THE GRADUATE INSTITUTE | GENEVA

INSTITUT DE HAUTES ETUDES
INTERNATIONALES ET DU DÉVELOPPEMENT

GRADUATE INSTITUTE OF INTERNATIONAL
AND DEVELOPMENT STUDIES

Graduate Institute of
International and Development Studies Working Paper
No: 06/2011

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Keywords: civil war, landmines, instrumental variables, household expenditures, height-for-age, weight-for-age, Angola.

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1 Introduction

This paper estimates the causal impact of landmines on child health and household expenditures in Angola by exploiting geographical variations in landmine intensity. It contributes to the rapidly expanding literature on the socio-economic consequences of wars and conflicts (see for instance Miguel & Roland(forthcoming) for the case of Vietnam). More specifically we add to the extremely limited literature on the impact of landmines on households, which has thusfar been limited to two studies. In the case of Mozambique Merrouche (2006) finds large and statistically significant effects of landmine contamination on poverty and consumption per capita, while Merrouche (2008) detects important effects of landmine contamination on returns to education in Cambodia. In our work we generate plausibly exogenous variation in the intensity of landmine contamination using the distance separating each commune from a set of rebel headquarters as motivated by a simple model of strategic mining. This is in contrast to both studies by Merrouche, where distances to borders are used as a source of exogenous variation in landmine contamination. However borders are a possibly less convincing exclusion restriction due to their geographic and economic significance that may directly affect response variables such as household income.

During the long period of civil unrest, as many as 1.5 million Angolans may have died, an estimated 20% of the population was displaced, and over 6 million landmines were said to have been planted (UNHCR). While all Angolan provinces are affected by landmines, the within-province variation in mine contamination is substantial. According to the Landmines Impact Survey completed in 2007, whose data we use in the present paper, the number of impacted communities amounts to 8% of the 23,504 communities in Angola (Survey Action Center, 2007). An estimated 2.4 million people live in landmine impacted communities, with 0.6 million living in high - or medium-impact communities. Overall, approximately 17% of all citizens are still living in mine-impacted communities in spite of Humanitarian Mine Action that began in 1994 with the Lusaka Protocol.

The Angolan Landmine Impact Survey design uses the Suspected Hazard Area as the main unit of observation, identifying 3,293 Suspected Hazardous Areas (henceforth, SHAs) in Angola, whose locations are mapped in Figure 1. We use the georeferenced location of SHAs to build our landmine intensity variable.[1]

Our instrumental variables estimates indicate that Suspected Hazard Areas have large, significant and negative effects on weight-for-age (WAZ), height-for-age (HAZ), and household expenditures. Our household estimates suggest that current benefit-to-cost ratios neglect the wider impacts of landmines on households.[2]

The rest of this paper is organized as follows. Section 2 outlines the theoretical impacts of landmines on child health and expenditures. In section 3, we present our basic empirical specification, and show why OLS-based estimates of the impact of Suspected Hazard Areas are likely to be biased. In section 4, we spell out our identification strategy. The data are described in section 5. Section 6 discusses reduced form estimates. Section 7 presents baseline instrumental variables estimates of the impact of Suspected Hazard Areas on child anthropometrics and household expenditures per adult equivalent. Section 8 concludes with a discussion of the implications of our results for landmine clearance.

2 The impact of landmines on households and child health

The impact of landmines on child health has been mainly investigated with respect to direct physical injury, trauma, loss of earnings, cost of prosthetics and rehabilitative care. However there are potentially wider impacts on household welfare as proxied by child health and household expenditures. As we cannot single out specific impacts, our results capture the sum and interaction of various causal pathways.

Landmines are primarily used to deny access to land to enemy troops. They can effectively depopulate whole sections of a country, degrade land (Behre, 2007), disrupt agriculture, increase costs of transportation, damage economic infrastructure and ultimately affect income and employment opportunities. Farming is particularly hard-hit, as well as any activity that depends crucially on transportation. In addition, farming activities may be forced to move to drought-prone and less fertile soils. During the conflict in Angola, the Mavinga Valley, once a fertile area in the southeast, was largely abandoned, and populations were pushed into drought-prone environments (Doswald-Beck *et al.*, 1995).

Another channel through which mines impact household welfare and child health is education. Children, mothers and household members are likely to have problems to access schooling. Local school premises may be mined and roads to more distant schools blocked. Concomitantly, awareness-raising campaigns usually carried out in schools (e.g. mine education, hygiene, HIV, etc.) will reach less into remote and landmine contaminated areas.

In terms of health, both direct and indirects impacts can be identified: First, landmine casualties often overwhelm medical infrastructure already weakened by conflicts. Mine victims require long-term stays in hospitals, multiple surgeries, and large quantities of blood. In Mozambique, landmine victims represented less than 4% of surgical admissions but their care mobilized 25% of hospital resources, according to Sheehan & Croll (1993). Providing care and rehabilitation for landmine victims requires diverting resources away from vaccination, sanitation, nutrition, and vector-control programs (Center For Disease Control, 1997; Williams, 1995, 1996; Kakar *et al.*, 1996). Second, landmines increase the cost of providing relief and health-care to populations in need due to mined roads, bridges and infrastructure. For instance, while it cost US$80 to deliver one ton of relief supplies by road from Lobito to Huambo in 1980, it cost US$2,000 by air, and landmines along the delivery routes made land transportation infeasible in Angola (UNICEF, 1996). Populations from conflict-impacted areas also tend to have weakened immune systems.

In this case mine contamination may hinder both prevention and medical treatment early on. This facilitates the diffusion of diseases and pathogens across the population.

Finally, mines deny the use of soil and grazing lands. Abandoned mined lands can become havens for disease vectors. For instance, in Zimbabwe, minefields are said to have prevented the eradication of the tsetse fly and diseases such as foot-and-mouth disease (Human Rights Watch, 1997; Rupiya, 1998).

3 Empirical specification

We aim to quantify the impact of landmines, as proxied by Suspected Hazard Areas, on household expenditures and child health. Child anthropometrics can be expected to be directly and indirectly affected by landmines. In contrast to expenditures, anthropometrics are a particularly reliable proxy of household welfare. This is because child nutritional status is primarily determined by: (i) household expenditures, (ii) maternal education (usually, literacy), (iii) access to basic services such as clean water and healthcare, and (iv) the relative power of women within the household (*ceteris paribus*, an increase in household income that accrues to women will tend to be devoted to goods and services that improve child nutrition, whereas a similar increase in household income that accrues to men will not). The height-for-age $z-$score (HAZ) is a standard indicator of long-run nutritional status that reflects spells of malnutrition over a prolonged period. The weight-for-age $z-$score (WAZ) is a short-run indicator of nutritional status. Both of these indicators are calculated for children between 0 and 60 months of age, and are expressed as deviations (measured in standard deviations) with respect to a well-nourished reference population. While the choice of the reference population will, of course, influence summary statistics, it will in general not affect parameter estimates in regression analysis when differences in reference populations will be absorbed by the intercept.

Let i denote children, h households, c communes, and let N be sample size. The basic structural equation that we are seeking to estimate is given by:

$$y_{ihc} = x_{ihc}\alpha + m_c\beta + \varepsilon_{ihc} \tag{1}$$

where y_{ihc} is the $N \times 1$ vector associated with the outcome of interest (such as child health), x_{ihc} is an $N \times K$ matrix of child, household and commune control variables, m_c is the number of SHAs in a given radius around the capital of a commune, and ε_{ihc} is a disturbance term. Our purpose is to consistently estimate the impact of SHAs on our outcome variable.

We decompose the disturbance term into two components:

$$\varepsilon_{ihc} = \lambda_c + \eta_{ihc} \tag{2}$$

where λ_c represents commune-level unobservables that affect the outcome, while η_{ihc} are child- or household-level unobservables.

