Landmines and Spatial Development
Appendix V
Validation Luminosity-Development *

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Abstract

This Appendix first reviews works showing that satellite imagery on light density at night is a good proxy of economic activity both across and within countries placing an emphasis on Africa. It also gives cross-country associations revealing a significant within-country correlation between luminosity and GDP across African countries. Second, the Appendix presents evidence illustrating a significant association between luminosity and proxies of well-being (public goods, household assets, and education) across African and Mozambican regions using data from the Demographic and Health Surveys (DHS). The link between luminosity and education is present both across urban and across rural districts. Third, the Appendix presents regression-based and graphical evidence of a strong association between luminosity and education across Mozambican localities using information covering the universe of population from the 1997 and 2007 Censuses. Forth, given the uncovered heterogeneity between landmine clearance and luminosity in localities (not) connected to colonial transportation and localities with(out) agricultural markets (cantinas), the Appendix shows that the correlation between satellite imagery on light density at night and years of schooling is present across all these different categories of localities.

*Additional material can be found at www.land-mines.com

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1 Luminosity and Development

1.1 Literature

The increasing availability of big data with a spatial dimension has opened a way to the "meso-approach" in the empirical literature of comparative development and growth (see Michalopoulos and Papaioannou (2018)). Among such geo-referenced data, satellite images of light density have been widely used to capture economics activity at the local level. Building on Elvidge, Baugh, Kihn, Kroehl, and Davis (1997) and Doll, Muller, and Morley (2006), Henderson, Storeygard, and Weil (2012) first showed the potential of luminosity data to economics, uncovering that light density at night is a strong proxy of economic activity across and within countries. Many empirical works have since used satellite data on light density at night to study a plethora of questions. Pinkovskiy and Sala-i-Martin (2016a) use luminosity to construct revised data on poverty rates across countries, finding that global poverty has been falling considerably in most parts of the world, including Africa. Michalopoulos and Papaioannou (2014) and Pinkovskiy (2017) use luminosity to examine whether national institutions correlate with regional development close to the borders. Michalopoulos and Papaioannou (2013) aggregate the luminosity data across ancestral ethnic homelands to explore the link between contemporary development and deeply-rooted precolonial political organization. Alesina, Michalopoulos, and Papaioannou (2016) use luminosity data to construct proxies of regional inequalities across ethnic homelands and administrative regions and explore the association between spatial inequalities and development. Hodler and Raschky (2014) use luminosity to examine regional favoritism. Campante and Yanagizawa-Drott (2018) use city-level luminosity data to assess the role of long-distance flight on the spatial allocation of economic activity. Henderson, Squires, Storeygard, and Weil (2018) use finely disaggregated luminosity data to explore the role of geographical features on the spatial distribution of economic activity. Michalopoulos and Papaioannou (2018) review this body of research, while Donaldson and Storeygard (2017) review the wider research agenda that used satellite data in economics.

While not problem-free, luminosity data entail some advantages. First, cross-country comparability is high, as the information is measured in a consistent way and does not reflect biases from statistical institutions (Henderson et al. (2012)). Second, coverage is global (with the exception of the poles). Third, satellite data are able to capture a sizable portion of economic activity and urbanization at a fine resolution, of roughly 1 km^2 (in the equator), thus allowing meaningful within-country spatial analyses. Fourth, luminosity data are available at the yearly frequency since 1992 and thus permit for meaningful within-country over time analyses.

Taking advantage of the disaggregated nature of the data, the literature has used various transformations of luminosity at different levels of analysis. These include the sum of total night light in a given region, province, or country, the share of lit pixels, the average night light, and the log of average night light, either per square kilometer or per capita (sometimes a small number is added

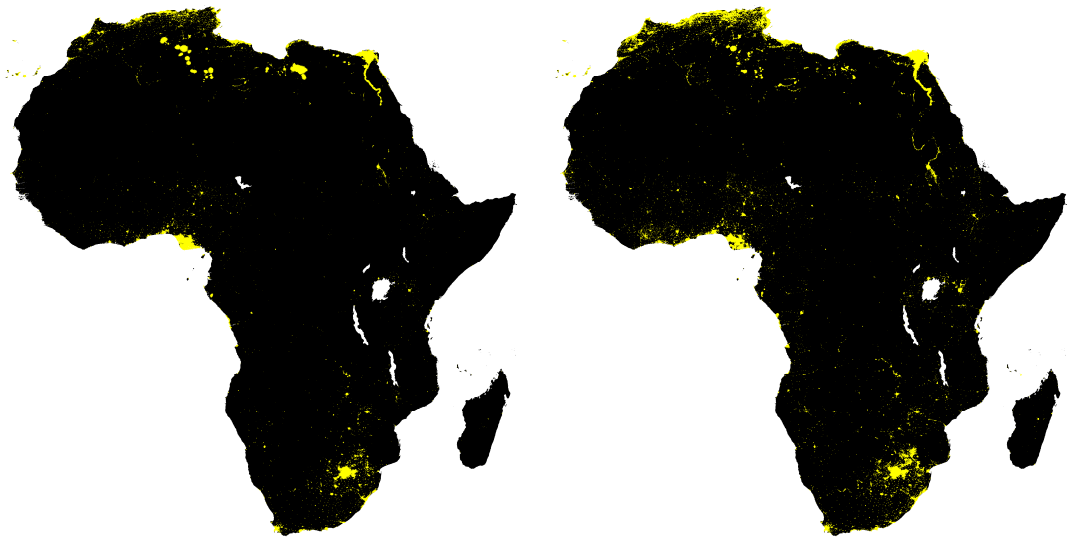


Figure 1: **Luminosity in Africa: 1992 and 2013**

before taking the log to account for the presence of zeros). Many high-resolution studies employ a binary, $0-1$, transformation that accounts for the highly nonlinear nature of the data. Even if there is a discussion on whether the correlation between lights and development is stronger in levels or growth rates, luminosity is a powerful proxy of development for regional analyses in conflict-ridden regions and those with poor-quality national statistics. And these are the places where understanding the causes of underdevelopment is more important (see Chen and Nordhaus (2011), Henderson, Storeygard, and Weil (2012), and Nordhaus and Chen (2014)).[1] Figures 1 and 2 illustrate the distribution of luminosity in 1992 and in 2013 for Africa and Mozambique, respectively.

1.2 Elasticity between Luminosity and GDP

The association between luminosity and GDP across countries is strong. Henderson, Storeygard, and Weil (2012) show that a robust correlation emerges when estimating the association between luminosity and GDP in log differences over the period $1992-1993$ to $2005-2006$ across 170 countries. They uncover an elasticity of 0.32 and an R^2 of around 0.28.

Thanks to its fine resolution, luminosity allows comparisons of economic activity across regions within countries. Estimates at the subnational level reveal that the correlation between luminosity and GDP holds when controlling for nationwide common factors. At a global scale, Hodler and Raschky

[1] Nordhaus and Chen (2014) conclude that "there may be substantial cross-sectional information in lights data for countries with low-quality statistical systems".

