model 1) and the household's crop surplus, for example, the fraction of the rice harvest that was sold to

[5]The supporting information (pp. A8–A10) provides further details on descriptive statistics and bombing intensity across fertility and price zones.

**TABLE 1 Conditional Impact of Bombing on Agriculture**

| | Outcome Variable: Field Productivity | | |
|---|---|---|---|
| | (1) Area Farmed (% total field) | (2) Area Farmed (m$^2$) | (3) Rice Harvest (USD/m$^2$) |
| Bombing | $-0.01^{**}$ | $-428.82^{**}$ | $-0.02^{**}$ |
| | (0.00) | (41.57) | (0.00) |
| Bombing × Low-Fertility | $0.01^{*}$ | $393.29^{**}$ | 0.01 |
| | (0.00) | (58.77) | (0.01) |
| Low-Fertility Soil | 0.07 | $-162.93^{**}$ | $-0.15^{\dagger}$ |
| | (0.05) | (760.58) | (0.09) |
| Constant | $0.22^{*}$ | $8{,}694.95^{**}$ | 0.04 |
| | (0.09) | (1,482.31) | (0.17) |
| Observations | 3,636 | 3,636 | 3,636 |
| Price zone fixed effects | √ | √ | √ |
| Pretreatment covariates | √ | √ | √ |
| Adjusted $R^2$ | 0.17 | 0.14 | 0.01 |

*Notes*: OLS, Unit: Field. Reference category: High-Fertility Soil. Standard errors in parentheses. Bombing is transformed log( *pounds* + 1). $^{\dagger}p < 0.1$; $^{*}p < 0.05$; $^{**}p < 0.01$.

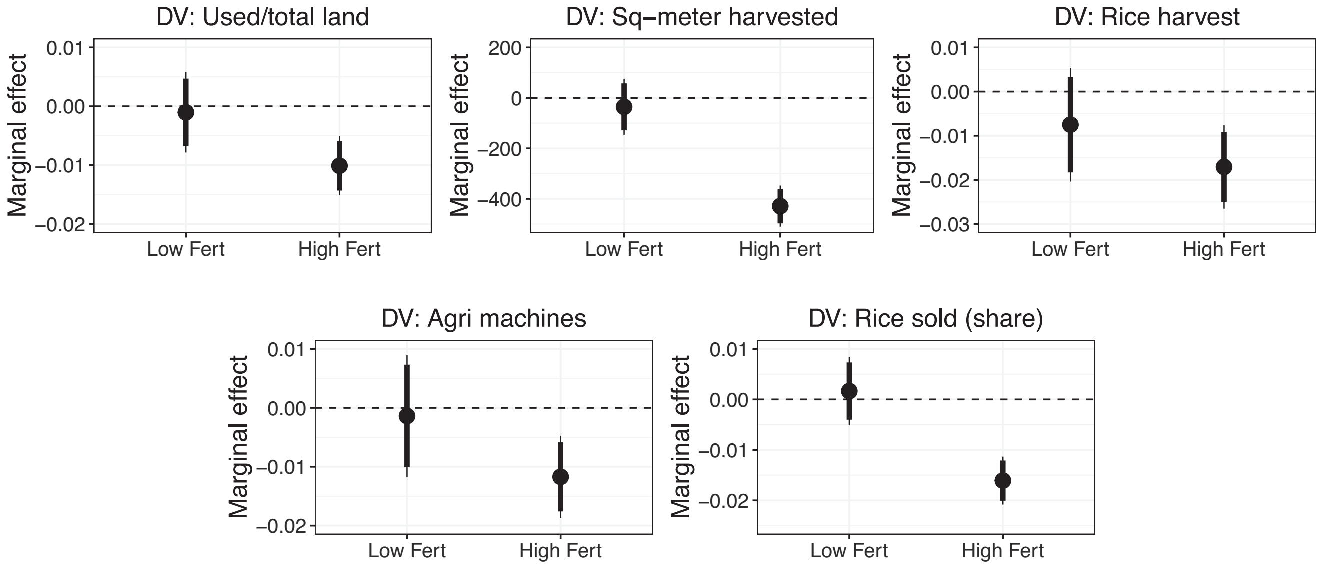
market (Model 2). On high-fertility land, moving from no bombing to the sample mean decreases the number of machines by 0.13. The bombing coefficient is small (–0.02) because very few households own machines. The mean sample household owns 0.32 machines, and interviews suggest that many farmers borrow or rent machines from other villagers. Shifting from no bombing to the sample mean, the rice surplus also drops 18%, relative to 41% at the control condition (i.e., non-bombed, high-fertility household). This represents a 44% decline in market sales. By comparison, bombing in the low-fertility condition appears to have no significant effect, as seen in Figure 2. In sum, the places where bombs already detonated (low-fertility, bombed units) tend to behave similarly to their non-bombed, low-fertility counterparts, suggesting that the destructive effect of a bomb explosion may dissipate with time. However, farming on bombed, high-fertility soil still carries high risk, and

