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【要旨】

We examine the impacts of perceived landmine risk on the welfare of agricultural villagers more than two decades after the end of civil conflict in Cambodia, which lasted from 1970 to 1998, using Cambodian censuses. Using an instrumental variable approach, we find that the perceived risk of landmines has some long-lasting effects despite significant efforts toward demining. Perceived landmine risk is associated with lower crop productivity, higher crop diversity, and higher labor rates among children aged 5–14 years. However, we do not find any significant transition away from agricultural production due to perceived landmine risk or effects on school attendance among the 5–9-year cohort or on child marriage among the 13–14-year cohort.

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Perceived risk of landmines and the welfare of Cambodian agricultural households

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Abstract: We examine the impacts of perceived landmine risk on the welfare of agricultural villagers more than two decades after the end of civil conflict in Cambodia, which lasted from 1970 to 1998, using Cambodian censuses. Using an instrumental variable approach, we find that the perceived risk of landmines has some long-lasting effects despite significant efforts toward demining. Perceived landmine risk is associated with lower crop productivity, higher crop diversity, and higher labor rates among children aged 5–14 years. However, we do not find any significant transition away from agricultural production due to perceived landmine risk or effects on school attendance among the 5–9-year cohort or on child marriage among the 13–14-year cohort.

Keywords: Landmines, Agriculture, Welfare, Household, Children, Cambodia

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1. Introduction

> *The landmine cannot tell the difference between a soldier or a civilian – a woman, a child, a grandmother going out to collect firewood to make the family meal… The landmine is eternally prepared to take victims. In common parlance, it is the perfect soldier, the "eternal sentry."*
>
> Jody Willams (Nobel Peace Prize Lecture)
> Oslo, December 10, 1997

Landmines pose a great threat to people. Landmines can be found on roads, in agricultural fields, along borders, and around critical infrastructure, thus impeding access to food, water, and other necessities (International Campaign to Ban Landmines [ICBL], 2024). Landmines are a widely used weapon in poor countries because of their low cost (around USD 1 per unit) (Chiovelli et al., 2025). At present, the locations of most landmines are not recorded. Efforts to remove mines are costly (Harris, 2000) and thus proceed slowly. Although the annual number of casualties has decreased, landmines still pose a lasting risk to local populations after the fighting has come to an end.

Mine fields, agricultural work, and local household welfare are all intertwined. Farmland often overlaps with suspected hazardous areas where mines make agricultural work potentially dangerous. Even after mine-removal efforts, there is a risk that one or more mines might have been overlooked. Chiovelli et al. (2025) report that a period of 4–6 years after the initial clearance of all hazards in a locality in Mozambique was needed in order to observe brighter and stable luminosity of nighttime light—a proxy for increased economic activities.

The perceived risk of landmines is thought to constrain agricultural production (e.g., land constraint,[1] concentration on unproductive land, Wade, 2011), suppress crop productivity, and lower the quality of farm products. The constraint in farm size might reduce productivity and necessitate greater use of family labor (Ayaz & Mughal, 2024). Decreased productivity is generally associated with increased child labor[2] (Edmonds & Pvcnik, 2005; Dumas, 2020), child marriage,[3] and school interference (Edmonds & Theoharides, 2021). However, to our knowledge, the effects of perceived landmine risk have not been investigated empirically.

In addition, perceived landmine risk might lead the local population to adapt by diversifying crop production, adjusting intrahousehold labor, or engaging in non-agricultural work. Such adaptation might also lead to structural change. To our knowledge, no studies have investigated economic adaptation due to the explosive remnants of warfare in rural areas.

We examine these issues, using data from three sources: the Cambodian Baseline Survey on Mine and Explosive Remnants of War (2009-2014), which contains the locations of landmines; a dataset of geocoded landmine clearance progress from 1992 to 2019; and the Cambodian Agriculture Census 2023 (CAC 2023). Using an instrumental variable (IV) approach and district fixed effects, we estimate the possible impacts of a perceived landmine risk index on temporary crop productivity, diversity, average working hours outside the agricultural sector among household members, child labor, child marriage, and school attendance of children aged 5–14 years. The perceived landmine risk index is defined as the

[1] The Cambodia Landmine Impact Survey reports the largest impact of landmines on villages is the insufficiencies of agricultural land (CMAC, 2020, page 4).
[2] The International Labor Organization (ILO) defines child labor as work that is harmful to the physical and mental development of children (URL: https://www.ilo.org/topics/child-labour/what-child-labour). ILO-UNICEF (2024) reported that 138 million children worldwide are involved in child labor, mainly in agriculture, among which 54 million are engaged in hazardous work.
[3] The United Nations Children's Fund (UNICEF) defines child marriage is any formal marriage or informal union between a child under 18 years of age and another person. (URL: https://www.unicef.org/protection/child-marriage). Child marriage is associated with maternal and infant morbidity (mortality), depression, sexually transmitted diseases, and domestic violence (Krafft et al., 2024).

product of the number of landmine contamination locations within a 1-km buffer ring from the map points of the villages and the ratio of remaining (plot) areas to be demined in the future, dividing into the total (plot) area to be cleared within the 1-km buffer ring. We also conduct a robustness check by changing the assumption of the 1-km buffer distance to 500 m and 2 km.

We find long lasting impacts of perceived landmine risk. Specifically, perceived risk of landmines is associated with lower crop productivity and greater crop diversity, perhaps in an effort for households to secure a subsistence income. However, we do not find that perceived landmine risk is associated with greater working hours outside of agricultural activities. The perceived risk of landmines is statistically significant in explaining child labor in agricultural work, perhaps due to the labor-intensive nature of temporary crops under land constraints. However, the perceived risk of landmines has no significant impact on child marriage (among children aged 13–14 years), school attendance (among children aged 5–9 years), and child labor for work outside the agricultural sector.

Our study contributes to the literature in several aspects. We contribute to the rich literature on the impacts of remnants of warfare (e.g., Davis & Weinstein, 2002; Brakman et al., 2004; Miguel & Roland, 2011; Merrouche, 2011; Arcand et al., 2015; Islam et al., 2016; Saing & Kazianga, 2019; Guo 2020; Yamada & Yamada, 2021; Le et al., 2022; Kim, 2023; Riano & Valencia Caicedo 2024; Prem et al., 2025; Chiovelli et al., 2025) and the medium- and long-term impacts of fear/repression (Bühler & Madestam, 2023) on health, human capital, and economic development. Specifically, our study provides new evidence on the long-lasting effects from perceived risk of landmines on crop productivity and diversification, even after clearance. To our knowledge, this is the first study to provide evidence of landmine adaptation among affected farmers.

The remainder of the paper is organized as follows. Section 2 describes the context of civil conflict in Cambodian and its aftermath. Section 3 describes the data. Section 4 introduces

our method and econometric specifications. Section 5 reports the main results with a discussion on the mechanisms and policy implications. Section 6 presents the conclusion and some outstanding issues.