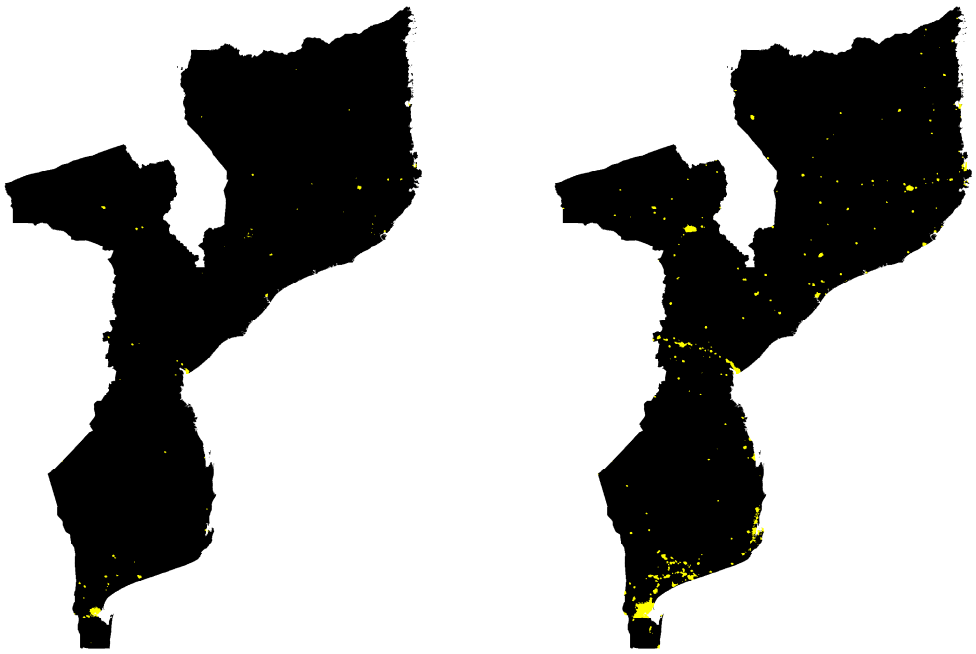


Figure 2: **Luminosity in Mozambique: 1992 and 2013**

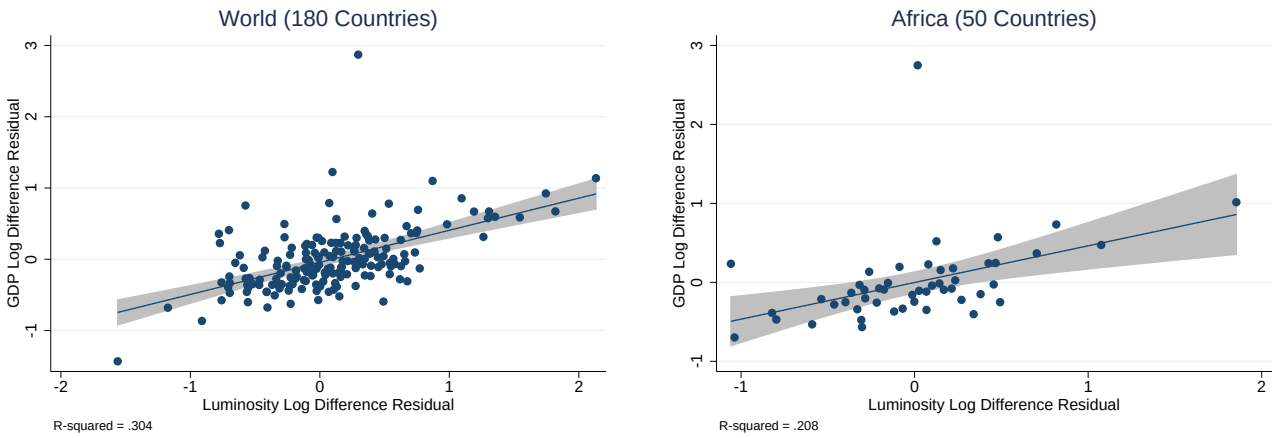


Figure 3: **GDP and Luminosity. Log Differences 1992-1993 and 2012-2013: World and Africa**

(2014) show that log luminosity and log output are related at the regional level. Similarly, Gennaioli, La Porta, De Silanes, and Shleifer (2014) in a sample of 1503 regions across 83 countries estimate the elasticity to be around 0.25.

Following Henderson, Storeygard, and Weil (2012), we estimated the elasticity between luminosity and GDP in log differences over the period $1992-1993$ to $2013-2012$ for 180 countries. We uncover an elasticity of 0.45 (with a standard error of 0.04) and an R^2 of 0.30 (see left panel of Figure 3). We

then explored the relationship for a subset of 50 African countries. The estimated elasticity is 0.46 (with a standard error of 0.08) with an R^2 of 0.20 (see right panel of Figure 3).

2 Luminosity and Well-Being across African Regions

While many works have shown that luminosity is a good proxy of local economic activity, especially in under-developed and war-prone countries (e.g., Henderson, Storeygard, and Weil (2012), Chen and Nordhaus (2011), Michalopoulos and Papaioannou (2013), Pinkovskiy and Sala-i Martin (2016)) we further cross-validated luminosity using data from the Demographic and Health Surveys (DHS); these surveys have been widely used in development economics to proxy individual well-being, household wealth, and access to basic public goods.

2.1 DHS and Luminosity: Africa

We collected data from 69 georeferenced surveys covering 31 Sub-Saharan African countries over the period $1999 - 2015$. We aggregated the data at the second-level administrative unit level using the boundaries from GADM (Global Administrative Areas).[2] GADM delineates Africa into $6,157$ sub-national (admin-2) regions; of these regions, $2,455$ contain at least one DHS enumeration area (village/town) with data on household wealth. The DHS wealth index is generated via a principal component analysis of a household's assets including television, bicycle, materials used in the housing construction, water access, and sanitation facilities. The resulting DHS composite wealth index places individual households on a continuous (or quartile) scale of relative wealth within a country for a given survey. Overall, we use data from approximately $743,000$ households.

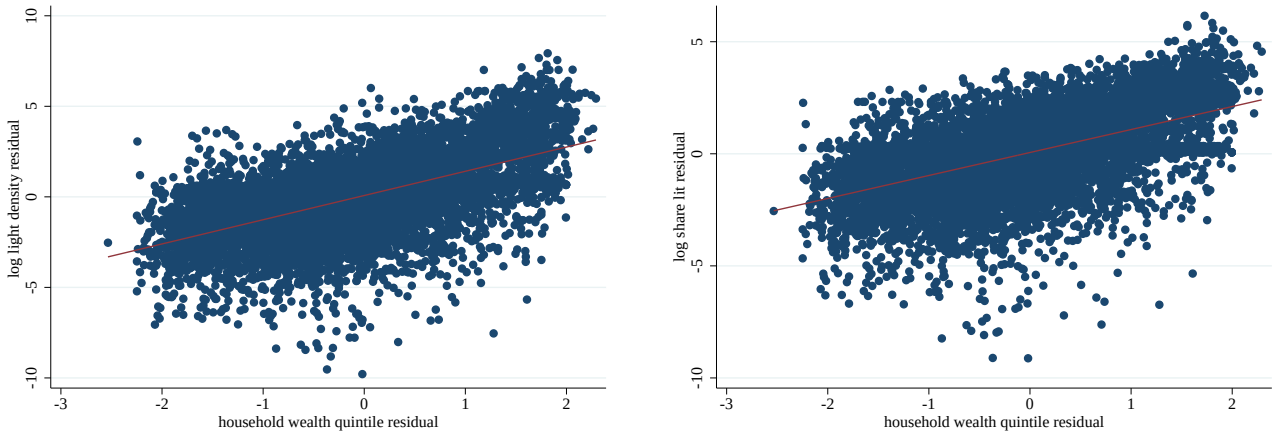


Figure 4: **Luminosity - DHS Wealth Index Association across African Regions**

[2]GADM provides only admin-1 boundaries for Comoros, Cape Verde, Lybia, Lesotho, Mauritius, and Seychelles.