There is a danger that OLS estimates of (1) will lead to an inconsistent estimate of β, since the number of landmines (SHAs) is likely to be correlated with commune-level unobservables λ_c. For example, the decision of rebels or government forces to engage in military operations in an area is likely to be correlated with commune characteristics that are not adequately captured by the household- and commune-level observables that are included in x_{ihc}. Estimating (1) with commune-specific fixed effects solves this problem, but variables such as m_c can then no longer be identified. As a result, we include fixed effects at the hierarchically higher provincial level and thus rely on within-province variation. Provincial dummies should explain a sizeable portion of the variance of SHAs and will also account for endogeneity issues driven by province-level unobservables. Commune-specific random effects are not feasible, because the likely endogeneity of landmines implies that m_c will be correlated with the commune-level random effects. Consequently, the only solution is instrumental variables. We base our identification strategy on the history of the conflict and the strategic use of landmines.

4 Identification strategy

The idea behind our identification strategy is informed by the nature of the guerrilla warfare that characterized the larger part of the Angolan conflict. Landmines have been called the "poor man's weapon." They have the deadly characteristics of being versatile in their strategic usage, of costing as little as US$1 to produce and of requiring little technical skill to use. In the Angolan context they were primarily used for route denial, ambush, bridgehead mining, defensive mining of key structures and facilities as well as a psychological weapon of war to terrorize inhabitants (Human Rights Watch, 1993; McGrath, 2000).

All actors who took part in the Angolan conflict used landmines.[3] The government and Cuban forces laid extensive minefields around their bases in and around towns. Mines were also laid extensively around infrastructure such as airports, power pylons, water sources and bridges. This strategy is still visible in the geographical distribution of SHAs today. After the Cold War and the end of international support to both UNITA and the government, landmines became a weapon of choice, particularly for increasingly cash-strained UNITA. The strategic value of landmines as a "force multiplier" further increased with UNITA's change of military strategy from semi-conventional warfare to mobile guerilla warfare, and the movement's loss of its historical strongholds in Bailundo, Andulo and Jamba in 1999.

We use the distance to the center of gravity of UNITA's headquarters in the Planalto (Central Highland) region as our exclusion restriction. This region had been intensively mined for both offensive and defensive purposes by both sides. Our hypothesis is that communities closer to the center of gravity of UNITA headquarters are likely to display a higher intensity of mining.

The *Planalto*, Angola's geographical heartland, was the center of UNITA's influence. UNITA aimed to keep the government away from these areas. The ethnic majority in these areas is Ovimbundu, Jonas Savimbi's ethnic group. The region initially supported UNITA, seduced by the professed self-sufficiency rhetoric of the movement. In 1992, the region voted for Savimbi in the presidential elections that were lost by UNITA at the national level.[4]

UNITA's attachment to the *Planalto* region is thus mainly based on historical ethnic support. Unlike other ethnic groups in Angola the Ovimbundus did not come into contact with the Portuguese until the 18^{th} century. They were organized into several powerful kingdoms —Bié, Andulo, Huambo and Bailundo— of which Bailundo was dominant. Only at the turn of the 20^{th} century, after the Bailundo Revolt (1902), were the Ovimbundu kingdoms subdued.[5] The construction of the Benguela railway line between 1903 and 1929 allowed the spread of Ovimbundu settlements into the interior of the province of Moxico (Cornwell, 2000).

The main UNITA headquarters that we use to construct our instrument, N'Harea, Mungo, Bailundo, Cuemba and Andulo are all located in Ovimbundu heartland. While these localities are historically important and relevant for UNITA's identity, they are small peri-urban settlements. After UNITA had set-up headquarters in these locations, the organization strove to preserve their geographical remoteness, which was seen as a strategic asset, and did not pursue any development activities for the settlements involved.[6] Note also that little direct fighting occurred in this area until the fall of the various headquarters in late 1999. The most important battles occurred around the cities of Huambo, Kuito and Malanje, which are relatively far from the Planalto headquarters.[7]

Our instrument is based on the center of gravity of UNITA's Planalto headquarters. Figure 2 gives a satellite overview of UNITA headquarters and their center of gravity.

Due to the relatively small geographical distances between the various headquarters, the average latitude and longitude is also a good proxy for the center of gravity. Using the distance to the nearest UNITA headquarters gives us results which are similar to those presented in what follows. However we prefer the use of the center of gravity as it represents an aggregate measure of the contentiousness of the area, while at the same time being situated in a location that is unlikely to be a source of endogeneity. The map presented in Figure 1 gives the center of gravity of UNITA headquarters and the locations of Suspected Hazard Areas, as well as the communes in our sample.

4.1 Distance to rebel headquarters and strategic mining

In this section we formalize our identification strategy and provide a theoretical basis for the specification that we adopt for our first-stage reduced forms. Consider a simple model of rebel mining. The geographical distance between the main rebel stronghold and the government is normalized to one, with the population being contended by the rebels and the government being distributed uniformly over this unit interval. The rebels lay mines optimally according to a simple linear function:

$$m = a + bt, \tag{3}$$

where t is the distance from the rebel stronghold and a and b are optimally chosen so as to maximize support. Note that more complicated functional forms for the mining function could be envisaged, but that we confine our attention for the time being to a simple affine specification.[8]

The utility of a representative individual in location d who supports the government depends upon the summation *over all locations* between the government and the rebels of the disutility provoked by the mines. A priori, it appears to be reasonable to assume that the disutility generated by a given density of mines is greater the closer the mines are to the individual. Consider an individual located at distance d from the rebel headquarters, and consider the disutility inflicted upon this individual by mines located between her and rebel headquarters (i.e. to her "left"). Mines located right next to the individual (and thus at distance d from the rebel headquarters) yield greater disutility than mines located at a distance d away (which would correspond to mines at a distance 0 from rebel headquarters). We express this by writing the (negative) utility inflicted on an individual situated at a distance d from rebel headquarters by mines located at a distance t from rebel headquarters as:

$$-m\frac{t}{d}. \tag{4}$$

Thus, mines located at rebel headquarters (at $t = 0$) have *no* effect on the individual's utility, while mines located right next to the individual (at $d = t$) have the largest (negative) effect on his utility. This expression gives the disutility inflicted by mines located at each point to the left of the individual. Conversely, for mines located to the individual's right (and thus between the individual and government headquarters) we write the utility as:

$$-m\left(\frac{1-t}{1-d}\right) \tag{5}$$

We must then sum up over all mines located to the left of the individual –which corresponds to $t \in [0, d]$ – and all mines located to the right of the individual –which corresponds to $t \in [d, 1]$. This yields:

$$u^G = \bar{u} - \int_0^d (a + bt)\left(\frac{t}{d}\right) dt - \int_d^1 (a + bt)\left(\frac{1-t}{1-d}\right) dt, \tag{6}$$

where $\bar{u}$ denotes the reservation utility, and we have replaced m using the expression from (3). We further assume that the utility of a representative individual from supporting the rebels is $u^R = \bar{u}$. The simplifying assumption here is that we assume that individuals see the *government* as being responsible for being unable to contain rebel mining.

To find the location d^* of the individual who is indifferent between supporting the government and supporting the rebels we set $u^R = u^G$ and solve for d. This yields:

$$d^* = -1 - \frac{3a}{b}. \tag{7}$$

Rebels maximize their welfare by choosing the parameters a and b that determine the intensity of mining at each location t. The benefits to laying mines is garnering the support of the population and is given by d^* (the number of people who support the rebels). For simplicity, we assume that the cost of laying m mines at distance t from the rebel headquarters is quadratic in that distance and linear in the number of mines, and is thus equal to:

$$cm\frac{t^2}{2}, \tag{8}$$

where c is a cost parameter. Since the rebels have to determine how many mines to lay at each distance t from their headquarters along the unit interval, the rebels' maximization problems is given by:

$$\max_{\{a,b\}} \; d^* - \int_0^1 cm\frac{t^2}{2}dt \quad s.t. \quad m \geqslant 0. \tag{9}$$

Solving for the optimal mining parameters a^* and b^*, this simple model predicts that the total number of mines is a *decreasing* function of the distance to rebel headquarters, since the optimal mining function is given by:

$$m^* = \max\left[0, \frac{27}{2c} - \frac{18}{c}t\right]. \tag{10}$$

A graphical illustration of this is provided in Figure 3.

