Landmines and Spatial Development*

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Abstract

Landmine contamination affects the lives of millions in many conflict-ridden communities long after the cessation of hostilities. Yet, little research exists on its role in post-conflict recovery. In this study, we explore the economic consequences of landmine clearance in Mozambique, the only country that has moved from heavily contaminated in 1992 to mine-free status in 2015. First, we collected thousands of reports from the numerous demining actors, constructing for the first time a detailed catalogue tracing the evolution of clearance operations throughout this 23-year long process. Second, we explore the co-evolution of demining and local economic activity, as reflected in satellite images of light density at night, finding a robust positive association. Third, we investigate heterogeneity to gain some insight on the mechanisms at work. Economic activity responds strongly to clearance of the transportation network and of rural localities hosting local agricultural markets. Fourth, recognizing that landmine removal reconfigured the accessibility to the transportation infrastructure over time, we apply a "market-access" approach to quantify its direct and indirect consequences. Demining conferred substantial improvements in aggregate economic activity with its benefits extending also to localities without any contamination. Fifth, counterfactual policy simulations project considerable gains had the fragmented process of clearance been centrally coordinated, prioritizing clearance of the colonial transportation routes.

Keywords: Africa, Development, History, Land Mines.
JEL classification Numbers: N47, N77, O10, O55

1 Introduction

The millions of refugees escaping conflict-ridden parts of the world in recent years, has added urgency in understanding (the absence of) economic growth in the aftermath of violence. Shedding light on the factors that enable a swift post-conflict recovery is vital, since sluggish growth may push a war-torn region back to the vicious circle of violence, poverty, and refugees flows (IGC (2018)). The consequences of conflict are multifaceted, permeating all aspects of the societal fabric; loss of lives, injuries, the destruction of infrastructure, distrust, and the deterioration of institutional capacity, among others. Nevertheless, one conspicuous legacy of conflict is that of landmine and other unexploded ordnance (UXOs) contamination.[1]

"*Peace agreements may be signed and hostilities may cease, but landmines and explosive remnants of war are an enduring legacy of conflict*" states in its introduction the 2017 Landmine Monitor. In spite of landmines' extensive use in civil wars after WWII and the salience of this topic for the international community,[2] there has been little research quantifying their role in post-conflict recovery. This paper aims to start filling this gap by focusing on Mozambique, the only country so far that has moved from "heavily contaminated by landmines" in 1992 to "landmine-free" status in 2015.

Landmines have been coined "*the weapon of the poor*", as they cost as little as one dollar and can be manufactured by militias at an even lower cost. Pol Pot, Cambodia's Khmer Rouge infamous leader reportedly argued that "*a landmine is a perfect soldier, it doesn't need food or water, it doesn't take any salary or rest, and it will lie in wait for its victim.*" Hence, it is not surprising that they have been extensively used in many civil wars; among others, in Cambodia, in Angola, in Congo, in Colombia, in Afghanistan, in the Caucasus region, and during the breakup of Yugoslavia. Human Rights Watch estimated in 1993 that in the previous 25 years, 5 million mines were manufactured globally. Today mine contamination remains a serious threat in more than 50 countries, most importantly in Angola, Afghanistan, Cambodia, Somalia, Sudan, but also in frontier/developing economies, including Colombia, El Salvador, Nicaragua, Ukraine, and Myanmar (Landmine Monitor, 2015, 2016, 2017). Media reports suggest widespread ongoing use in Syria, Iraq, Libya, Yemen, Nigeria, and Myanmar.[3]

Landmines are a particularly damaging legacy of wars, as they remain active, hidden on the ground long after the cessation of hostilities posing an incessant threat to the population. According to Graca Machel, an expert of the UN Secretary-General on the "Impact of Armed Conflict on Children" and former minister of education of Mozambique "*landmines are uniquely savage in the history of modern*

[1] Landmines are containers of explosive material with detonating systems that are triggered by contact with a person or vehicle. They are designed to incapacitate that person or vehicle through damage caused by an explosive blast, fragments, or, in the case of some antitank mines, a jet of molten metal.

[2] Its importance can be glimpsed by the NGOs, government agencies, donors and commercial partners that engage in mine-related activities. For example, there are 14 agencies under the auspices of the UN mine-action program, which as of 2008 was active in 43 countries. Conservative estimates put the annual budget of landmine and UXO clearance to an average of 700 million USD (Landmine Monitor, 2016).

[3] Recently, the New York Times documented the use of hundreds of thousands of landmines in the Yemen's Civil War. The use of landmines has been quite extensive in international wars, including WWI and WWII. Nevertheless, conventional armies, unlike warring parties in civil wars, keep records of minefields that greatly facilitate their clearance.

conventional warfare not only because of their appalling individual impact, but also their long-term social and economic destruction" (UN General Assembly Resolution 48/157, 1996). The Landmine Monitor has recorded more than $110,000$ mine/UXO fatalities, since its (partial) global tracking in 1999 and -if anything- these are underestimates, as landmine casualties go often unrecorded due to states' weak capacity, misgovernance, and misreporting in hospitals and clinics (Landmine Monitor (2017), Ascherio *et al.* (1995)). Naturally, the attention of the international community and media has been on the victims; yet, landmines affect the lives of millions of people, who live, play, and work in landmine-affected areas. For example, the 2001 Mozambique Landmine Impact Survey estimated that around 3 million people were living in communities significantly affected by landmines. Once people bitterly learn of contamination they adjust their living by avoiding suspected areas. But, even when contamination does not result in more victims, the economic and social ramifications of fragmentation and isolation are ever present. Our study is a first step to offer a quantitative assessment of the economic consequences of demining.

1.1 Results Preview

In this paper, we examine the economic impact of landmine and UXO clearance on the Mozambican economy that emerged in 1992 from 25 years of warfare severely damaged with hundreds of thousands of landmines across roughly $7,000$ minefields scattered across its vast territory. In September 2015, with support from international agencies, foreign governments, and the strength of the Mozambican people, Mozambique was officially declared "landmine free".[4]

Our analysis proceeds in six steps. First, we present the self-collected, cross-validated data on thousands of clearance operations, conducted by dozens of demining actors. We are able to provide the first time a complete documentation of landmine and UXO clearance for any country in the world, a non-negligible contribution as such data are not available from any government or the United Nations.

Second, we examine the spatial distribution of minefields and the timing of their clearance looking at the role of end-of-war (in 1992) and at-independence (in 1975) factors. In line with the historical narrative and our interviews with practitioners regarding the localized and fragmented nature of clearance operations (discussed briefly below and in detail in the Online Appendix), we find that the timing of demining is weakly related to geographic, location, and economic characteristics.

Third, we trace how local economic activity reacts to landmine clearance across localities over time. To bypass data unavailability, especially in the 1990s when Mozambique was among the poorest nations in the world, we use satellite images of light density at night that are available at a fine spatial resolution and at a yearly frequency since 1992. After showing that luminosity correlates strongly with

[4] HALO Trust (2007) provides the definition of landmine free, "*That is not to say that there are no more mines remaining. Unfortunately, the manner in which the war was conducted means that mines may remain in isolation which nobody alive knows anything about, and their presence will go undetected until such time that they explode or are uncovered. But, nevertheless, there are no more areas left to demine, nobody in the north of the country can point at an area and say 'I think there are mines there*".

measures of wealth and education across regions in Mozambique, we compare luminosity in localities, where demining took place in a given year/period, to those localities that were either not contaminated or were mined but not cleared yet. The analysis shows that local economic activity picks up robustly upon the removal of landmines and UXOs.

Fourth, we explore heterogeneity to shed light on the mechanisms at work. Demining localities disconnected from the transportation network, and those without agricultural points of exchange, leaves no visible imprint on local development. In contrast, clearance of rural localities hosting local agricultural markets (*cantinas*) and localities along the transportation network translates into substantial improvements in economic activity.

Fifth, recognizing the fact that clearing landmines in one locality may impact economic activity elsewhere via transportation network linkages, we examine the economy-wide consequences of landmine clearance. We employ recently-developed techniques in quantitative trade (e.g., Eaton and Kortum (2002), Arkolakis, Costinot, and Rodríguez-Clare (2012), Donaldson and Hornbeck (2016), Donaldson (2018)), and apply a "market-access" approach that captures both the direct and indirect effects of clearance. The analysis reveals economically considerable and statistically precise effects of landmine removal. Spillovers are strong, as the "market access" - luminosity elasticity is highly significant even in localities that were spared from contamination. We also examine the association between localities' market access and luminosity looking at clearance interventions targeting the at-independence infrastructure network and imposing the pre-civil-war distribution of the population. The estimates ["beta" coefficients of around $0.2-0.3$] are in line with the estimates of the effect of large infrastructure projects in other contents, such as the extensions of railways in the United States in the late 19th century (Donaldson and Hornbeck (2016)) or the Golden Quadrilateral highway system in India in the 2000s (Alder (2017)).

Sixth, we conduct counterfactual policy simulations to assess the effect of landmine clearance. As a starting point, we approximate how much luminosity would have increased in absence of any landmine clearance, finding that in this extreme scenario aggregate light density in 2015 would have been roughly 70% lower. Given a light-GDP elasticity of around 0.3 (Henderson, *et al.* 2012), this translates into an output boost of around 20%. We then approximate the costs of the fragmented and non-coordinated nature of clearance process that (especially in the early stages) took place under chaotic conditions and was further impeded by devastating floods in $2000-2001$, corruption, and donor fatigue in the mid-*2000s*. We estimate a counterfactual removal plan that prioritizes the three colonial "corridors" connecting the three main ports (Maputo, Beira, and Nacala) with the mainland, followed by the clearance of the highway connecting the south to the central regions, and finally clearing the rest of contaminated areas. The comparison of actual demining with this heuristic counterfactual reveals substantial losses from the absence of central, strategic prioritization.

1.2 Related Literature

There is little academic research assessing the role of landmine clearance and none on its aggregate economic consequences. Our study connects to several research strands that have developed largely in parallel.

First, our findings contribute to our understanding of the economic legacy of civil wars (see Blattman and Miguel (2010) for a thorough overview). Works based on cross-country comparisons and case studies (e.g., Collier and Hoeffler (2007), Collier and Sambanis (2005)) show that civil wars slow down economic activity; and, while typically growth resumes at the end of conflict, the strength and timing of the recovery varies considerably.[5] Landmine contamination and the speed of clearance may partially account for the observed heterogeneity, yet there is not much work. Exceptions are Merrouche (2008), who presents cross-sectional correlations across 126 Mozambican districts between contamination and poverty rates and Arcand, Rodella-Boitreaud, and Rieger (2014), who using survey data from Angola, document cross-district associations between contamination and malnutrition.[6] Besides focusing on the consequences of landmines, an important, but unexplored consequence of warfare, we bring into this body of research a theoretically-grounded approach that is well-suited to quantify spatial spillovers in agriculture-based, rural communities. This may be important as most within-country empirical studies exploit regional variation in a "control"-"treatment" framework that works well when spatial inter-dependencies are absent (weak). In our context, we find that landmine clearance generates sizeable spatial externalities.

Second, from a methodological standpoint, our paper relates to recent works in trade and urban economics that apply insights from general equilibrium trade theory to study the aggregate, direct and indirect, effects of transportation infrastructure on economic activity (see Donaldson (2015) for an overview). In an important paper, Donaldson and Hornbeck (2016) adopt the Ricardian model of Eaton and Kortum (2002) to derive a reduced-form expression linking changes in regional welfare (income) to changes of a region's market access, that reflects its proximity via the transportation system to all other markets, scaled by population and income. They then document that aggregate effects of the railroad expansion in the US, as reflected in agricultural land values, during the 19th century are considerably larger than local effects, which influential research by Fogel (1964) had estimated as being small. A similar approach has been applied in a variety of other contexts, including the building of colonial railroads in India (Donaldson (2018)), the construction of large Indian highways (Alder (2017)), and post-independence road construction in Sub-Saharan Africa (Jedwab and Storeygard

[5]From a theoretical standpoint, the post-war speed of recovery is ambiguous. In the neoclassical model, economic activity rebounds quickly and recovery is strong, as conflict often destroyed capital. Yet, in absence of external interventions, recovery is sluggish in "poverty-trap" models that are commonly used/assumed in development policy circles (e.g., Sachs (2005), Duflo and Banerjee (2011)).

[6]There is some connection between our paper and studies on bombardment. Miguel and Roland (2011) and Dell and Querubin (2017) quantify the long-run effects of the bombing of Vietnam on the economy, local governance, and insurgency. Lin (2016) shows that the bombing of Cambodia entailed small on average effects, that are however considerable in soil-rich areas. Davis and Weinstein (2002) look at the economic geography after the WWII bombing of Japan.

(2018)).

We employ a market-access approach to examine an understudied issue, the removal of landmines and other explosive war remnants. This framework appears useful in addressing some policy-relevant questions. What are the aggregate, as opposed to local, effects of removing landmines? How shall NGOs, international organizations, and governmental agencies design the clearance of minefields once the war is over, a critical issue nowadays in Cambodia, Colombia, and other countries?

Third, our focus on the legacy of a devastating civil war that left Mozambique contaminated with hundreds of thousands of landmines connects our work to the broader agenda on the origins of African (under)-development (see Bates (2007) and Collier and Gunning (1999) for overviews of the role of post-independence policies and Michalopoulos and Papaioannou (Forthcoming) for a review of the burgeoning literature on historical legacies). Since landmine clearance is often funded by foreign donors and development agencies (as in Mozambique), there is also some relation of our work with the large literature on foreign aid (see Easterly (2009) and Easterly and Pfutze (2008) for reviews).

Fourth, our paper contributes to practitioner/applied works on the topic (e.g., Cameron, Gibson, Helmers, Lim, Tressler, and Vaddanak (2010), Keeley (2006), Elliot and Harris (2001), often summarized in the annual editions of Landmine Monitor). Most impact assessment reports that practitioners conduct are qualitative focusing on a single (few) community(ies) and most case studies fail to uncover significant economic effects of landmine clearance (see DFID (2014) for a review). Medical research, in contrast, uncovers significant adverse effects, but given lack of data on landmines and considerable under-reporting of fatalities and amputations, it is based on tiny samples (see Frost et al. (2017) for a review).[7]

Paper Structure The paper is structured as follows. In the next section, we provide an overview of the use of landmines in Mozambique and the 23 year-long process of clearance. In Section 3 we present and describe the self-collected data on landmine clearance. In section 4 we report panel specifications that examine the within-locality correlation between landmine clearance and local development. In Section 5 we explore heterogeneity of the correlation between luminosity and demining. Section 6 reports the market-access estimates that quantify the direct and indirect effects of landmine clearance. In section 7 we present counterfactual policy experiments that quantify the role of landmine clearance on economic activity and the losses from the absence of coordinated prioritization. In section 8 we discuss the implications of our findings and offer some thoughts on future research.

[7] Ascherio *et al.* (1995) conducted surveys in two Mozambican provinces shortly after the war and estimated ratios of fatal and non-fatal landmine injuries of $8.1 - 8.2$ per $1,000$ (roughly $3.8^0/_{00}$ deaths, $3.2^0/_{00}$ amputations, and $1.1^0/_{00}$ other injuries). These estimates are ten-times higher than the ones based on hospital or amputee-assistance-programmes. Roughly 75% of fatalities happen before the victim reaches a health center.

2 Historical Background

This section provides a brief account of the use of landmines $(1964-1992)$ and the subsequent clearing efforts, a process that lasted more than twenty years $(1992 - 2015)$. In Appendix I we provide an overview of the Mozambican war of independence $(1964-1974)$ and the ensuing civil war $(1977-1992)$, discussing the strategic objectives of the parties and the use of landmines. In Appendix II we provide a detailed description of the gigantic landmine clearance process.