**TABLE 2 Conditional Impact of Bombing on Agriculture**

| | Outcome Variable: Investment and Surplus | |
|---|---|---|
| | (1) Machines Owned (#) | (2) Rice Sold to Market (% of harvest) |
| Bombing | $-0.01^{**}$ | $-0.02^{**}$ |
| | (0.00) | (0.00) |
| Bombing × Low-Fertility | $0.01^{\dagger}$ | $0.02^{**}$ |
| | (0.01) | (0.00) |
| Low-Fertility Soil | $-0.09$ | $-0.17^{**}$ |
| | (0.07) | (0.04) |
| Constant | $0.25^{**}$ | $0.29^{**}$ |
| | (0.08) | (0.08) |
| Observations | 2,910 | 2,064 |
| Price zone fixed effects | √ | √ |
| Pretreatment covariates | √ | √ |
| Adjusted $R^2$ | 0.05 | 0.08 |

*Notes*: OLS, Unit: Household. Reference category: High-Fertility Soil. Standard errors are in parentheses. Bombing is transformed log( *pounds* + 1). $^{\dagger}p < 0.1$; $^{*}\ p < 0.05$; $^{**}p < 0.01$.

**FIGURE 2 Marginal effect of bombing on agricultural outcomes, conditional on soil fertility**




*Note*: The plot shows the marginal effect of bombing with 90% and 95% confidence intervals.

households are deterred from investing in capital inputs, farm less of their property, and produce less output compared to their non-bombed, high-fertility counterparts.

## Legacy Effect on Livelihoods

Do undetonated bombs have legacy effects beyond farming? I analyze whether households threatened by unexploded ordnance are able to diversify their rural activities by regressing livestock/poultry sales and fish sales on the log-transformed bombing intensity, soil fertility, and their interaction. As can be seen in Table 3, the coefficient on bombing in Models (1) and (2) is negative and statistically significant, suggesting that high-fertility households face declining animal sales with bombing. On average, a household on unbombed, high-fertility land earned US$117 from livestock and poultry sales in the past twelve months. Moving from no bombing to the sample mean, these sales fall by US$63. Similarly, fish sales fall by US$99, an 80 percentage point decline from the fish sales of non-bombed, high-fertility households (US$124). At the same time, the marginal effect on low-fertility soil (seen in Figure 3) is statistically insignificant.

One may reasonably wonder whether declining agricultural sales influence household income. Table 3 Model (3) examines the past year's cash income, transformed $\log(x+1)$. As hypothesized, the coefficient on bombing is negative and statistically significant. Moving from no bombing to the sample mean on high-fertility land decreases log-transformed income by 0.5 units. Put another way, while a household on high-fertility, unbombed land makes an average of US$505, a similar household that experienced an average amount of bombing makes US$301, a 60% reduction in income. By contrast, the marginal effect of bombing for low-fertility households is insignificant (see Figure 3).

Unexploded ordnance do not appear to change family structure. Figure 3 shows how the marginal effects for both fertility categories overlap with zero. The null effects suggest that other factors such as access to contraception, child morbidity, and health clinic proximity may override the economic incentives to increase the family labor pool.