4.2 Validity of the exclusion restriction

Our proposed instrument must satisfy two conditions. First, conditional on the child-, household- and commune-level covariates included in x_{ihc}, the distance to the center of gravity of UNITA headquarters must be a statistically significant determinant of the intensity of SHAs facing commune c. Second, it must, conditional on x_{ihc}, be orthogonal with respect to λ_c.

A number of confounding factors that may potentially affect both the outcome and the intensity of SHAs are included in the empirical specification. As previously mentioned, the location upon which our instrument is based is rather remote. The distance of a given commune to the center of gravity of UNITA headquarters might be inversely related to the commune's remoteness, which itself might well be correlated with household and commune-level unobservables that affect the response variable(s). Therefore, we include, amongst the covariates, variables that will control for remoteness, such as the distance of communes to Luanda and to their respective provincial capitals. We also control for the distance of communes to the Benguela railway. This was a *de facto* frontline between the government and UNITA during the conflict, even when the war mutated into its guerrilla warfare phase. The railway runs from the port city of Benguela (Benguela province) to the border town of Luau (Moxico province), connecting with the Zambian and Congolese (DRC) railway networks.[9] It covers a distance of 1,344 km and crosses four provinces (Benguela, Huambo, Biè and Moxico). Apart from a brief period in 1980, the line was closed for the duration of the civil war. An additional variable which indicates the side of the Benguela railway on which the commune is located is also included. Finally, a conflict intensity variable representing the total number of casualties in a given radius over the 1975-2000 period is included.

One of the limitations of Angolan data is the absence of disaggregated population density estimates. Instead we argue that the total of length of roads (*picadas*) in the commune is a close proxy of population density, remoteness, and the amount of infrastructure. In addition, our *picadas* variable controls for the strategic mining of roads and public infrastructure, which may be correlated with our instrument, SHAs, and our outcome variables.

It is well known that Angola is rich in natural resources. In particular oil and diamond mines are related to a variety of factors such as infrastructure, income, and conflict intensity. Diamonds were particularly important to UNITA, while oil proved to be critical for the government's funding. Thanks to the mostly offshore nature of oil in Angola, production was never interrupted during the war, ensuring a steady flow of resources to the government. Although UNITA briefly controlled Cabinda, the government kept control over oil production there. To account for these factors we control for the number of diamond mines and oil fields in appropriate radii around each commune.[10]

Last but not least, household-level control variables such as whether the household was displaced during the war, and whether infants and heads were born in the province of residence also contribute to our accounting for potential omitted variables that might invalidate our identification strategy. We also include a rural/urban dummy.

To summarize our identification strategy: SHA intensity is a decreasing function of the distance to the center of gravity of UNITA headquarters. Letting z_c^{UNITA} denote this distance to each commune, our identification strategy suggests that the underlying first-stage reduced form that corresponds to the structural equation specified in (1) should be given by:

$$m_c = x_{ihc}\gamma + z_c^{UNITA}\pi + \nu_{ihc} \tag{11}$$

with $\pi < 0$. In terms of the theoretical model presented in section 4.1, $x_{ihc}\gamma$ corresponds to the parameter a^*, while π corresponds to the parameter b^* in the optimal mining function given in equation (10). Whether or not z_c^{UNITA} does provide any modicum of identification can be explicitly tested by examining the statistical significance of π.

5 Data

One particularity of the empirical results presented in this paper is that we obtain them using two separate household surveys collected during the final period of the Angolan civil war. Thus, while empirical results are always open to doubt, these should be less so to the extent that we obtain similar results using two completely different household surveys, carried out by different organizations in different parts of the country. The first household survey that we use is the *Inquerito aos agregados familiares sobre despesas e receitas* (national household survey on expenditures and incomes, henceforth referred to as IDR). The second is the Multiple Indicator Cluster Survey (MICS).

The IDR was conducted in 1999-2000 in the provinces of Cabinda, Luanda, Lunda Norte, Benguela, Namibe, Huila and Cunene. Given the unstable security situation at the time, the survey is roughly representative of areas of Angola under effective government control and has a strong urban component, limitations that should be kept in mind in interpreting the corresponding results. Angola is made up of 18 provinces. The survey was carried out by the *Gabinete de monitarização das condições de vida da população*, of the *Instituto nacional de estatística* (INE), in the *Ministerio do planeamento* (MINPLAN). The IDR 2000 includes information on household composition, expenditures, education, health and fertility behavior. It uses a stratified sampling design in which 12 households were surveyed in a random fashion in 226 *aldeias* (villages) in rural areas and *bairros* (neighborhoods) in urban areas, in 50 communes. While language cannot be exactly equated with ethnicity, it remains a good proxy in the case of Angola. In the IDR we can control for the language spoken by the household head. Summary statistics for the IDR 2000 data are presented in Table 3.

The MICS was conducted in 2001 (April-October) by the INE and the United Nations Children's Fund (UNICEF). It covers 6,252 households in all 18 provinces. The MICS reviews 42 indicators specifically designed by UNICEF to assess the situation of children under five years of age and women 15 to 49 years old in terms of health, nutrition, water, sanitation, hygiene, education and child protection. Although most communes were under effective government control, many had previously been under UNITA influence. Relatively more households were surveyed in urban areas than in the IDR. Ethnicity and language questions were omitted from the MICS. Summary statistics for the MICS data are presented in Table 2.

Our data concerning landmines stems from the 2007 Landmines Impact Survey (LIS). It was coordinated by the Survey Action Network in the 18 provinces of Angola from 2004 to 2007. The LIS is a complete countrywide survey which covers all but 19 of the 556 communes, of which 383 were found to be impacted. A total of 28,000 people took part in community interviews in the 1,988 impacted communities. The LIS provides various types of information such as the number of recent victims (for the previous two years) and earlier victims. It also classifies communes by the level of impact, the number of SHAs and the types of socio-economic blockages attributed to landmines.

For our purposes, the key variable is constituted by the locations of SHAs. This allows us to address the issue of contamination *beyond* the directly impacted community. The LIS allows one to distinguish between different types of landmines (anti-personnel, anti-tank and unexploded ordnances). The survey identified 3,293 SHAs, with Moxico and Bié representing 30% (965) of all SHAs in the country. If the number of SHAs of Uíge and Kuando Kubango are also added, these fours provinces represent 50% of the SHAs in Angola. 60% of impacted communities "only" have one SHAs and 85% have one or two SHAs. The LIS indicates that 58% of impacted communities (and 62% of the SHAs) have one type of mine. The number of SHAs reported to have anti-tank mines is 952 and the number reported to have anti-personnel mines is 2,723.[11]

All of the LIS data are geo-referenced. Using a world gazetteer we geo-referenced both our IDR and MICS datasets with the communal capital, the lowest level possible given our data.[12] We then calculate the number of mines within various radii of these communal capitals. We concentrate on relatively large radii, between 50 and 150 km, for two reasons. First, we are interested in seeing whether landmines have an impact that goes beyond the directly affected communities. Second, the size of communes varies substantially. For instance, in the IDR the mean area is 20,070 km^2 with a standard deviation of 25,102 km^2. The chosen radii do a relatively good job of covering varying degrees of commune size. Radii that are too small may over- or under-estimate the number of mines for households located far from the communal capital.