2.1 Conflict and Landmine Use

Mozambique's experience with landmines starts with the war of independence. The Portuguese planted large minefields along the border with Tanzania to prevent the fighters of the Front for Liberation of Mozambique (FRELIMO), the main independence movement, to enter the country. The colonial administration also planted mines along key infrastructure projects to protect them from the insurgents, including a minefield of $80,000$ mines along the Cahora-Bassa dam, the largest in Africa. In turn, FRELIMO used landmines for military purposes, to demoralize the colonial army, destabilize the countryside, and cut road communications. Mozambique becomes independent in 1975. But conditions deteriorate, as the country enters one of the most disruptive civil wars since WWII. The main warring parties, FRELIMO that was now in government, backed by socialist countries, and the Mozambique Resistance Movement (RENAMO), supported initially $(1977 - 1980)$ by Rhodesia and subsequently from South Africa's apartheid regime, extensively used landmines for military purposes, to protect infrastructure (e.g., electricity pylons and roads), to terrorize the civilian population, to shield borders and block rearmament, and to ring-fence towns, villages, and farms. Between the late 1970s and the early 1990s, FRELIMO and RENAMO disseminated landmines in a wholesale fashion mostly targeting civilians (Human Rights Watch (1997)). Militias, thugs, and other groups also used landmines in their strategy of terror and for a plethora of other reasons.

2.2 Mozambique at the End of the War (1992). The Problem of Landmines

Mozambique was destroyed at the end of the civil war. According to the Penn World Table statistics, it was the third poorest country in the world; a Human Rights Watch (1992) report suggested that "*parts of the country had returned to the stone age and Mozambique has to be built from scratch.*" Landmines and unexploded ordnance posed massive problems and interacted crucially with other devastating consequences of the civil war. Mozambican refugees in neighboring countries (approximately 1.5 million) and internally displaced (roughly 3 million out of a total population of around 15 million) could not return to their homes. Initial assessments put the number of landmines to millions. Contamination was widespread along the main transportation routes. Electricity pylons, dams, and power stations were also heavily mined. A country with one of the most advanced hydroelectric dams in the world -that was meant to provide energy also to neighboring countries- was without electricity. Mines had been planted around schools, police stations, and government buildings, typically used as the local rebel or government headquarters. Recognizing this challenge the General Peace Accord signed in Rome in September 1992 required in Protocol VI that FRELIMO and RENAMO "*organize and implement mine-clearing operations*" and provide assurances that they will not "*prevent mine-clearing operations.*"

HALO Trust 1994 survey, conducted for the United Nations Office for Humanitarian Assistance Coordination, provides an early account of the extent of contamination. First, the problem was mostly on the extensive -rather than the intensive- margin, as the "*use of landmines in Mozambique is characterized by a highly dispersed pattern*". The report suggested a "*figure of hundreds of thousands [mines] is probable*". A handful of mines can have adverse effects. For example, eight mines cleared in 1996 were preventing $20,000$ people in Mahniça valley from returning to their villages. Human Rights Watch (1997) report makes a similar point. "*During a Norwegian Peoples Aid mine clearance operation in Maputo province, a team was sent in 1994 to clear the village of Mapulenge, which had been the center of a community of about $10,000$ people. It had been deserted for some four years because it was locally believed to be heavily mined. After three months of work, the clearance team reported finding four mines; these, and the rumor of many more, were sufficient to depopulate the entire area.*" Second, infrastructure was heavily mined; the report stated that in the southern and central provinces "*all dams, railway lines, electricity substations and pylon lines should be assumed to be mined*" and a similar though somewhat better assessment applied to the northern districts. Third, the survey pointed out that the number of landmines is "*not of great importance*", as "*what matters is the number of areas which the population believes to be mined and therefore do not enter.*" Fourth, UXOs posed also a challenge, as due to rainfall and landslides, they would move around, blend with mud, and become hard to detect.

2.3 Landmine Clearance

2.3.1 Land Release Process

Mines are usually buried within 15 centimeters of the earth's surface, which makes verification a difficult task. Even for mines laid on the ground, detection is hard, as vegetation grows back and floods and rock-slides move landmines. Detection becomes even harder as surveyors search for landmines placed years ago by actors that often are not around anymore. Over time, the mine-action community has acknowledged that attempting to clear all areas suspected of contamination (known as "suspected hazardous areas" - SHA) is infeasible. The initial classification of SHA is often based on word-of-mouth collected well after their plantation, under insecure conditions. Cancelling "false positive" SHA or updating their status to confirmed hazardous areas (CHA) is an essential task, done via non-technical surveys (NTS). NTS gather information by visiting the area, interviewing farmers, village leaders, and (ex) military personnel. In cases of sufficient evidence of contamination, a technical survey (TS) that collects more precise information follows. Usually, a TS concludes with the clearance of the hazard(s) and the issuing of a completion report. TS detection methods are similar to those used for clearance; they include manual labor, animal detection, flail and tiller machines, trollers, and wide-area detectors like magnetometers. These practices first came into place at the end of 2001 with the issuance of the Handbook of International Mine Action Standards (IMAS) and were last revised in February 2016.[8] Hence, it is in the absence of best practices that one needs to understand clearance operations in Mozambique during the 1990s and early/mid-2000s.

2.3.2 Phase 1. (1992 – 1999)

The 1992 Peace Accord specified that the UN had to work with the national authorities to coordinate and conduct clearance. However, the UN was unprepared for this huge task and the government was weak (GICHD (2005)). The UN wanted to establish its own mine action unit, but donors were skeptical and preferred to proceed with specialized NGOs. Humanitarian operators were left at their own, with no direction. UN initiatives were prevented or delayed by FRELIMO and RENAMO, as well as internal frictions, Human Rights Watch (1997). Up until the 1994 elections, there were just a few interventions targeting war camps and some border roads, as priority was given to the return of refugees.

Since 1994, demining operations emerged along three distinct areas and humanitarian programmes. First, The HALO Trust, a British-American NGO, started operating in the northern provinces. By 1999, it was employing close to 200 deminers. Second, the Norwegian People's Aid (NPA) started demining in the central provinces in 1993; by 1999, NPA was employing close to 500 deminers. Since 1998 Handicap International (HI, recently renamed Humanity and Inclusion), an international humanitarian network, started clearance in Inhambane and subsequently in Sofala. Third, with the help of the UN, the government established the Accelerated Demining Program (ADP) in 1995 that contracted with commercial operators and NGOs targeting the southern provinces of Maputo, Gaza, and later Inhambane. ADP was slow in clearing and in the initial stage, its focus was on training. By the end of 1998, ADP employed 10 platoons of 50 deminers each.

The first phase can be characterized as a preparatory one; the country established centers for training, operators started conducting non-technical surveys, and a few organizations proceeded with demining (North). Besides the minimal progress on clearance, the government, the UN, and NGOs had an incomplete and quite fragmented picture of the problem. Osório Mateus Severino, director of Mozambique's mine clearance operations describes the situation in 1997: "*We must have a clear idea of what the landmine situation in Mozambique is. We are in the dark about that, and without a sound knowledge of the situation, it is impossible to define a strategy, let alone determine the cost and resources needed for clearance operations*", Human Rights Watch (1997).

[8]IMAS is sponsored by the United Nations Mine Action Service (UNMAS), with the support from a variety of organizations, including the Geneva International Centre for Humanitarian Demining (GICHD).

2.3.3 Phase 2. (1999 – 2006)

The establishment of the National Demining Institute (IND) in 1999 marks the beginning of the second phase of demining. Donor funding increased from approximately $5 - 8$ millions per year in $1993 - 1996$ to around 15 millions during $1999 - 2004$. The IND commissioned a countrywide survey in 2001. Mozambique's Landmine Impact Survey (MLIS) found that landmines affected 123 out of 128 districts. MLIS recorded $1,374$ SHA totalling roughly $560,000,000$ square meters. Approximately 3 million people lived in communities with at least modest contamination. While the survey had flaws,[9] it provided guidance, serving as a key input for Mozambique's first five-year $(2002 - 2006)$ mine-action plan.

Sadly, when landmine clearance gained momentum, Mozambique experienced devastating floods in 2000 in the Southern provinces killing about 600 people, displacing more than $200,000$ and affecting the lives of about two million. A major flood hit the central provinces the next year. These events stretched the government's capacity; and delayed mine clearance by complicating the detection of landmines and UXOs. Moreover, allegations for corruption erupted in 2003 that led to donor fatigue. As a result some actors suspended their operations and international funding declined from about 20 millions in 2002 to 5 millions in 2007. The UN's collaboration with the IND ended in 2005, leaving the best-trained staff unpaid, lowered the speed of demining in the southern and central provinces. The second phase ends, however, with a considerable success, as HALO Trust declared in 2007 the northern provinces as "landmine-free".

2.3.4 Phase 3. (2007 – 2015)

The third phase commences with the government's second five-year Mine Action Plan $2008 - 2014$. This plan was based on (i) 2007 Halo Trust Mine Impact Free (MIFD) survey that declared the three northern provinces and Zambezia "landmine free" and (ii) a baseline assessment of conditions in Southern provinces, based on other operators' (HI and NPA) records. The surveys revealed that in spite of the evident progress, there were three times as many mines than previously thought; more than 600 new mine-contaminated areas were listed. The problem was far from being solved.

Clearance proceeded at a brisk pace. HALO Trust moved to Maputo and to Manica and Tete in the center. APOPO, a Belgian-Tanzanian NGO experimenting with the use of rats for detection, got involved in Gaza and then in Manica. HI moved beyond Inhambane assisting also in Sofala and Manica. Donors returned as the problem was still acute and because local capacity improved. Foreign aid for clearance increased fourfold. The last phase is characterized by increased efficiency; the government and NGOs had learned from past mistakes and precise technical surveys aided demi-

[9] The Government (2008) summarizes: "*The large size of Mozambique and the absence of a functional road network in much of it, extensive flooding in parts of the country in* 2001, *the widespread distribution of mine-affected communities, the absence of comprehensive and accurate national gazetteer (i.e., official listing of communities and their geographic coordinates), the lack of accurate maps and an appropriate scale, the impossibility of applying in its entirety the SAC protocol for false-negative sampling, and, the nature, availability and quality of expert opinion.*"

ning. International standardization of processes also helped. The last plan's timeline was (roughly) respected; in September 2015, Mozambique was declared landmine free.

3 Data

This Section presents the newly-compiled georeferenced data on landmine clearance, as well as data on the transportation network and development. Mozambique is divided into 10 provinces and the city of Maputo, the capital. We conduct our analysis across $1,187$ admin-4 units (localities),[10] the lowest administrative divisions. In terms of land area, Mozambican localities are between municipalities ("cantons") and arrondissements in France and had a median population of $11,515$ in 2007.

3.1 Landmine Clearance

We went over around $7,000$ completion, clearance and progress reports, and technical surveys compiling a dataset that records interventions from 1992 till 2015 with as much information as possible. This is a non-negligible component of our contribution, as the international community lacks a complete coding of clearance operations for any country, as the process involves dozens governmental and non-governmental organizations, commercial firms, and international agencies, and not very transparent (especially in the pre-2001 period). Below, we briefly discuss the data collection, describe some of the data features, map contamination at the end of the war, and plot the evolution of clearance. Appendix *III* details data compilation, gives examples, presents summary statistics, and visualizations.

Our dataset stores $7,423$ interventions that have taken place in $6,712$ confirmed hazardous areas (CHA) between 1992 and 2015. The vast majority of the CHA (91%) had exactly one demining intervention, whereas the remaining 611 CHA (9%) had on average 2.16 interventions (and associated reports). We will be using interchangeably demining intervention and CHA clearance.

3.1.1 Data Collection

We started our data collection by accessing the Information Management System for Mine Action (IMSMA) database stored at the National Institute of Demining (IND) in Maputo.[11] This database lists suspected and confirmed hazardous areas along with clearance activities at the intervention level. IMSMA coverage starts in 1993 and ends in October 2015. Coverage, however, is uneven across the years. Entries' quality, accuracy, and detail are rather imprecise during the early phase ($1993-1999$), improve somewhat with the MLIS report in 2001, and become precise after 2007. IND officials told us that the database is (almost) complete post-2007, but coverage declines for the earlier periods.

[10] We aggregate the respective localities for Maputo, Matola, Beira, Chimoio, Nampula, and Nacala (population exceeding $200,000$). There are 140 districts (admin-2 units) and 417 postos administrativos (admin-3 units).

[11] Around 80% of mine-action programmes around the world use IMSMA, which is the United Nations preferred information management system. IND started using this database system in the mid-2000s (and especially after 2007). We are grateful to the authorities and IND director, Alberto Maverengue Augusto, for granting us access.

We corrected inconsistencies, deleted duplicates, and going over hand-written reports, we cleaned the IMSMA data. Our final dataset includes $6,231$ interventions from the IND database.

We then collected, processed, and digitized data of the interventions of Halo Trust, HI, NPA, and APOPO, using these organizations' internal records. This served two purposes. First, we validated the IMSMA entries, making sure that all post-2008 interventions were recorded. Second, we expanded coverage in the pre-2007, and especially the pre-2001 period. We added 827 interventions from HALO Trust's dataset and 39 interventions from the NPA.[12]

Subsequently, we retrieved information from the activities of smaller operators in the 1990s. For example, we discovered 68 operations conducted by GTZ, the German Agency for Technical Operations with MineTech in Manica in the mid-late 1990s. We also reached out to former deminers working under the Accelerated Demining Program and reconstructed 35 not-recorded interventions.[13]

As clearance in-between the 1992 peace treaty and the 1994 elections was conducted under the UN, we accessed the mission archives (UNOMOZ) and digitized maps of early interventions. We also accessed USAID reports to digitize Project Caminho, the main demining operation of the early phase.

We digitized all Mozambique-wide surveys that aimed to map landmine-affected areas at the time of the survey. We procured the 1994 HALO Trust Report that identified 981 SHA, the $2000-2001$ MLIS report that identified $1,099$ SHA, the 2007 HALO Trust report that covered the centre-south provinces, and the 2007 completion survey of operations for the northern provinces. Besides locating suspected hazardous areas (SHA), these reports also recorded past clearance operations and thus allowed us to supplement the dataset. We added 38 clearance operations from the $2000-2001$ MLIS and 251 CHA clearance operations from the 2007 "Baseline Assessment" report.

3.1.2 Report Quality and Characteristics

Confirmed hazardous areas differ considerably. Some interventions regard large minefields in terms of area and number of landmines, as for example, the ones stretching the Tanzanian border, cleared by Halo Trust between $2003-2006$. Others regard the clearance of road segments that could be as long as 208 kilometers (Macata-Malema road cleared in 2006). Some CHAs entail a handful of mines blocking, for example, access to wells or streams. Others cover small areas outside schools, townhouses, etc.

The details of clearance reports differ. At the minimum, they include the demining operator, coordinates, the start, and completion date. The average time from start to finish of a demining intervention is 123.2 days; the median is 8 days, as 41.6% of interventions started and finished on the same day. Around half (56%) mention the size of the contaminated area (in square meters), while most post-2008 reports also delineate polygons of contamination. The average demining operation cleared

[12] We visited the NPA warehouse in Tete and accessed all hand-written reports covering $1993-2000$. We went over 70 clearance reports. IND's dataset did not have an entry for 27 interventions that were thus stored as new data. 43 interventions matched the IND database and thus allowed us to validate their accuracy in the IMSMA database.