Finally, I consider whether unexploded ordnance increase migration, as farmers are forced to look outside the village for safer economic opportunities. In Table 4, the positive and significant bombing coefficient confirms the hypothesis. Moving from no bombing to the sample mean, time away increases by 0.41 weeks, from 0.44 weeks at the no-bombing condition. In other words, the average amount of bombing increases an individual's migratory time by 91% or 3 days. By comparison, Figure 3 demonstrates how the marginal effect of bombing on low-fertility land is statistically insignificant.

Given the incentives to look elsewhere for safer employment, why is the migration effect size so small? Farmer interviews suggest that job mobility is prohibitively costly, particularly because work opportunities in the agricultural sector are tied to land ownership.

**TABLE 3 Conditional Impact of Bombing on Livelihoods**

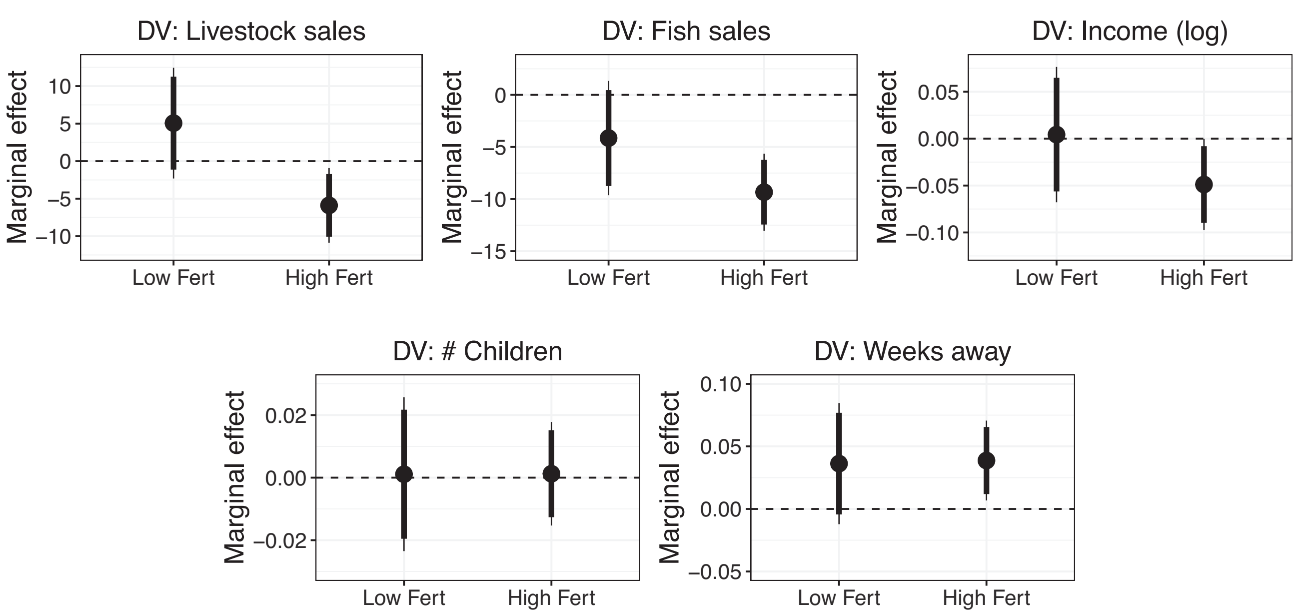
| | Outcome Variable: Diversification and Welfare | | | |
|---|---|---|---|---|
| | (1) Livestock/Poultry Sales | (2) Fish Sales | (3) Logged Cash Income | (4) Number of Children |
| Bombing | −5.89 | −9.34 | −0.05 | 0.00 |
| | (2.54) | (1.89) | (0.02) | (0.01) |
| Bombing × Low-Fertility | 10.96$^{**}$ | 5.19$^{\dagger}$ | 0.05 | 0.00 |
| | (3.94) | (2.93) | (0.04) | (0.01) |
| Low-Fertility Soil | −65.73 | −73.54$^{\dagger}$ | −1.25$^{*}$ | −0.04 |
| | (50.60) | (37.63) | (0.50) | (0.17) |
| Constant | 143.84$^{*}$ | 214.98$^{**}$ | 14.85$^{**}$ | 1.59$^{**}$ |
| | (56.59) | (42.08) | (0.55) | (0.19) |
| Observations | 2,894 | 2,894 | 2,894 | 2,910 |
| Price zone fixed effects | √ | √ | √ | √ |
| Pretreatment covariates | √ | √ | √ | √ |
| Adjusted $R^2$ | 0.02 | 0.04 | 0.01 | 0.02 |

*Notes*: OLS, Unit: Household. Reference category: High-Fertility Soil. Standard errors are in parentheses. Bombing is transformed $\log(pounds + 1)$. $^{\dagger}p < 0.1$; $^{*}p < 0.05$; $^{**}p < 0.01$.