2. Civil conflict in Cambodia (1970–1998) and its aftermath

The civil conflict in Cambodia started with a civil war (1970–1975) between the Khmer Republic administration and the Khmer Rouge. Between 1975–1979, the Khmer Rouge held power and established Democratic Kampuchea. In December 1978, alongside the Kampuchean United Front for National Salvation, Vietnam launched a full-scale attack on the Khmer Rouge in response to the Khmer Rouge's repeated border attacks and genocidal policies. The Khmer Rouge regime collapsed within a few weeks and retreated to western Cambodia and bases along the Thailand–Cambodia border. From there, they waged a prolonged guerrilla war throughout the 1980s. To protect their territory and block the Khmer Rouge intruders, Vietnamese troops deployed a defense line, often known as the K5 (defense) plan, the K5 conscription program, or the Bamboo Curtain. The defense line along the border was heavily mined. Although the pullout of Vietnam troops was completed in 1989 and the Paris Peace Accords were concluded in 1991, fighting between the Cambodian government and resistance factions lasted until 1998 (Merrouche, 2011).

The legacy of the warfare (1970–1998) is known not only for the genocide carried out by the Khmer Rouge that killed 1.7–3 million people[4]—approximately a quarter of the Cambodian population at that time—but also for the numerous landmines, which are sometimes referred to as "eternal soldiers." It is estimated that 4–6 million mines[5]—equivalent to between

[4] Source: https://news.un.org/en/story/2022/09/1127521
[5] Source: https://cmac.gov.kh/what-we-do/clearance-and-disposal/

one-third and one-half of Cambodia's 1998 population—were laid underground. ICBL (1999) regards Cambodia as among the most mined countries in the world. An early estimation indicates that 664 km^2 is known to be mined and another 1400 km^2 is suspected to be mined. The National Landmine Survey (2000–2002) indicates that 46% of all Cambodian villages overlap with suspected hazardous areas (Cambodia Mine Action Centre [CMAC], 2010, p.16). CMAC reports that mines were laid indiscriminately, without records, by all factions throughout the conflict.[6]

Despite massive clearance efforts, the risk to the population remains high. From 1992 to 2005, clearance was slow but then ramped up owing to increased funding and the deployment of dedicated equipment. The ICBL (2024) praised Cambodia for achieving the world's largest clearance, removing mines from 167.53 km^2 of land in 2023 alone. The annual causalities caused by landmines plunged from 1,153 in 1999 to just 21 in 2023.[7] Despite this progress, the ICBL (2024) still ranks Cambodia among the countries mostly heavily contaminated with antipersonnel mines (with 4,330 suspected hazardous areas covering an area of 435 km^2) as of the end of 2023. To date, about 1.2 million units have been destroyed,[8] but this is far below the official estimate of 4–6 million of laid landmines.

In addition, clearance does not immediately mean the land is free of risk, particularly in agricultural production. The United Nations Mine Action Service (2020, p.2) and the Geneva International Centre for Humanitarian Demining (2006, p.62) suggest that national authorities[9] use a default search depth ≥13 cm below the original surface when information on local mines is not reliable. This means that if the default depth is close to 13 cm, even when clearly stated

[6] Source: https://cmac.gov.kh/impacts/
[7] Source: https://cmac.gov.kh/impacts/.
[8] As of December 2023. Source: https://cmac.gov.kh/what-we-do/clearance-and-disposal/.
[9] Clearance of landmines in Cambodia (by the Cambodian Mine Action Standards) follows the international standards. The depth of search and method of clearance are written clearly in the land-release documentation.

in the land-release document, the perceived risk of landmines would persist in areas where agriculture is an economic activity. It can take some time for a clearance area to become released land. The National Mine Action Strategy 2018–2025 published by the Royal Government of Cambodia (2017) suggests that all parties are aware of the perceived risk of landmines. It goes on to say that the quality management of land released after demining should "… be maintained and strengthened to provide confidence to beneficiaries … and that released land is indeed safe to use."

3. Data

We construct separate datasets for households, children aged 5–14 years, and villages. The first two datasets come from the CAC 2023, the Baseline Survey on Mine and Explosive Remnants of War (2009–2014), and map points of villages and administrative shape files from the Cambodian National Institute of Statistics (NIS).

First, CAC 2023 is the second national agricultural census conducted by the NIS. According to the NIS (2025), CAC 2023 covered all households in the country, except for four districts in Phnom Penh and villages with fewer than five agricultural holdings in the 2019 General Population Census. That means CAC 2023 covers 14,201 of Cambodia's 14,577 villages. One of the questionnaire items asked detailed information about each household member.

Second, we use the Baseline Survey on Mine and Explosive Remnants of War (2009–2014). The data contains detailed geographic information system (GIS) locations (map points) of mines and explosive remnants of warfare from a survey conducted during 2009–2014.[10] The data were collected by CMAC and the Victim Assistance Authority and distributed by the

[10] The data are housed and available at the Open Development Cambodia website (https://data.opendevelopmentcambodia.net/en/dataset/erw). We note that the scope of contamination locations is close to the conventional suspected hazard areas rather than the precise locations of the land mines.

Office for the Coordination of Humanitarian Affairs. We include only locations associated with landmines; 24,244 such locations accounted for about 84% of all contamination locations in the Baseline Survey. Also, we use the clearance GIS data during 1992–2019 and the plots to be demined in the future as of December 2019. We use only plots associated with landmines.

Third, we use the shape file of Cambodia from the NIS to create some spatial variables. We calculate the nearest distances from each village map point to a proxy of the defense line during the period of Vietnamese troop occupation (D_v). The 600-km long K5 defense line (see Figure 1) was heavily mined to fence off Khmer Rouge's infiltration during 1984–1989.[11] The K5 defense line is approximately the same as the border with Thailand. We overlay the shape file of Cambodia with a 100-m buffer to a shape file of Thailand from GADM 4.1 (URL: www.gadm.org) with a 100-m buffer. We use the intersection between the two shapes as a proxy for the K5 defense line. We connect this information at village level to the three datasets.

[Insert Figure 1 here]

In addition, we use the village codes to connect the data with the shape files of Cambodian communes and districts (in 2019) and the latest available GIS map points of villages (in 2011) provided by the NIS. Unfortunately, because of changes in administration divisions (names) in the past two decades, we have to make a tradeoff between the invaluable location of villages in order to identify the impacts of perceived landmine risk and the sample size. We are unable to identify about 2,680 of the 14,577 villages.

The third dataset contains village-aggregated data from the Economic Census 2022 conducted by the NIS. The census included items on various business identities. We further distinguish whether the business has registered with the Ministry of Commerce, Provincial

[11] Wade (2011) notes that landmines were laid along both sides of the Thailand–Cambodia border. In Thailand, it is known as the protective barrier against the Khmer Rouge's massive agrarian efforts from the mid-1970s.

Department of Commerce, or the General Department of Taxation or Taxation Branch. We restrict the sample to villages that are also under the scope of the agriculture census.

Finally, we omit some outliers and missing information. The first consists of 1,255,502 households. The second covers 835,200 children aged 5–14 years across 599,414 households. The third is 10,749 villages. The descriptive statistics of the final datasets are presented in appendices A.1, A.2, and A.3.

