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Landmines, Poverty and Recovery: Instrumental Variables Evidence from Mozambique*

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Abstract

The International Campaign to Ban Landmines production and use estimates that there are more than 80 billion landmines in the ground in more than 80 countries. Despite the scale of the problem and large investments by OECD countries to clear mines in low income countries, the economic consequences of landmine

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contamination have been so far unexamined by economists working on the economics of wars, perhaps due to the lack of data thus far. This paper exploits a unique dataset on landmine contamination intensity covering 126 Mozambican districts. Because landmines (unlike other weapons) are used as a weapon of choice to protect territories, the empirical strategy uses an indicator of distance to strategic borders as an instrumental variable to correct for selection in landmine placement. Instrumental variables estimates indicate a large effect of landmine contamination on poverty and consumption several years after the ceasefire. Hence, despite the very high cost to clear a mine a conservative cost-benefit evaluation of the national demining program indicates that the program generates a large positive return.

JEL codes: O1, O55

1 Introduction

The International Campaign to Ban Landmines production and use estimates that there are more than 80 billion landmines in the ground in more than 80 countries. Mozambique is among the most severely affected countries (in terms of both the number of mines and the size of the land area contaminated) along with Angola, Afghanistan, Cambodia and Vietnam. Cambodia with a population of 10 million has between 4 and 6 million landmines on the ground. In Afghanistan, it has been estimated that 88 per cent of the land is unusable due to landmine contamination. In some parts of Angola landmines have reduced food production by more than 25 per cent (Landmine Monitor

Report, several years).

Landmines may be considered a serious threat to long-term development and post-war recovery. They adversely affect agricultural development, human capital development and often block access to public infrastructure (roads, schools, power line, water plants, dams). Landmines have removed vast areas of land and resources from productive use. As more agricultural land is taken out of production, regions which were once self-sufficient become dependent upon outside sources for their food. In addition, the mining of irrigation systems and water-delivery plants adversely affects productivity in mine-free regions. Impoverishment is also reflected in the depreciation of assets caused by the presence of mines. In the absence of valuable assets, access to credit is restricted which reduces investments in new technologies and fertilizer. This in turn hampers productivity and agricultural growth.

Landmines are one of the most widely used weapons in contemporary conflicts because they are cheap to buy and profitable to sell. Despite the growing awareness within the international community that what has come to be known as the "global landmine crisis" has far-reaching consequences on development, effort to clear landmines is taking place in only 34 countries. A major factor explaining such under-investment in landmine clearance is probably the cost: while a landmine costs about 3 dollars to produce, according to the UN mine action program, it costs between 300 to 1000 dollars to clear a mine. As a consequence policymakers in landmined countries often argue that investing in landmine clearance cannot yield a positive return. This may be the case because landmines remain active for a limited time varying between 25 to 50 years

(see Landmine Impact reports).

Most landmine clearance programs are financed by OECD countries through bilateral or multilateral assistance. Landmine clearance assistance has followed a steady upward trend during the last ten years with a rapid acceleration started in 1999 with the signature by hundreds of countries of a Treaty to Ban Landmine Use and Production. The European Community (EC) assistance amounted to 42 million Euro in 2002, a 48 per cent increase relative to the previous year. The US remains the largest aid donor with about 80 million USD allocated to 37 countries worldwide. Between 1993 and 2002 the US invested 560 million USD in mine action assistance of all forms: demining, technical assistance, mine action education and so on so forth (Source: Landmine Monitor Report issues 1999 to 2003). Both the US and EC mine action programs expect to include an increasing number of countries in the coming years. In 2002, the top recipients were Afghanistan ($ 64.4 million); Iraq ($30.6 million) ; Cambodia ($ 27.3 million) and Mozambique ($ 18 million). For Afghanistan demining assistance from the EC and US represents about 15 per cent of total Overseas Development Assistance funds received. Despite growing donors assistance to clear landmines there is scant empirical evidence on the economic impact of landmine contamination to assess the cost-effectiveness of these large interventions.