When asked if he would leave his farm to find other work, one respondent explains, "I don't know where I would even go. Even if I did have a lead, it doesn't mean I would actually leave. My land *here* is my job" (Interview 1, May 3, 2018). Another farmer has already built a house near his wife's ancestral village. "It's too late to try to live anywhere else," he says, "so I'm trying to figure out how to make a living here. I don't have much of a choice. I don't have anywhere else to go, so I keep working on my farm here" (Interview 14, May 8, 2018). In sum, farmers are constrained by the sunk costs of their investments.

Lastly, multiple outcomes confirm bombing's null effect on low-fertility soil. One idea advanced by this finding is that a detonated bomb does *less* long-term economic damage than an undetonated bomb. A bomb

**FIGURE 3 Marginal effect of bombing on economic outcomes, conditional on soil fertility**




*Note*: The plot shows the marginal effect of bombing with 90% and 95% confidence intervals.

explosion may inflict lasting trauma (Balcells 2012), but in the long-run destructed communities are able to converge back to steady-state production. By contrast, an undetonated bomb acts as a time capsule, marking the place in time when development stopped. More than fifty years after the Vietnam War, affected farmers are still unable to safely take advantage of machinery or even the entirety of their field. Notably, these findings deviate from the major theoretical predictions in the existing literature on the legacy effects of US bombings, which use less fine-grained data and find little evidence of persistent developmental impacts in Japan, Germany, and Vietnam (Brakman, Garretsen, and Schramm 2004; Davis and Weinstein 2002; Miguel and Roland 2011). The null effect of bombing is plausible in certain areas, though it might stem from differences in land quality rather than in capital structures (Miguel and Roland 2011) or baby booms (Davis and Weinstein 2002).[6]

**TABLE 4 Conditional Impact of Bombing on Migration**

| | Outcome Variable: Migration Weeks Away from Home |
|---|---|
| Bombing | 0.04* |
| | (0.02) |
| Bombing × Low-Fertility | –0.00 |
| | (0.03) |
| Low-Fertility Soil | 0.05 |
| | (0.33) |
| Constant | −1.22** |
| | (0.36) |
| Observations | 13,524 |
| Price zone fixed effects | √ |
| Pretreatment covariates | √ |
| Adjusted $R^2$ | 0.01 |

*Notes*: OLS, Unit: Individual. Reference category: High-Fertility Soil. Standard errors are in parentheses. Bombing is transformed $\log(pounds + 1)$. $^{\dagger}p < 0.1$; $^{*}p < 0.05$; $^{**}p < 0.01$.

## Conclusion

Does war leave a lasting legacy on development? This research establishes a new, long-term consequence of political violence through the transformation of land. Bomb fuses tend to fail on high-fertility targets, leaving rural households to fend off the dangers associated with unexploded ordnance. Facing a trade-off between immediate safety and future yield, these farmers produce 50% less rice and collect 60% less income than their counterparts on non-bombed, similarly-fertile land.

The main finding of this article—that leftover weapons make land more dangerous and impoverish civilians for decades—is striking within the context of the political economy literature on the legacy of war. Perhaps the most prevalent set of explanations points to the strength, policies, and behaviors of post-war regimes that shape developmental pathways (Charnysh 2019; Doyle and Sambanis 2006; Fortna 2008; Matanock 2017). A burgeoning literature points to the lingering effects of violent trauma on intergenerational preferences (Balcells 2012; Lupu and Peisakhin 2017; Rozenas, Schutte, and Zhukov 2017). What is missing from these accounts is an appreciation of the role that human ecology plays in explaining where civilians can resume their prewar livelihoods.