4. Method and specifications

We use an instrumental variable approach. First, we aim to estimate the relationship (β) between the perceived risk of landmines at the village level (T_v) and outcomes (y_{vi}) using district fixed effects ($\gamma_{district}$) at the household, children, and village levels in a reduced form as follows.

$$y_{vi} = \beta \times T_v + \alpha \times C_{vi} + \eta \times \gamma_{district} + \epsilon_i, \quad (1).$$

We deploy robust standard errors clustered at the district level. Details of the specification for equation (1) are as follows.

Main outcomes (y_{vi})

We calculate three outcomes (y_{vi}) per household i from questionnaires (Form C) of CAC 2023. The first is the logarithm-adjusted[12] total value of (all kinds of) temporary crops produced by households (in the past 12 months) per square meter (based on the land area set aside for temporary crops). The logarithm value is a measure of crop productivity. The second is the number of unique temporary crops (based on unique crop codes) that households planted in the past 12 months. The second outcome is a proxy for crop diversity. The third is the average number of working hours per household member (age >14 years) for economic activities

[12] We use the inverse hyperbolic sine transformation of the raw value m for any logarithm-adjusted variables. The logarithm-adjusted value is $\ln\left(m + \sqrt{m^2 + 1}\right)$.

outside agricultural production per day in the past 12 months; this acts as a proxy for the getaway from agricultural work.

Three outcomes (y_{vi}) per children i aged 5–14 years in village v come from the questionnaires (Form 3) of CAC 2023. The first (B09) asks whether the household member has engaged in any agricultural activities in last 12 months. The second (B11) asks whether the person engaged in any non-agricultural economic activities. In addition, children aged 5–14 years were asked the same set of questions. We define the first two outcomes of family work corresponding to children aged 5–14 years as child labor.[13] The third question (B06) asked the marital status of all household members aged 13 years or older. Any kind of status other than single for children aged 13–14 years is treated as a form of child marriage. For the heterogenous analyses, we construct the outcomes for each age cohort (i.e., 4–9, 10–14, and 13–14 years).

Finally, we count the total number of workers involved in businesses (distinguishable into business registration and tax code registration) located in each village as the outcome (y_{vi}) per village. The number of workers is a proxy of labor demand for local villagers and the probability of structural change.

Control variables (C_{vi})

We use a similar set of control variables at the household level for both estimations at the household and children levels. The control variables are the total number of water pumps, lawn mowers, fertilizer spreaders, tractors, cars, motorcycles, and solar generators used directly in crop production,[14] a dummy for using irrigation, the logarithm of land area used for

[13] Following the definition of child labor by ILO, we define child labor as the involvement of any children (aged 5-14 years) in (agriculture) economic activities in the past 12 months. Agricultural work can be hazardous because it exposes workers to pesticides, heat, reptiles, insects, repeated injuries, and so on (Edmonds, 2007).

[14] Although the controls are straightforward to productivity outcomes, they might also work with outcomes of child labor. In a clustered randomized trial in the Philippines, Edmonds and Theoharides (2020) find that productive assets are associated with more child labor.

temporary crops,[15] and whether the land is close to home. We also include dummies for three different land ownership types (legal, non-legal possession, rented land, and other—the baseline). The type of ownership might be associated with agriculture productivity, as suggested by Gottlieb and Grobovšek (2019).

Moreover, we have few differences in controls for the three different datasets. For estimation at the children level, we control for the gender and age of the children. We add the number of household members over 14 years of age who are involved in agricultural production and in economic activities other than agriculture.

Main explanatory variable (T_v)

The perceived landmine risk index (T_v) is calculated from two steps. First, we count the total number of contamination locations from landmines only and restrict to locations with clearly identified fear levels by the Baseline Survey team,[16] falling within a 1-km buffer from the map points of each village. We assume that landmines are uniformly distributed within contamination areas. In the raw data,[17] over 96% of the locations were marked as the highest on the fear scale ("high" and "medium"). The total number of contamination locations (N_c) can measure the potential influence of villagers' perceived risk of landmines.[18] Second, we discount the counted number (N_c) by using a clearance ratio. The ratio is formed by dividing the for-future-clearance plots by 2019 ($Future_v$) by all plots ($Total_v$) that are cleared (1992–2019) ($Past_v$) or those that are to be cleared (demined) after 2019 ($Future_v$). All calculated plots

[15] Ayaz & Mughal (2024) suggest that farm size and productivity are well connected. Meanwhile, Bhalotra & Heady (2003) find a wealth paradox applied to girls: children in land-rich households are more likely to work than those in land-poor households.
[16] See Figure 1.
[17] See appendix A.4 for detailed information on the fear level in the raw data.
[18] In CAC 2023, only 0.45% (89.47%) of the households have their agricultural parcel far away from (close to) their residence; 10.07% of the households have a home lot only.

($Past_v$ and $Future_v$) are areas within the 1-km buffer ring from the map points of the village.[19] Specifically, we use the following formula:

$$T_v = N_c \times \frac{Future_v}{Total_v}, \quad (2)$$

where $Total_v = Past_v + Future_v$. The index ($T_v$) is a proxy of how much fear measured from the Baseline Survey remains after discounting the clearance efforts (1992–2019). The larger magnitude of the index (T_v), the higher the perceived risk of landmines in 2022–2023. In addition, we exclude observations in villages that had some contamination locations from the Baseline Survey within a 1-km buffer ring from its map points and had a record of clearance but did not have a piece of land regarded as for-future-clearance (to be demined in the future).[20]

The perceived risk of landmines (T_v) per village in equation (1) is not random and might be associated with some factors in the error terms (ϵ_i), such as productivity of farmland. The endogeneity problem might lead to a bias estimation of β in equation (1). Therefore, we need to use an IV to reduce biases as well as for our claim of causal inference.

Instrumental variable (D_{v1})

We use the relative distance from each village to the nearest point on the K5 defense line (D_{v1}) compared with other villages of the same district as the IV. We perform the estimation using the following reduced form equation with district fixed effects as the first stage:

$$T_v = \delta \times D_v + \theta \times C_{vi} + \varphi \times \gamma_{district} + \varepsilon_i. \quad (3).$$

We use the estimation results from equation (3) to estimate equation (1) as the second stage.

[19] We set $T_v = N_c$ when information for both $Future_v$ and $Past_v$ was not available.

[20] Formula (2) makes such villages becoming the same as villages with no perceived landmine risk. To achieve a cleaner comparison, we exclude about 34,347 (24,602) such observations belonging to 247 villages to get the final samples of 1,255,502 (835,200 children) for our estimations. This is a roughly 2.6%–2.9% reduction in the sample size. In addition, we performed the analysis with the inclusion of such observations, and the interpretation of the results was the same as the reported results. These results are available upon request.

D_v can be considered a valid IV for several reasons. First, the K5 defense line was decided by Vietnamese army leaders to prevent the Khmer Rouge from entering the Cambodian territory held by Vietnamese troops during 1984–1989. This means the placement of mines was out of Cambodian villagers' control. In late 1979, the Khmer Rouge was forced to retreat to the northern and western Cambodia, where they employed guerrilla tactics for more than a decade (1979–1989). In addition, the district fixed effects ($\gamma_{district}$) in all equations would be expected to mitigate the plausible drawbacks that the distance to the border with Thailand might be associated with historical trade, ethnic, and cultural influences. $\gamma_{district}$ captures the time-invariant similarity in natural conditions (i.e., soil), climate, agricultural production methods, ethnicity, and culture within a district.