Our conflict intensity variable is based on the painstaking work of Ziemke (2007). She used archives, libraries and news agency files (a total of 186 sources from over 20 countries were involved) to construct a database of individual battle and massacre events that took place in the Angolan war over a 41 year period (1961-2002). We construct a conflict intensity variable using the number of casualties within various radii over the 1975-2000 period. Again, we chose relatively large radii so as to match the communal area and so as to at least match or overlap with the SHAs radius. In the baseline results, we use the number of casualties in a 150 km radius. Results are qualitatively similar with larger or smaller radii.

Diamonds and oil played a major role in the Angolan conflict, funding UNITA and the government, respectively. We rely on DIADATA, a dataset compiled by researchers from the Peace Research Institute Oslo (PRIO) that identifies the sites of diamond mines across Angola. DIADATA consists of 1,175 entries for diamond occurrences in 53 countries. There are 52 entries for Angola. Distances and radii between the communes and the different diamond mines were computed so as to be able to account for the strategic importance of diamonds in Angola. We calculate the number of diamond mines in a 150 km radius around each commune. To create our oil variable we use the petroleum datasets also provided by PRIO. The petroleum dataset contains information on all known oil and gas deposits throughout the world. Two datasets are available: one for on-shore deposits and another for off-shore deposits. We use the number of oil deposits within a 150 km radius of the commune.[13]

6 Reduced form estimates

Results for the reduced form given by equation (11) are presented in Table 4 for the MICS data and in Table 5 for the IDR data. The dependent variable is given by the total number of SHAs within various radii of the commune. To understand the meaning of SHAs, consider the simple correlation between the number of SHAs and recent mine victims across 15 provinces, displayed in Figure 4. An additional SHA leads to 0.77 additional fatal victims.

These first-stage reduced forms correspond to the instrumental variables results presented below for the child health response variables in MICS and the expenditures response variable for IDR. Virtually identical results are obtained when we consider the first-stage reduced forms for the child health model using the IDR dataset. All specifications include a rich set of child-, household- and communal-level covariates, listed in the summary statistics in Table 2 for MICS and in Table 3 for IDR.[14] Due to the different designs of the two surveys, covariates differ slightly for the MICS and IDR regressions. IDR provides information on languages spoken (a proxy for ethnicity as mentioned earlier), while MICS features more health-related information on children, such as vaccinations. In addition, we include provincial fixed effects. Standard errors are clustered at the commune level in order to account for common shocks affecting all observations within a given commune.

As predicted by our simple theoretical model, the negative relationship between the distance to the UNITA center of gravity and SHAs is significant and robust across different radii and across both datasets. Consider the column with the number of SHAs within a 150 km radius. The marginal effect of moving 1 km away from the center of gravity of UNITA headquarters is to reduce total SHAs by 0.53 using the MICS sample. In the IDR sample, an additional kilometer leads to a decrease of 1.25 SHAs. While the point estimates are different, the fact that we obtain roughly the same result using two completely different surveys suggests that our identification strategy is not entirely devoid of validity.

Due to their possible impact on landmine intensity, we also report the coefficients associated with a number of commune-level covariates in Table 4 for MICS and in Table 5 for IDR.[15] When interpreting these results one should keep in mind the substantially different coverage of both surveys. In MICS we find a positive relationship between SHAs and the distance to Luanda (for 100 km, 75 km, 50 km), as well as to the provincial capital (for 100 km, 75 km). In the IDR sample the effects of these distances are not statistically different from zero. In MICS we find a positive and significant relationship between casualties and SHAs for the 150 km radius, and a negative and signifcant one for the 75km radius. This relationship is negative and significant in the IDR model for the 100 km, 75km and 50 km radii. 1,000 additional casualties decrease the number of SHAs within 100 km by six. In MICS there is a positive, but not significant correlation of SHAs with the distance to the Benguela frontline. In the IDR sample we find a large, positive and significant correlation with this frontline. As one moves away from the frontline, the number of SHAs increases.

7 Empirical results

Baseline linear instrumental variables results for child height-for-age $z-$scores (HAZ) are presented in Table 6 for MICS and in Table 7 for IDR. The corresponding weight-for-age $z-$score (WAZ) results are presented in Table 8 for MICS and in Table 9 for IDR. Results for log household expenditures per adult equivalent are presented in Table 10 for the IDR sample. Corresponding OLS estimates and Hausman tests of exogeneity are reported below the IV estimates.

Irrespective of the sample we use, we find a large, negative and statistically significant impact of SHAs on HAZ. Consider the results which correspond to the number of SHAs within a 150 km radius in Tables 7 and 6: an additional 100 SHAs reduce HAZ $z-$scores by 0.65 in the MICS sample, and by 0.45 in the IDR sample. Similarly, for the 50 km radius, an additional 100 SHAs lead to a reduction of 0.89 in HAZ in MICS and of 1.00 in IDR. If we compare a commune with zero SHAs within 50 km to a commune with 43.05 SHAs in MICS (the sample standard deviation), we find a difference of 0.39 ($= -0.00897 \times 43.05$) in HAZ. This is 24% of the sample standard deviation in HAZ $z-$scores. Furthermore, the Hausman test of exogeneity indicates that the OLS estimates for the 100 km, 75 km and 50 km radii are significantly downward-biased. For instance, using the OLS estimate for 50 km in MICS, the difference would be -0.068 ($= -0.00157 \times 43.05$). This amounts to a mere 4% rather than 24% of the sample standard deviation. Repeating the exercise for IDR and the 50 km radius, a commune that moves from zero to 12.3 SHAs, suffers from a reduction in HAZ $z-$scores of 0.12 ($= -0.01004 \times 12.3$), which corresponds to 8% of the sample standard deviation. Note that OLS and IV results for IDR are statistically equivalent, as we fail to reject the null-hypothesis of exogeneity, under the usual maintained hypothesis that our identification strategy is valid.

Results for short-term child health are equally striking, but not as robust across surveys. As shown in Tables 8 and 9, the marginal impact of SHAs on WAZ is, as expected, negative. The effect is statistically different from zero at the 5% level of confidence across all radii for MICS, while we find negative, but insignificant effect in the IDR sample. An additional 100 SHAs within 150 km reduce WAZ $z-$scores by 0.405 in MICS and 0.195 in IDR. If we compare a commune with zero SHAs within 75 km to a commune with 60.7 SHAs in MICS (the sample standard deviation), we find a difference of 0.25 ($= -0.00405 \times 60.7$) in WAZ. This is 20% of the sample standard deviation in WAZ $z-$scores. For MICS, the OLS results are significantly downward biased for 100 km, 75 km and 50 km. Note that we fail to reject the null of exogeneity for IDR, which suggests that we should prefer the OLS results over their IV counterparts.

A few remarks are in order so as to facilitate interpretation of the differences in results between the IDR and MICS samples. Mean mine intensity, as well as variance, is substantially higher in MICS than in IDR. Two reasons explain this. First, roughly 8% of households in the IDR sample are in rural areas, compared to 33% in MICS. Second, the MICS survey spans 61 communes in all 18 provinces. Some of these communes had previously been under UNITA influence, while the IDR surveyed 50 communes in the seven provinces that were solidly under government control. One would expect both of these factors to lead to greater mine intensity in MICS. Note also that children under five years of age have worse HAZ and WAZ scores in MICS than in IDR.

Turning to household expenditures per adult equivalent in the IDR sample, SHAs have a large, negative and significant impact. Consider the 150 km radius in Table 10: an additional 10 SHAs within 150 km leads to a 4.5% reduction in household expenditures. Comparing a household in a commune free of SHAs within 150 km with a household in a commune with 62.44 SHAs (the sample standard deviation), the difference in expenditures is 28% ($= 62.44 \times 0.45$).