[13] For example, we added: (i) interventions on the railway bridge in Magude (Maputo) in 1995; (ii) a clearance operation on a trail in Chizapela (Inhambane) in 1998; (iii) a demining activity on a military position in Madaucane (Inhambane).

64,949 square meters (a square with a side of 250 meters); while the median is 2,500 square meters. The largest minefield is 45,870,000 m^2 (a square with a side of 2.2 km). The most complete reports give also information on the number of landmines (manufacture, type, origin), along with maps, the demining team, equipment, and a brief description. A typical entry reads, "*a minefield covering an area of* 18,893 *square meters was cleared by Halo Trust on a civil war battle trench nearby Matsinho village in Manica province in* 2015".

3.1.3 Landmine Contamination and Clearance

Figure 1 - Panel *A* illustrates the spatial distribution of confirmed hazardous areas across the country. The map, thus, provides an ex-post visualization of the extent of contamination at the end of the war. 3,092 clearance operations took place in the third phase of demining (post-2008), 3,418 in the second phase (2000 – 2007) and 913 in the first phase (1992 – 1999).

All provinces are affected, though intensity differs. The most contaminated provinces are in the South: Maputo (1,211), Manica (1,053), Inhambane (992), and Sofala (936), areas that RENAMO targeted in the brutal phases of the civil war. Table 1 tabulates the statistics by province and period, while in Appendix III we provide province-specific mappings. There is considerable variation within

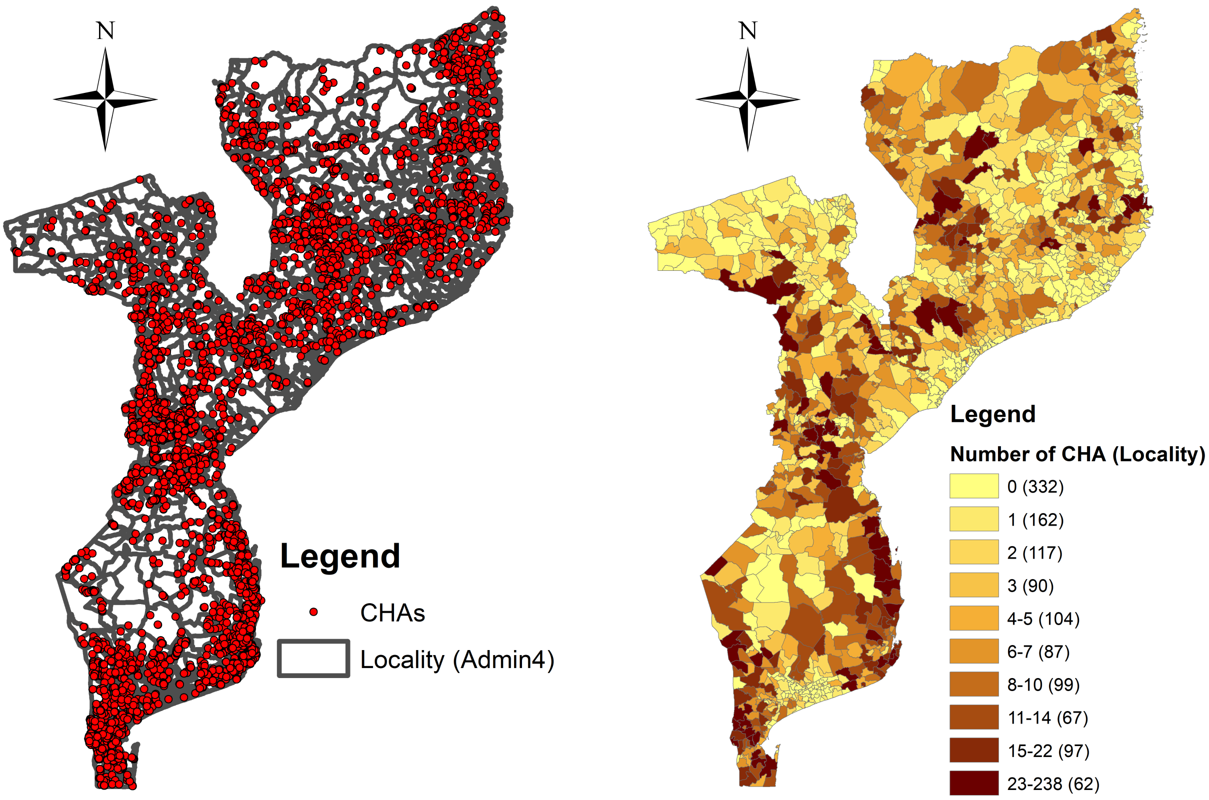


Figure 1: **Panel A: Location of CHAs Panel B : CHAs across Localities**

provinces. Figures 2$a-c$ portray interventions during the three phases of demining in Manica, North of Maputo. Contamination is intense along the railway connecting Harare, Zimbabwe, to the port city of Beira in the Indian Ocean. Contamination is heavy along the paved road connecting the city of Chimoio close to the border with Zimbabwe to the North. In the initial phase, the few interventions were scattered. After 1999 clearance accelerates. The large minefields bordering Zimbabwe in the South-East are cleared in the last phase when also the main cities and the railroad are fully cleared.

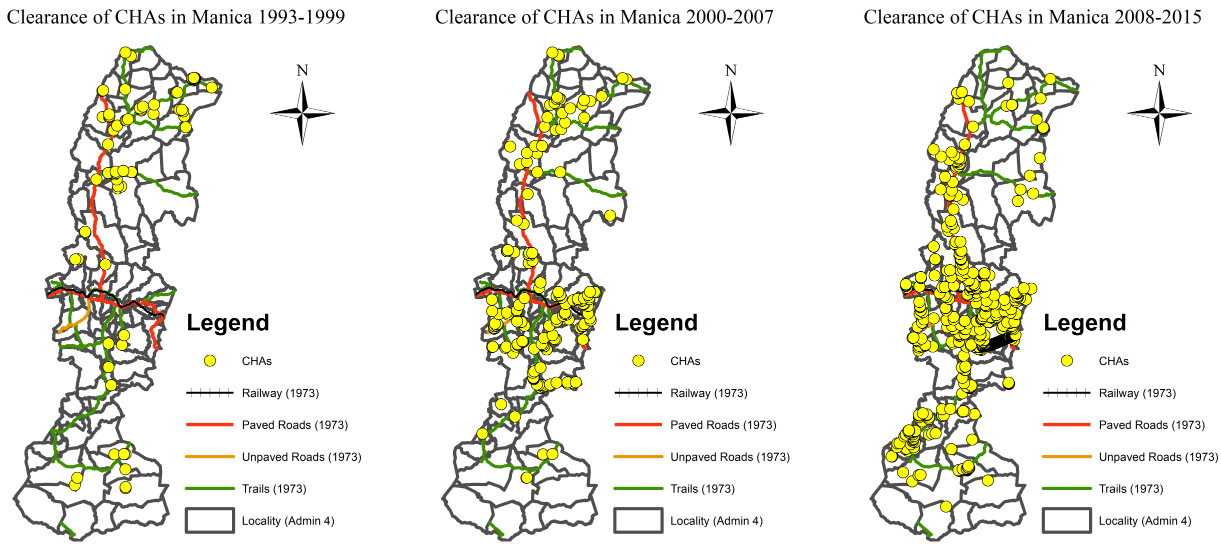


Figure 2: Interventions in Manica

We aggregate the data across admin-4 units. Figure 1 - Panel B illustrates the spatial distribution of confirmed hazardous. 72.03% of localities (855 out of the 1,187) had at least one contaminated site. The average locality has 6.25 CHA with a standard deviation of 14.16. When we focus on the 855 mined localities, the mean (median) is 8.68 (4) with a standard deviation of 16.04.

3.2 Roads and Railroads

We collected information on the transportation network, roads, railways, bridges, and navigable rivers. From the National Road Administration, we obtained maps of roads in 2011, with information on their condition (paved, unpaved or trail). Data for the rail network come from the Ministry of Transport and Communication. There are three main rail-lines, connecting the coastal areas along the Indian Ocean to inland: the Northern line links Nacala to Malawi; the central line connects Beira to Harare; and the Southern route goes from Maputo to South Africa (and also to Zimbabwe and Swaziland). A peculiar feature of the Mozambican rail network, a colonial legacy, is the absence of any connection among the three main railroads. We also collected data on navigable rivers from the Ministry of Transportation. With the exception of the Zambezi river, that effectively cuts the country in the middle, the other rivers do not accommodate large or medium-sized boats. Using archival data, we digitized maps on the conditions and quality of the transportation network in 1973. We also collected information on railroad conditions and status (functioning or destroyed) at the end of the civil war.

3.3 Population and Development

We digitized the pre-clearance, amidst the civil war, population census of 1980, as well as the post-war censuses of 1997 and 2007. [At the time of the writing, the national statistical agency has not yet processed the $2017 - 2018$ Census.]

Obtaining a reliable, time-varying, fine-resolution proxy of economic activity for one of the poorest countries in the world that emerged ruined from years of violence with nominal state capacity, vast swaths of land virtually inaccessible due to widespread landmine contamination is a challenge. Following Henderson, Storeygard, and Weil (2012) and subsequent works (summarized in Michalopoulos and Papaioannou (2018)), we proxy regional development using satellite imagery on light density since 1992 at a resolution of approximately one square kilometer. In Appendix IV we show that luminosity correlates strongly with (i) mean years of schooling using data from the 1997 and the 2007 censuses (as well changes during this time period) and (ii) wealth proxies constructed by the Demographic and Health Surveys (DHS). These associations apply both to rural and urban areas. Panels A and B of Figure 3 depict the distribution of lit localities in 1992 and 2015, respectively. As of 1992, only 11% of the localities had some detectable luminosity. This percentage jumps to 42% in 2015.

3.4 Other Data

We used a plethora of additional data that we describe in detail in the Appendix. We compiled proxies of civil war intensity from Domingues et al. (2011), Robinson (2006), and the UCDP GED (Sundberg and Melander (2013)). 16% percent of localities experienced at least one civil war event. We also digitized colonial-era information on the presence of *cantinas,* that were used to collect cash crops and ship them to the main cities. Around 58% of the localities hosted at least one *cantina*. Table 2 gives summary statistics at the locality level.[14]

3.5 Correlates of Confirmed Hazardous Areas (CHA)

To better understand the spatial distribution of landmines placed during the war of independence and the civil war, we examined its correlates. We run linear probability, probits, and negative binomial ML models associating the likelihood (and the number) of CHAs with geographic and location-specific characteristics (e.g., proximity to roads, railroads, and borders), civil war intensity, and early development proxies (e.g., population density in 1980 and the presence of cantinas). Given the absence of any work on the strategic use of landmines, this examination is far from trivial, as it carries lessons

[14]In Appendix III we tabulate the respective summary statistics for the localities for which we recovered 1980 population $(1,077$ out of the $1,187$ localities). There are no major differences between the two samples.

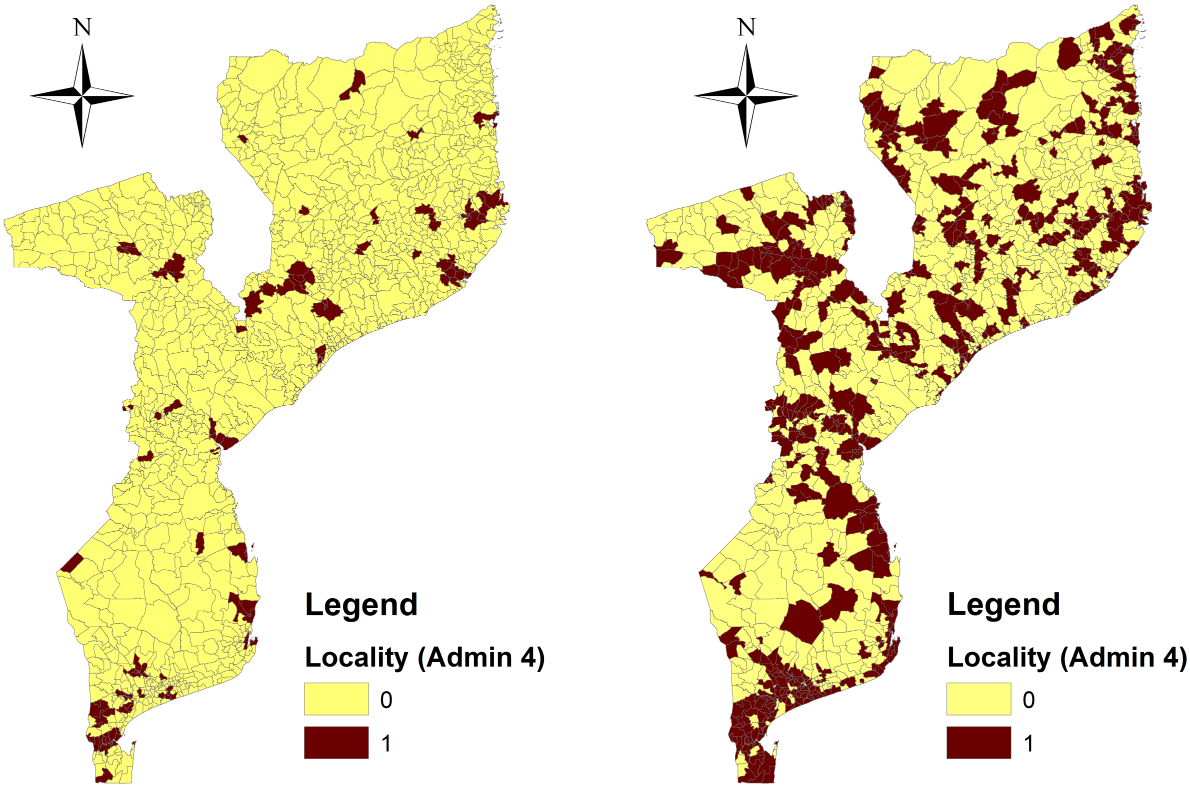
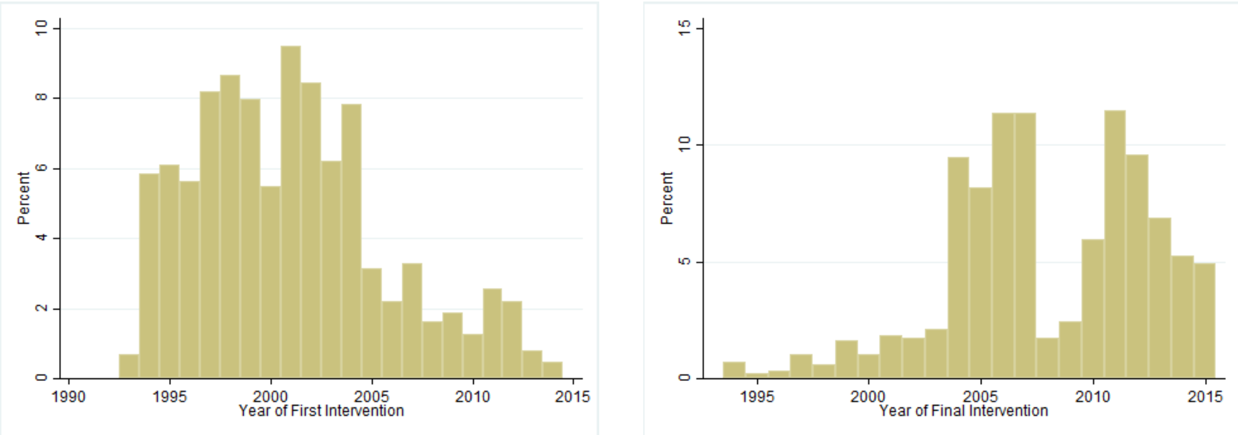


Figure 3: **Panel A: Lit Localities in 1992 Panel B : Lit Localities in 2015**

to practitioners. But, for brevity, we report and discuss the results in Appendix V. The analysis yields the following. First, in accordance with the historical narrative, contamination is high along the borders with Zimbabwe (reflecting the minefields set up by FRELIMO, Zimbabwean rebels and the Rhodesian army in the 1970s), Swaziland, and Tanzania (where the Portuguese planted minefields to block FRELIMO's raids during the independence war). Second, the colonial transportation network was heavily mined. Third, landmine placement was, on average, higher in larger in terms of area and population localities. Fourth, contamination was higher in places that experienced more civil conflict.