Figure 4 plots regional luminosity against the DHS composite wealth index, netting out country-survey fixed effects. On the left panel, we employ a logarithmic transformation of the luminosity data (that range from 0 to 63). On the right panel, and since admin-2 units are typically large, we use the log share of lit pixels. There is an evident strong, and highly significant correlation between the wealth index and both transformations of luminosity. This correlation is similar to Weidmann and Schutte (2017) and Bruederle and Hodler (2018) who also report strong associations between luminosity and DHS-based proxies of well-being. The relationship is not driven by outliers. The R^2 is around $0.30 - 0.35$. The coefficient on the DHS wealth index is around 1.3 implying that 10 percent increase in luminosity is associated with a 0.77 increase in the wealth index that ranges from 1 to 5 ($1/1.3 \simeq 0.769$).

2.2 DHS and Luminosity: Mozambique

In Figure 5 we plot luminosity against the DHS composite wealth index across the 124 Mozambican admin-2 districts using the 2011 survey that covers $13,919$ households and the 2009 survey that covers $6,097$ households.[3] The correlation is quite strong with an R^2 of around $0.49 - 0.51$; while far from perfect, luminosity does reflect regional development. The estimate on the DHS wealth index is 1.6, suggesting that a 10% increase in cross-district luminosity is associated with a 0.62 points increase in the DHS composite wealth index ($1/1.6 \simeq 0.625$).

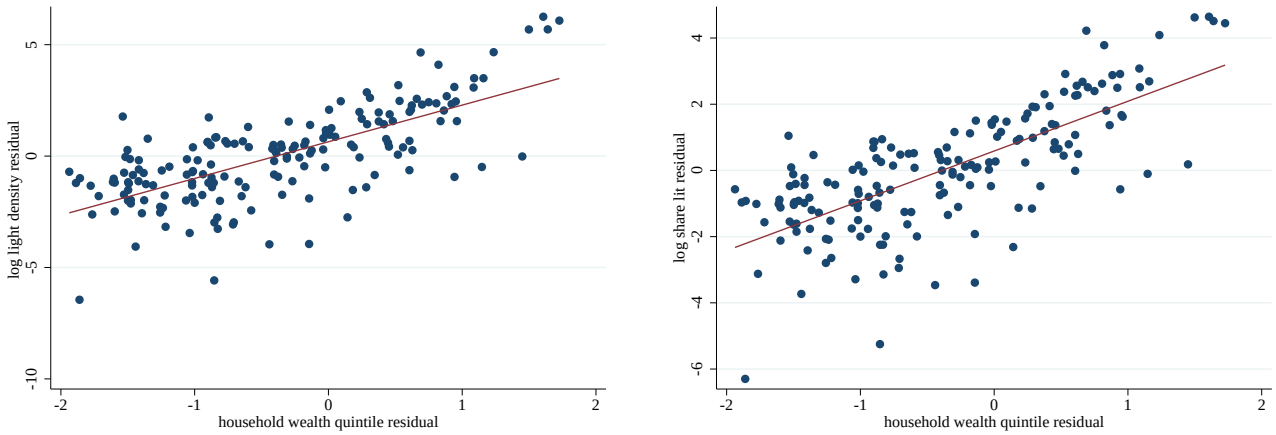


Figure 5: **Luminosity - DHS Wealth Index Association across Mozambican Districts**

In Figure 6 we report the means of the deviation from the sample mean of the DHS composite wealth index for the unlit and lit Mozambican admin-3 units (391 postos administrativos), respectively, pooling together the 2009 and 2011 surveys and partialling out survey fixed effects**.** The mean of the

[3]Since the year of interview varies within the survey, we assigned to each household the corresponding value of luminosity of their admin-2 district of residence in that year. We then construct the average luminosity at the admin-2 level for both surveys.

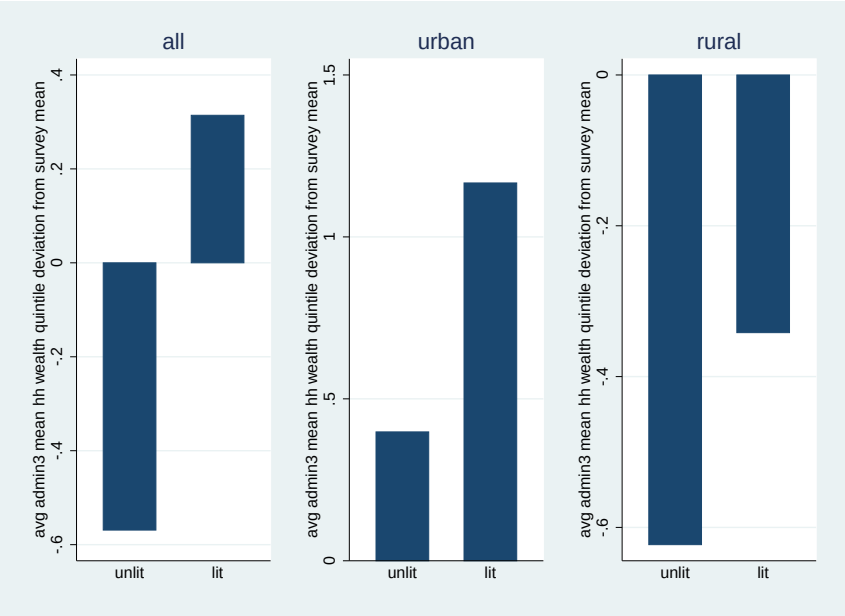


Figure 6: Luminosity - DHS Wealth Index Association Mozambican Admin 3

DHS composite wealth index is always larger for the lit administrative units compared to the unlit ones. The difference is particularly pronounced for urban regions where the average DHS wealth index is almost three times larger than the unlit counterpart. A similar pattern applies to rural districts.[4] A regression analysis corroborates the graphical illustration. Being lit increases the DHS composite index by 1.5, that is almost half of the sample mean (3.21). As the graphs suggest, the effect differs between urban (an increase of 2) and rural (an increase of 0.32) administrative units.

In Figure 7 instead of looking at the composite wealth index, we report the means of the deviation from the sample mean of years of schooling separately for the lit and unlit admin-3 units. In lit districts, individuals report on average 1.8 more years of schooling, which is around 40% of the sample mean (4.67).

[4]The DHS team follows the Mozambique's National Institute of Statics (INE) definition of Urban - Rural classification. Urban population is defined as the population living in one of the 23 cities and 68 towns of Mozambique. The remaining part of the population is classified as rural.