8 Concluding remarks

This paper has explored the impact of landmines on child health and household expenditures in the last years of the Angolan conflict. Our instrumental variables approach is based upon the plausibly exogenous variation in landmines intensity generated by the distance separating the communes of our sample from the center of gravity of UNITA Planalto headquarters.

Linear instrumental variables estimates, based on two sets of household survey data collected in 2000/2001 (IDR and MICS) indicate that landmines lower height-for-age, weight-for-age and household expenditures beyond the immediately affected communities. These results confirm the far-reaching and lasting consequences of landmines for households in times of conflict and beyond. Yet, unlike other scourges afflicting countries emerging from conflict, landmines are a finite problem: once removed, they do not come back.

Our results have important implications for landmine clearance. While removing landmines is a fairly straightforward undertaking from the technical standpoint, it remains an expensive process and the commitment of donors to demining has been waning. While 100% mine removal may not be feasible for a country such as Angola, our results indicate that landmines have a far larger impact than has traditionally been envisioned by mine action, a finding that has major implications for cost-benefit analysis of mine removal. Including micro-level estimates such as the impact of landmines into cost-effectiveness analyses of landmine removal is indeed expected to substantially modify the demining cost-benefit ratio.

More specifically, our findings suggest that (i) The cost-effectiveness of mine removal in comparison to other forms of mine action (e.g. mine risk actions) has been underestimated, (ii) The LIS calculates an impact score to prioritize clearance, indicating the severity of contamination in a commune. This score is based on the number of recent victims, the number of different types of socioeconomic and institutional blockages, and the type of munition (landmines and/or unexploded ordnances). This calculation overweighs recent victims in the final score. A complementary calculation could include the landmine impact on child health and household expenditures.

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Notes

[1]Our landmine intensity variable thus refers to the number of Suspected Hazardous Areas rather than the number of landmines as such.

[2]In 2008, the Halo Trust estimated the cost of landmine removal at an average of US$499 per mine, or US$2.30 per square meter. Authors' communication with Halo Trust Angola - December 2009.

[3]Unfortunately, the Landmine Impact Survey has no information on the type and origins of landmines, and hence we do not know which side planted them. Demining operators in Angola found more than 40 different types of mines built in 15 countries

[4]Savimbi based his rejection of the national elections on the support he received from this region and promptly marched on the cities of Huambo and Kuito. This led to sieges of the two cities, which did not welcome UNITA with open arms as the movement had expected. UNITA inflicted a particularly ruthless siege on Kuito, which lasted for over nine months. Fighting resulted in the direct and indirect death of an estimated 30,000 people, notably from starvation.

[5]Jonas Savimbi's grandfather, Sakaita, fought in this revolt/war.

[6]"Although of questionable strategic significance, Bailundo, a shabby town in the central highlands, is the traditional capital of Mr Savimbi's Ovimbundu people. It was the seat of the king, and also the starting point of the 1902 Ovimbundu rebellion against Portugal, the colonial power. It is, therefore, of great symbolic importance" *The Economist* , Battling in the rain, 7 October 1999.

[7]The distance between these cities and the closest UNITA Planalto headquarter is: 200 km for Malanje, 70 km for Huambo and 97 km for Kuito.

[8]In spirit our model follows the optimal contract literature (Holmström, 1979) in that we are optimizing with respect to a *function* of distance. In that literature, our functional form restriction would be equivalent to restricting one's attention to affine functions when considering, say, an optimal sharecropping contract.

[9]In 1931, when the Benguela Railway was completed, the Belgians extended their line from the important junction of Tenke to meet it near Dilolo.

[10]In 1993, UNITA captured the onshore oil city of Soyo in Cabinda. The government responded by hiring the South African mercenary firm Executive Outcome (EO) which managed to secure the entire oil producing region. The government further extended the EO contract to train the national army.

[11]The Landmine Impact Survey also provides data specific to recent landmine victims. The survey identifies 341 casualties in the 24 months preceding the survey, of which 79% were men, with 75% of those between the ages of 15 and 44. The province of Moxico represent one third of the total number of casualties. The survival rate of 50% in Angola is lower than that in other mine-affected countries. The rate is usually closer to 60% and sometimes as high as 70%. While this level of data provides information on the "profile" and characteristics of the victims, it should be noted that a significant portion of those killed were in fact traveling outside of their own community. They were therefore not "known" to the impacted community and were consequently classified as "unknown".

[12]See, for example, the website: www.fallingrain.com.

[13]All of the covariates based on distance (including the distance to Luanda, to the corresponding provincial capital and to the Benguela railway) were computed using ArcGis and spatial tools in R.

[14]The same covariates are included in the structural equation so as to avoid what Jerry Hausman would call a "forbidden regression." Also note that we exclude expenditures from the child health models in the IDR, given that it is likely to be endogenous. Excluding it is *a priori* reasonable from the econometric standpoint, given that we argue that our instrument is exogeneous with respect to expenditures, particularly in light of all of the geographical control variables that we include.

[15]We do not report household and individual level covariates in the reduced form as they have no meaningful effect on landmine intensity though the inclusion is essential from the econometric standpoint.

Province	Total Communities	Impacted Communities	% of Impacted Communities
Moxico	1,698	290	17%
Bié	2,825	282	10%
Uíge	2,208	172	8%
Kuando Kubango	886	171	19%
Kwanza Sul	1,997	169	8%
Huambo	2,938	153	5%
Benguela	1,807	127	7%
Kunene	426	126	30%
Malanje	1,868	87	5%
Bengo	543	74	14%
Lunda Sul	736	73	10%
Huíla	1,863	72	4%
Zaire	741	66	9%
Kwanza Norte	815	64	8%
Lunda Norte	1,059	30	3%
Cabinda	387	27	7%
Namibe	420	3	1%
Luanda	291	2	1%
TOTAL	23, 508	1, 988	8%

Table 1: Prevalence of Suspected Hazardous Areas by Province in the Landmine Impact Survey