3.6 Correlates of Timing of Clearance

We then examined the evolution of clearance, looking separately at the first and last intervention. Panel A Figure 4 plots for every year the share of localities that had their first demining operation. By the end of 1994, when the first democratic elections took place, clearance operations had started in 56 localities. By 2000, the cumulative percentage (number) of localities where some clearing had taken place was 48.53% (415 out of 855 contaminated). It jumps to 89.12% in 2007. Panel B - Figure 4 depicts the yearly evolution of the share of fully cleared localities. At the end of 1994, less than 1% (6) localities were cleared. The percentage (number) increases to 5.61% (48) in 2000.



Panel A: First Intervention across Localities **Panel B : Last Intervention across Localities**

Figure 4: **Distribution of the Timing of Intervention across Localities**

Roughly half (442) of localities were fully cleared by 2007 with 11% being cleared that same year. The average (median) number of years to clear a locality is, however, 6.99 (6) with a standard deviation of 5.93. The difference between the timing of the first and last clearance is not because operations take years (on average a CHA is cleared in four months), but because there were several interventions in each locality. Due to the fragmented and localized nature of demining and the errors of the initial surveys, demining operators had to go back and forth, visiting different contaminated localities multiple times during the $1992 - 2015$ period. Despite localities being relatively small, about two-thirds of the size of the average US county, interventions in a given year within a locality rarely led to clearance of the entire unit (see Appendix III).

We then associated the years elapsed between 1992 and the year of the first (and the last) intervention with locality-specific features to understand how clearance was prioritized. In Appendix V we detail the analysis that yields the following: First, the timing of the initial intervention is related to only a few observable characteristics; the explanatory power of the model is low. In line with the historical narrative, early interventions took place in areas close to the border with Malawi, as one of the objectives was to bring back the one million refugees in this country. Landmine clearance started earlier in localities that experienced warfare during the civil war and in more densely populated ones. Overall localities with railroads or primary roads do not seem to be targeted earlier. Second, when we examine the correlates of years elapsed till full clearance, we also find that the main correlates are proximity to the borders. Localities alongside the main transportation network or more populous ones do not get rid of mines earlier. The analysis suggests that by and large the process of clearance did not follow a systematic pattern; reflecting among other things the lack-of-coordination, IND's limited capacity, the ad-hoc and short-term nature of contractors (as financially constrained NGOs were doing fund-raising for specific CHA each time), the flaws of the 1994 and 2001 surveys, the big floods of $2000 - 2001$, and the subsequent back and forth of the international community.

4 Landmine Clearance and Local Development

In this section, we explore the within-locality association between landmine clearance and local development. Before presenting the results, it is important to keep in mind that the uncovered correlations do not necessarily identify causal effects. First, while the timing of landmine clearance does not seem to follow a systematic pattern, demining was not an outcome of strict randomization. Second, spatial interdependencies are likely, as clearing a particular locality from landmine contamination may have positive or even negative (via population relocation) spillovers. Third, despite our efforts to record all clearance interventions, measurement error is present.

4.1 Panel Estimates

The estimation approach looks at the coevolution of luminosity and CHA clearance, netting out locality-specific, time-invariant characteristics and allowing for province-specific time trends. The specification reads:

$$y_{i,t} = \mu_i + \mu_{t,p} + \beta CLEAR_{i,t} + \eta_{i,t} \quad (1)$$

$y_{i,t}$ is economic activity in locality i, as reflected in nighttime luminosity, in year (period) t. We conduct the analysis at the yearly level and at the end of each of the three main demining periods (1999, 2007, 2015) beginning in 1992.

To account for the non-linear nature of the dependent variable, we apply two transformations. First, we focus on the extensive margin of luminosity using an indicator that equals one if the locality is lit. Second, we use the log of light density augmented by a small number.[15] We use two proxies of demining, $CLEAR_{i,t}$. $Cleared\ Threats_{i,t}$ denotes the logarithm of one plus the cumulative number of cleared CHA.[16] The binary $Cleared_{i.t}$ indicator takes on the value of 0 while a locality is contaminated and becomes 1 the year it becomes landmine free and remains 1 thereafter; the variable equals zero for all localities that were never contaminated. The vector of locality-specific constants, μ_i, captures time-invariant, local characteristics that may affect development and landmine clearance; for example, proximity to borders, presence of cantinas, and topological features. The province-time constants, $\mu_{t,p}$, account for the idiosyncratic process of demining across the Mozambican regions, unobserved time trends, and allows us to compare localities with broadly "similar" histories and geographies.

Table 3 reports the panel estimates. Standard errors are clustered at the admin-2 (district) level, as this accounts both for serial correlation and spatial (within-district) interdependencies.[17] The table also reports [in brackets] standardized "beta" coefficients that reflect the change in the outcome

[15] We add half the minimum positive value in the data; $\ln(0.0001 + light/km^2)$.

[16] We use the cumulative number, so positive coefficients imply an increase in luminosity after clearance.

[17] Clustering at the coarser province level or at the finer posto level (admin 3) or applying Conley's correction to account for spatial interdependencies yield smaller standard errors. We also experimented with double clustering at the time (year/period) and the district-province-posto level. Standard errors are similar to the ones in Table 3.

variable to a one-standard-deviation increase of the explanatory variable. Columns (1)-(4) exploit annual variation, while columns (5)-(8) give demining-period estimates.

Across all permutations, the clearance proxy ($Cleared\ Threats_{i,t}$ and $Cleared_{i.t}$) enters with a significantly positive estimate. This implies that economic activity, as reflected in luminosity, increases significantly in localities that become partially or fully cleared compared to localities that have not been (fully) cleared and localities without any contamination. The standardized "beta" coefficient in column (1) implies that a one-standard deviation increase in the number of cleared CHA increases log luminosity by 0.071 standard deviations. In columns (3) and (4) we examine how the extensive margin of luminosity reacts to a decline or the elimination of CHAs. Clearing a locality from all contaminated hazardous areas increases the likelihood of being lit by roughly 4%; this estimate should be compared with the 9.8% likelihood of a locality being lit in 1992.

In columns (5)-(8) we examine the association between light density and landmine clearance over the medium run (7 year periods). A benefit of these specifications is the reduction in measurement error in the exact timing of operations. Moreover, it may take time for economic activity to pick up after clearance. The magnitudes are uniformly larger suggesting that demining's payoffs materialize over time. Specification (8), for example, suggests that the likelihood of a locality being lit increases by around 8 percentage points when fully cleared. To gauge the economic significance of the coefficients, we estimated the elasticity between light density and development proxies across Mozambican localities using the 2009 and 2011 Demographic and Health Surveys as well as the 1997 and 2007 censuses [see Appendix IV]. The difference in education between lit and unlit localities is around 1 year and DHS tabulations suggest that lit compared to unlit localities are on average 18% percentage points wealthier (in terms of the DHS composite wealth index).

4.2 Further Evidence and Sensitivity Analysis

We perturbed the specifications across various dimensions to examine robustness and better understand the associations. We discuss our findings briefly below and in detail in Appendix VI.

4.2.1 Alternative Outcomes

We examined the association between CHA clearance and population. The panel and the difference specifications over the $1992-2007$ period reveal a positive but in general small and not always significant association. This is probably driven by the fact that clearance, particularly in the first years, facilitated the return of Mozambicans that had fled during the war.

We then explored the relationship between landmine clearance and (i) building of new roads and (ii) improvements of the colonial transportation network. Demining in unrelated to new road construction. Nonetheless, clearance correlates significantly with improvements in the colonial-era, road-railroad network, revealing a plausible mechanism at play.

4.2.2 Measurement Error

Part of our contribution is the provision to the international community for the first time an almost complete documentation of landmine clearance operations for any heavily-mined country. While we did cross-validate many of the entries, conducted dozens of interviews with deminers, and consulted hundreds of reports, measurement error cannot be ruled out. We, thus, commence the sensitivity analysis trying to account for error in clearance.

First, we restrict estimation to the Northern provinces, where data is less noisy. Almost all clearance operations were carried out by HALO Trust, the only organization that since its arrival was recording interventions in a consistent manner using IT systems. Moreover, the quality of the reports is evidently higher with more details. The luminosity-clearance correlations retain statistical significance.

Second, we associated luminosity with the log of one plus the number of cleared confirmed hazardous areas (CHA) and the log of one plus the number of suspected hazardous areas (SHA) that surveyors "cancelled" upon further examination, as they were based on false information or misreporting. CHA clearance continues to enter with a significantly positive coefficient; luminosity does not correlate with the cancellation of erroneously recorded SHA, as in most instances locals were already using the suspected land, roads, etc. It is actual demining that correlates with luminosity.

Third, we examined whether luminosity increases as early as the first demining operation or when the locality is completely cleared from contamination. Economic activity picks up when a locality is fully cleared; we do not detect any significant change in luminosity between the initial and the final intervention. This finding further suggests that development projects concurrent to demining an/or the mere presence of deminers are unlikely to be driving the observed positive association between demining and regional development.

Fourth, we repeated estimation focusing exclusively on rural localities[18] to assuage concerns that the luminosity-development correlation reflects hard-to-account-for differences between rural and urban locations. The correlation retains statistical and economic significance.

4.2.3 Sensitivity Checks

We conducted a plethora of sensitivity checks. First, we dropped Maputo, Beira and Nacala, both because luminosity is extremely high and because contamination was relatively low in these cities. Second, we dropped all localities in the Maputo province to minimize concerns that the estimates reflect the sizable differences in urbanization and development between this province and the rest of the country. If anything, the coefficients increase. Third, we stopped in 2013 (rather than 2015)

[18]We use the 1997 census classification to distinguish between rural and urban households. The Census classifies as urban households those residing in 23 cities and 68 towns. We then define as rural those localities where 100% of the inhabitants are classified as such. Given the very high levels of employment in agriculture (exceeding 80%), 96% of localities are exclusively rural.

to account for the change in the satellite technology recording luminosity. The estimates are stable. Fourth, we estimated dynamic panel specifications with the annual data (though the data are noisier). Due to inertia in luminosity, the "long-run" association between clearance and local development is larger than the yearly estimates and quite close to the period estimates (which are our preferred ones). Fifth, we looked only within contaminated localities. Standard errors increase, as we lose roughly 30% of the sample, but the estimates retain significance. Sixth, instead of deriving the locality estimates of landmine contamination based on the number of demining interventions we used the number of CHA. Results are similar. Seventh, we run long-run difference specifications, as this allows accounting for conditions at the end of the war. Changes in luminosity correlate strongly with changes in CHA clearance, even controlling for cantinas, population density, road and railroad presence, and 1992 luminosity. Eighth, to further account for unobserved trends, we augmented the baseline specification with interactions between features of the colonial transportation infrastructure and other time-invariant locality traits with period-specific constants. The estimates retain statistical significance, decreasing only modestly. Ninth, we controlled for new road construction and improvements of the pre-existing transportation network, as landmine clearance is related to road improvements. The estimates remain intact suggesting that the local association between demining and economic activity operates above and beyond its relationship with improvements in the transportation network.

5 Heterogeneity

The specifications reveal a significant boost in economic activity after clearance. But this does not necessarily imply that landmine clearing is equally beneficial. In this Section, we explore heterogeneity with respect to intervention and to locality features, as this may provide clues into the mechanisms behind the uncovered link between demining and local development.

5.1 Intervention Characteristics

We start by exploring heterogeneity with respect to *intervention* characteristics. We used the CHA coordinates to classify interventions into 7 non-mutually-exclusive categories based on proximity to roads and railroads (using a distance cutoff of 100 meters to the 1973 network), navigable rivers (cutoff of 100 meters), borders (cutoff 10 kilometers), villages and towns (radius of 1 kilometer), electricity pylons-grid (100 meters radius), cantinas (radius of 1 kilometer), and centroids of civil war violence (radius of 1 kilometer).[19] Table 4 reports estimates, where we interact the number of cumulative cleared hazardous areas (in (1) and (2)) and the cleared dummy (in (3) and (4)) with indicators reflecting the type of the contaminated area. On the one hand, reducing the number of

[19] 16% of all CHAs were found along the transportation network; 14% placed within a kilometer from villages' and towns' centroids; 8% are found along border areas and a similar percentage was traced close to cantinas; 10% of CHAs were found either in areas that experienced civil war violence and along the electricity grid. 61% of CHAs, which are not sufficiently close to any of the aforementioned features, are in the residual category.

contaminated areas along roads-railroads and clearing areas around villages and towns, especially the ones with cantinas, is associated with significant increases in luminosity. On the other hand, removal of landmines placed in remote areas (the residual category), close to national borders, and rivers does not seem to lead to increases in luminosity. Clearing border areas is negatively related to luminosity, though the estimate is statistically insignificant. A likely explanation is that landmine clearance facilitated the relocation of refugees in the early post-conflict period from border camps.[20]

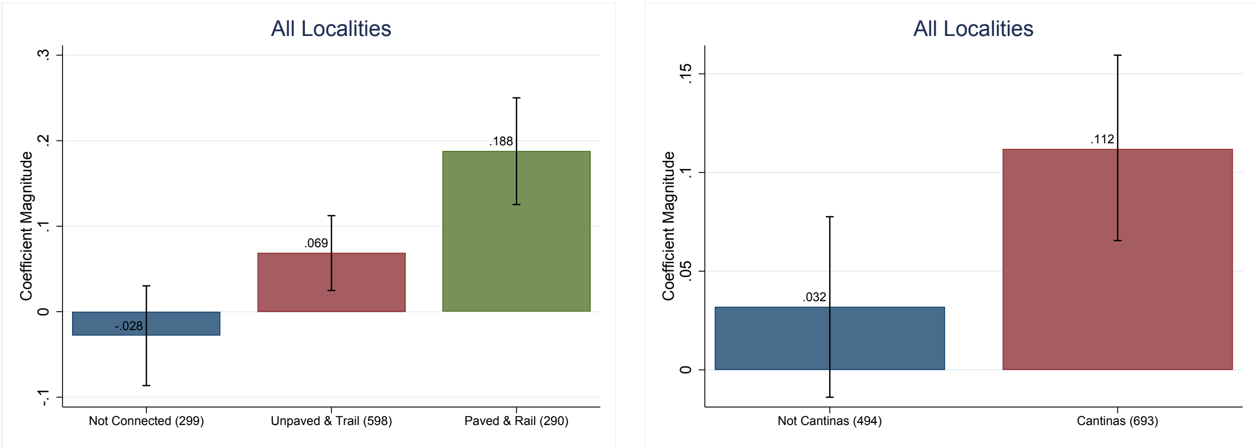
5.2 Locality Characteristics

Then, we explored heterogeneity with respect to a *locality's* characteristics. We start by looking at localities' connectivity to the colonial transportation network. 290 localities host primary roads or railroads; 598 are connected to the transportation system only via unpaved roads or trails whereas 299 appear non-connected. Figure 5 plots the coefficients (and standard errors) when we allow the clearance indicator to differ across these three groups (Appendix VI reports the corresponding panel estimates). The correlation between luminosity and CHA clearance is positive and highly significant for connected localities, while it is close to zero and statistically insignificant for non-connected ones. The likelihood that the satellite will detect light is 19 percentage points higher when operators clear localities connected via primary roads and railroads; the estimate for localities intersected by secondary and tertiary roads is around 7%. Landmine clearance is not followed by significant increases in luminosity across non-connected localities.