In estimation using district fixed effects, the coefficient δ in equation (2) is expected to have negative sign and be interpreted as follows. If a village *j* is located closer to the K5 defense line compared with another village *k* in the same district, village *j* would have had more landmine contamination locations of compared with village *k* (See Figure 1 for a visual layout of landmine contamination locations and villages in Cambodia). Consequently, the perceived risk of landmines would be relatively higher.

Second, in our later estimations, we show that the relative distance to the K5 plan line is negatively associated with the perceived risk of landmines, and the association is statistically significant. Third, the relative distance within a district to the K5 defense line has local variation. It is less likely to directly affect the outcomes of interest, including crop productivity, diversification, working hours, child labor, school attendance, and child marriage.

Our IV is similar to the one used by Merrouche (2011) but has some advantages. Merrouche (2011) proposed the distance of each district to the K5 defense as an IV but later used the proportion of the district population that spoke a language other than Khmer in the

actual estimations. Our IV has more variations because it is more detailed, at two levels lower than district—the village level. In addition, we use district fixed effects, which pinpoint closer to the local variation (and control for ethnic differences as well). We calculate the geodesic distance in kilometers.

5. Results

5.1 Crop productivity, diversity, and agricultural getaway

We find that the perceived risk of landmines is associated with lower productivity (quality) of temporary crops. As seen in Table 1, higher perceived risk of landmines is associated with a lower logarithm-adjusted value of crop value per square meter. The negative relationship results are stable regardless of additional control variables, which is also the main difference among the estimations in Table 1. The added control variables include measures of production methods, economies of (land) scale, and land ownership variation. Furthermore, in the first stage, the estimation shows a strong negative relationship between the relative distance to the K5 defense line within a district and the perceived risk of landmines (F-value > 16).

[Insert Table 1 here]

We find evidence of production adaptation (from the farmers) to cope with lower productivity associated with perceived risk of landmines. In villages with high perceived risk of landmines, farmers diversify the types of crops they grow (Table 2). By growing a greater variety of crops, farmers increase their sources of income from agricultural work throughout the year. Such diversity might have raised the productivity level, as suggested by Sodjahin et al. (2025). The results also suggest that the negative effects found in crop productivity might have been even worse without such diversification.

[Insert Table 2 here]

We examine whether farmers adapt by engaging in non-agricultural work. Economic activities outside the agriculture sector would generate income to offset the constraint of cropland if such economic activities are land-saving. Furthermore, such changes would lead to structural transformation.

First, we investigate the supply side. We alter the outcome as working hours per household member (age >14 years) per day in the 12 months prior to the census in a sector other than agriculture. The results in Table 3 suggest that farmers still engaged mainly in agricultural work. The coefficients of interest are negative and statistically insignificant.

[Insert Table 3 here]

Second, on the demand side, we test whether contamination locations might limit employment by businesses that take risks to locate nearby. We use the number of workers as the outcome for similar estimations.[21] The results in Table 4 suggest that perceived risk of landmines is not necessarily associated with a significantly lower number of workers (associated with either registered or unregistered businesses) or fewer job opportunities. Thus, the results suggest that engaging in agricultural work would be from the supply side. In addition, an attempt was made to check heterogeneity across industries, but the data do not support this. The data have a large number of observations with missing information on industries.[22]

[Insert Table 4 here]

5.2 Child labor, child marriage and school attendance

The low value per kilogram of temporary crops in connection with the perceived risk of landmines might lead to child labor. Farmers with a year-round labor shortage might have to utilize their children in production, particularly during harvest season (Edmonds, 2007; Basu

[21] We are aware that people do not necessarily find jobs in their villages because jobs in nearby villages are also acceptable.
[22] Although the economic census has a question on the international standard industrial codes (ISIC), the information is available for only 258 of the total 753,670 businesses in the raw data.

& Van, 1998; Beegle et al., 2006). We test this hypothesis by using the number of children aged 5–14 years who are involved in crop production as the outcome. We find that the perceived risk of landmines is associated with child labor in agricultural activities (Table 5). However, we do not find an association with child labor in other economic activities.

[Insert Table 5 here]

We also examine whether such involvement in temporary crops may interrupt school attendance and lead to child marriage in the worst case. Child marriage might serve as compensation to households in villages affected by landmine contamination for the shortage of labor for a period of time. Following tradition (*twee bomrae* in Khmer), potential Cambodian grooms would work for the parents of his bride-to-be during the prenuptial period and even after the elaborate wedding ceremony (Heuveline & Poch, 2006). Child marriage is not always illegal,[23] and despite the legal minimum marriage age of 18 years, in 2022, 18% (3%) of Cambodian women (men) aged 20–24 years had married before 18 years of age (NIS, 2023).

The negative effects on school attendance and child marriage are statistically insignificant (Table 6). Similarly, we did not find any statistically significant relationship between perceived risk of landmines and child marriage among children aged 13 and 14 years (Table 7). Our results on child marriage in the present-day generations are distinct from but support those by Saing & Kazianga (2019), who show that the age at first marriage for Cambodian females was reduced in those who were directly exposed to higher U.S. bombing intensity. Our outcomes measure the present generation rather than the war-time generation.

[Insert Table 6 and 7 here]

[23] Cambodian laws provide for some exceptions to the age of consent for marriage. For example, the 1989 Marriage and Family law girls under the age of 18 years to marry if they are pregnant (https://www.refworld.org/legal/legislation/natlegbod/1989/en/1467). In addition, civil code 2007 (Article 948) allows marriage for individuals who are at least 16 years of age if their parents or guardian consent (http://www.skpcambodia.com/storage/uploads/files/Civil%20%26%20Civil%20Procedure%20Laws/Civil%20code%20Eng.pdf)

We further decompose the outcomes by age cohort: 5–9 and 10–14 years. We find that the effects on child labor in agricultural activities persist across birth cohorts (see appendices A.5 and A.6). In addition, the effects on lower school attendance are statistically significant among older cohort (aged 10–14 years).

5.3 Robustness checks

We consider 2 km and 500 m as two other assumptions on distances from the map points of villages to count the number of landmine contamination locations in order to establish the perceived landmine risk index—defining the control group. Under these two different assumptions, we also find statistically significant impacts of perceived landmine risk on outcomes related to crop diversification and child labor in agricultural production (see appendix A.8). Although the impacts on the productivity outcome remain negative, they become statistically insignificant at the 10 percent level.

5.3 Possible mechanisms and policy implications

We discuss the results along with several policy implications that might help to overcome the perceived risk of landmines and improve the welfare of agricultural households. The perceived risk of landmines might lead to lower temporary crop productivity for several reasons. Before clearance, the land would be under constraint; for example, landmines might be located in places that are suitable for temporary crop production. The farmers would have to use unproductive land as a last resort. In addition, land that is fragmented by contaminated areas might reduce the potential for economies of scale.

The constraint of land due to perceived landmine risk leads to crop diversification but not structural changes. This might be because the level of education among villagers is not high enough to support such changes. We use the CAC 2023 to investigate the highest level of education attained by all villagers aged 23 years or older. Below primary completion is 49.8%.