This paper contributes to a rapidly growing literature on the economic consequences of wars and conflicts. Recent contributions to this literature include Miguel and Roland (2005), Abadie and Gardeazabal (2003) and La Ferrara and Guidolin (2005). Miguel and Roland (2005) evaluate the long term economic impact of US bombing in Vietnam

and find no effect of U.S. bombing on poverty rates, consumption levels, infrastructure, literacy or population density through 2002. Abadie and Gardeazabal (2003) use the event study approach to study the relationship between civil war, per capita output and private investment in the context of terrorism in the Basque Country. Similarly, La Ferrara and Guidolin (2005) exploit the sudden end of the conflict in Angola to study the relationship between civil war and the value of firms. The economic consequences of landmine contamination have been so far largely unexamined by economists working on the impact of wars on development perhaps due to the lack of data thus far. Here I use a unique dataset on the incidence of landmine contamination covering 126 districts of Mozambique.

Mozambique offers an ideal setting for this study for several reasons. First of all, the data necessary for the analysis including measures of landmine contamination, information on the national demining program and variables of economic performance were readily available and all measured at district level. Second, Mozambique is one of the rare countries to have adopted a clearance program immediately after the end of the conflict it experienced. Third, Mozambique is one of the most heavily mined countries and (as a consequence) one of the top aid recipient. It is estimated that mine action funding for Mozambique totalled $ 177 million from 1993-2002 (Landmine Monitor Report 2003). Concerning the choice to focus on a single country, it is motivated by the fact that problems of omitted variables are likely to be less than in a cross-country sample because sub-regions within a country are more similar with regard to observable and unobservable characteristics.

The ordinary least squares (OLS) method may be inadequate to identify causal effects of landmine contamination intensity on welfare due to potential selection in landmine placement and measurement error. To address this issue, an instrumental variables (IV) approach is applied using as instrument a measure of the distance to regions heavily mined by both factions for purely strategic reasons related to military actions i.e. the borders with Zimbabwe, Malawi and Tanzania. IV estimates are found to be much larger than OLS estimates consistently with the presumption that more mines where led in more economically developed regions. The point estimate implies that a change from the average landmine contamination intensity to zero is associated with a 10.63 percentage points fall in the poverty rate.

I then use the estimate of the average impact of landmine contamination intensity on the daily consumption per capita to derive the benefit of the landmine clearance program. Under conservative assumptions on the length of the benefit period, the benefit appears to largely outweighed the total cost of the national demining program over the period 1993-2004.

The remainder of the paper is organized as follows. Section II gives a historical overview of the war and landmine use in Mozambique. Section III describes the data. Section IV develops the identification strategy. Section V discusses the results. Section VI reports the cost-benefit evaluation of the National Demining Program. Section VII concludes the paper.

2 The Context[1]

Mozambique today has a total population of 17.6 million. It is estimated that 64 per cent of the population lives off subsistence agriculture and that 2/3 of the population is in absolute poverty. The mean monthly consumption is today around 9.4 USD.

Armed opposition to the Portuguese began in 1964, led by the Mozambican Liberation Front (henceforth, FRELIMO). The Portuguese withdrew and granted control to FRELIMO in 1974, which instituted a one-party Marxist system. Around 1976 Mozambican National Resistance (henceforth, RENAMO), an opposition group supported by South Africa, initiated a violent insurrection against FRELIMO.

South Africa had an interest in destabilizing Mozambique for many political reasons. In 1980, the white minority government in South Africa anticipated problems resulting from a situation in which they were increasingly surrounded by hostile neighbors. A destabilized Mozambique allowed them to maintain their political and economic hegemony over the region (Vines, 1994).