We then investigated whether demining was more important for localities with agricultural markets before the civil war, comparing the association between luminosity and clearance in those with cantinas to those without. Cantinas were small trading posts, initially owned and operated by Portuguese or Asian settlers, specializing in "*the acquisition and transport of various types of produce (peanuts, cashews, cotton, corn, etc.) harvested by the natives to procure for the town dwellers*" (Bastos (2006)). Cantinas "*performed an essential role in agricultural marketing, providing seeds, textiles, domestic utensils, and agricultural implements to locals*" (Darch (2018)). They were the most widely available (and often the only) means for Mozambican farmers to sell their goods to the urban hubs, warehouse operators or factories (in the case of cashews). Cantinas were scattered across all provinces; 693 localities hosted at least one (average 1.43 [median 1]), whereas 494 did not have any.[21] Panel B of

[20] In Appendix VI we report various sensitivity checks on the heterogeneous association between luminosity and landmine clearance. For example, the results are similar if we restrict estimation to exclusively rural localities. As there is subjectivity on the radii and distance cutoffs, we experimented with alternative values. The patterns are robust. We also examined heterogeneity with respect to *report-based* characteristics. For 4,582 out of the 7,423 interventions we have information on the type of contamination. So, we classified operations into 10 non-mutually exclusive categories. The largest categories concern contamination of electricity pylons (13%), footpaths (12%), roads and railroads (11%), farms (10%), residential areas (10%) and areas of military importance, typically public buildings (schools, townhouse, clinics). The estimates although less precisely estimated (due to the missing information for roughly 40% of the clearance operations) are broadly consistent with the patterns found in Table 4.

[21] The presence of cantinas is correlated with the colonial transportation network. Nevertheless, there is significant variation. Among 299 localities not connected to the colonial transportation network, 124 host a cantina, (40%). Across



Panel A: Connected vs Non Connected **Panel B: Cantinas vs Non Cantinas**

Figure 5: **Heterogeneity on Locality Characteristics**

Figure 5 plots the coefficient estimates when we allow the clearance indicator to differ across the two sets of localities [Appendix VI reports the results]. The linear probability model estimates suggest that after clearance the likelihood of a locality without cantinas to turn lit increases by 3%, which is statistically indistinguishable from zero. The corresponding likelihood for localities with cantinas is 11 percentage points; the coefficient is precisely estimated.

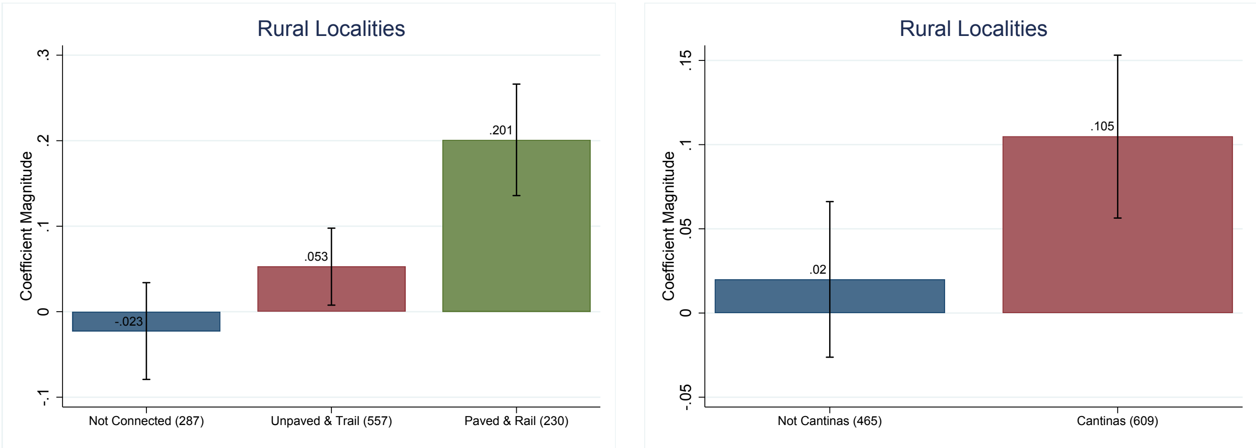
The uncovered heterogeneity appears robust to various perturbations (see Appendix VI). Nevertheless, two issues deserve a more detailed discussion.

Luminosity-Development Nexus One concern is that the heterogeneous response of luminosity to clearance is not indicative of the latter facilitating exchange of goods across space, but it merely reflects differences in how well light density captures economic activity across the different sets of localities. This may emerge, for example, if luminosity in non-connected and without cantinas localities does not proxy for economic activity. In Appendix IV we show that this is not the case. Using data on education from the 1997 and 2007 censuses, we show that changes in luminosity are robust predictors of changes in mean years of schooling both across connected (with cantinas) localities and across non-connected (without cantinas) ones over this 10-year interval.

Rural Area Analysis Another concern is that the uncovered heterogeneity reflects hard-to-account-for differences between rural and urban areas. While the locality-specific constants partly account for these, we repeated the analysis restricting estimation to exclusively rural localities. There is sizable variation in transportation connectivity and the presence of cantinas in the latter sample.[22]

the remaining 888 connected localities, 569 (64%) have at least one, while 319 localities (36%) do not.

[22] 230 rural localities have primary roads or railroads; 557 rural localities host unpaved roads or trails; and 289 localities are non-connected. 609 rural localities host (at least) one cantina, whereas 465 do not have any. For example, among the 287 rural localities without connectivity to the colonial transportation network, 121 host a cantina, (42%). Across



Panel A: Connected vs Non Connected **Panel B: Cantinas vs Non Cantinas**

Figure 6: **Heterogeneity on Locality Characteristics. Rural Localities**

Figure 6 plots the estimates (and standard errors), when we allow the coefficient to differ across connected and non-connected rural localities (Panel A) and across rural localities with and without cantinas (Panel B).[23] Landmine clearance boosts economic performance in rural localities connected to the transportation network, especially the ones with railroads and primary roads, and in rural localities with agricultural markets. In contrast, the within-rural-locality association between luminosity and clearance is muted and in general insignificant in rural localities non-connected to the transportation and those without cantinas. Moreover, the coefficients are quite similar to the full-sample estimates in Figure 5.

5.2.1 Summary

The analysis reveals an economically meaningful heterogeneity. Clearing hazardous areas along the transportation network and rural areas of commercial importance to the local community seem to map into larger economic payoffs than interventions in remote and at-the-border areas. These findings suggest that clearing the transportation infrastructure and agricultural trading hubs is likely to not only benefit the locality where the contaminated segment lies, but also generate externalities across connected regions. We explore this issue below employing a framework designed to assess spillovers across interconnected, agriculture-based, regional economies.

the remaining 787 connected localities, 488 (62%) have at least one cantina while 299 localities (38%) do not.

[23]In Appendix IV we show that luminosity correlates strongly with mean years of schooling in the sample of exclusively rural localities. The correlation is present both in levels and in differences with both transformations of luminosity.

6 Landmines and Aggregate Development. A Market- Access Approach

We now turn to the examination of the economy-wide effects of landmine clearance on development. We start by discussing the theoretical underpinnings of the empirical approach and proceed with a discussion of the construction of the "market-access" measures that requires the calculation of bilateral (locality-pair) transportation costs factoring in landmine contamination and road-railroad quality. We then report the baseline results and conclude with an overview of the sensitivity analysis. Appendix VII provides an in-depth discussion of the underlying theoretical framework, details on the construction of the market access measures, and discusses the various sensitivity checks.

6.1 Theoretical Foundations[24]

The conceptual framework of our empirical analysis follows Donaldson and Hornbeck (2016) and other recent works (e.g., Donaldson (2018), Alder (2017), Pérez-Cervantes (2014)) that, building on Eaton and Kortum (2002), develop Ricardian general equilibrium models of inter-district trade and spatial development. This setup is appropriate for agricultural economies, like Mozambique, where the share of employment in agriculture exceeded 80% in the 1990s, while nowadays hovers around 70%; the share of agriculture in GDP in Mozambique was around 40%. For example, Donaldson (2018) employs this framework to study the role of colonial railroads in India in late 19th - early 20th century, where agriculture's share in GDP was around 66% and the majority of Indian farmers were engaged in subsistence agriculture (see also Burgess and Donaldson (2017) on colonial railroads' impact on famines). Alder (2017) uses this framework to quantify direct and indirect effects of India's large highway system in the 2000s on income, as reflected in luminosity. Barjamovic, Chaney, Cosar, and Hortascu (2019) use a modified Eaton and Kortum (2002) setup to study trade during Assyrian times in 19th BC and predict the location of "lost" cities. Donaldson and Hornbeck (2016) quantify both the local and the aggregate effects of US railroads in the mid/late 19th century on the value of agricultural land.[25]

Donaldson and Hornbeck (2016) derive a "reduced-form" log-linear relationship from this set of models linking aggregate welfare (income) to a locality's "market access" (see also Alder (2017)).[26]

[24] Donaldson (2015) provides an eloquent review of this body of research. Costinot and Rodriguez-Clare (2014) give an overview of quantitative works on trade across and within countries.

[25] During that period employment share in agriculture in the US was around 50%. The same applies to India in the application of Alder (2017).

[26] Donaldson and Hornbeck (2016) show that the link between output and market access obtains also in an extension with separate agriculture and manufacturing sectors, where infrastructure investments (roads and railroads) affect both sectors via input-output linkages. We note, however, that throughout our analysis manufacturing employment in Mozambique is below 5%.

Alder (2017) shows that the log-linear association between income and market access obtains both when one assumes labor mobility (as Donaldson and Hornbeck (2016)) and when labor is immobile.

$$\ln(Y_o) = \kappa + \alpha_o + \lambda \ln(MA_o), \tag{2}$$

where a locality's o "market access" $[MA_o]$ is:

$$MA_o \approx \sum_{d=1}^{D} \tau_{o,d}^{-\theta} N_d(Y_d) \tag{3}$$

where N_d and Y_d reflect total population and total output of all but-the-origin locality. α_o are locality fixed effects, capturing technology, endowments, and other local features.

Market access (MA_o) for a given locality is the sum of the income (population) of all other localities, discounted by bilateral transportation costs ($\tau_{o,d} > 1$), scaled by a "trade elasticity" parameter (θ). The latter theoretically approximates localities' comparative advantage, with lower (higher) values pointing to stronger (weaker) comparative advantage.

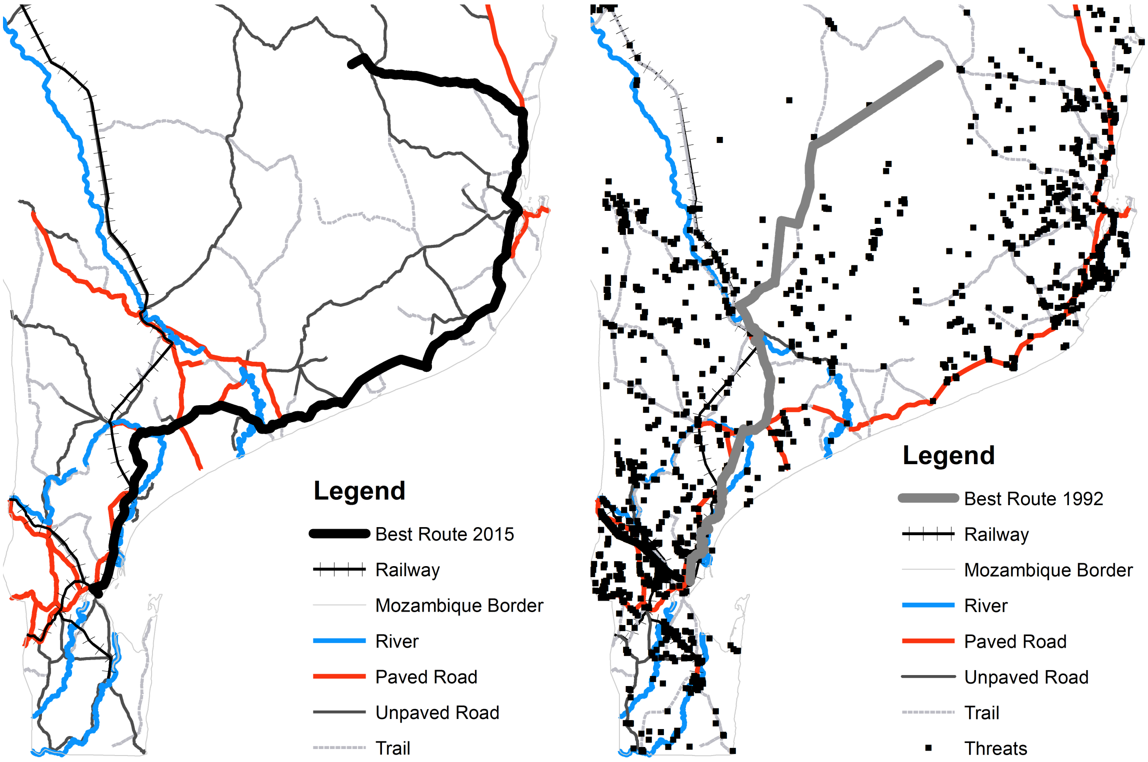
6.2 Market Access across Mozambican Localities

6.2.1 Bilateral Transportation Costs

Constructing a locality's market access requires estimating bilateral costs across all locality-pairs ($\tau_{o,d}$). The construction of transportation costs entails four steps. First, we create the transportation network that consists of railroads, paved roads, unpaved roads, trails, and navigable rivers. We also allow for straight-line connection on foot among localities' centroids (as Donaldson and Hornbeck (2016)).

Second, we parameterize the (relative) cost of the network's elements. We try to tie our hands following earlier and parallel works focusing on similar settings (Donaldson (2018), Donaldson and Hornbeck (2016), Alder (2017), and Jedwab and Storeygard (2018)). The most efficient (trade) technology is the railway, whose cost is normalized to 1 (Donaldson and Hornbeck (2016)). Following studies on road quality and transportation cost in Africa (Kim, Molini, and Monchuk (2012)) and Mozambique (Alemu and Van Schalkwyk (2008)), we set the relative cost of paved roads to 2 and of unpaved roads to 4. The relative costs of trails - that typically connect roads to villages and small towns - is 10, as they are in poor conditions and not much used for commerce. The relative costs for walking is 20 (Donaldson and Hornbeck (2016)). Given the tiny, if any, role of navigable rivers for local trade, we assign a relative cost of 15. The precise values of the cost parameters are not particularly important; what really matters are relative costs (e.g., using a paved road instead of a trail). In Appendix VII we show that the results are robust to alternative parameterization.

Third, regarding the role of landmines, we impose that the presence of a CHA within 100 meters of a road/railroad/trail/river is blocking usage of the respective segment. This accords with the clearance reports, the Mozambique-wide surveys, our interviews with deminers, and the reports of various specialized organizations (Landmine Monitor (2015), ICRC (2002)). In Appendix VII, we experiment with alternative cutoffs and relax the blocking assumption, finding similar results.