Primary school completion is 9.4%. 7.1% stop at secondary school completion. 5.5% finished grade 12 without a certificate. Less than 2% had a tertiary degree. Such low levels of education would impede the villager's ability to transition to other industries.[24]

When farmers cannot transition away from agricultural activities, they must adapt by using several measures. For example, they would need to increase the number of crops they grow each year and utilize their children in crop production, as our estimated results suggest. Fortunately, such child labor is not associated with significantly lower school attendance or child marriage in villages where the perceived risk of landmines persists.

Our findings suggest that policymakers should make solving the issue of low temporary crop productivity in the remaining clearance areas a higher priority. This is important because farmers are not able to engage in non-agricultural economic activities. In addition, the negative effects of perceived landmine risk on school attendance among children aged 10–14 years is worrisome. New economic (educational) policies should be implemented along with clearance efforts in order to shrink the gap. For example, a nudge from the government in the form of an investment incentive and improved market access would enhance the welfare of agricultural households. In addition, agricultural extension programs might help to increase productivity, raise income level, indirectly eliminate child labor, and increase the level of education.

6. Conclusions

We examined whether the perceived risk of landmines, via the number of landmine contamination locations (96% marked with medium and highest on the fear scale) within a 1-km buffer ring from the map points of the village, is associated with the welfare of agricultural households in Cambodia, including temporary crop productivity and diversity; structural

[24] This low educational attainment might have been caused by the Khmer Rouge genocide. Under the Khmer Rouge regime, the mortality rate was higher among well-educated populations (de Walque, 2006). De Walque (2006) further cites that in 1979, "the secondary school system was in disarray, with only few hundred teachers for the whole country.".

change in economic activities; and child labor, child marriage, and school attendance in children. We used the relative distance of each village to the nearest point on the K5 defense line established by Vietnamese troops combined with district fixed effects in order to identify the effects of perceived landmine risk. We find that perceived risk of landmines is associated with lower temporary crop productivity but greater diversity in crop types. We also find that perceived risk of landmines has a nexus with child labor among children aged 5–14 years in agricultural activities.

This study has several limitations that should be acknowledged. First, there is a data limitation. We predicted the existence of contamination locations unknown to all parties (villagers and the government), based on the fact that the number of collected items was only about half of the estimated number of mines laid. In addition, the Baseline Survey on Mine and Explosive Remnants of War (2009–2014) and clearance data (1992–2019) do not contain areas where self-demining took place. Furthermore, the contamination locations for the Baseline Survey were neither randomly selected nor included in a full census. As seen in appendix A.4, the early year surveys contain more potential locations. Moreover, there is a gap between the land classification (of suspected landmines or remnants of war) from the Baseline Survey and the actual collected items.

Second, our estimations do not account for the perceived landmine risk in villages not included in the Baseline Survey (2009–2014) and the most recent clearance (2020–2022), for which we were unable to obtain the corresponding data. However, the number of contamination locations in the Baseline Survey has decreased over the years, from thousands to just 21 locations in 2014, which might lower the risk of overlooking previously surveyed locations.

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FIGURE 1. VILLAGES AND LANDMINE CONTAMINATION LOCATIONS

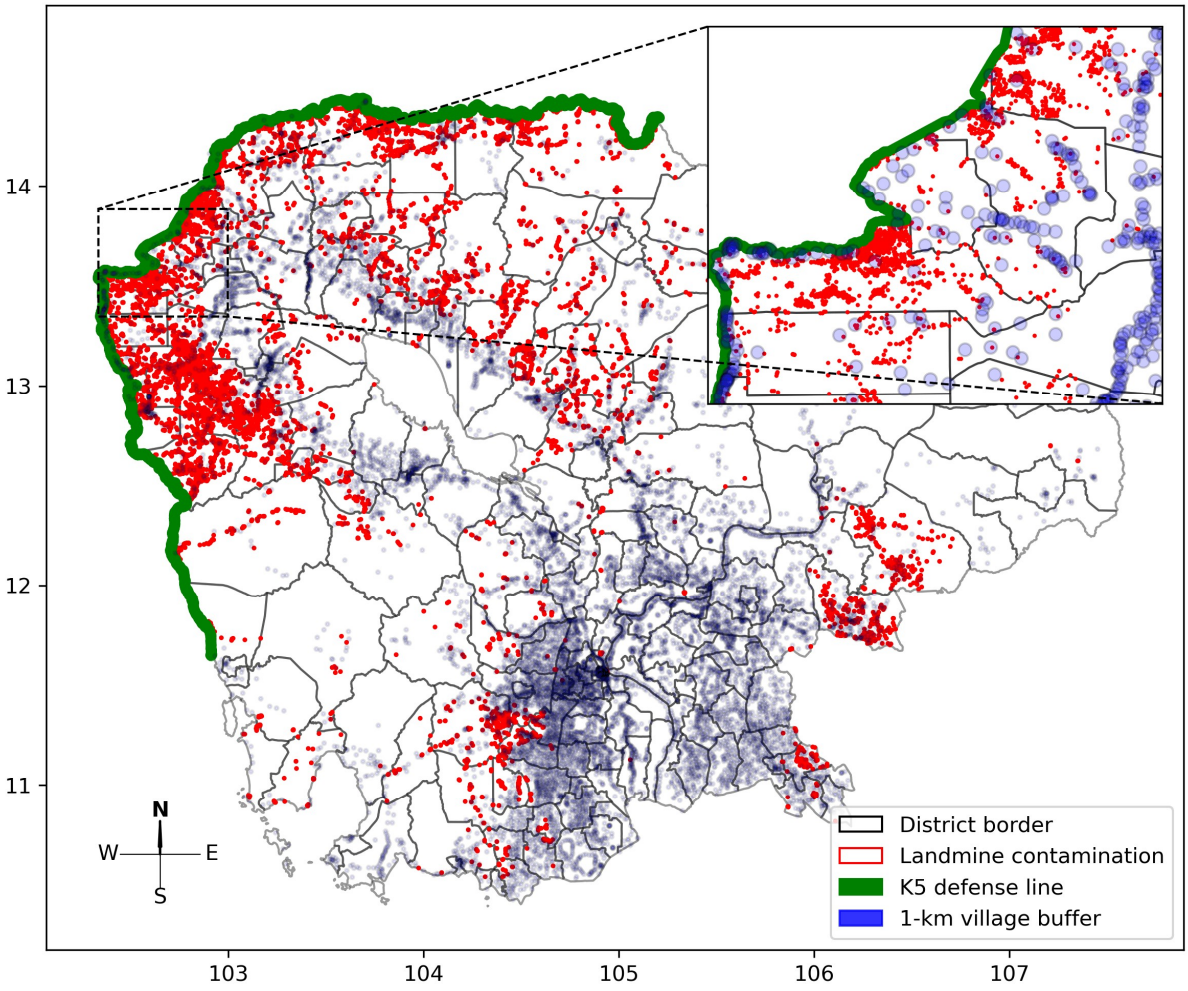


TABLE 1 CROP PRODUCTIVITY

Variables	Ln (crop value per m^2)	Ln (crop value per m^2)	Ln (crop value per m^2)
Second stage	(1)	(2)	(3)
Perceived risk of landmines	−0.5600*	−0.6528**	−0.4781*
	(0.3256)	(0.3295)	(0.2849)
First stage	Perceived risk of landmines	Perceived risk of landmines	Perceived risk of landmines
Distance to the K5 defense line	−0.012***	−0.012***	−0.012***
	(0.003)	(0.003)	(0.003)
F-test of excluded instruments	16.3	16.3	16.5
Controls			
Close to home, adjusted logarithm of total land for temporary crops, number of agricultural workers in the household	No	Yes	Yes
Number of tools, irrigation usage, land ownership[ψ]	No	No	Yes
District fixed effects	Yes	Yes	Yes
Observations	1,255,502	1,255,502	1,255,502

Notes: [ψ] Controls include the number of water pumps, lawn mowers, fertilizer spreaders, tractors, cars, motorcycles, solar generators, dummy for using irrigation, and dummies for three different types of land ownership types. Robust standard errors clustered at the district level are in parentheses *** p<0.01, ** p<0.05, * p<0.1.