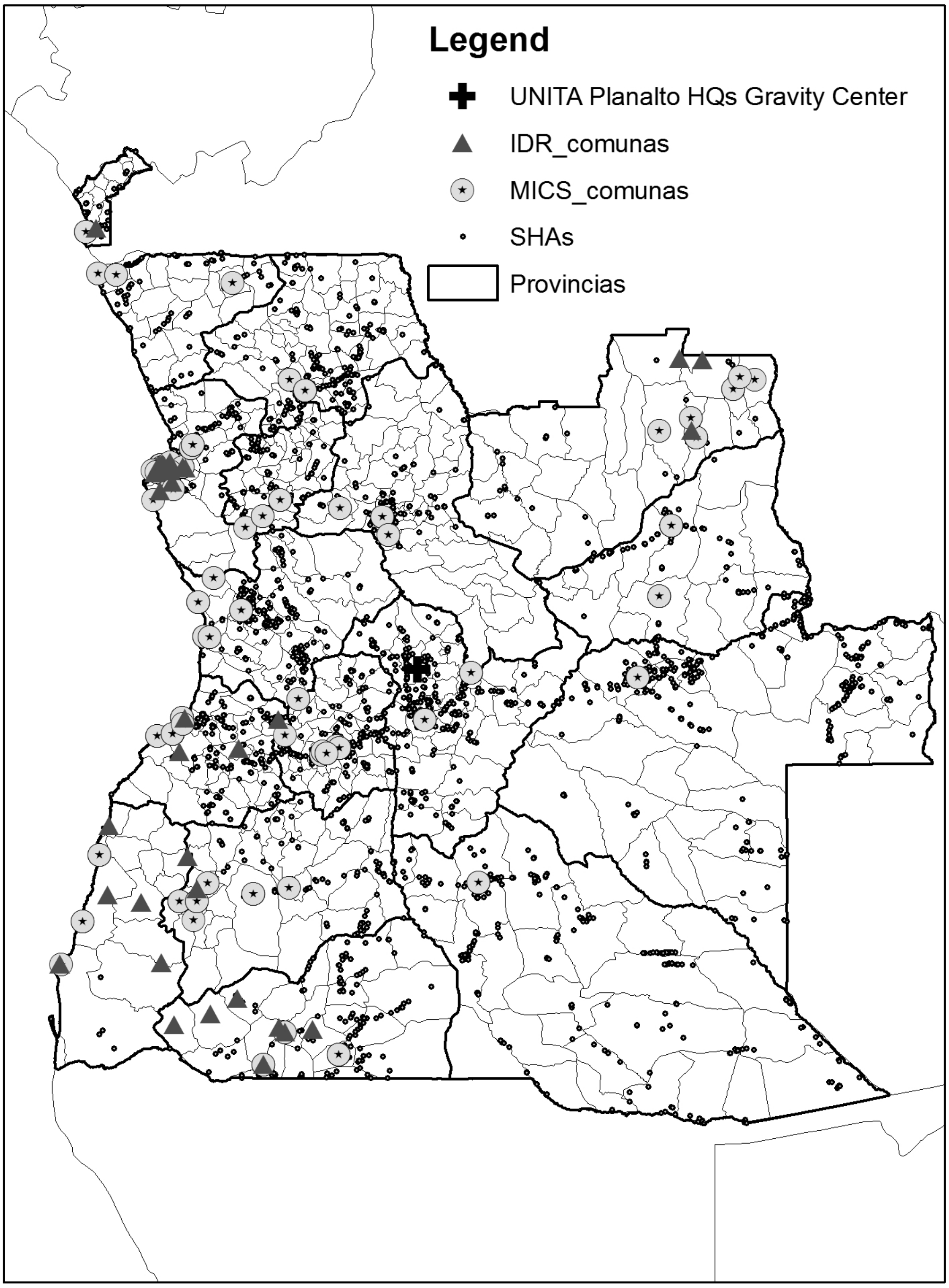

Figure 1: ArcGis Map of Angola with Suspected Hazard Areas, surveyed communes in MICS and IDR, and the center of gravity of UNITA headquarters