My findings also underline the fact that bombing is a composite intervention: some bombs explode on impact while others do not, and the failure rate varies according to surface conditions and technology. Though the effects of bombing might vary by context, there are good reasons to expect these findings to obtain beyond Cambodia. The United States still maintains an arsenal of 2.2 million cluster munitions in the US and 1.5 million abroad, despite innovations in precision-guided munitions. The last known US airstrike involving cluster munitions was 2009 in Yemen, but after a 2016 Saudi aerial attack of Yemen, survivors found the latest generation of US-manufactured cluster bombs. If American manufacturers continue to sell cluster munitions abroad, then unexploded ordnance should be treated as an enduring political problem rather than a one-off historical phenomenon.

It is, finally, worth considering how long these legacies may last. One would think that the number of undetonated bombs would decrease with time, and so would the risk—particularly if bombs closer to the surface pose the most danger and detonate first. Yet, the interviews suggest that the fear associated with the risk of detonation may have a longer half-life than the bombs themselves. Farmers, like researchers, appear to operate with incomplete information on bomb location and density, and evaluate threats based on their knowledge of local military history and land fertility. We still know little about what kinds of information about violent events are shared, precisely how cultural transmission works, and what the political implications are. Only further

[6]The main results are also robust to controlling for (post-treatment) Khmer Rouge violence (pp. A19–A21), bolstering my confidence that the effects of unexploded ordnance persist through multiple political regimes.

research can document the full extent to which military technology has profoundly limited the options for improving life in the developing world.

# References


Acemoglu, Daron, Tarek Hassan, and James Robinson. 2011. "Social Structure and Development: A Legacy of the Holocaust in Russia." *Quarterly Journal of Economics* 126(2): 895–946.

Balcells, Laia. 2012. "The Consequences of Victimization on Political Identities: Evidence from Spain." *Politics & Society* 40(3):311–47.

Bisin, Alberto, and Thierry Verdier. 2001. "The Economics of Cultural Transmission and the Dynamics of Preferences." *Journal of Economic Theory* 97(2):298–319.

Blattman, Christopher, and Edward Miguel. 2010. "Civil War." *Journal of Economic Literature* 48(1):3–57.

Boix, Carles, and Susan Stokes. 2003. "Endogenous Democratization." *World Politics* 55(4):517–49.

Borrie, John. 2003. *Explosive Remnants of War: A Global Survey.* Landmine Action.

Brakman, Steven, Harry Garretsen, and Marc Schramm. 2004. "The Strategic Bombing of German Cities during World War II and Its Impact on City Growth." *Journal of Economic Geography* 4(2):201–18.

Brooks, Sarah. 2014. "Insecure Democracy: Risk and Political Participation in Brazil." *Journal of Politics* 76(4):972–85.

Brown, Ryan, Verónica Montalva, Duncan Thomas, and Andrea Velásquez. 2019. "Impact of Violent Crime on Risk Aversion: Evidence from the Mexican Drug War." *Review of Economics and Statistics* 101(5):892–904.

Butler, Declan. 2008. "Further Delays to Full Agent Orange Study." *Nature* 452(7189):786.

Callen, Michael, Mohammad Isaqzadeh, James Long, and Charles Sprenger. 2014. "Violence and Risk Preference: Experimental Evidence from Afghanistan." *American Economic Review* 104(1):123–48.

Cambodia Development Resource Institute. 2008. "Impact of High Food Prices in Cambodia." Phnom Penh, Cambodia: CDRI.

Chandler, David. 1991. *The Tragedy of Cambodian History: Politics, War, and Revolution Since 1945.* London, UK: Yale University Press.

Charnysh, Volha. 2019. "Diversity, Institutions, and Economic Outcomes: Post-WWII Displacement in Poland." *American Political Science Review* 113(2):423–41.

Charnysh, Volha, and Evgeny Finkel. 2017. "The Death Camp Eldorado: Political and Economic Effects of Mass Violence." *American Political Science Review* 111(4):801–18.

Christensen, Darin. 2019. "Concession Stands: How Mining Investments Incite Protest in Africa." *International Organization* 73(1):65–101.