TABLE 2 CROP DIVERSITY

Variables	Number of unique crops	Number of unique crops	Number of unique crops
Second stage	(1)	(2)	(3)
Perceived risk of landmines	0.1943***	0.1556***	0.1536***
	(0.0564)	(0.0503)	(0.0506)
First stage	Perceived risk of landmines	Perceived risk of landmines	Perceived risk of landmines
Distance to the K5 defense line	−0.012***	−0.012***	−0.012***
	(0.003)	(0.003)	(0.003)
F-test of excluded instruments	16.3	16.3	16.5
Controls			
Close to home, adjusted logarithm of total land for temporary crops, number of agricultural workers in the household	No	Yes	Yes
Number of tools, irrigation usage, land ownership[ψ]	No	No	Yes
District fixed effects	Yes	Yes	Yes
Observations	1,255,502	1,255,502	1,255,502

Note: Same as Table 1. Robust standard errors clustered at the district level are in parentheses *** p<0.01, ** p<0.05, * p<0.1.

TABLE 3 AVERAGE WORKING HOURS PER PERSON OUTSIDE AGRICULTURE

Variables			
	Working hour pp	Working hour pp	Working hour pp
Second stage	(1)	(2)	(3)
Perceived risk of landmines	−0.0646	−0.0835	−0.0548
	(0.4332)	(0.4332)	(0.4325)
First stage	Perceived risk of landmines	Perceived risk of landmines	Perceived risk of landmines
Distance to the K5 defense line	−0.012***	−0.012***	−0.012***
	(0.003)	(0.003)	(0.003)
F-test of excluded instruments	16.3	16.3	16.5
Controls			
Close to home, adjusted logarithm of total land for temporary crops, number of agricultural workers in the household	No	Yes	Yes
Number of tools, irrigation usage, land ownership[ψ]	No	No	Yes
District fixed effects	Yes	Yes	Yes
Observations	1,255,502	1,255,502	1,255,502

Note: Same as Table 1. Robust standard errors clustered at the district level are in parentheses *** p<0.01, ** p<0.05, * p<0.1.

TABLE 4 NUMBER OF WORKERS IN THE VILLAGE

Variables	All	Firms with registration	Firms with registration and tax code
	Number of workers	Number of workers	Number of workers
Second stage	(1)	(2)	(3)
Perceived risk of landmines	−93.3672	−23.8126	−20.8777
	(70.7037)	(20.3904)	(17.3017)
First stage	Perceived risk of landmines	Perceived risk of landmines	Perceived risk of landmines
Distance to the K5 defense line	−0.016***	−0.016***	−0.016***
	(0.004)	(0.004)	(0.004)
F-test of excluded instruments	15	15	15
District fixed effects	Yes	Yes	Yes
Observations	10,749	10,749	10,749

Notes: Robust standard errors clustered at district level are in parentheses *** p<0.01, ** p<0.05, * p<0.1.

TABLE 5 CHILD LABOR

Variables	Child labor (Agri)	Child labor (Agri)	Child labor (Other)	Child labor (Other)
Second stage	(1)	(2)	(3)	(4)
Perceived risk of landmines	0.1217**	0.1189**	0.0012	0.0014
	(0.0536)	(0.0520)	(0.0017)	(0.0016)
First stage	Perceived risk of landmines	Perceived risk of landmines	Perceived risk of landmines	Perceived risk of landmines
Distance to the K5 defense line	−0.013***	−0.013***	−0.012***	−0.013***
	(0.003)	(0.003)	(0.002)	(0.003)
F-test of excluded instruments	16.3	16.5	16.3	16.5
Controls				
Age and gender of the child	Yes	Yes	Yes	Yes
Household's characteristics$^{\Psi}$	No	Yes	No	Yes
District fixed effects	Yes	Yes	Yes	Yes
Observations	835,200	835,200	835,200	835,200

Notes: $^{\Psi}$ Controls include dummy for female household head, number of older (age >14 years) agricultural workers within the household, number of older (age >14 years) workers within the household engaged in economic activities other than agriculture, dummy for whether the cropland is close to home, adjusted logarithm of total land for temporary crops, total number of water pumps, fertilizer spreaders, tractors, cars, motorcycles, solar generators, dummy for using irrigation, and dummies for three different land ownership types. Robust standard errors clustered at the district level are in parentheses *** p<0.01, ** p<0.05, * p<0.1.

TABLE 6 SCHOOL ATTENDANCE OF CHILDREN AGED 5–14 YEARS

Variables	School attendance	School attendance
Second stage	(1)	(2)
Perceived risk of landmines	−0.0157	−0.0183
	(0.0166)	(0.0167)
First stage	Perceived risk of landmines	Perceived risk of landmines
Distance to the K5 defense line	−0.013***	−0.013***
	(0.003)	(0.003)
F-test of excluded instruments	16.3	16.5
Controls		
Age and gender of the child	Yes	Yes
Household's characteristics[ψ]	No	Yes
District fixed effects	Yes	Yes
Observations	835,200	835,200

Notes: [ψ] Same as Table 5. Robust standard errors clustered at district level are in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

TABLE 7 CHILD MARRIAGE (AGED 13 AND 14 YEARS)

Variables	All	Females	Males
	Child marriage	Child marriage	Child marriage
Second stage	(1)	(2)	(3)
Perceived risk of landmines	−0.0050	−0.0100	−0.0002
	(0.0112)	(0.0125)	(0.0109)
First stage	Perceived risk of landmines	Perceived risk of landmines	Perceived risk of landmines
Distance to the K5 defense line	−0.013***	−0.013***	−0.013***
	(0.003)	(0.003)	(0.003)
F-test of excluded instruments	16.3	16.9	15.2
Controls			
Age and gender of the child	Yes	Yes	Yes
Household's characteristics[ψ]	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes
Observations	187,335	94,696	92,639

Notes: [ψ] Same as Table 5. Children are aged 13 and 14 years. Robust standard errors clustered at the district level are in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