Panel A: Optimal Route 2015 **Panel B: Optimal Route 1992**

Figure 7: **Least-Cost Route according to Dijkstra's Algorithm**

Fourth, we approximate the travel time from each locality to all other localities using Dijkstra's algorithm that solves for the lowest-cost path between any two localities' centroids. We compute the shortest paths in 1992 and at the end of the three phases of demining.

Figure 7 illustrates the Google-maps-style algorithm-derived shortest route between Maputo and Funhalouro, a locality approximately 600 km north of the capital. Panel A shows the optimal path at the end of 2015. As all hazardous areas have been cleared, the algorithm employs the most efficient network elements, yielding an identical to the "google maps application" path for a 9-hour journey. The route for 1992, illustrated in Panel B is different. As the main primary road (highway $N1$, connecting Maputo to the Centre alongside the Indian Ocean) and the secondary road linking Funhalouro to $N1$ are blocked by dozens of minefields, the algorithm uses the non-contaminated parts of the transportation network relying often on unpaved roads and trails; this results in a 3.5-fold cost increase.

6.2.2 Trade Elasticity

The literature has produced a range of trade elasticity (θ) estimates (from 2.5 to 10) depending on the context (e.g., manufacturing or agriculture trade). As a benchmark, we follow Donaldson (2018), Donaldson and Hornbeck (2016) and Alder (2017) and use a value of 3.88. This estimate is close to the midpoint ($2.79 - 4.46$) of the estimates that Simonovska and Waugh (2014a,b) produce in their careful estimation of the trade elasticity in comparative advantage models of agriculture-level trade. This value is similar to the one that Jedwab and Storeygard (2018) use in their analysis of the impact of roads on Africa's urbanization. In Appendix VII we experiment with alternative values finding similar results.

6.3 Market Access Measures

We construct two market access measures. First, we estimate market access proxying aggregate demand (total output) in the destination locality with the sum of lights, $Y_{d,t}$. This approach is similar to Alder (2017), who also uses satellite images of light density to proxy local output in Indian localities; it is also conceptually similar to Donaldson and Hornbeck (2016), who use total agricultural land value across US counties during the late 19th century. Second, we use total population ($N_{d,t}$), an approach that is similar to Donaldson and Hornbeck (2016) and Jedwab and Storeygard (2018). We construct the market access measures in the beginning of each of the main periods of demining (1992, 1999, and 2007) and in 2015 when the country was declared landmine free. For the market access in 1992 we use the 1973 network and the census population of 1980 (and luminosity in 1992). For the 1999 market access measure, we use the 1998 network and the population census of 1997. For the 2007 market access, we use the infrastructure network in 2003 and the census population of 2007. For the market access in 2015 we use the transportation infrastructure of 2011 with the population of 2007, as the very recent Census is not available yet. Table 2 reports summary statistics.

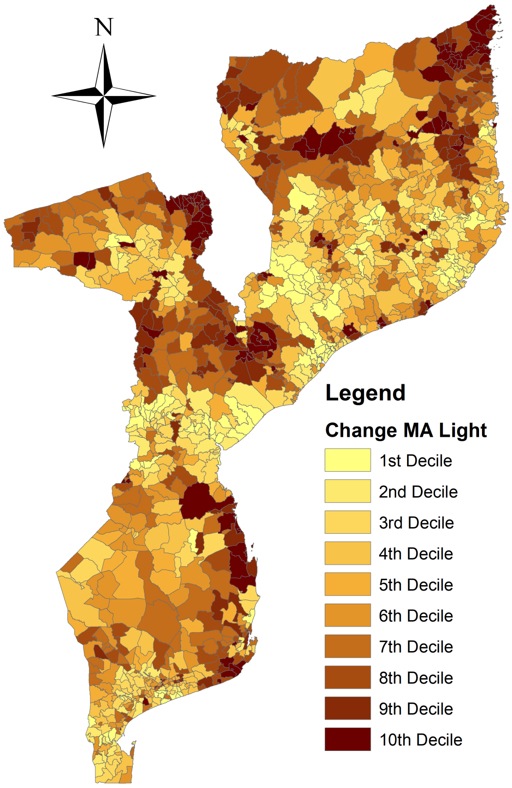
Figures $8a - b$ plot changes in the market access measures over the period $1992 - 2015$, darker colors indicate larger increases. The correlation of changes in the two market access measures is 0.50.[27] There is considerable variation in changes in market access, even within provinces. Province constants explain just 19% and 5% of the overall variability. Even when we add admin-2 constants, there is still sizeable variability, as the R^2 is far from one, 0.57 and 0.32 with the luminosity and the population-based market access, respectively. We also calculate various modified market access measures that we discuss below.

6.4 Results

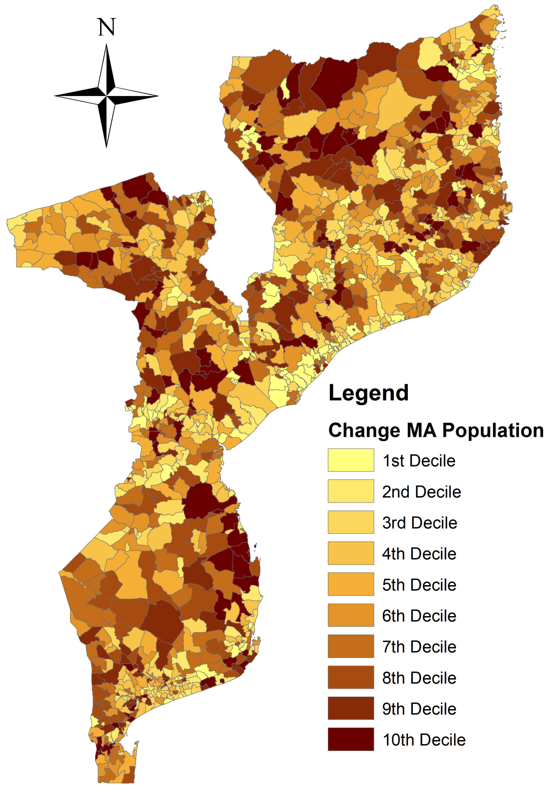
6.4.1 Empirical Specification

We estimate the relationship between a locality's level of development, as reflected in luminosity ($y_{i,t}$) and its market access ($MA_{i,t}$), running variants of the following equation:

[27] The mean (median) of long-run changes in the luminosity-based market access measure is 5.55 (5.53) and the standard deviation is 2.12. The average (median) of changes in the population-based market access measure is 2.90 (2.8) and the standard deviation 1.26.



Panel A: Change in Log MA1 (Luminosity)



Panel B: Change in Log MA2 (Population)

Figure 8: **Change in Contemporaneous Market Access**

$$y_{i,t} = \mu_i + \mu_{t,p} + \lambda \ln[MA_{i,t}] + \zeta_{i,t}. \tag{4}$$

μ_i and $\mu_{t,p}$ are locality constants and province-specific time effects, respectively. The coefficient on the market access ($MA_{i,t}$) reflects both the direct and indirect effects on local economic activity of improved accessibility, due to landmine clearance and road-railroad improvements and extensions.

6.4.2 Baseline Luminosity - Market Access Elasticity

Table 5 reports the baseline estimates of the luminosity - market access association. The elasticity with the luminosity-based market access measure is 0.29 in (1); with the population-based market access measure in (3) the elasticity is 0.25. The linear probability model estimates in (2) and (4) suggest that a one-standard deviation increase in market access increases the likelihood that the locality is lit by $5\% - 6\%$. In columns (5)-(8) we augment the specification with the log number of cleared CHA.

While theoretically the coefficient on the market access measure captures both direct and indirect effects, controlling for landmine contamination is interesting for a couple of reasons. First, it allows gauging the relative importance of the direct and spillover effects. Second, unlike the buildup of transportation infrastructure, landmine clearance may increase land productivity, by releasing unused land. Third, a significant local estimate may reflect positive intra-locality commerce effects (though in Mozambique such trade is minimal). Fourth, the coefficient on market access may be attenuated, as there is always some subjectivity on the exact parameterization (Donaldson and Hornbeck, 2016).

Two patterns emerge. First, the luminosity - market access elasticity continues to be highly significant, indicating the presence of spillovers. The estimate drops by around $10\% - 20\%$. Second, the coefficient on landmine clearance also retains statistical significance, though the estimate drops by around 20%, compared to the estimates in Table 3 that solely examined the "local" impact of demining. Local and spillover effects seem to be at play, a finding that is similar to Donaldson and Hornbeck (2016) and Alder (2017). The comparison of the standardized coefficients [in brackets] of the market access and the CHA clearance variable shows that spillovers are considerable; they are twice as large as the "direct" effect with the luminosity-based market access proxy (in (5) and (6)) and equally large to the "local" effects with the population-based market access (in (7)-(8)).

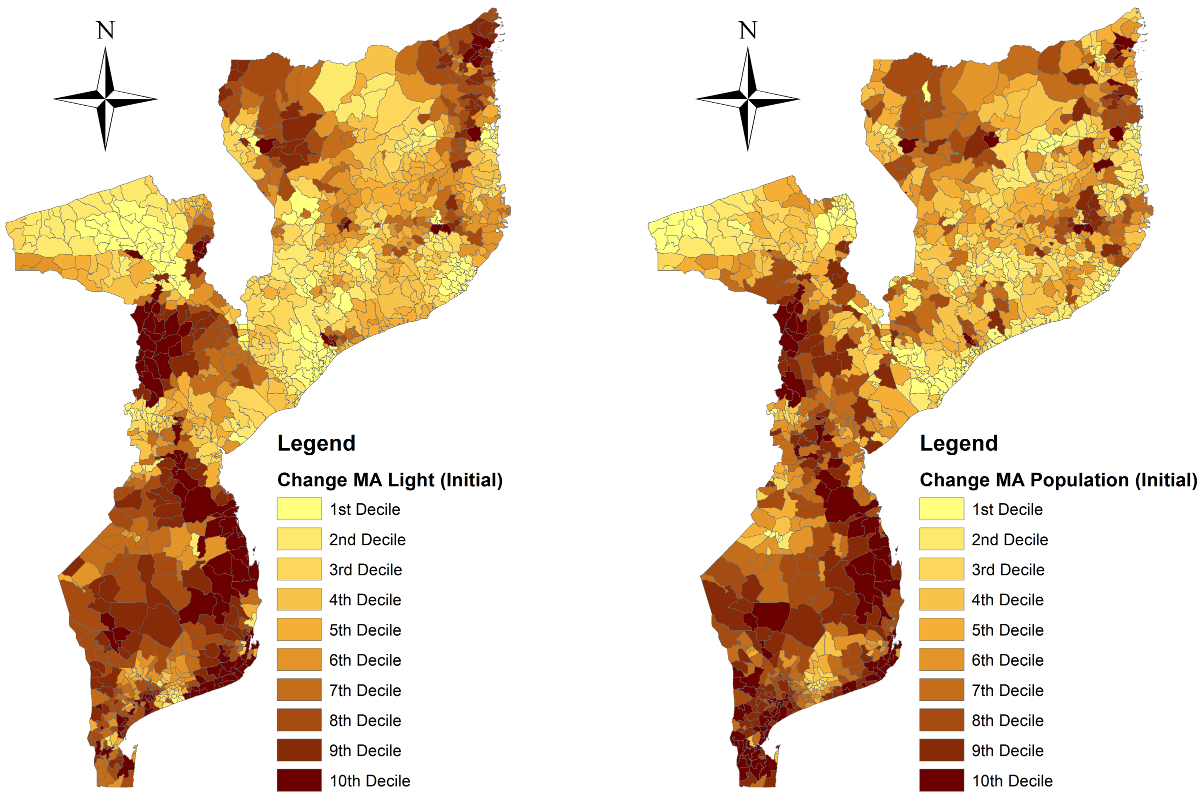
6.4.3 Luminosity - Market Access Elasticity in Non-Contaminated Localities

A sharper way to isolate spillovers is to look at localities without contamination. For these 332 localities (28% of the sample) changes in market access are driven by demining operations or other developments (new roads, improvements of old roads) in other interconnected localities. Another benefit of looking at these localities (that in the difference-in-difference specifications were part of the "control" group) is that endogeneity concerns regarding the timing of clearance operations are muted. Non-contaminated localities are somewhat smaller, less densely populated, and less likely to have a primary road or railroad, as compared to contaminated ones. Table 6 reports the results. The coefficient on log market access continues to be statistically significant. The estimates are similar to the full-sample ones. A 10% increase in "market access" increases luminosity by approximately 2.7% and the likelihood that the locality will be lit by 3.2%. The standardized coefficient is $0.2 - 0.3$, further illustrating the economic significance of spillovers.

These results show that the market access effects of CHA clearance operate beyond the local consequences of demining. The existence of such a relationship in non-contaminated by landmines areas suggests strong general equilibrium effects of clearance on spatial development, driven by the evolving accessibility to the transportation network.

6.4.4 Fixing Initial Conditions (Transportation Network and Population-Luminosity)

Transportation costs and hence localities' market access changes both because of landmine clearance and because of new road construction and improvements of the existing transportation network. Market access also reflects changes in population/development. To isolate the impact of landmine clearance, we recalculated (equation (3)) the two market access proxies (based on luminosity and on population), fixing the transportation network to the one left by the Portuguese in 1973 and holding all localities' luminosity (population) fixed in its 1992 (1980) level. Figures 9$a-b$ map the long-run changes of the two "market access" measures that are net of any swings in population and new road-railroad development, effectively capturing the role of landmine clearance on the accessibility of localities via the pre-independence transportation network.[28] The correlation between the changes in market access that use initial conditions to the analogous ones that also reflect population movements and new road development (illustrated in Figures 8$a-b$) is around 0.45.



Panel A: Change in Log MA1 (Luminosity) Pre-clearance Network-Population

Panel B: Change in Log MA2 (Population) Pre-clearance Network-Population

Figure 9: **Change in Market Access. Initial Conditions**

In Table 7 we report estimates that link luminosity to market access imposing the pre-clearance transportation network (1973), population (1980 Census), and luminosity (1992). We continue controlling for the direct effect of clearance. The elasticity ("beta" coefficient) on the luminosity-based market access measure is 0.26 (0.20). The linear probability model estimate (in (2)) is 0.025 implying that a one standard deviation increase in market access (around 1.2) is associated with a 3 percentage points rise in the likelihood that the locality will be lit. The coefficient on the market access proxy

[28] The mean (median) of long-run changes in the luminosity-based market access measure is 1.20 (0.82) and the standard deviation is 1.26. The average (median) of changes in the population-based market access measure is 0.52 (0.20) and the standard deviation is 0.82.

is also highly significant (in (3)-(4)). The log number of cleared hazardous areas that captures the direct role of clearance continues to enter with a significant estimate. In columns (5)-(8) we control for new roads-railroads and improvements in the old transportation network. While the improvement of roads-railroads is a significant correlate of local development, this does not affect the market access coefficient; this is to be expected, as by fixing initial conditions, the market access measures only reflect the decline in transportation costs due to CHA clearance of the network at-independence.