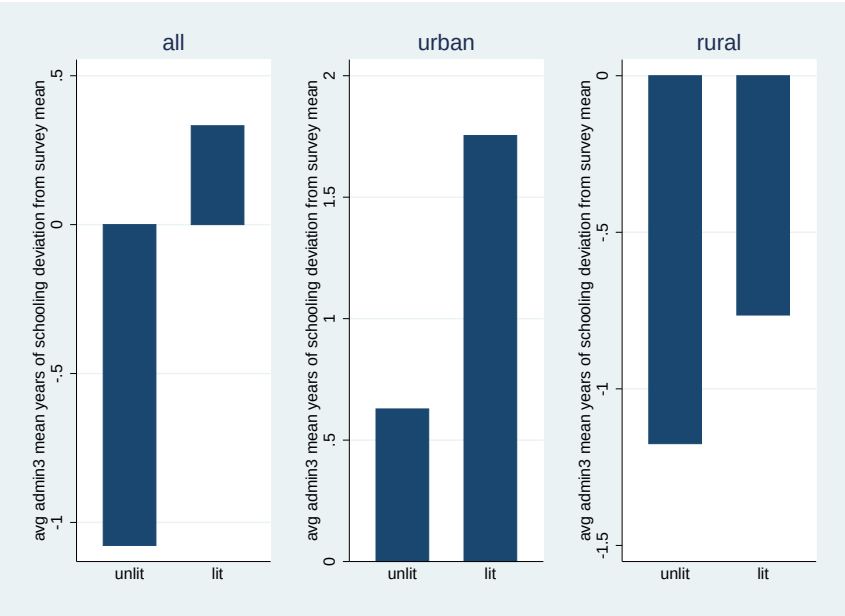


Figure 7: Luminosity - Education Association across Mozambican Admin 3

3 Luminosity and Education across Mozambican Localities. Evidence from the 1997 and 2007 Census

In an effort to cross-validate the luminosity data with development proxies at exactly our level of analysis, i.e., Mozambican localities, we managed to access the universe of the Mozambican Population and Housing Census in 1997 and 2007.[5] According to the 1997 Census, the total count of the Mozambican population was $15,529,300$ individuals; the 2007 census includes $20,579,265$ individual records. We aggregated the individual records at the locality level (four-level administrative units) using the 2007 administrative division shapefile. After merging the two censuses, we work with a sample of $1,154$ localities. As Barro and Lee (2013), we compute years of schooling for the adult population older than 15 years. The average years of schooling across localities for the 15+ population in 1997 is just 0.7 (with a standard deviation of 0.55), reflecting the devastating legacy of the war of independence and the subsequent civil war; in 2007 the average years of schooling across districts increases notably to 2.32 (with a standard deviation of 1). Turning now to satellite imagery on light density at night, luminosity is low both in both years. The percentage of lit localities was 15.9% and 23% in 1997 and in 2007, respectively.

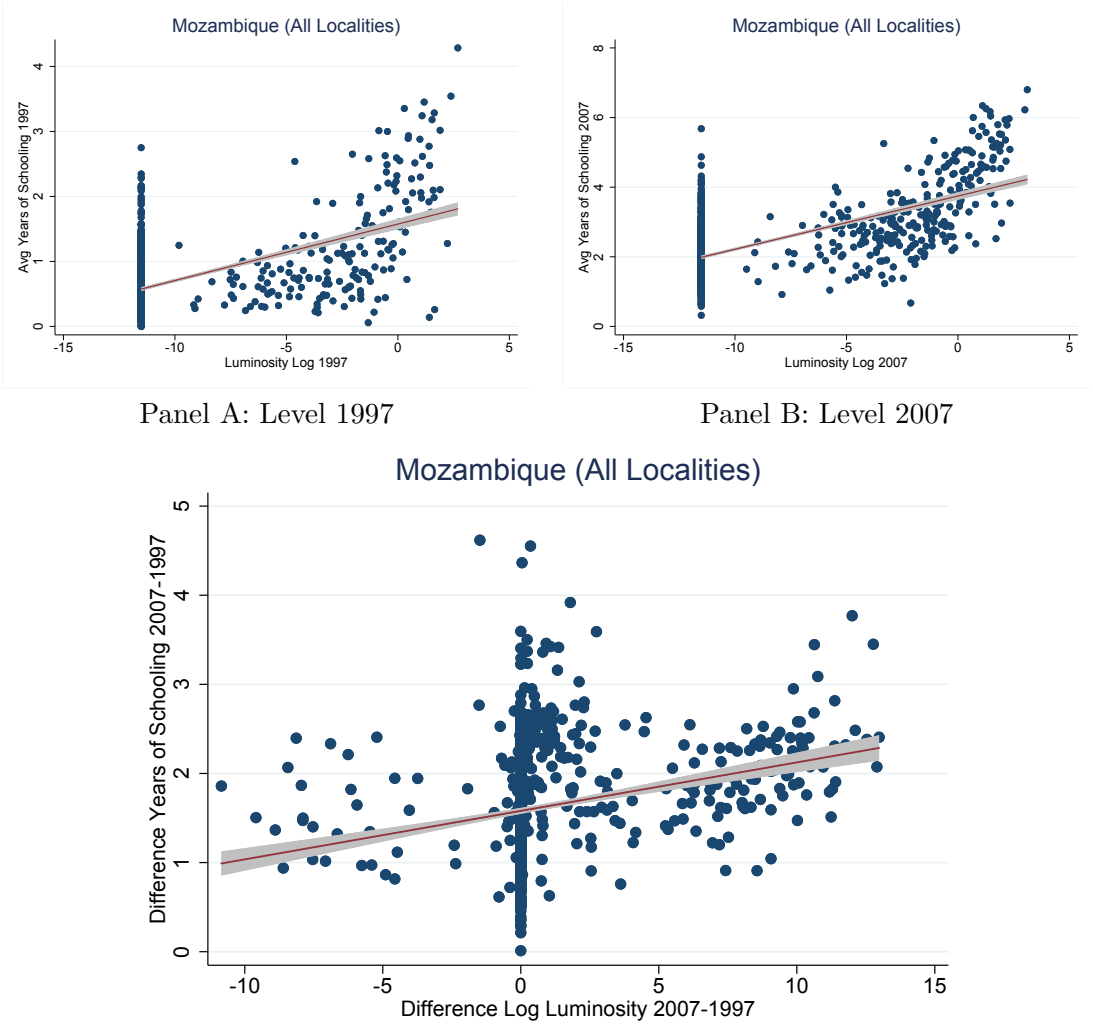
3.1 Baseline Cross-Validation

Figure 8 - Panel *A* plots average years of schooling against luminosity in 1997; as in the paper we take the log of the sum of lights in a given locality adding a very small number, we similarly add half of the minimum value of luminosity before taking the log. There is a positive and significant correlation between education and (log) luminosity. Table 1, column (1) reports the corresponding regression estimates; standard errors are (conservatively) clustered at the admin-2 region level to account for spatial correlation. The R^2 is around 0.3. In column (2) we associate mean years of schooling with a binary index that takes on the value one for lit localities and zero otherwise. Compared to unlit localities, mean years of schooling is 0.68 years higher in lit ones, a considerable difference given the low mean. Columns (3) and (4) repeat the analysis in 2007; this is after a decade of robust growth. The association between schooling and luminosity is positive and highly significant; the estimated slopes are larger, more precisely estimated, and the in-sample fit increases. Figure 8 - Panel *B* provides a visualization of the specification in column (3). The estimate in (4) suggests that mean years of schooling is 1.3 years higher in localities where the satellite detects some light.