A.1 DESCRIPTIVE STATISTICS OF THE HOUSEHOLD DATA

Variables	Mean	SD	Min	Max
Households' Outcomes				
Adjusted logarithm of the total value of crop per square meter	5.9523	1.4993	0	10.0938
Number of unique crops	1.0951	0.3152	1	9
Average non-agricultural working hours per involved household member per day (in last 12 months)	3.0312	3.3090	0	9.2055
Household's characteristics				
Female as household head (=1, =0 if otherwise)	0.1855	0.3887	0	1
Adjusted logarithm of total area of land used for temporary crops in last 12 months (m^2)	9.7164	0.9638	2.3124	12.1007
Number of agricultural workers within the household	2.4965	1.1312	1	15
Number of water pumps	0.2364	0.4248	0	1
Number of lawn mowers	0.0425	0.2017	0	1
Number of fertilizer spreaders	0.0020	0.0447	0	1
Number of tractors	0.0384	0.1922	0	1
Number of car	0.0064	0.0795	0	1
Number of motorcycles	0.4110	0.4920	0	1
Number of solar generator	0.0007	0.0274	0	1
Use irrigation (=1 if using for agricultural production, =0 if not)	0.2364	0.4248	0	1
Legal land possession (=1 if yes, =0 otherwise)	0.9841	0.1250	0	1
Non-legal land possession (=1 if yes, =0 otherwise)	0.0067	0.0817	0	1
Rented land (=1 if yes, =0 otherwise)	0.0084	0.0911	0	1
Other type of land possession (the baseline) (=1 if yes, =0 otherwise)	0.0008	0.0280	0	1
Village's characteristics				
Perceived risk of landmines	0.1128	0.7581	0	27
Distance to the K5 defense line (km)	185.8068	84.1199	0.060	362.8658

Note: N= 1,255,502.

A.2 DESCRIPTIVE STATISTICS OF THE CHILDREN'S DATA

Variables	Mean	SD	Min	Max
Children's characteristics				
Child labor (Agriculture) (=1 if the child involved in agricultural activities in last 12 month, =0 otherwise)	0.1514	0.3585	0	1
Child labor (Other) (=1 if the child involved in economic activities other than agriculture in last 12 months, =0 otherwise)	0.0043	0.0656	0	1
School attendance (=1 if attending school, =0 if otherwise)	0.9024	0.2967	0	1
Child marriage (=1 if the marital status is married/living together, widowed, divorced/separated, =0 if never married/never live with partner)	0.0052	0.0716	0	1
Gender (=1 if female, =0 if male)	0.4868	0.4998	0	1
Age (in years)	9.7325	2.8684	5	14
Household's characteristics				
Female as household head (=1, =0 if otherwise)	0.1500	0.3571	0	1
Logarithm of total size of agricultural holding (in m^2)	9.8006	0.9911	2.4918	12.2061
Number of agricultural workers (age >14 years) within the household	2.3069	0.9442	1	13
Number of workers (age >14 years) within the household doing other economic activities than agriculture	0.8898	1.0065	0	11
Number of water pumps	0.2343	0.4236	0	1
Number of lawn mowers	0.0548	0.2275	0	1
Number of fertilizer spreaders	0.0023	0.0483	0	1
Number of tractors	0.0423	0.2013	0	1
Number of cars	0.0077	0.0872	0	1
Number of motorcycles	0.4346	0.4957	0	1
Number of solar generators	0.0011	0.0325	0	1
Use irrigation (=1 if using for agricultural production, =0 if not)	0.2278	0.4194	0	1
Legal land possession (=1 if yes, =0 otherwise)	0.9808	0.1373	0	1
Non-legal land possession (=1 if yes, =0 otherwise)	0.0079	0.0887	0	1
Rented land (=1 if yes, =0 otherwise)	0.0103	0.1011	0	1
Other type of land possession (the baseline) (=1 if yes, =0 otherwise)	0.0009	0.0307	0	1
Village's characteristics				
Perceived risk of landmines	0.1229	0.7617	0	27
Distance to the K5 defense line (km)	179.894	84.3304	0	362.8658

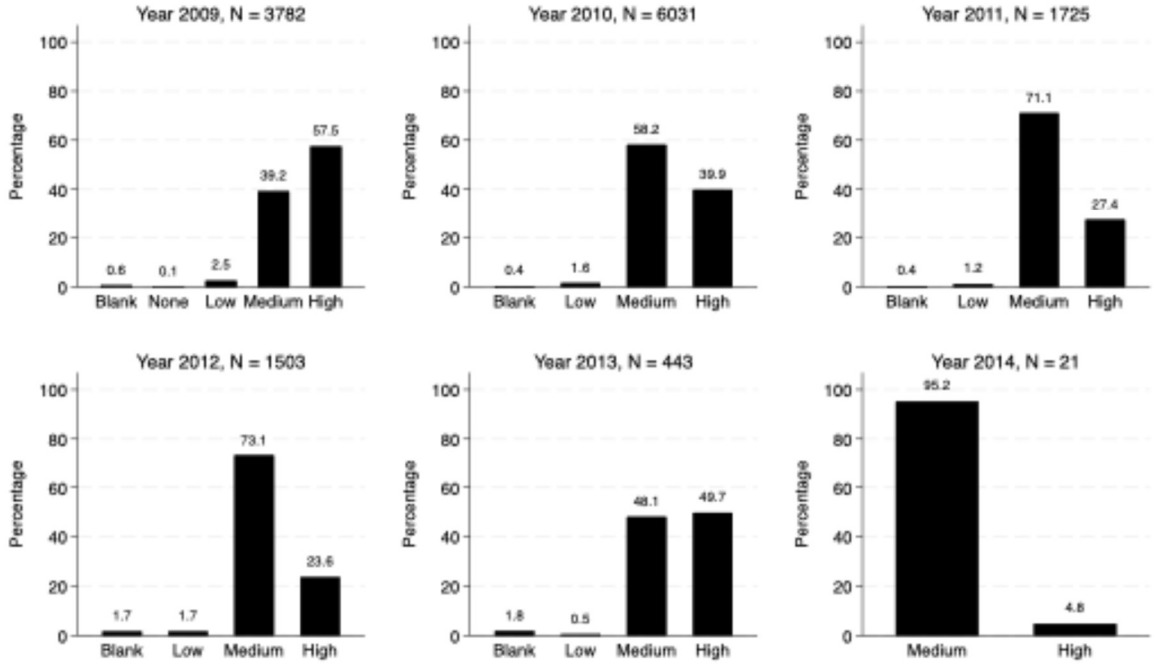
Note: N= 835,200.

A.3 DESCRIPTIVE STATISTICS OF THE VILLAGE-LEVEL DATA

Variables	Mean	SD	Min	Max
Within the village				
Total workers in businesses	142.0179	696.1225	1	38,641
Among which,				
Registered with Authorities of Commerce	15.0581	243.1580	0	16,537
Registered with Authorities of Taxation	7.3528	146.0988	0	10,134
Other characteristics				
Perceived risk of landmines	0.1248	0.8374	0	27
Distance to the K5 defense line (km)	182.3778	81.7033	0.066	362.8658

Note: N= 10,749.

A.4 LEVEL OF PERCEIVED RISK OF LANDMINES BY YEAR OF SURVEY



Notes: Data from the graphs are from the raw data of the Baseline Survey. N is number of surveyed locations that differ across years.