Collier, Paul, VL Elliott, Håvard Hegre, Anke Hoeffler, Marta Reynal-Querol, and Nicholas Sambanis. 2003. *Breaking the Conflict Trap: Civil War and Development Policy.* Washington, DC: World Bank.

Daskin, Joshua, and Robert Pringle. 2018. "Warfare and Wildlife Declines in Africa's Protected Areas." *Nature* 553(7688):328.

Davis, Donald, and David Weinstein. 2002. "Bones, Bombs, and Break Points: The Geography of Economic Activity." *American Economic Review* 92(5):1269–89.

De Groot, Gerard. 2005. *The Bomb: A Life.* Cambridge, MA: Harvard University Press.

Dell, Melissa, and Pablo Querubin. 2017. "Nation Building through Foreign Intervention: Evidence from Discontinuities in Military Strategies." *Quarterly Journal of Economics* 133(2):701–64.

Dercon, Stefan. 2002. "Income Risk, Coping Strategies, and Safety Nets." *World Bank Research Observer* 17(2):141–66.

Diamond, Jared. 1999. *Guns, Germs, and Steel: The Fates of Human Societies.* New York: W.W. Norton & Company.

Doyle, Michael, and Nicholas Sambanis. 2006. *Making War and Building Peace: United Nations Peace Operations.* Princeton, NJ: Princeton University Press.

Dunning, Thad. 2008. *Crude Democracy: Natural Resource Wealth and Political Regimes.* Cambridge, UK: Cambridge University Press.

Ebihara, May. 1971. "Svay, a Khmer Village in Cambodia." PhD thesis. Columbia University.

Ehrlich, Isaac, and Gary Becker. 1972. "Market Insurance, Self-insurance, and Self-protection." *Journal of Political Economy* 80(4):623–48.

Fafchamps, Marcel. 1992. "Cash Crop Production, Food Price Volatility, and Rural Market Integration in the Third World." *American Journal of Agricultural Economics* 74(1): 90–99.

Fortna, Virginia Page. 2008. *Does Peacekeeping Work? Shaping Belligerents' Choices after Civil War.* Princeton, NJ: Princeton University Press.

Fouka, Vasiliki. 2019. "How Do Immigrants Respond to Discrimination? The case of Germans in the US during World War I." *American Political Science Review* 113(2):405–22.

Haberman, Clyde. 2016. "A Lingering Legacy of Wars: Unexploded Bombs." *New York Times*, October 3.

Herbst, Jeffrey. 2000. *States and Power in Africa: Comparative Lessons in Authority and Control.* Princeton, NJ: Princeton University Press.

Ismay, John. 2017. "U.S. Will Keep Older Cluster Munitions, a Weapon Banned by 102 Nations." *New York Times*, December 1.

Jakiela, Pamela, and Owen Ozier. 2019. "The Impact of Violence on Individual Risk Preferences: Evidence from a Natural Experiment." *Review of Economics and Statistics* 101(3):547–59.

Jalan, Jyotsna, and Martin Ravallion. 1999. "Are the Poor Less Well Insured? Evidence on Vulnerability to Income Risk in Rural China." *Journal of Development Economics* 58(1):61–81.

Kim, Young-Il, and Jungmin Lee. 2014. "The Long-run Impact of a Traumatic Experience on Risk Aversion." *Journal of Economic Behavior & Organization* 108:174–86.

King, Colin. 2000. *Explosive Remnants of War: A Study on Submunitions and Other Unexploded Ordnance.* Geneva: International Committee of the Red Cross.

Kocher, Matthew, Thomas Pepinsky, and Stathis Kalyvas. 2011. "Aerial Bombing and Counterinsurgency in the Vietnam War." *American Journal of Political Science* 55(2):201–18.

Lipset, Seymour. 1959. "Some Social Requisites of Democracy: Economic Development and Political Legitimacy." *American Political Science Review* 53(1):69–105.

Lupu, Noam, and Leonid Peisakhin. 2017. "The Legacy of Political Violence across Generations." *American Journal of Political Science* 61(4):836–51.

Lyall, Jason. 2009. "Does Indiscriminate Violence Incite Insurgent Attacks? Evidence from Chechnya." *Journal of Conflict Resolution* 53(3):331–62.