Since in the paper we exploit the link between landmine clearance and luminosity over time, we also explored the correlation between changes in education and changes in luminosity across Mozambican localities. Figure 8 - Panel *C* portrays the significant within-locality correlation between luminosity and education. The estimate in column (6) suggests that mean years of schooling increase by 0.33 in localities that turn lit over the $1997 - 2007$ period compared to localities that remain unlit.

[5] At the time of the writing, the 2017 Census has not been released by the Mozambican statistical agency.

Figure 9 gives a graphical illustration of the coevolution of education and luminosity. The figure shows changes in mean years of schooling across four groups of localities: *i*) 29 localities that were lit in 1997, but unlit in 2007; *ii*) 881 localities that were unlit both in 1997 and in 2007; *iii*) 112 localities that while unlit in 1997 turn lit in 2007; *iv*) 156 localities that appear lit both in 1997 and in 2007. Mean years of schooling over this decade increased by 1.5 years in localities that were unlit both in 1997 and in 2007. In contrast, unlit in 1997 localities that turn lit in 2007 experience a considerably higher increase in mean years of schooling, 2 years on average. Hence, luminosity clearly reflects the growth in schooling years in these localities. The same applies when we look at lit localities in 1997. The increase in schooling is 1.5 years for those that in 2007 appear unlit. In contrast, the corresponding number for those localities that remained lit in 2007 is 2.2 years.



Panel A: Level 1997

Panel B: Level 2007

Panel C: Difference 2007 - 1997

Figure 8: Luminosity - Years of Schooling Association across Mozambican Localities

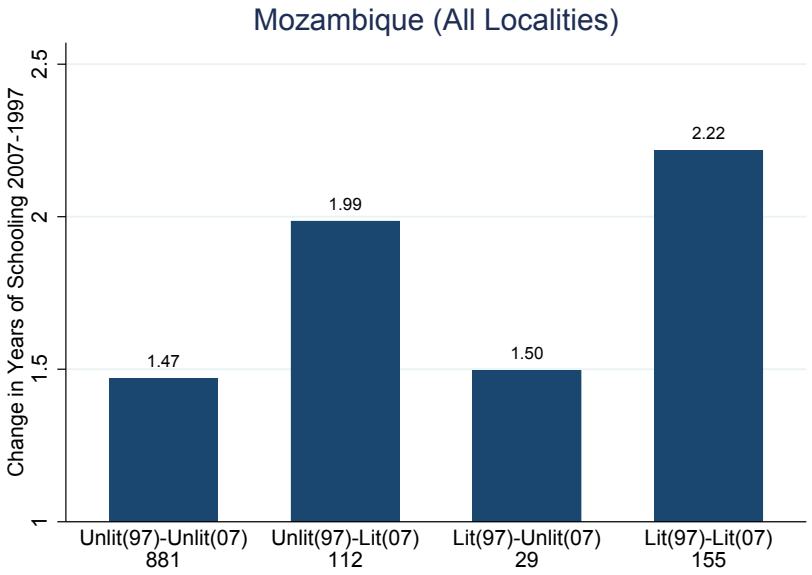


Figure 9: Change of Lit (Dummy) and Changes of Years of Schooling Association across Mozambican Localities

Table 1: **Luminosity and Years of Schooling (Census)**

	All Localities					
	Schooling 1997		Schooling 2007		Δ Schooling 2007-1997	
	(1)	(2)	(3)	(4)	(5)	(6)
Light Log 1997	0.087***					
	(0.008)					
Lit (Dummy) 1997		0.685***				
		(0.067)				
Light Log 2007			0.153***			
			(0.008)			
Lit (Dummy) 2007				1.306***		
				(0.083)		
Δ Log Light					0.054***	
					(0.006)	
Δ Lit						0.329***
						(0.046)
R-squared	.307	.206	.415	.301	.0718	.0367
Observations	1,154	1,154	1,154	1,154	1,154	1,154

Notes: This table reports OLS estimates associating the average years of schooling (Census 1997 and 2007) with luminosity. The dependent variable in columns (1)-(2) is the average years of schooling in 1997. In columns (3)-(4), the dependent variable is the average years of schooling in 2007; while, the dependent variable in columns (5)-(6) is the change in the average years of schooling between 1997 and 2007. Light Log 1997 (2007) is the log of luminosity plus the half of the minimum positive value of luminosity in 1997 (2007). Lit (Dummy) 1997 (2007) is an indicator that takes the value of one if the locality appears to be lit in 1997 (2007). Δ Light Log 2007 is the change of the log of luminosity plus the half of the minimum positive value of luminosity. Δ Lit (Dummy) is e change in the lit indicator over the period 1997-2007. Standard errors in parentheses are clustered at the district (admin 2) level. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

3.2 Cross-Validation across Rural Localities

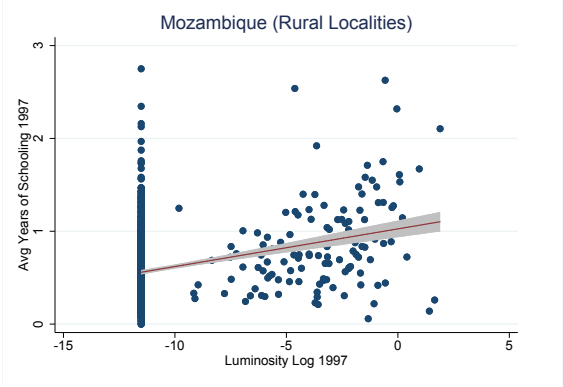
One may worry that the significant positive correlation between luminosity and education reflects differences between urban and rural areas; this is a particular concern for the cross-sectional estimates. We thus repeated the exercise focusing only on rural localities. Using data from the 1997 census, which classifies households as urban or rural, we compiled locality-specific means of urbanization. Given the very high levels of employment in agriculture (exceed 80% in both years) and low urbanization rates, 96% of Mozambican localities are exclusively rural; 100% of the population is classified as rural (not residing in the 23 cities or 68 towns that the statistical agency defines as urban). We observe urban households in just 104 localities[6].