The country emerged from a long and brutal war at the end of 1992 with the distinction of being one of the poorest countries in the world. The war inflicted about 18 billion dollars worth of damage in a country where the GNP was less than two Billion (Willett, 1995). It had an enormous human, capital and economic impact, in terms of death, disability, displacement, and trauma suffered by the population. In addition, the war destroyed the social and economic infrastructure, including hospitals,

[1] This section heavily relies on Heynen et al (2003), Vines (1994,1997), and Landmine Impact survey report (2003) at http://www.sac-na.org/surveys_mozambique.html.

trading posts, schools, roads, bridges, railways and energy facilities. An estimated 58 per cent of the existing 5886 primary schools in Mozambique were destroyed or forced to close during the war. Of the 1,195 health posts in 1985, 500 were closed or destroyed. Warfare often resulted in the wholesale destruction of villages and landmines were used indiscriminately to deny people access to their farms and other means of survival.

Landmines constitute the primary obstacle to the reconstruction and development in Mozambique. Although systematic use of landmines in Mozambique occurred as far back as 1965 in the conflict between the Portuguese and FRELIMO, FRELIMO and RENAMO laid the majority of landmines between 1978 and 1990 (Vines, 1997). Many tactics determined the placement of mines, including the random deployment of mines and the deliberate targeting of civilian populations (Vines, 1994). Because of the need to protect their land-based interests from the RENAMO insurgency, FRELIMO used landmines for defensive purposes. In many cases, initial mine fields were laid around strategic installations, but often these proved inadequate against attacks. Hence, FRELIMO in many cases continued to add to sites until large areas extending well beyond the immediate perimeter of installations were protected. In doing so, they often disrupted large parcels of arable land as well as important transportation routes (Heynen et al, 2003). As part of a larger-scale strategy, FRELIMO laid many mines along its border with South Africa during the 1980s fearing increased collaboration between RENAMO and South African forces (Vines, 1994).

Alternatively, RENAMO laid mines primarily in an attempt to devastate the government's economy. RENAMO frequently mined commonly used roads in order to slow

and divert troop movement, as well as to stop deliveries of military goods and transport of agricultural produce. In order to attack troops directly, RENAMO laid mines in large rural tracts that were used for troop movement and food collection and production. Airfields used by the government were also mined in order to further prevent the movement of people and goods (Heynen et al, 2003). According to the Mozambique landmine impact survey (MLIS), landmines currently affect all 10 provinces of Mozambique and 123 out of 128 districts. This is apparent in Map 1 which maps the area contaminated by district per 10.000 km2. According to the same survey, at least 1.5 million persons, representing no less than nine per cent of the national population in 1997, live close to a landmined area. In addition, landmines frequently block access to agricultural land; roads; and non-agricultural land used for hunting, gathering firewood, and other economic and cultural purposes. A total of 2,145 landmine victims is recorded among which 172 had come to harm during the two years preceding the survey. Male outnumbered female by a factor of almost three to one. The most frequently represented victims age groups were from the working age population; 30 to 59 years among women (62.1% of female victims) and from 15 to 44 years among men (57.4% of male victims). Individuals who survive a landmine accident most often suffer from irreversible trauma. Although it is difficult to precisely record the number of people who have been injured by landmines (due to under-reporting especially in highest mined areas), the estimated number of amputees for Mozambique ranges between 9,000 and 12,000 and children represent a non-negligible share of these victims (Landmine Impact Reports UN). Children with disabilities who are excluded from education are virtually

certain to be life-long poor.

3 The Data

The main dependent variables investigated in the paper are: the poverty headcount index, the poverty gap and daily per-capita consumption obtained from the International Food Policy Institute who was exceptionally granted access to the household survey (IFPRI, Simler, K., and V. Nhate (2002)[2]). These indicators, all measured at district level, have been computed by using consumption data from the 1996 household survey. The National statistics Office of Mozambique usually does not grant access to the survey. The survey is a multi-purpose household and community survey, in the same vein as the World Bank's Living Standard Measurement Study (LSMS) surveys, and was designed and implemented by the National Institute of Statistics. The data collection took place from February 1996 through April 1997, covering 8,250 households living throughout Mozambique. The sample is designed to be nationally representative, as well as representative of each of the ten provinces, the city of Maputo, and along the rural/urban dimension. It is the first survey of living conditions in Mozambique with national coverage, and is the only national survey that measures welfare using comprehensive income or expenditure data. Two indicators of poverty are used: the poverty gap (PG) and the headcount index (HI). The later measures the share of a district population living under the poverty line (one dollar a day). The former is