Martin, Michael, Ben Dolven, Andrew Feikcert, and Thomas Lum. 2019. "War Legacy Issues in Southeast Asia: Unexploded Ordnance (UXO)." *Congressional Research Service*, June 3.

Matanock, Aila. 2017. *Electing Peace: From Civil Conflict to Political Participation*. Cambridge, UK: Cambridge University Press.

McGrath, Rae, and Richard Lloyd. 2000. *Cluster Bombs: The Military Effectiveness and Impact on Civilians of Cluster Munitions*. Bucks: UK Working Group on Landmines.

Miguel, Edward, and Gerard Roland. 2011. "The Long-run Impact of Bombing Vietnam." *Journal of Development Economics* 96(1):1–15.

Moyes, Richard. 2002. *Explosive Remnants of War: Unexploded Ordnance and Post-conflict Communities*. London: Landmine Action.

Neives, Evelyn. 2018. "The 'Endless War' of Land Mines in the Balkans." *New York Times*, April 4.

Nesbitt, Harry. 1997. *Rice Production in Cambodia*. International Rice Research Institute.

Nut, Annie, and Pascal Simon. 2016. *'Finishing the Job': An Independent Review of the Mine Action Sector in Cambodia*. Geneva International Centre for Humanitarian Demining.

Perlman, Janice. 2006. "The Metamorphosis of Marginality: Four Generations in the Favelas of Rio de Janeiro." *Annals of the American Academy of Political and Social Science* 606(1):154–77.

Ross, Michael. 2013. *The Oil Curse: How Petroleum Wealth Shapes the Development of Nations*. Princeton, NJ: Princeton University Press.

Rozenas, Arturas, Sebastian Schutte, and Yuri Zhukov. 2017. "The Political Legacy of Violence: The Long-term Impact of Stalin's Repression in Ukraine." *Journal of Politics* 79(4):1147–61.

Ruan, Juan Carlos, and Jill Macheme. 2001. "Landmines in the Sand: The Falkland Islands." *Journal of Conventional Weapons Destruction* 5(2):13.

Sachs, Jeffrey, and Andrew Warner. 2001. "The Curse of Natural Resources." *European Economic Review* 45(4-6):827–38.

Schelling, Thomas. 2008. *Arms and Influence*. London: Yale University Press.

Sheehan, Neil. 1998. *A Bright Shining Lie: John Paul Vann and America in Vietnam*. New York: Random House.

Stellman, Jeanne Mager, Steven Stellman, Richard Christian, Tracy Weber, and Carrie Tomasallo. 2003. "The Extent and Patterns of Usage of Agent Orange and Other Herbicides in Vietnam." *Nature* 422(6933):681.

Stern, Jeffrey. 2018. "From Arizona to Yemen: The Journey of an American Bomb." *New York Times Magazine*, December 11.

Thaler, Richard. 1983. "Illusions and Mirages in Public Policy." *Public Interest* 73.

Uk, Krisna. 2016. *Salvage: Cultural Resilience among the Jorai of Northeast Cambodia*. Ithaca, NY: Cornell University Press.

US Congressional Report. 1995. "Unexploded Ordnance: A Coordinated Approach to Detection and Clearance is Needed."

Voigtländer, Nico, and Hans-Joachim Voth. 2012. "Persecution Perpetuated: The Medieval Origins of Anti-Semitic Violence in Nazi Germany." *Quarterly Journal of Economics* 127(3):1339–92.

Voors, Maarten, Eleonora Nillesen, Philip Verwimp, Erwin Bulte, Robert Lensink, and Daan Van Soest. 2012. "Violent Conflict and Behavior: A Field Experiment in Burundi." *American Economic Review* 102(2):941–64.

Walter, Barbara. 2004. "Does Conflict Beget Conflict? Explaining Recurring Civil War." *Journal of Peace Research* 41(3):371–88.

Wood, Geof. 2003. "Staying Secure, Staying Poor: The 'Faustian Bargain.'" *World Development* 31(3):455–71.

Zani, Leah. 2019. *Bomb Children: Life in the Former Battlefields of Laos*. Durham, NC: Duke University Press.

# Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

**Appendix A**: Data and measurement
**Appendix B**: Alternative regression models
**Appendix C**: Alternative explanations