Table 2 reports the regression estimates, while Figures $10a - c$ provide visualizations of the cross-sectional and the within-rural-locality correlation between years of schooling and luminosity. First, the cross-sectional correlation appears strong in both census years with either transformation of luminosity. The implied magnitudes are smaller as compared to the full-sample estimates. For example, the estimate in column (4) suggests that compared to unlit localities, mean years of schooling is 0.86 higher (while in the full sample the difference is 1.3). Second, the correlation in differences is also highly significant, suggesting that human capital accumulation moves in tandem with increases in luminosity in the rural parts of Mozambique. Figure $9c$ illustrates the strength of the $2007 - 1997$ difference association. The slope in the rural sample in (5) is similar to the one estimated in the full sample. The results with the lit indicator in column (6) are also similar to the full sample one (0.31 compared to 0.33). Figure 11 illustrates that satellite imagery of light density at night does capture increases in education across rural localities. Bars (1) and (2) plot changes in mean years of schooling for unlit in 1997 localities; schooling increases by 1.45 years in localities that remain unlit in 2007 and it increases by 1.91 years for those that turn lit in 2007. Bars (3) and (4) zoom in on lit in 1997 localities; those that stay lit in 2007 experience an increase of 2 years of schooling, while the analogous increase for those that turn unit is 1.47. Not only these differences are considerable, but they are very similar to the full sample ones, reported in Figure 9.

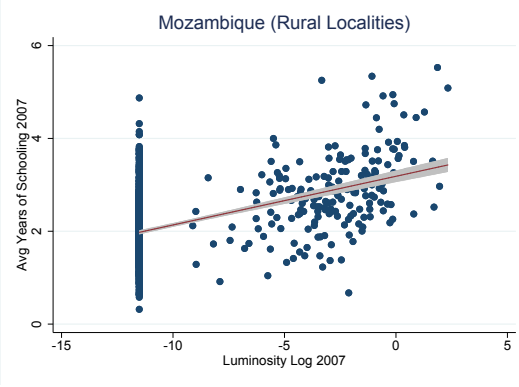
3.3 Summary

The cross-validation analysis across Mozambican localities with the 1997 and 2007 Censuses shows that luminosity correlates strongly with education at the same level as the unit of analysis employed in the paper. This applies not only to the cross-section but also over time. This is important as our analysis on the role of landmine clearance on spatial development, as reflected in luminosity, explores within-locality over time variation. The correlation between luminosity and education is strong also when we solely focus on rural localities.

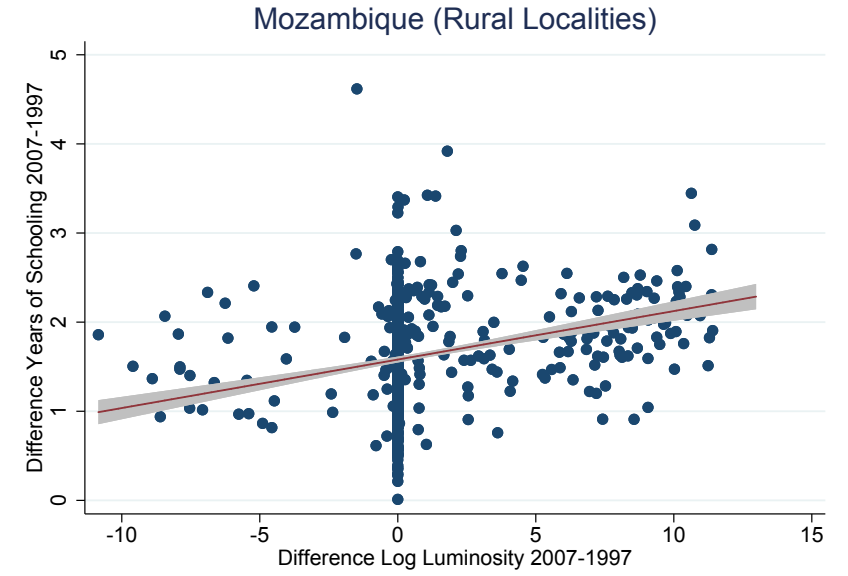
[6]The smallest town to be classified as urban from the Mozambique Statistical Institute is Vila de Nova Mambone (Govuro) in Inhambane province with a population of around 1800 inhabitants in 1997.



Panel A: Level 1997



Panel B: Level 2007



Panel C: Difference 2007 - 1997

Figure 10: Luminosity - Years of Schooling Association across Mozambican Rural Localities

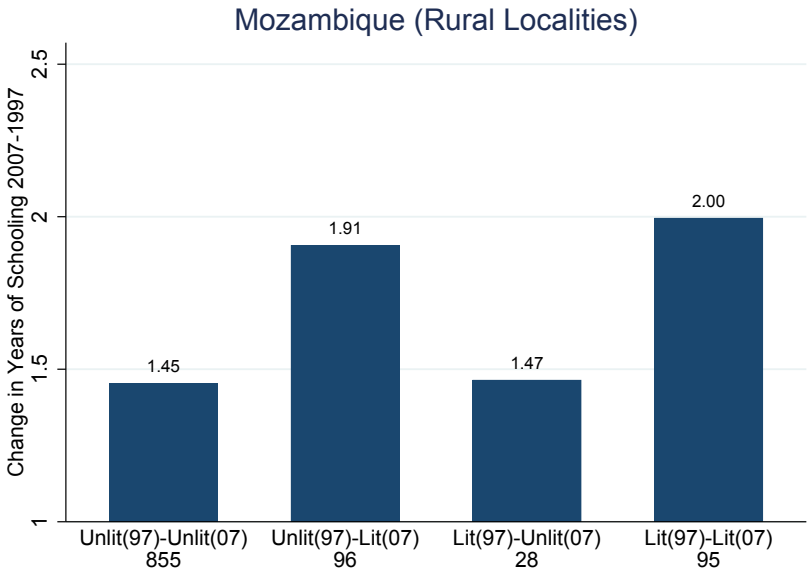


Figure 11: Change of Lit (Dummy) and Changes of Years of Schooling Association across Mozambican Rural Localities

Table 2: **Luminosity and Years of Schooling (Census)**

	Rural					
	Schooling 1997		Schooling 2007		Δ Schooling 2007-1997	
	(1)	(2)	(3)	(4)	(5)	(6)
Light Log 1997	0.041***					
	(0.007)					
Lit (Dummy) 1997		0.301***				
		(0.053)				
Light Log 2007			0.105***			
			(0.009)			
Lit (Dummy) 2007				0.856***		
				(0.079)		
Δ Log Light					0.049***	
					(0.006)	
Δ Lit						0.308***
						(0.049)
R-squared	.0835	.0639	.225	.183	.0647	.0395
Observations	1,050	1,050	1,050	1,050	1,050	1,050

Notes: This table reports OLS estimates associating the average years of schooling (Census 1997 and 2007) with luminosity. The dependent variable in columns (1)-(2) is the average years of schooling in 1997. In columns (3)-(4), the dependent variable is the average years of schooling in 2007; while, the dependent variable in columns (5)-(6) is the change in the average years of schooling between 1997 and 2007. Light Log 1997 (2007) is the log of luminosity plus the half of the minimum positive value of luminosity in 1997 (2007). Lit (Dummy) 1997 (2007) is an indicator that takes the value of one if the locality appears to be lit in 1997 (2007). Δ Light Log 2007 is the change of the log of luminosity plus the half of the minimum positive value of luminosity. Δ Lit (Dummy) is e change in the lit indicator over the period 1997-2007. Standard errors in parentheses are clustered at the district (admin 2) level. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

4 Luminosity and Education across Mozambican Localities. Heterogeneity

The analysis in the main paper reveals considerable heterogeneity. The panel estimates show that the correlation between landmine clearance and luminosity appears: (*i*) stronger for localities intersected by the colonial transportation network, as compared to non-connected ones; and (*ii*) stronger in localities that had agricultural markets (cantinas) before the civil war. Given the uncovered heterogeneity, we examined the correlation between luminosity and schooling separately across connected and non-connected localities as well as localities with and without cantinas. The analysis below shows that luminosity is a robust predictor of economic performance, as captured by mean years of schooling, across all these subsets of localities. These associations reassure that the uncovered differential association between demining and luminosity does reflect a heterogeneous response of local development to clearance (and it is not because luminosity does not predict well-being in non-connected to the transportation network localities without agricultural markets).