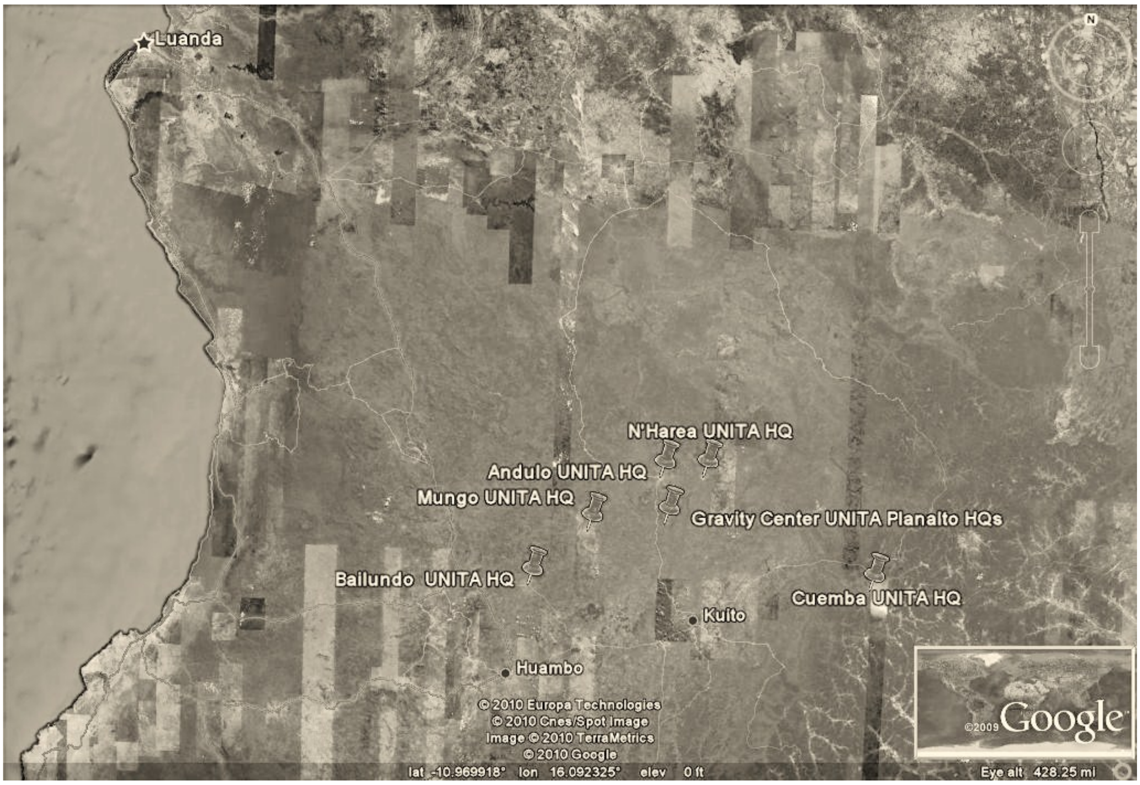

Figure 2: UNITA Headquarters and their center of gravity

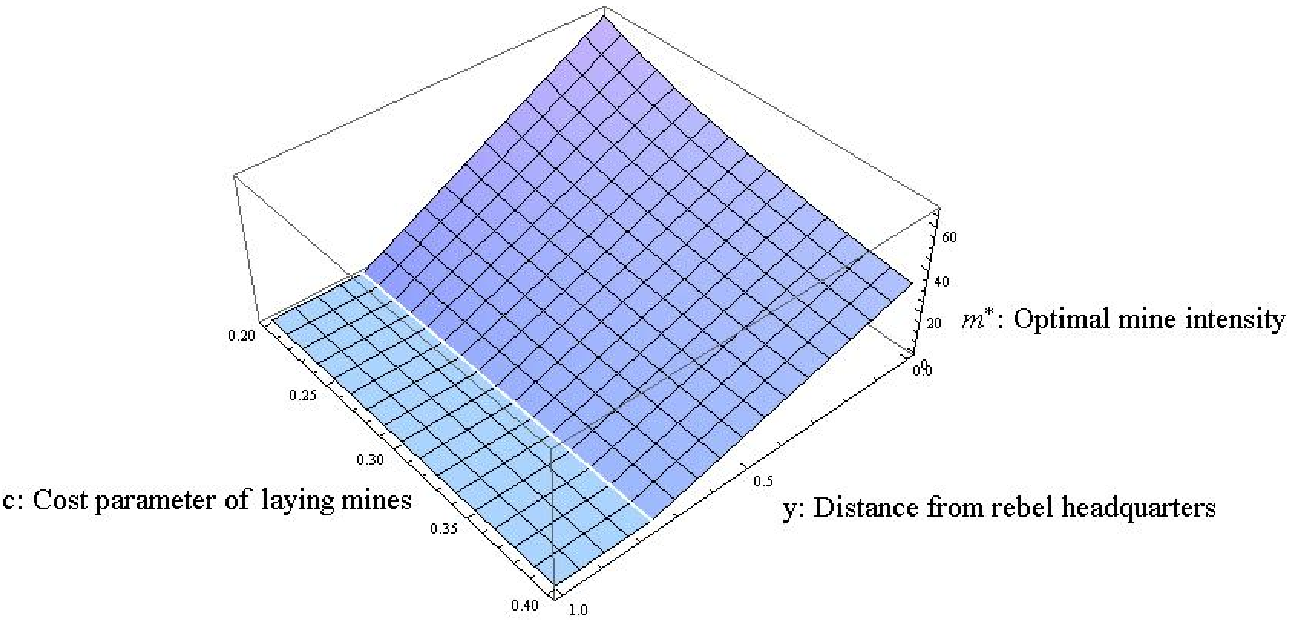

Figure 3: Graphical representation of the rebel's optimal mining function

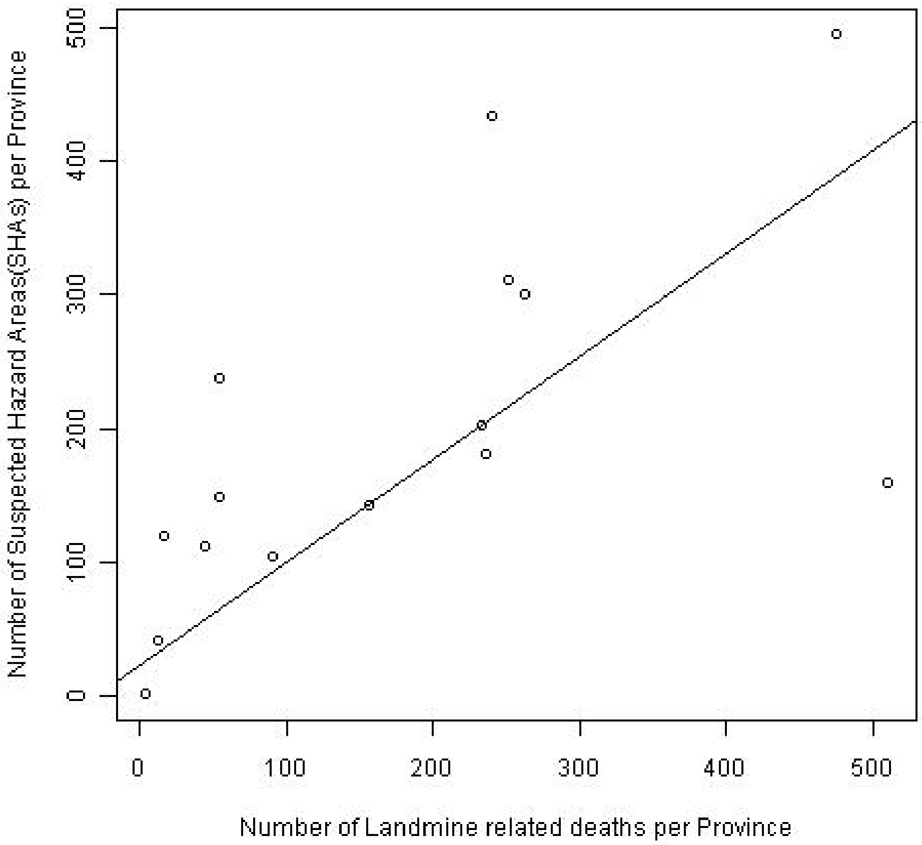

Figure 4: Simple Correlation between the number of landmine-related deaths from 1975 to 2001 and the number of Suspected Hazard Areas across 15 provinces ($\beta = 0.7685; s.e. = 0.2464$)

Variables	mean	median	sd	min	max
Child Specific Variables					
Weight-for-Age Z-Score (0-5 yrs)	-1.324	-1.38	1.223	-4.94	4.97
Height-for-Age Z-Score (0-5 yrs)	-1.66	-1.77	1.619	-5	4.94
Age in Months	27.94	27	16.96	0	59
Child is Male	0.4993	0	0.5001	0	1
Child is Born in Province	0.9496	1	0.2188	0	1
Breastfed Child	0.9714	1	0.1666	0	1
Child has Vaccination Card	0.6495	1	0.4772	0	1
Polio Vaccination	0.83	1	0.3757	0	1
Diphtheria Vaccination	0.5225	1	0.4995	0	1
Measles Vaccination	0.494	0	0.5	0	1
BCG Vaccination	0.6651	1	0.472	0	1
Diarrhea	0.2358	0	0.4246	0	1
Accute Respitory Infection in the Past	0.07854	0	0.269	0	1
Iodized Salt	0.3465	0	0.4759	0	1
Household Specific Variables					
Sex of Head	0.7898	1	0.4075	0	1
Age of Head	37.64	36	11.1	15	70
Married Head	0.8025	1	0.3981	0	1
Head without Schooling	0.2111	0	0.4081	0	1
Head with Primary Schooling	0.6896	1	0.4627	0	1
Head with Secondary Schooling	0.09482	0	0.293	0	1
Literate Head	0.6316	1	0.4824	0	1
War-Displaced Head	0.1698	0	0.3755	0	1
Head Born in Province	0.4418	0	0.4967	0	1
Wealth Quintile	3.103	3	1.398	1	5
Household Size	6.327	6	2.713	2	21
Access to Water in the House	0.0299	0	0.1703	0	1
Cement Walls	0.02544	0	0.1575	0	1
Electricity	0.2477	0	0.4317	0	1
Rural Area	0.3322	0	0.4711	0	1
Commune Specific Variables					
Distance to UNITA Center of Gravity	428.7	463.9	161.1	73.94	849
Suspected Hazardous Areas in 150 km radius	194	181	135.5	3	532
Suspected Hazardous Areas in 100 km radius	109.2	81	83.81	1	325
Suspected Hazardous Areas in 75 km radius	73.92	55.00	60.71	0.00	237.00
Suspected Hazardous Areas in 50 km radius	46.33	31	43.05	0	165
Distance to Luanda	510.9	515.5	277.5	1.02	953.5
Distance to Provincial Capital	29.18	2.076	51.6	0	255
Casualties in 150 km radius	6085	4443	460	327	19930
Distance to Benguela Frontline	261.7	222.7	200.1	0.2343	771.2
North of the Benguela Frontline	0.6629	1	0.4728	0	1
Length of Communal Roads(m)	121700	58440	180900	0	920500
Oilfields in 150 km Radius	3.352	0	6.368	0	25
Diamond Mines in 150 km Radius	0.4634	0	0.9092	0	4

Table 2: Summary statistics for the MICS survey, 4482 observations, selected categories for categorical variables

Variables	mean	median	sd	min	max
Child Specific Variables					
Weight-for-Age Z-Score (0-5 yrs)	-1.202	-1.26	1.176	-4.99	4.69
Height-for-Age Z-Score (0-5 yrs)	-1.58	-1.62	1.43	-4.99	2.97
Age in Months	28.1	28	17.08	0	59
Child is Male	0.5112	1	0.4999	0	1
Baby Born in Province	0.9477	1	0.2227	0	1
Household Specific Variables					
Log Income Per Adult Equivalent	5.698	5.724	1.055	0.281	8.923
Sex of Head	0.7798	1	0.4144	0	1
Age Group of Head	5.427	5	2.371	1	11
Married Head	0.5815	1	0.4933	0	1
Years of Education of Head	4.51	5	2.143	0	8
Literate Head	0.8144	1	0.3888	0	1
Head Speaks Portugese	0.221	0	0.415	0	1
Head Speaks Umbundo	0.2599	0	0.4386	0	1
Unemployed Household Head	0.02693	0	0.1619	0	1
War-Displaced Head	0.5088	1	0.5	0	1
Head Born in Province	0.5086	1	0.5	0	1
Household Size	5.816	5	3.032	1	30
Ratio of Dependents vs. Non-Dependents	1.143	1	0.9366	0	8
Access to Water in the House	0.1438	0	0.3509	0	1
Cement Walls	0.3713	0	0.4832	0	1
Electricity	0.5666	1	0.4956	0	1
Rural Area	0.08309	0	0.276	0	1
Commune Specific Variables					
Distance to UNITA Center of Gravity	558.20	500	141.70	282.70	845.10
Suspected Hazardous Areas in 150 km radius	93.92	77	62.44	3	278
Suspected Hazardous Areas in 100 km radius	43.67	49	33.89	1	204
Suspected Hazardous Areas in 75 km radius	30.29	35	24.17	0	140
Suspected Hazardous Areas in 50 km radius	13.2	5	12.3	0	67
Distance to Luanda	480.7	444.9	330.1	0	953.5
Distance to Provincial Capital	44.21	30.58	54.74	0	638.1
Casualties in 150 km radius	5345	4492	2788	136	10720
Distance to Benguela Frontline	351	393.40	211.20	1.77	774
North of the Benguela Frontline	0.5696	1	0.4952	0	1
Length of Communal Roads(m)	155700	65420	264800	0	920500
Oil Fields in 150 km Radius	0.800	0	1.01	0	3
Diamond Mines in 150 km Radius	2.014	0	5.658	0	18

Table 3: Summary statistics for the IDR survey, 9171 Observations in the household expenditures model, 7684 Observations in the anthropometric models, selected categories for categorical variables.