6.4.5 Sensitivity Analysis & Further Evidence

We performed many robustness checks that we report in detail in Appendix VII. First, we used alternative values for the trade elasticity (θ) that quantifies the role of transportation costs. We experiment with both the low (2.7) and the high-end (5.23) estimates of Simonovska and Waugh (2014a,b) regarding agriculture-based Ricardian models of trade. We even tried higher values. The results are robust. Second, we experiment with Harris' (1954) "market potential" measure (equal to $\sum_{d=1}^{D} \tau_{o,d}^{-1} N_d$). The luminosity - market potential association retains significance. Third, we associated luminosity with transportation costs using a simple measure of locality's connectivity to all others taking the shortest path via the transportation infrastructure. By not taking into account market size (population or luminosity), we isolate the impact of landmine clearance from population-income. There is a strong negative association between transportation distance and development, reassuring that the estimates do not reflect the particular parameterization of the market access measure or the theory-imposed structure. Fourth, given the importance of Maputo, Beira, and Nampula-Nacala for Southern, Central, and Northern Mozambican trade with neighboring countries we inflated the population/luminosity of the port cities adding the values of Johannesburg (South Africa), Harare (Zimbabwe), and Malawi, respectively. The estimates are similar. Fifth, we altered the parameterization of transportation costs. Among other tests, we used the exact parametrization of Jedwab and Storeygard (2018) that focus on Sub-Saharan Africa over $1960 - 2000$.[29] The results remain similar. Sixth, we dropped railways, as their role for intra-country commerce is limited, finding similar estimates. Seventh, we relaxed the assumption that mines block usage of affected transportation, assuming instead higher passage costs. Results remain intact. Eighth, we used perturbed market access measures that exclude adjacent localities, as this isolates market access changes from clearance operations far from the locality. This exercise also accounts for potential spatial clustering in demining activities. The market access is modestly attenuated and remain statistically significant. Ninth, we account for differential unobserved trends interacting locality characteristics pre-1992 with period-specific constants. Market access estimates are unaffected. Finally, we estimated the luminosity - market access correlation in long-run differences, as this allows controlling for pre-clearance features. The luminosity - market

[29]The parametrization of Jedwab and Storeygard (2018) is 1 for highways, 1.33 for paved roads and railroads, 2 for unpaved roads, 6.66 for trails (earthen roads), and 13.33 for walking with no roads. This parameterization is close to ours, the main difference being that railroads are costlier than primary paved roads.

access elasticity continues to be highly significant.

7 Counterfactual Policy Simulations

7.1 Mozambique without Demining

What would have been Mozambique's aggregate economic activity in 2015, had the international community and the government left the problem of contamination entirely unresolved? We address this (undoubtedly extreme) scenario estimating a simple policy counterfactual simulation that approximates the economy-wide impact of clearance. The counterfactual (that follows Donaldson and Hornbeck (2016)) works as follows. First, we calculate locality to locality lowest cost path connections with landmines (i.e., without clearance) in the 1973 transportation network. Second, we estimate two counterfactual luminosity-based market access statistics. The first assumes that landmines' presence does not alter the actual distribution of luminosity; the second assigns to each locality its share in 1992 multiplied by the sum of luminosity in 2015. Third, we calculate the difference between actual market access in 2015 (when the country was landmine free) and the counterfactual measures that approximate localities' market access in the absence of any clearance. We then sum the (exponent of the) differences in realized and counterfactual market access across all localities multiplied by the baseline luminosity-market access elasticity (0.25). This sum approximates the aggregate (integrated over all localities) effects of CHA clearance.[30]

Table 8 reports the comparison of realized market access with the two counterfactuals. The counterfactual that uses actual luminosity growth suggests that luminosity would have been 58.7% lower in absence of clearance. The counterfactual that imposes the 1992 distribution of luminosity suggests that Mozambique's luminosity in the absence of any clearance in 2015 would have been 70.4% lower. Given a GDP - luminosity elasticity of around $0.25 - 0.35$ (Henderson, Storeygard, and Weil (2012), see also Appendix IV) these counterfactual exercises imply that Mozambique's GDP in 2015 (14.8 billion USD) would have been $15\% - 25\%$ lower.[31] An alternative way is looking at growth impacts; as the current landmine clearance process lasted 23 years, these tabulations suggest an impact of landmine clearance of around $0.7 - 1.0$ percentage points per year.

7.2 Coordination and Prioritization

We now ask how the market access would have changed if demining operators had followed a coordinated strategy (under perhaps the United Nations or the National Government) that would prioritize

[30] Following Donaldson and Hornbeck (2016), we compute the percentage decline in luminosity as $\sum(((exp(\hat{\beta} * (\log \text{MA cf}_t - \log \text{MA act}_t)) - 1) * Light_t) * 100/\text{Total Light}_t)$

[31] Unfortunately, information on the financial cost of landmine clearance going back to 1992 is incomplete and available only from secondary sources. However, it seems that on average $10 - 15$ million USD dollars were spent just for clearance and technical surveys, resulting in a total cost of around $350 - 500$ million USD (in 2017 dollar terms).

clearance of localities along the transportation network, as clearing this type of contamination seems to have had larger local benefits (Table 4) and strong externalities (Table 6).

Using the spatial general equilibrium model of intra-country (across-locality) trade and the econometric estimates, we simulate an alternative demining process that follows naturally from a simple reading of Mozambique's history and its economic geography. The counterfactual works as follows: In the first period ($1992 - 1999$), demining prioritizes clearance along the three development corridors, where primary roads and railroads connect Maputo, Beira, and Nampula to the interior. In the second period ($2000 - 2007$), clearance continues across the three corridors and then targets the main highway ($N1$) connecting the South to the Central coastal areas and the North. In the third period ($2008 - 2015$) clearance focuses on localities where there is still contamination. To be consistent with the localities cleared in each period, we match the number of simulated localities to the cleared ones (e.g., the simulation clears 39 localities in the first-phase, matching the actual number of cleared localities).

Table 9 reports the average change of the actual and the simulated market access at the end of each phase of demining (1999, 2007, and 2015). The table gives changes in market access fixing luminosity and infrastructure to the 1992 levels so as to isolate landmine clearance. At the end of each period, we compare the change in the actual market access to its simulated counterpart. Panel A focuses on the entire clearance period ($1992 - 2015$). Actual changes in market access are identical to the simulated changes, as by 2015 all contaminated localities are cleared both in reality and in our simulation. The mean (median) increase in market access is 1.21 (0.83). Panel B looks at the $1992 - 1999$ period. During the first phase of demining only 39 localities were fully cleared. The average increase in log market access is thus small, 0.11. The increase in market access under the counterfactual demining process is moderately higher, 0.13, as we impose that the same number of localities is cleared. Panel C looks at $1992 - 2007$ period; 442 localities were fully cleared. This resulted in an average (median) increase in log market access of 0.63 (0.31). However, had the country pursued a coordinated approach targeting the central nodes of its pre-war transportation network, the increase in market access would have been substantially higher. The mean increase in log market access of the simple counterfactual is 0.99, 50% higher than the realized one. The median increase of simulated log market access is 0.56, 80% higher than the actual one.

Figure 10 provides a more-in-depth illustration of the costs of the absence of centralization and prioritization. The figure plots the average of the realized and the counterfactual change in log market access for 4 groups of localities in 2007, the end of the second phase when half of the contaminated localities were cleared. (i) Localities that were cleared both in reality and in our counterfactual (156). These are localities close to the development corridors and along the main South-Centre highway. (ii) Cleared by 2007 localities that are not prioritized by our counterfactual (286). (iii) Contaminated localities that had not been cleared by 2007, but are cleared in our simulation (286 localities). (iv) Localities that were not cleared by 2007 and are not prioritized in our simulation, as they are far from

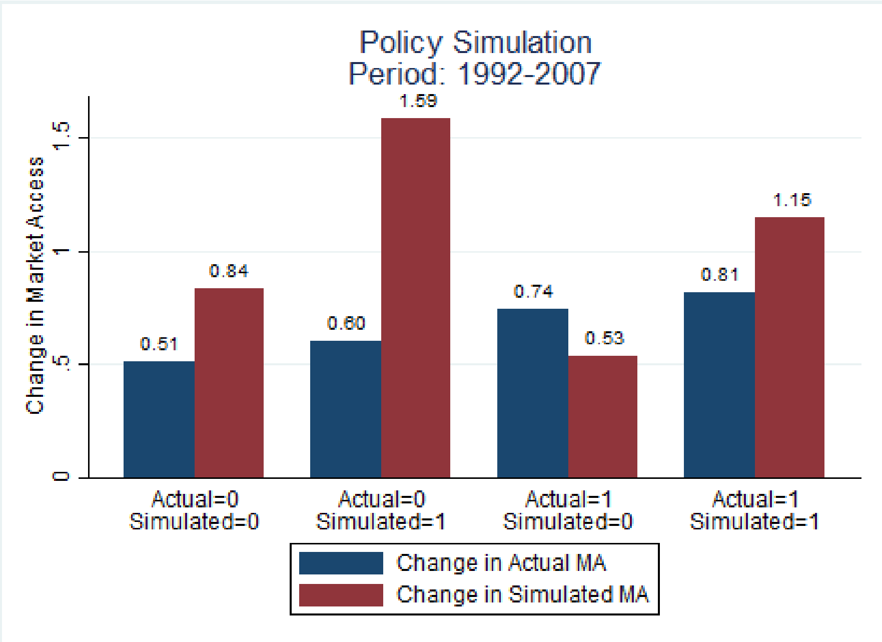


Figure 10: **Policy Simulation Period 2**

the development "corridors" and the main highway.

Let us start with localities that were neither cleared in reality nor in our counterfactual. Log market access increased by 0.51, as they gained from clearance in interconnected areas. Had clearance targeted the central nodes of the transportation system, log market access would have increased way more; the average increase in counterfactual log market access is 0.84. Median changes in log market access (not shown) are also sizable, 0.47 for the counterfactual and 0.27 for the actual.

Turning now to localities that were fully cleared in reality and are also cleared in the counterfactual, the average (median) increase of realized log market access is 0.81 (0.56). In our counterfactual, the mean (median) increase is larger, 1.15 (0.97), as the simulated market access gets a boost from clearance of other central localities.

The increase in actual log market access in the localities that had been treated in reality by 2007, but are not prioritized in our counterfactual is higher. The average change of realized log market access is 0.74, while the change in the counterfactual log market access is 0.53 (medians 0.49 versus 0.25). The "mirror" image of this difference is comparing actual and counterfactual market access in localities that were not cleared in reality, but are cleared in our counterfactual. The average (median) increase of realized log market access is 0.60 (0.24). Market access increased in spite of the absence of clearance, as these localities benefited from landmine removal operations in other places. But the counterfactual increase in log market access is significantly larger, 1.59 (and the median 1.21).

This simple counterfactual suggests sizable losses associated with the non-coordinated and with lack of prioritization process of landmine clearance; yet, a word of caution is in order. Our counterfactual analysis does not take into account humanitarian aspects, at-the-time information, coordination, and central planning costs. Hence, this policy counterfactual is not meant to supplant existing prioritization strategies, but rather to complement them. We should stress here that our economic-potential prioritization is not inconsistent with health-motivated concerns, as the scant international data suggest that casualties, amputations, and injuries are equally likely in remote and more connected places (Landmine Monitor (2016, 2017, 2018); Frost, et al. (2017)). The simulations offer an informative, hands-off approach in crafting a sound demining strategy in the presence of economic externalities, which the Mozambican case suggests are sizable, though not much-considered by the landmine clearance community at that time.

8 Discussion

We conclude with a discussion of possible paths for future research and some policy implications.

8.1 Future Work

Landmines affect the lives of millions around the world. Cheap to obtain and easy to manufacture, their appeal to warring parties, militias, and rebels is unlikely to fade. Our paper is a first step towards a better understanding of landmines' legacy shedding light on the consequences of demining on local and aggregate economic activity in Mozambique. Clearly, we need more research to assess the mechanisms at work. Using individual-level data, it will be illuminating to examine how the clearance of landmines and of other improvised explosive devices shapes poverty, land use, agricultural productivity, and educational outcomes. Another avenue is examining the effects of landmines on health, as given data unavailability on landmines and poor recording of fatalities, injuries, and mental health, medical research is purely descriptive relying on tiny samples. At the same time, anecdotes from contaminated communities suggest that landmines entail sizable environmental costs; hence, future work could assess their role in livestock, wildlife, and conservation.

Landmine contamination is one of the many deleterious facets of civil warfare; not limited to child soldiering, refugee flows, forced labor, extortion, violence against women and children, and mutilations. Future research should dig deeper into these aspects, understand their heritage and spatial interdependencies, and explore how they interact with each other both in the context of conflict as well for post-conflict recovery.

8.2 Policy

Clearly, we need more research. Nonetheless, our analysis from Mozambique, the only so far heavily contaminated by landmines country to be declared landmine free, carries some policy implications. First, demining operators and governments should take into account the fact that clearance boosts economic performance in areas close to roads and railroads, and local agriculture trade hubs. District prioritization is a complex process that factors in various considerations. The Mozambique experience suggests that the economics should be one of them. Given the recent evidence on the benefits of transportation infrastructure on regional trade, this finding may not be that surprising. Yet, it stands in contrast to the traditional *modus operandi* of demining operators that -if anything- often prioritize remote areas.

Second, the comparison of the small-to-moderate "local" effects of demining with the larger "economy-wide" estimates and the associated counterfactual policy simulations revealing significant losses from the scattered and non-coordinated process that characterized Mozambique in the 1990s and early 2000s, stresses the importance of coordination and central planning. This has immediate implications for the design of mine-action programmes in Cambodia, Afghanistan, Colombia, and other heavily-mined countries, where the international community is currently working on.

Third, our findings offer some backing to the efforts of the international community to persuade governments to expand the International Mine Ban Treaty on Anti-Personnel landmines of 1999 to also cover anti-tank (anti-vehicle) landmines. By debilitating the transportation network, anti-tank landmines hinder economic recovery, as development is fueled by the flow of goods, people, and ideas.

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Table 1: **Affected Localities and Demining Totals.**

	Full Sample			Period 1		Period 2		Period 3	
	Localities		Interventions	Localities	Interventions	Localities	Interventions	Localities	Interventions
Province	Total	Affected	Total	Fully Cleared	Total	Fully Cleared	Total	Fully Cleared	Total
Cabo Delgado	130	98	508	0	3	86	484	12	21
Gaza	129	70	453	9	63	17	205	44	185
Inhambane	79	75	992	1	117	11	471	63	404
Manica	104	85	1053	2	79	7	197	76	777
Maputo	78	71	1211	3	187	2	163	66	861
Nampula	172	106	612	6	124	91	477	9	11
Niassa	87	73	572	3	96	41	430	29	46
Sofala	80	70	936	3	121	12	255	55	560
Tete	127	71	327	6	43	21	76	44	208
Zambezia	201	136	759	6	80	115	660	15	19

Notes. This Table reports the number of fully cleared localities and the number of interventions across the Mozambican provinces and by period: 1992 − 1999, 2000 − 2007, and 2008 − 2015.

Table 2: **Summary Statistics**

	Full Sample					
	Observations	Mean	Standard Deviation	Median	Min	Max
Share of Contaminated localities in 1992	1187	0.720	0.449	1	0	1
Number of Threats in 1992	1187	6.253	14.164	2	0	238
Lit 1992	1187	0.098	0.297	0	0	1
Lit 1999	1187	0.177	0.382	0	0	1
Lit 2007	1187	0.227	0.419	0	0	1
Lit 2015	1187	0.422	0.494	0	0	1
Log Luminosity 1992	1187	-10.579	2.924	-11.5	-11.5	2.51
Log Luminosity 1999	1187	-9.858	3.736	-11.5	-11.5	2.83
Log Luminosity 2007	1187	-9.344	4.197	-11.5	-11.5	3.11
Log Luminosity 2015	1187	-7.633	4.800	-11.5	-11.5	3.15
Paved Road 1973 (dummy)	1187	0.171	0.377	0	0	1
Unpaved Road 1973 (dummy)	1187	0.021	0.144	0	0	1
Trail 1973 (dummy)	1187	0.660	0.474	1	0	1
Railway 1992 (dummy)	1187	0.130	0.336	0	0	1
Navigable River (dummy)	1187	0.228	0.420	0	0	1
Cantinas (dummy)	1187	0.584	0.493	1	0	1
Civil War (dummy)	1187	0.158	0.365	0	0	1
Log MA Light 1992	1187	-15.767	3.127	-16.4	-22.3	-5.54
Log MA Light 1999	1187	-14.104	3.274	-14.6	-20.9	-4.49
Log MA Light 2007	1187	-12.809	3.190	-13.2	-20.9	-1.75
Log MA Light 2015	1187	-10.214	2.409	-10.5	-16	-.765

Notes: This table reports the summary statistics of the main variables at the locality level.