A.5 EFFECTS AMONG CHILDREN AGED 5–9 YEARS

Second stage	Child labor (Agri)	Child labor (Other)	School attendance
Perceived risk of landmines	0.0923**	–0.0002	–0.0124
	(0.0432)	(0.0014)	(0.0256)
First stage	Perceived risk of landmines	Perceived risk of landmines	Perceived risk of landmines
Distance to the K5 defense line	−0.012***	−0.012***	−0.012***
	(0.003)	(0.003)	(0.003)
F-test of excluded instruments	16.2	16.2	16.2
Controls			
Age and gender of the child	Yes	Yes	Yes
Household's characteristics$^{\Psi}$	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes
Observations	379,505	379,505	379,505

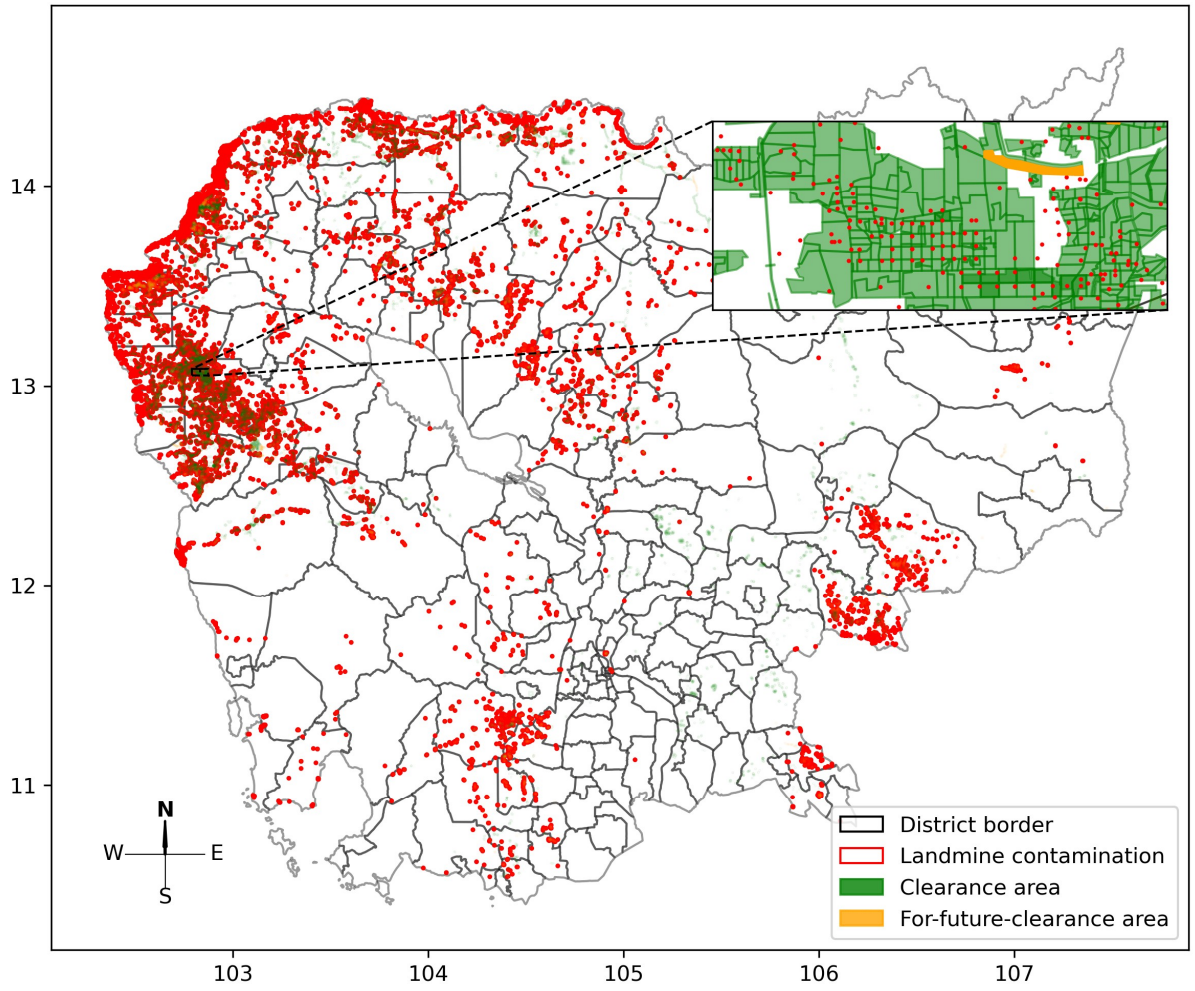
Notes: $^{\Psi}$Same as Table 1. Robust standard errors clustered at the district level are in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

A.6 EFFECTS AMONG CHILDREN AGED 10–14 YEARS

Second stage	Child labor (Agri)	Child labor (Other)	School attendance
Perceived risk of landmines	0.1363**	0.0024	–0.0248*
	(0.0619)	(0.0026)	(0.0146)
First stage	Perceived risk of landmines	Perceived risk of landmines	Perceived risk of landmines
Distance to the K5 defense line	−0.013***	−0.013***	−0.013***
	(0.003)	(0.003)	(0.003)
F-test of excluded instruments	16.6	16.6	16.6
Controls			
Age and gender of the child	Yes	Yes	Yes
Household's characteristics$^{\Psi}$	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes
Observations	455,695	455,695	455,695

Notes: $^{\Psi}$Same as Table 1. Robust standard errors clustered at the district level are in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

A7. CLEARANCE AREAS AND FOR-FUTURE-CLEARANCE AREAS (LANDMINES ONLY)



Notes: Clearance areas indicate where clearance was completed between 1992–2019. For-future-clearance areas are as of 2019.

A.8 ROBUSTNESS CHECK: 2-KM AND 500-M BUFFER

Variables (Second stage)	Household			Children				Village
	Ln (crop value per m^2)	Number of unique crops	Working hour pp (non-Agri.)	Child labor (Agri)	Child labor (Other)	School attendance	Child marriage (aged 13–14 years)	Employment by businesses
2-km buffer	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Perceived risk of landmines	−0.1466	0.0471**	−0.0187	0.0372**	0.0006	−0.0060	−0.0016	−29.3194
	(0.0894)	(0.0183)	(0.1341)	(0.0168)	(0.0005)	(0.0055)	(0.0036)	(22.6420)
F-test of excluded instruments	11.8	11.8	11.8	12.1	12.1	12.1	11.7	10.6
District FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,254,230	1,254,230	1,254,230	833,944	833,944	833,944	187,106	10,724
500-m buffer	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Perceived risk of landmines	−1.3230	0.4479***	−0.1925	0.3228**	0.0052	−0.0542	−0.0166	−282.0418
	(0.8226)	(0.1381)	(1.1627)	(0.1505)	(0.0043)	(0.0431)	(0.0297)	(214.0650)
F-test of excluded instruments	12.6	12.6	12.6	11.6	11.6	11.6	12.4	13.7
District FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,271,925	1,271,925	1,271,925	846,658	846,658	846,658	189,705	10,867

Notes: All specifications are using same set of control variables as in Table 1–7 correspondingly. Robust standard errors clustered at district level are in parentheses (*** p<0.01, ** p<0.05, * p<0.1).