[2] I refer to their paper for a detailed description of how these indicators were derived using the 1996 household survey.

the mean distance separating the population from the poverty line (with the non-poor being given a distance of zero), expressed as a percentage of the poverty line. The poverty gap ratio (PGR) is the sum of the income gap ratios for the population below the poverty line, divided by the total population; hence it is a measure of the depth of poverty. The consumption measure includes food and nonfood items, acquired through home production, market purchases, transfers, or payments in kind. Consumption also includes the imputed use value of household durables, and an imputed rental value for owner-occupied housing[3].

Landmine contamination intensity is also measured at district level by the fraction of land contaminated (per 10000 km2) in 1996. The data are available from the National demining Institute. I use district level data because data at a more disaggregated level are not available but also because this choice allows to reduce bias from spillover effect whereby landmine contamination in one region would also affect neighboring regions. Table 1 reports descriptive statistics of the main variables used in the analysis.

4 Identification Strategy

Several elements highlighted in the previous section suggest that landmines were not randomly placed which renders an ordinary least squares approach inadequate to identify the causal effect of landmine contamination on welfare (e.g. poverty). Indeed, in such a framework, landmine contamination and poverty will be spuriously negatively

[3]See Simler, K., and V. Nhate (2002) for details.

correlated if more landmines were led in more fertile lands. A way to correct for endogeneity is to exploit an exogenous source of variation in landmine contamination intensity. I use an indicator of distance to the borders heavily mined by both factions for purely strategic reasons as an instrumental variable for landmine contamination intensity. Unlike other weapons, landmines are often used as a weapon of choice to protect borders. During the war the governmental forces (FRELIMO) heavily mined the border areas with Zimbabwe and South Africa to counter rebels infiltration while on the other side, the rebels (RENAMO) heavily mined the borders with Malawi and Tanzania to harm the flows of refugees. Relative to the extreme east and west borders, these areas are relatively centrally located. This suggests a non-linear inverted U-shaped relationship between the districts' longitude and landmine contamination intensity. This is confirmed in Table 2 which reports the regression of landmine contamination intensity on the longitude squared with and without geographical controls (i.e. elevation, average rainfall precipitation in 1996, a coast dummy, latitude and longitude) in column (1) and (2) respectively. This represents the first stage of a two-stage-least-squares estimation of the impact of landmine contamination intensity on welfare where the excluded instrument in the second stage is the longitude squared.

5 Results

Poverty Table 3 column (1) reports the OLS and IV estimates of the impact of a 1/10000 fraction of contaminated land on poverty measured by the headcount

index. All regressions include a full set of geographical controls. The OLS estimate is significant statistically but suggests a very marginal relationship between landmine contamination intensity and poverty. The IV estimate is much larger than the OLS estimate which is consistent with the presumption that more mines were led in more prosperous regions and with the fact that measurement error biases OLS estimates downwards. The IV estimate has the expected sign, is statistically significant at standard levels and relatively large in magnitude. The point estimate implies that a change from the average landmine contamination intensity to zero is associated with a 10.63 percentage points fall in the fraction of people living under the poverty line. This is a large but reasonable estimate given that the headcount index sample mean is 70 per cent. The poverty rate is a rather crude measure of poverty and so I also use the poverty gap as a measure of poverty. The result is confirmed. This means that clearing landmines in Mozambique would contribute to reducing both the level and the depth of poverty.

Consumption The average effect of landmine contamination intensity on the daily per capita consumption is also very large. While the OLS estimate suggests again a very small average effect, the IV estimate implies that going from zero to the average landmine contamination intensity translates into a 1395.11 mt (local currency) decrease in the daily per capita consumption. This is a very large effect representing about 27 per cent of the actual mean daily consumption per capita.