Table 3 reports the summary statistics of schooling and luminosity in the various subsets. We now look across $1,073$ localities for which we also have information from the 1980 population census. Table 4 tabulates localities with respect to transportation connectivity and the presence of rural agricultural markets.

Table 3: **Descriptive Statistics**

	Population 1997 Sample					
	Observations	Mean	Standard Deviation	Median	Min	Max
Avg Years of Schooling 1997	1154	0.701	0.553	.537	0	4.29
Light Log 1997	1154	-10.057	3.525	-11.5	-11.5	2.69
Lit (Dummy) 1997	1154	0.159	0.366	0	0	1
Avg Years of Schooling 2007	1154	2.321	1.002	2.09	.319	6.8
Light Log 2007	1154	-9.315	4.219	-11.5	-11.5	3.11
Lit (Dummy) 2007	1154	0.230	0.421	0	0	1
	Population 1980 Sample					
	Observations	Mean	Standard Deviation	Median	Min	Max
Avg Years of Schooling 1997	1073	0.708	0.553	.549	0	4.29
Light Log 1997	1073	-10.020	3.555	-11.5	-11.5	2.69
Lit (Dummy) 1997	1073	0.164	0.370	0	0	1
Avg Years of Schooling 2007	1073	2.327	0.999	2.09	.319	6.8
Light Log 2007	1073	-9.277	4.243	-11.5	-11.5	3.11
Lit (Dummy) 2007	1073	0.234	0.424	0	0	1

Notes: This table reports the summary statistics for luminosity and mean years of schooling of population aged 15 and older.

Table 4: **Tabulation Localities by Connectivity and Cantinas**

	All Localities		Rural Localities	
	Number of Localities	Percentage	Number of Localities	Percentage
Non Connected	256	24	249	25.6
Unpaved and Trails	544	50.6	511	52.4
Paved and Railways	273	25.4	215	22
Non Cantinas	419	39	399	41
Cantinas	654	61	576	59
Total	1,073		975	

Notes: This table reports the number and the percentage of localities (i) intersected by paved roads of railroads; (ii) intersected by secondary (unpaved) roads or trails; and (iii) non-connected to the pre-independence (in 1973) transportation network. The table also reports the number and the percentage of localities with and without cantinas (local agricultural markets).

4.1 Connectivity to the Colonial Transportation Network

Figure 12 maps the road and railroad system just before independence in 1973. There are a handful of primary roads and just three main and two subordinate railway lines, connecting the port cities of Maputo, Beira, and Nacala with the interior.

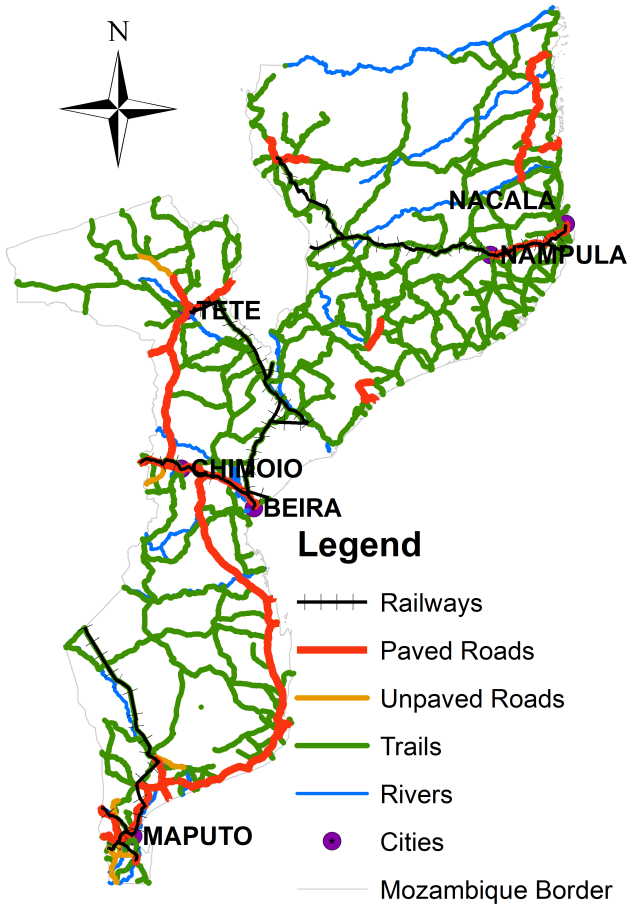


Figure 12: Distribution of Cantinas in 1965

The colonial transportation network system, albeit limited, intersects 817 localities. Railroads and primary roads intersect 273 localities, while 544 localities have secondary roads or trails. The colonial infrastructure network did not connect at all 256 localities.

Table 5 reports the within-locality correlation between years of schooling and luminosity across all (in columns (1)-(3)) and rural-only (in columns (4)-(6)) Mozambican localities, distinguishing between: (*i*) those connected via primary roads or railroads; (*ii*) localities connected via secondary roads or trails; and (*iii*) non-connected localities. For brevity, we omit the cross-sectional specifications that all yield highly significant correlations. Panel *A* reports estimates with log luminosity and Panel *B* with the lit/unlit binary index. Panel *A*, columns (1)-(3) show that changes in luminosity correlate

Table 5: **Luminosity and Years of Schooling (Census) - Heterogeneity on Transportation Network in 1973**

	Panel A. Log Luminosity					
	All Localities			Rural Localities		
	Paved & Rail	Unpaved & Trail	Non Connected	Paved & Rail	Unpaved & Trail	Non Connected
	Δ Schooling 2007-1997					
	(1)	(2)	(3)	(4)	(5)	(6)
Δ Log Light	0.033***	0.060***	0.045***	0.030***	0.055***	0.046***
	(0.010)	(0.010)	(0.012)	(0.010)	(0.012)	(0.012)
R-squared	.0451	.0759	.0413	.0387	.0681	.0437
Observations	273	544	256	215	511	249
	Panel B. Lit (Dumy)					
	All Localities			Rural Localities		
	Paved & Rail	Unpaved & Trail	Non Connected	Paved & Rail	Unpaved & Trail	Non Connected
	Δ Schooling 2007-1997					
	(1)	(2)	(3)	(4)	(5)	(6)
Δ Lit	0.169**	0.365***	0.283***	0.161**	0.336***	0.309***
	(0.078)	(0.082)	(0.090)	(0.069)	(0.097)	(0.091)
R-squared	.015	.0412	.0311	.0165	.041	.0367
Observations	273	544	256	215	511	249