Table 3: **Land Mine Removal and Local Development.**

	Yearly				Demining-Phase Estimation (1992, 1999, 2007, 2015)			
	Log Luminosity		Lit		Log Luminosity		Lit	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cleared Threats	0.329***		0.037***		0.469***		0.058***	
	(0.073)		(0.007)		(0.098)		(0.011)	
	[0.071]		[0.080]		[0.107]		[0.129]	
Cleared (dummy)		0.373***		0.038***		0.755***		0.083***
		(0.109)		(0.011)		(0.182)		(0.020)
		[0.037]		[0.038]		[0.082]		[0.088]
Number of Localities	1,187	1,187	1,187	1,187	1,187	1,187	1,187	1,187
Locality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time x Province FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	.168	.166	.124	.121	.241	.238	.224	.22
Observations	27,301	27,301	27,301	27,301	4,748	4,748	4,748	4,748

Notes: This table reports panel fixed effects OLS estimates associating luminosity with landmine clearance. The dependent variable in columns (1)-(2) and (5)-(6) is the log of luminosity plus the half of the minimum positive value of luminosity. The dependent variable in columns (3)-(4) and (7)-(8) is an indicator that takes the value of one if the locality appears to be lit. Columns (1)-(4) report yearly specifications (1992-2015). Columns (5)-(8) focus on 4 yearsthat correspond to the three main phases of landmine clearance, namely 1992, 1999, 2007 and 2015. Cleared Threats is the logarithm of one plus the number of accumulated cleared confirmed hazardous areas (CHA). Cleared is an indicator variable the takes the value of 0 when the locality is contaminated and becomes 1 the year and for all subsequent years that the locality is landmine free; the indicator equals zero for all localities that were not contaminated. All specifications include locality-specific fixed-effects and province-year specific fixed effects (constants not reported). Standard errors in parentheses are clustered at the district (admin 2) level and standardized "beta" coefficients [in brackets]. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

Table 4: **Heterogeneity Across Intervention Characteristics.**

	Demining-Phase Estimation (1992, 1999, 2007, 2015)			
	Log Luminosity	Lit	Log Luminosity	Lit
	(1)	(2)	(3)	(4)
	Cleared Threats		Cleared (Dummy)	
- Road and Railway (100m)	0.381**	0.054**	0.433**	0.057**
	(0.191)	(0.022)	(0.218)	(0.024)
	[0.045]	[0.063]	[0.037]	[0.048]
- Border (10000m)	-0.388	-0.027	-0.532	-0.017
	(0.267)	(0.031)	(0.371)	(0.048)
	[-0.029]	[-0.020]	[-0.019]	[-0.006]
- Cantinas (1000m)	0.580**	0.063**	0.643*	0.063*
	(0.259)	(0.027)	(0.327)	(0.036)
	[0.050]	[0.053]	[0.042]	[0.040]
- Civil War (1000m)	0.558	0.030	1.325***	0.087*
	(0.357)	(0.037)	(0.439)	(0.045)
	[0.037]	[0.019]	[0.060]	[0.038]
- River (100m)	0.090	0.048	0.149	0.038
	(1.126)	(0.136)	(0.798)	(0.099)
	[0.002]	[0.010]	[0.004]	[0.009]
- Village (1000m)	0.785***	0.061***	0.988***	0.089***
	(0.189)	(0.020)	(0.224)	(0.025)
	[0.087]	[0.067]	[0.082]	[0.072]
- Electricity Grid (100m)	0.350	0.021	0.365	0.041
	(0.283)	(0.030)	(0.393)	(0.046)
	[0.017]	[0.010]	[0.012]	[0.013]
- Residual	-0.078	0.008	0.008	0.019
	(0.097)	(0.011)	(0.157)	(0.018)
	[-0.015]	[0.015]	[0.001]	[0.020]
Number of Localities	1,187	1,187	1,187	1,187
Locality FE	Yes	Yes	Yes	Yes
Time x Province FE	Yes	Yes	Yes	Yes
R-squared	.26	.235	.264	.236
Observations	4,748	4,748	4,748	4,748

Notes. This table reports panel fixed effects OLS estimates exploring whether the association between demining activities and local development varies by the type of CHA categories cleared. The dependent variable in columns (1)-(2) is the log of luminosity plus the half of the minimum positive value of luminosity. The dependent variable is columns (3)-(4) is an indicator that takes the value of one if the locality is lit. All columns focus at 4 yearsthat correspond to the three main phases of landmine clearance, namely 1992, 1999, 2007 and 2015. We split our variable of interest the Number of Accumulated Cleared Threats into seven non-mutually exclusive categories, according to some GIS-based distance thresholds. Columns (1)-(2) report the Log Number of Accumulated Threats split into the seven categories; Columns (3)-(4) report the corresponding dummy version of each GIS category. We classify the different categories as follows: i) Roads and Railways if a threat's centroid is within 100 meters from a road or a railway; ii) Border if a threat's centroid is less than 10,000 meters from the country border; iii) Cantinas if a threat's centroid is less than 1,000 meters from a village with a colonial commercial hub; iv) Civil War if a threat's centroid is in a buffer of 1,000 meters from an event of the Civil War; v) River if a threat's centroid is less than 100 meters distant from a river or lake; vi) Village if a threat's centroid is within 1,000 meters from a village; and Electricity Grid if a threat's centroid is in a buffer of 100 meters from the electric grid or pylon. The Residual category includes all the remaining threats. All specifications include locality-specific fixed-effects and province-year specific fixed effects (constants not reported). Standard errors in parentheses are clustered at the district (admin 2) level and standardized "beta" coefficients [in brackets]. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

Table 5: **Market Access. Baseline Estimates.**

	Demining-Phase Estimation (1992, 1999, 2007, 2015)							
	Contemporaneous				Direct Effect			
	Log Luminosity	Lit	Log Luminosity	Lit	Log Luminosity	Lit	Log Luminosity	Lit
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log Market Access, Light	0.296***	0.032***			0.274***	0.029***		
	(0.064)	(0.007)			(0.064)	(0.007)		
	[0.262]	[0.278]			[0.242]	[0.254]		
Log Market Access, Population			0.248***	0.025***			0.187***	0.017**
			(0.069)	(0.008)			(0.067)	(0.007)
			[0.150]	[0.148]			[0.113]	[0.101]
Cleared Threats					0.393***	0.049***	0.375***	0.049***
					(0.094)	(0.010)	(0.108)	(0.012)
					[0.090]	[0.111]	[0.086]	[0.110]
Number of Localities	1,187	1,187	1,077	1,077	1,187	1,187	1,077	1,077
Locality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time x Province FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	.248	.229	.249	.228	.254	.235	.254	.234
Observations	4,748	4,748	4,308	4,308	4,748	4,748	4,308	4,308

Notes: The table reports panel fixed effects OLS estimates associating luminosity with market access. The dependent variable in columns (1), (3), (5), and (7) is the log of luminosity plus the half of the minimum positive value of luminosity. The dependent variable is columns (2), (4), (6), and (8) is an indicator that takes the value of one if the locality is lit. All specifications focus on 4 years that correspond to the three main phases of landmine clearance, namely 1992, 1999, 2007 and 2015. Market Access, Light is the logarithm of luminosity-weighted market-access. Market Access, Population is the logarithm of population-weighted market-access. In columns (5)-(8), we control for the Cleared Threats, that is the logarithm of one plus the number of accumulated cleared confirmed hazardous areas (CHA) in the locality in given year. All specifications include locality-specific fixed-effects and province-year specific fixed effects (constants not reported). Standard errors in parentheses are clustered at the district (admin 2) level and standardized "beta" coefficients [in brackets]. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

Table 6: **Market Access in Non-Affected**

	Demining-Phase Estimation (1992, 1999, 2007, 2015)			
	Contemporaneous			
	Log Luminosity		Lit	
	(1)	(2)	(3)	(4)
Log Market Access, Light	0.270***	0.032***		
	(0.099)	(0.011)		
	[0.279]	[0.318]		
Log Market Access, Population			0.297**	0.033**
			(0.135)	(0.015)
			[0.208]	[0.223]
Number of Localities	332	332	291	291
Locality FE	Yes	Yes	Yes	Yes
Time x Province FE	Yes	Yes	Yes	Yes
R-squared	.189	.167	.205	.173
Observations	1,328	1,328	1,164	1,164

Notes: The table reports panel fixed effects OLS estimates associating luminosity with market access, focusing on the localities that were not contaminated by landmines. The dependent variable in columns (1)-(2) is the log of luminosity plus the half of the minimum positive value of luminosity. The dependent variable is columns (3)-(4) is an indicator that takes the value of one if the locality is lit. All specifications focus on 4 years that correspond to the three main phases of landmine clearance, namely 1992, 1999, 2007 and 2015. Market Access, Light is the logarithm of luminosity- weighted market-access. Market Access, Population is the logarithm of population-weighted market-access. All specifications include locality-specific fixed-effects and province-year specific fixed effects (constants not reported). Standard errors in parentheses are clustered at the district (admin 2) level and standardized "beta" coefficients [in brackets]. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

Table 7: **Market Access and Direct Effects fixing Initial Network and Initial Development**

	Demining-Phase Estimation (1992, 1999, 2007, 2015)							
Accounting For:	Direct Effect				Direct Effect, New Road, and Old Road Improvement			
	Log Luminosity	Lit	Log Luminosity	Lit	Log Luminosity	Lit	Log Luminosity	Lit
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log Market Access, Light (Initial)	0.260**	0.025**			0.261**	0.025**		
	(0.113)	(0.012)			(0.114)	(0.012)		
	[0.199]	[0.186]			[0.200]	[0.188]		
Log Market Access, Population (Initial)			0.663***	0.054***			0.665***	0.055***
			(0.178)	(0.019)			(0.178)	(0.019)
			[0.358]	[0.285]			[0.359]	[0.288]
Cleared Threats	0.424***	0.053***	0.334***	0.046***	0.387***	0.049***	0.303***	0.043***
	(0.092)	(0.010)	(0.106)	(0.012)	(0.091)	(0.010)	(0.104)	(0.011)
	[0.097]	[0.119]	[0.077]	[0.104]	[0.089]	[0.110]	[0.070]	[0.096]
New Road (dummy)					0.014	0.018	-0.083	0.006
					(0.206)	(0.023)	(0.215)	(0.024)
					[0.002]	[0.019]	[-0.009]	[0.006]
Old Network Improved (dummy)					0.451**	0.044**	0.448**	0.042**
					(0.183)	(0.020)	(0.178)	(0.020)
					[0.052]	[0.050]	[0.051]	[0.047]
Number of Localities	1,187	1,187	1,077	1,077	1,187	1,187	1,077	1,077
Locality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time x Province FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	.243	.226	.259	.236	.245	.227	.261	.237
Observations	4,748	4,748	4,308	4,308	4,748	4,748	4,308	4,308

Notes: The table reports panel fixed effects OLS estimates associating luminosity with market access, fixing both the transportation network and the luminosity (population) for the construction of market access. The dependent variable in columns (1), (3), (5), and (7) is the log of luminosity plus the half of the minimum positive value of luminosity. The dependent variable is columns (2), (4), (6), and (8) is an indicator that takes the value of one if the locality is lit. All specifications focus on 4 years that correspond to the three main phases of landmine clearance, namely 1992, 1999, 2007 and 2015. Market Access, Light is the logarithm of luminosity-weighted market access fixing the transportation network to 1973 and holding all localities' luminosity fixed at their 1992 level. Market Access, Population is the logarithm of population- weighted market access fixing the transportation network to 1973 and holding all localities' population fixed at their 1980 level. In columns (1)-(4), we control for the Cleared Threats, that is the logarithm of one plus the number of accumulated cleared confirmed hazardous areas (CHA) in the locality as of a given year. In columns (1)-(4), we add i) new road, an indicator that takes the value of one in the year and for all subsequent years that a new road construction takes place in a given locality; ii) old network improved, an indicator variable that takes the value of one in the year and for all subsequent years following the improvement of an old road (corresponding to the 1973 road infrastructure network). All specifications include locality-specific fixed-effects and province-year specific fixed effects (constants not reported). Standard errors in parentheses are clustered at the district (admin 2) level and standardized "beta" coefficients [in brackets]. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

Table 8: **Counterfactuals I. No Land Mine Clearance**

	Percent Decline MA without Demining Activities	Percent Decline in Luminosity without Demining Activities
Market Access, Light	2007 (obs=1187)	
No demining activities	58	30.2 (1.7)
No demining activities & Assuming the Luminosity Distribution in 1992	62.3	41.9 (1.7)
Market Access, Light	2015 (obs=1187)	
No demining activities	59.4	58.7 (2.4)
No demining activities & Assuming the Luminosity Distribution in 1992	75.3	70.4 (1.7)

Notes. Each row reports the counterfactual impact on luminosity of under the scenario that the problem of landmines contamination was unsolved. Panel A reports the counterfactual stopping in 2007; while Panel B give the counterfactual results for 2015. In the first row of each panel, the landmines are on the ground and the actual luminosity shares are used for computing the counterfactual. In the second row, landmines contamination is present but locality luminosity shares are fixed to their 1992 level and we redistribute the total level of luminosity in (2007) 2015 accordingly. Robust standard errors clustered by admin-2 are reported in parentheses, when available.

Table 9: **Counterfactual II. Policy Experiment Simulation**

Dependent Variable	Δ Market Access Network and Luminosity (Initial)			
	Mean	Median	Observations	# of Affected used in Simulation
			Period: 1992-2015	
Actual (log)	1.21	0.83	1187	855
Simulated (log)	1.21	0.83	1187	855
			Period: 1992-1999	
Actual (log)	0.11	0.00	1187	39
Simulated (log)	0.13	0.01	1187	39
			Period: 1992-2007	
Actual (log)	0.63	0.31	1187	442
Simulated (log)	0.99	0.56	1187	442

Notes. This Table reports the results of a policy experiment simulation, comparing the change of the actual Market Access with its simulated counterpart. The simulation prioritizes the demining interventions as follows: i) in the first period, demining activities take place on the three main corridors starting from Maputo, Beira, and Nacala; ii) in the second period, landmine clearance targets the N1 highway, paved roads, unpaved roads and trails; iii) in the last period, all the rest of the country is cleared. In the first two periods, we match the number of simulated cleared localities to the actual cleared ones (39, 442). All the Market Access measures are obtained by focusing on the predetermined components of market access i) the transportation network is fixed to the one available in 1973 and ii) the development proxies weighting the bilateral transportation costs are held fixed to their 1992 values. Actual (log) is the change in log Market Access weighted by the total luminosity in 1992 in all the destination localities. Simulated (log) is the change in log Market Access weighted by the total luminosity in 1992 obtainable under the simulated prioritization of demining efforts.