Transmission Channels Table 4 reports further evidence on the impact of landmine contamination with the aim of highlighting possible transmission mechanisms. Unfortunately without access to the household survey containing information on households access to public services and infrastructure this exercise cannot be carried out in detail but here I consider some additional outcomes that are possibly relevant: the female-to-male ratio, the average family size, the number of firms in the district, the number of employees working in these firms and the size of these firms´businesses. Given the small number of mine victims recorded so far relative to the aggregate population one expects the population structure to be altered mostly through migration effects and this may be reflected in variations in sex ratios. The number of firms located in a district and their size is also worth examining because one could presume that firms will have a higher incentive to locate in districts offering a better access to public services and infrastructure. Given that one major effect of land mines is blocked access to infrastructure (in particular roads and bridges) this is a relevant outcome to consider here.

The impact of landmine contamination intensity on the sex ratio is insignificant statistically. If one expected landmine contamination to alter the family structure through male migration then this result suggests that landmine contamination is associated with insignificant migration flows across districts[4]. I also find no significant effect on the average family size and population density. This result is somehow re-

[4]Short distance migration i.e. within districts and international migration of refugees to neighboring countries may have been larger.

assuring because a recurrent issue in program evaluation is that OLS estimates can be biased due to migration selectivity. If the war caused selective migration this introduces a (non-classical) measurement error into the outcome variables. The total effect of landmine contamination would include (i) the direct effect of mines in the original, resident population; (ii) the change in the outcome variables caused by the compositional change in the population via migration that is induced. In this case the effect of interest is only given by the first term, if all pre-contamination site populations have the same mean characteristics or if the pre-contamination site population is representative (Rosenzweig and Wolpin (1988)). Based on these results however, I find no evidence that migration flows have been large enough across districts to significantly alter the conclusions drawn so far.

In the third to fifth columns I report results for the number of firms located in a district and indicators of firms size. The estimates are all insignificant statistically which may be explained by the fact that while landmines were led mostly in rural areas these firms are located mostly in urban areas. Hence, these results provide good control experiments.

6 Comparing Costs and Benefits of the National Demining Program

In 1992 Mozambique initiated a demining program mostly financed through aid received from OECD countries. The National Demining Institute (IND) is a semi-autonomous

governmental institute reporting directly to the Minister of Foreign Affairs, which coordinates all mine clearance activities in the country. A total of about 58 million square meters of land was cleared from 1993 to 2004 at a cost of about 96 million dollars.

The estimates of the average impact of mine contamination on the consumption per capita can be used to compare the cost of demining and the additional wealth generated by the demining program. The program yearly cost is given by the aggregate aid received each year since the program is almost entirely financed through aid; the government contribution is negligible. It includes all forms of assistance i.e. technical or purely financial.

Several assumption are needed for the calculation of the program's discounted net present value. Given that most mines remain active for periods varying between 25 and 50 years I will report results assuming the program generates benefits over 25 and 50 years. In addition, I assume a 5 per cent yearly discount rate and report all monetary variables in 2004 USD. I assume a zero population growth over time because the marginal effect may not be the same in the long-run on a larger population.

So, the program benefit is calculated as follows:

$$Benefit = \alpha * \left[P * \left(LC^{93-04}\right)\right] \tag{1}$$

Where LC_d^{93-04} is the total area decontaminated during the period 1993-2004 as a fraction of the country surface multiplied by 10000. α is the estimated average effect of 1/10000 of contaminated land on the daily consumption per capita (=0.39 dollar).

P is the population in 2004. The benefit is then multiplied by 365 to get the yearly benefit.

I compute the present benefit value and compare it to the immediate cost. The results of this exercise are reported in Table 5. As can be seen, whatever the assumption made on the length of the benefit period the net benefit is very large.