Dependent Variable: Number of Suspected Hazardous Areas				
	150km	100km	75km	50km
Exclusion Restriction:				
Distance to Center of Gravity of UNITA	-0.52821	-0.23635	-0.39262	-0.38139
Headquarters	0.16234	0.07390	0.10951	0.12503
Selected Covariates:				
Distance to Luanda	0.05128	0.16004	0.33184	0.40254
	0.19634	0.06853	0.09249	0.10174
Distance to Provincial Capital	0.01802	0.02827	0.03007	-0.01559
	0.08033	0.04411	0.05104	0.04690
Casualties in 150km radius	0.00989	-0.00027	-0.00141	-0.00063
	0.00206	0.00072	0.00057	0.00096
Distance to Benguela Frontline	0.14475	0.08701	0.23081	0.20582
	0.13005	0.06522	0.13593	0.13017
North of Benguela Frontline	15.65693	15.08552	4.48970	-2.43224
	11.04594	4.15461	4.66979	5.49835
Length of Communal Roads	0.00000	0.00002	-0.00002	-0.00004
	0.00003	0.00001	0.00002	0.00002
Diamond Mines in 150km radius	-5.22286	-0.45640	-0.39370	-1.22988
	1.51194	0.60484	1.37352	1.10479
Oil Field in 150km radius	5.58410	-8.06115	2.92031	9.15549
	5.78057	2.24418	2.92125	3.58419

Table 4: First-stage reduced forms of the determinants of total number of Suspected Hazardous Areas for various radii in the anthropometric models for the MICS survey. 4482 observations, child-specific, household-specific, commune-specific variables, and provincial dummies included. Standard errors clustered at the commune level (N=61) below estimates.

Dependent Variable: Number of Suspected Hazardous Areas

	150km	100km	75km	50km
Exclusion Restriction:				
Distance to Center of Gravity of UNITA	-1.25093	-1.37331	-0.95528	-0.48506
Headquarters	0.16088	0.16701	0.12118	0.04744
Selected Covariates:				
Distance to Luanda	-0.05054	0.07651	0.02142	0.02002
	0.05031	0.04689	0.02654	0.01394
Distance to Provincial Capital	-0.05271	0.04566	-0.00664	0.00334
	0.05588	0.05535	0.03185	0.01465
Casualties in 150km radius	0.00090	-0.00540	-0.00499	-0.00236
	0.00298	0.00215	0.00172	0.00096
Distance to Benguela Frontline	1.04440	1.10951	0.83497	0.38993
	0.16217	0.14892	0.09011	0.04620
North of Benguela Frontline	-2.12067	-20.35406	-3.34341	5.89500
	11.44744	11.28704	6.99748	3.68577
Length of Communal Roads(m)	0.00014	0.00005	0.00003	0.00002
	0.00011	0.00010	0.00006	0.00004
Diamond Mines in 150km radius	4.58338	-1.00164	-8.40326	5.09150
	10.92932	3.73916	2.29850	2.31324
Oil Field in 150km radius	-54.76691	9.38604	13.50405	3.06677
	82.25747	73.43410	43.23391	25.59207

Table 5: First-stage reduced forms of the determinants of total number of landmines for various radii in log expenditures per adult equivalent models for IDR. Results for the anthropometric regressions are qualitatively very similar. 9171 observations, child-specific (anthropometric model only), household-specific, commune-specific variables, and provincial dummies included. Standard errors clustered at the commune level (N=50) below estimates.

Dependent Variable: Child HAZ in 2001 (MICS)

	150km	100km	75km	50km
beta-IV	-0.00648	-0.01447	-0.00871	-0.00897
	0.00255	0.00595	0.00372	0.00378
beta-OLS	-0.00326	-0.00449	-0.00108	-0.00157
	0.00157	0.00379	0.00206	0.00233
Test of exogeneity: p-value	0.14681	0.05209	0.01684	0.01834

Table 6: Instrumental variables estimates of the effect of Suspected Hazardous Areas across various radii on child height-for-age (HAZ) z-scores. 4482 observations, child-specific, household-specific, commune-specific variables, and provincial dummies included. Standard errors clustered at the commune level (N=61) below estimates.

Dependent Variable: Child HAZ in 2000 (IDR)

	150km	100km	75km	50km
beta-IV	-0.00450	-0.00397	-0.00578	-0.01004
	0.00208	0.00190	0.00258	0.00386
beta-OLS	-0.00493	-0.00456	-0.00662	-0.01438
	0.00159	0.00139	0.00184	0.00546
Test of exogeneity: p-value	0.82054	0.67217	0.70262	0.39673

Table 7: Instrumental variables estimates of total number of Suspected Hazardous Areas for various radii on child height- for-age (HAZ) z-scores. 7684 observations, child- and household-specific household-specific, commune-specific variables, and provincial dummies included. Standard errors clustered at the commune level (N=50) below estimates.

Dependent Variable: Child WAZ in 2001 (MICS)

	150km	100km	75km	50km
beta-IV	-0.00405	-0.00904	-0.00544	-0.00560
	0.00188	0.00444	0.00248	0.00241
beta-OLS	-0.00238	-0.00127	-0.00010	0.00012
	0.00135	0.00319	0.00119	0.00133
Test of exogeneity: p-value	0.30376	0.05380	0.03778	0.01734

Table 8: Instrumental variables estimates of the effect of Suspected Hazardous Areas across various radii on child weight-for-age (WAZ) z-scores. 4482 observations, child-specific, household-specific, commune-specific variables, and provincial dummies included. Standard errors clustered at the commune level (N=61) below estimates.

Dependent Variable: Child WAZ in 2000 (IDR)

	150km	100km	75km	50km
beta-IV	-0.00195	-0.00172	-0.00250	-0.00435
	0.00156	0.00160	0.00226	0.00336
beta-OLS	-0.00355	-0.00240	-0.00319	-0.00936
	0.00164	0.00141	0.00201	0.00437
Test of exogeneity: p-value	0.37308	0.53240	0.68133	0.18362

Table 9: Instrumental variables estimates of total number of Suspected Hazardous Areas for various radii on child weight- for-age (WAZ) z-scores. 7684 observations, child- and household-specific household-specific, commune-specific variables, and provincial dummies included. Standard errors clustered at the commune level (N=50) below estimates.

Dependent variable: Household Income in 2000 (IDR)

	150km	100km	75km	50km
beta-IV	-0.00448	-0.00408	-0.00586	-0.01155
	0.00248	0.00192	0.00248	0.00586
beta-OLS	-0.00298	-0.00492	-0.00705	-0.01164
	0.00167	0.00142	0.00204	0.00398
Test of exogeneity: p-value	0.32874	0.35970	0.40927	0.98220

Table 10: Instrumental variables estimates of total number of landmines for various radii on log expenditures per adult equivalent. 9171 observations, household-specific, commune-specific variables, and provincial dummies included. Standard errors clustered at the commune level (N=50) below estimates.