Notes: This table reports OLS estimates associating the change in the change in luminosity between 1997 and 2007 with average years of schooling over the period 1997-2007, splitting the sample of localities connected through paved roads and railways [columns(1) and (4)], connected through unpaved roads [columns(2) and (5)] and trails, and non-connected [columns(3) and (6)] colonial transportation network. The dependent variable is the average years of schooling in 1997 in column (1)-(3); the average years of schooling in 2007 in column (4)-(6); and the in the average years of schooling between 1997 and 2007 in column (7)-(9). Log Light 1997 (2007) is the log of luminosity plus the half of the minimum positive value of luminosity in 1997 (2007). Δ Log Light is the change of the log of luminosity between 1997 and 2007. Lit (Dummy) 1997 (2007) is an indicator that takes the value of one if the locality appears to be lit. Δ Lit is the change of lit indicator over the period 1997-2007. Standard errors in parentheses are clustered at the district (admin 2) level. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

significantly with changes in schooling across all three subsets of localities. The slopes are comparable across connected and non-connected localities. This applies both to the full sample and when we focus on rural localities only (columns (4)-(6)). Panel *B* estimates are similarly significantly positive for non-connected and connected localities. Again this pattern is present when we look exclusively across rural areas. Increases in luminosity map into increases in schooling across all three types of localities. Moreover, the estimate in the non-connected regions that are likely to be somewhat less developed is not lower than in connected localities.

4.2 Colonial Cantinas

Figure 13 portrays the distribution of cantinas in the mid-1960s across the country. The cantinas were small-scale trading posts, usually owned and operated by Portuguese settlers or Asian migrants that bought local farmers' harvest surplus (e.g., cashews, corn, peanuts, cotton) and then sold it to the urban centers. At the same time, their owners (cantineros) sold seeds, textiles, fertilizers, domestic utensils, and agricultural implements to the locals. The exchange was often in barter and, in some

cases, cantinas provided trade credit to local farmers. Effectively cantinas were the main conduit of agricultural trade from the peasants to main urban hubs and factories (in the case of cashews).

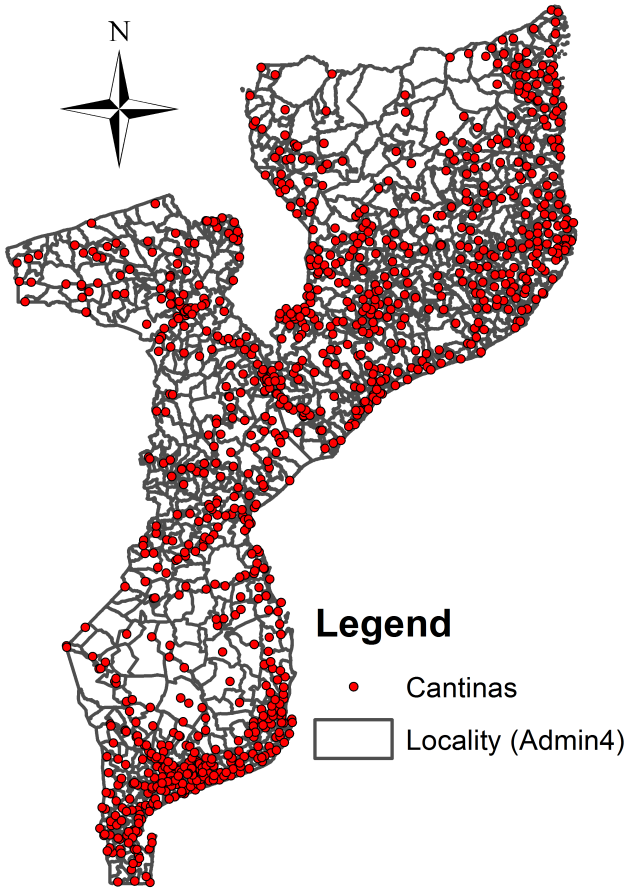


Figure 13: Distribution of Cantinas in 1965

We digitized the information on the exact location of cantinas and aggregated at the locality level. 693 (58%) localities have at least one cantina, while there are no cantinas in the remaining 494 localities (42%). The majority of the cantinas are in the South and in the North, as in the central provinces agricultural production was dominated by large concessionary firms. In the southern region, cantinas appear in 68% localities; while, in the northern provinces, 58% have at least one cantina. In central Mozambique, 50% of localities host a cantina.

Table 6 reports estimates from regressing changes in mean years of schooling over $2007 - 1997$ to changes in luminosity over the same period across localities with and without cantinas. Columns (1)-(2) report the estimates across the universe of localities, while columns (3) and (4) across rural ones. The slopes in Panel A where we use log luminosity on the RHS are highly significant across both groups of localities. Moreover, the estimates are quite similar between the two. In Panel B we use changes in whether a locality is lit between 1997 and 2007 on the RHS. The estimate is highly

significant and quite similar in magnitude for both groups.

Table 6: **Luminosity and Years of Schooling (Census) - Heterogeneity on Cantinas**

	Panel A. Log Luminosity			
	All Localities		Rural Localities	
	Cantinas = 1	Cantinas = 0	Cantinas = 1	Cantinas = 0
	Δ Schooling 2007-1997			
	(1)	(2)	(3)	(4)
Δ Log Light	0.054***	0.056***	0.047***	0.054***
	(0.007)	(0.010)	(0.007)	(0.011)
R-squared	.0826	.065	.0735	.059
Observations	654	419	576	399
	Panel B. Lit Dummy			
	All Localities		Rural Localities	
	Cantinas = 1	Cantinas = 0	Cantinas = 1	Cantinas = 0
	Δ Schooling 2007-1997			
	(1)	(2)	(3)	(4)
Δ Lit	0.319***	0.352***	0.281***	0.358***
	(0.059)	(0.093)	(0.058)	(0.100)
R-squared	.041	.0354	.043	.0365
Observations	654	419	576	399

Notes: This table reports OLS estimates associating the change in the change in luminosity between 1997 and 2007 with average years of schooling over the period 1997-2007, splitting the sample of localities with colonial Cantinas [column(1) and (3)] and localities without colonial Cantinas [column(2) and (4)]. The dependent variable is the change in the average years of schooling between 1997 and 2007. Δ Log Light is the change of the log of luminosity between 1997 and 2007. Δ Lit is the change of lit indicator over the period 1997-2007. Standard errors in parentheses are clustered at the district (admin 2) level. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

4.3 Summary

The analysis in this section shows that changes in luminosity are a robust predictor of changes in education across both connected to the colonial transportation network localities and those that are not connected. Furthermore, the luminosity-schooling link is equally strong in the sample of localities with local agricultural markets (during the colonial era) and in those without cantinas. Finally, changes in luminosity over time across rural Mozambican localities map into changes in economic activity as reflected in the number of years of schooling in each group of localities separately. These patterns assuage concerns that the heterogeneous association between demining and luminosity in non-connected localities (localities without cantinas) is due to the inability of satellite images at night to detect changes in economic performance in these rural regions.[7] Clearly this is not the case.

[7]Variation in luminosity changes between 1997-2007 can account for roughly 5% in variation in changes in years of schooling in each group of localities.

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