This analysis however has to be taken cautiously for at least three reasons. Firstly, if demining causes an increase in income, households could choose to save or invest rather than consume the additional wealth generated by the program. This would in turn result into a long-term growth effect. In this case the approach used undervalues the program's benefit. Secondly, a cost-benefit analysis of the demining program based on cross-section estimates of the effect of landmine contamination is relevant if the program´s impact is immediate and if its distributional effects are not important. Given that landmines are active for a limited time, if for some reason the program's impact takes several years to materialize, its profitability would fall dramatically. People may not adjust immediately to the program due to psychological factors or because the returns from (new) investments in cleared areas take time to materialize. Addressing this issue would require ideally a dynamic framework and unfortunately the required data are not available for most developing countries including Mozambique. Thirdly, if the instrumental variables approach does not fully isolate the impact of landmine contamination from the impact of other war damages correlated with it, the benefit of clearing mines may be over-valued to an undetermined extent.

7 Conclusion

The paper has provided evidence on the economic consequences of civil wars in the context of landmine contamination in Mozambique. The evaluation used aggregate data covering 126 districts and corrected for endogeneity using an instrumental variables framework. The identified causal effect of war on poverty and consumption several years after the cease-fire is sizeable and statistically significant. This result is in contrast with several recent inconclusive evaluations of the long term impact of war in developing countries e.g. Miguel and Roland (2005) study of Vietnam one of the most heavily mined countries in the world. One conclusion of this paper is that improving households access to infrastructure and land through mine clearance is likely to generate large returns and therefore considerably boost recovery in countries emerging from wars. Despite the high investments required to clear landmines I also show that such interventions may generate large net benefits provided the programs are implemented early enough after the conflict and designed to target regions really in need of assistance.

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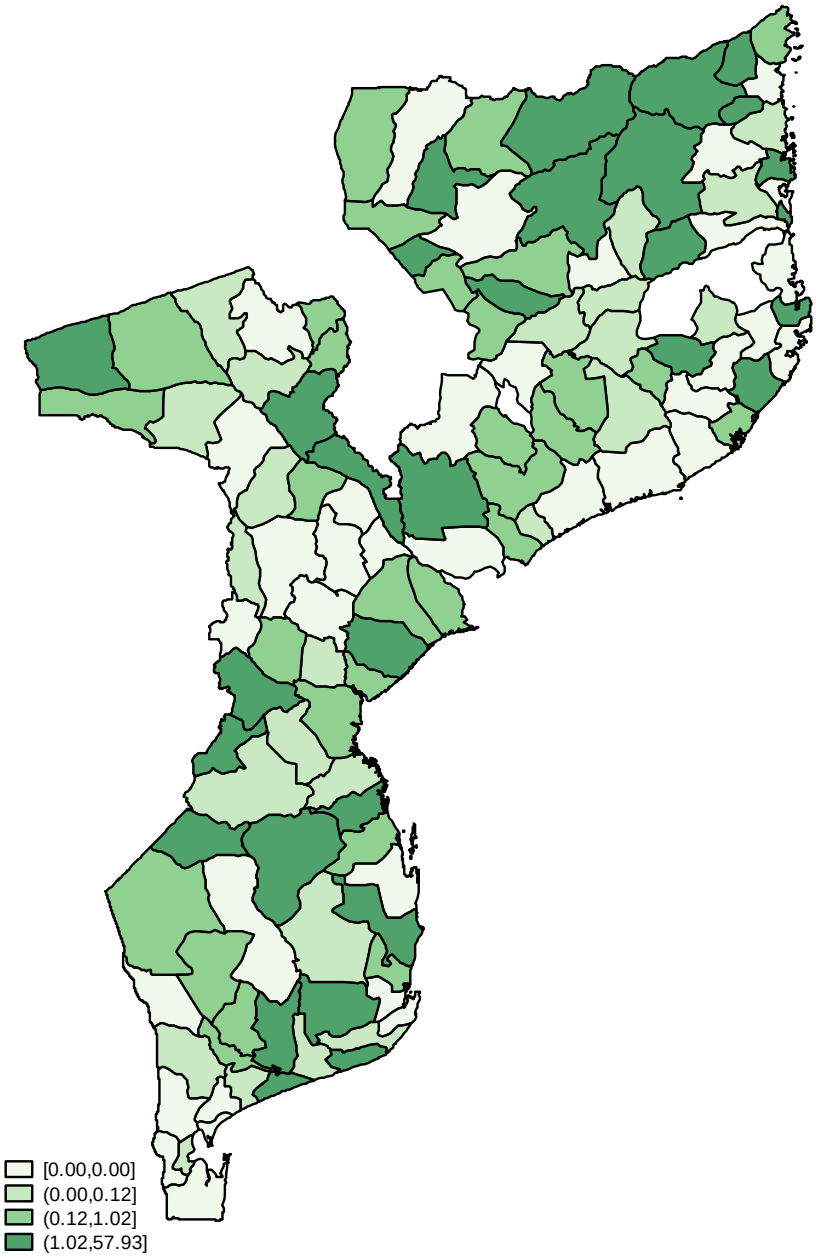

Map1 Proportion of Land Surface Cleared from Landmines from 1996-2004 (per 10.000 km2)

Table 1: Descriptive Statistics

Variables	Nbr.Obser.	Mean	Standard Deviation	Min	Max
Daily per capita Consumption (in Metical)	126	5 108	1 634,23	1534,82	13108,39
Headcount Index	126	70,5	13,7	22,8	98,6
Poverty Gap	126	32,7	12,3	6,9	72,6
Area landmined per 10000	126	0,319	0,9	0	5,793

Table 2: First Stage results for IV

Dependent variable: Area landmined per 10 000 km2

coefficient on	(1)	(2)
Instrument	-0,008***	-0,02**
Longitude Squared	(0,0004)	(0,011)
Geographical controls	no	yes
Nbr.Obser.	126	126
R-squared	0,03	0,17

Note: robust standard errors in parenthesis. Significant at 90 (*), 95 (**), 99 (***) percent confidence
Geographical controls include elevation, latitude, longitude, rainfall precipitation and a coastal dummy

Table 3: Effect of Landmine Contamination on Poverty and Consumption

	Headcount Index	Poverty Gap	Daily Comsumption per capita
OLS	1,81**	1,27	-187,16*
Area landmined per 10000	(0,89)	(0,83)	(108,74)
IV	33,33*	25,71*	-4373,4*
Predicted Area landmined per 10000	(18,92)	(14,75)	(2534,14)
Nbr.Obser.	126	126	126

Note: robust standard errors in parenthesis. Significant at 90 (*), 95 (**), 99 (***) percent confidence
All regressions include geographical controls i.e. elevation, latitude, longitude, rainfall precipitation and a coastal dummy

Table 4: Transmission Mechanisms

	Female-to-Male ratio	Average Family size	population density	log Number of Firms	log Number of Employees	log Business Size
OLS						
Area landmined per 10000	1,49*	0,008	3,11	-0,05	-0,05	-0,055
	(0,87)	(0,065)	(4,06)	(0,08)	(0,152)	(0,113)
IV						
Predicted Area landmined per 10000	-3,43	-0,35	-19,6	-1,58*	-1,33	-0,508
	(4,96)	(0,32)	(28,39)	(0,95)	(0,95)	(1,061)
Nbr.Obser.	126	126	126	126	126	126

Note robust standard errors in parenthesis. Significant at 90 (*), 95 (**), 99 (***) percent confidence
All regressions include geographical controls i.e. elevation, latitude, longitude, rainfall precipitation and a coastal dummy

Table 5: Cost-Benefit Analysis

Assumptions	
Interest Rate	5%
Area cleared 1993-2004	58 km2
Country surface	801 590 km2
Clearance Cost 1993-2004	96 Million USD
Population in 2004	19792000
Exchange Rate Metical per Dollar	11293,8
Discount Period	**50 years**
Present benefit value in dollars	37 billion USD
Discount Period	**25 Years**
Present benefit value in dollars	28,5 billion USD