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School electrification and academic outcomes in rural Kenya

Author
Josephat Koima
Michigan State University
Department of Agricultural, Food, and Resource Economics

Abstract

Governments in developing countries are making large investments in infrastructure to boost development. This paper investigates whether such investments have immediate impacts on education by focusing on school electrification in Kenya. Between 2014 and 2016, the government of Kenya embarked on an extensive electrification project targeting all schools. Schools near the grid network were connect to grid electricity while those further received solar photovoltaics. This increased the share of schools with electricity from 56% in 2014 to 94% in 2016. The paper also attempts to quantify the effects of lighting on education performance by relying on the off-grid (solar) electricity coefficients. To get to the mechanism of interest – lighting – this paper relies on the fact that solar power was installed in areas that had no grid electricity. In addition solar power at schools provides lighting in classrooms and has no spillovers outside school. Using a universe of 8^{th} grade students in public schools in Kenya, the paper finds no evidence that electricity affects test scores or enrolment in the short run. However, off-grid electrification increases completion by 1%. Using off-grid estimates, the paper concludes that lighting has a small positive impact on completion but not on test scores or enrolment.

IMPACT OF SCHOOL OF ELECTRIFICATION ON ACADEMIC PERFOMANCE: EVIDENCE FROM RURAL ELECTRIFICATION PROGRAM IN KENYA

1. INTRODUCTION

A number of developing countries are embarking on extensive rural electrification projects in an effort to improve household incomes and welfare. Electrification can affect incomes directly and indirectly. Electricity expands the set of possible income generating activities and provides light for extended working hours, and consequently increases income **(**Khandker *et al*., 2009 (b)**)** – this is an example of a direct mechanism. Indirect mechanisms may include positive electrification effects on education and health which in turn can lead to higher incomes. Specifically, improved and cheaper electric lighting increases time available for studying and hence can improve educational outcomes. There is a general consensus that education is a crucial investment in human capital and thus has long run impacts on labor market outcomes. There is also evidence of excessive indoor household pollution resulting from excessive use of kerosene or firewood lighting which emit harmful gases and soot (Baron and Torero, 2017; Lam *et al*., 2012(b); Bates *et al*., 2013). Pollution is likely to affect both short term educational attainment due to sickness and affect long term health outcomes (Lim *et al*., 2012). Baron and Torero (2017) finds evidence that grid electrification significantly reduces indoor pollution in El Salvador. Electrification can therefore improve health outcomes by reducing respiratory and pollution-related illnesses. This paper zeroes in on education and attempts to quantify the effects of school electrification on educational outcomes –test scores, enrollment, and completion –among 8th grade primary school students. In Kenya, schools close to the grid network were connected to the grid electricity while those farther away were provided with off-grid (solar) power by the government. Consequently, this study also aims to test whether grid and off–grid (solar) electricity have different effects on the outcomes listed above.

There are several channels through which electrification can affect academic outcomes. This paper offers three examples. First, electrification outside of school can increase parents' participation in income generating activities (Khandker *et al*., 2009a: Dinkleman, 2011). This can translate to improved outcomes to the extent that more income results in increased purchase of school inputs.

In addition, increased income can allow parents to reduce demand for child labor which frees more time for studying and school attendance. Second, electricity provides light that allows more studying hours after sunset and before sunrise. In addition, it may increase study time by reducing time spent cooking or fetching firewood. Third, substituting wood–based or kerosene–based lighting with electric lighting can improve health outcome by reducing respiratory and eye illnesses caused by toxic soot and gases emitted by non–electric light sources. This in turn increases school attendance and also performance. With more study time, and good health, students are likely to attend school more and perform better at school. These changes can translate to more academic progression and consequently higher rates of school completion. While there are many mechanisms at play, the mechanism of interest in this study is lighting. To achieve this, this paper argues that solar electricity only affects school outcomes through its light, and has no impact outside of the school (unlike electricity). Thus solar coefficients provide estimates of the impact of electrification through lighting.

Estimating the causal impact of rural electrification on a number of economic outcomes is challenging due to the presence of confounding factors arising from policy decisions and socioeconomic factors. For instance, governments are more likely to develop infrastructure in areas with great economic potential. Additionally, political connections and influences are likely to influence these decisions. Besides, those who are politically connected are likely to be wealthy individuals. These factors make it difficult to quantify the causal impacts of electrification. The literature on rural electrification focuses mainly on economic outcomes such as income and employment with the effects on education usually not being the main focus of the studies. Other elated literature also have to content with a number of shortcomings in their identification strategies mainly due to absence of natural experiments. A number of studies offer suggestive evidence that rural electrification improves welfare growth of rural households but based on descriptive and correlational studies between rural electrification and development (ADB 2010; Barnes, Peskin and Fitzgerald 2003; Cockburn 2005; Khandker 1996; Martins 2005).

The Kenyan situation provides an ideal setting for this study. In Kenya, electricity supply expansion has been an important government goal. Beginning in mid–2013, the government through the Rural Electrification Authority (REA) engaged in an ambitious project to connect all public primary schools with electricity to support it's the government's Digital Learning Programme. This was implemented by extending grid electricity to schools close to the grid network and installation of solar photovoltaics in off–grid areas. This project saw the rise of primary schools with electricity from 48% in 2014 to 80% in 2016. Schools with solar power rose from 7% in 2014 to 13% in 2016. In aggregate, schools with power rose from approximately 56% in 2013 to approximately 94% in 2016. While households did not receive similar coverage, households with electricity increased from 27% in 2013 to 55% in 2016 following electrification of an addition of 1.3 million households. This policy shock provides a convenient environment to study the effect of electrification. The rapid nature of the project reduces the likelihood of confounding policy factors that may affect academic outcomes.

The data used in this study is an unbalanced panel of the universe of all schools in Kenya, with 8th grade students, from 2014 to 2016. The main source of variation in school electrification is driven by the government's push to electrify public schools. Specifically, 73% of private schools are connected to the grid electricity compared to 44% of public schools in 2014. However, over time, the number of public schools rises to 78% and catches up with private schools by 2016. Initially, the same share (7%) of both private and public schools have off–grid electricity but the share of public schools rises to about 13% by 2016. Given that private schools decisions on location and electrification status are likely to be endogenous, this paper restricts analysis to public schools only. The analysis is only for 8th grade students since examination data is only available and is nationally representative for 8th grade primary school students. Panel fixed effects provides flexibility in handling endogeneity concerns and is thus used as the primary identification strategy. The panel fixed effects model, finds no statistically significant effects of either grid or off–grid electrification on test scores and enrolment. However, there is some evidence that off–grid electrification may increase school completion by 1%. This is a small effect. This result may suggest that solar effects only provide positive benefits to a school while grid electrification potentially has negative spillovers outside of school. For instance, while light may encourage more completion, this effect is offset by students dropping out to exploit employment opportunities created by arrival of grid electrification. On net, these effects cancel out. Regarding the mechanisms at play, and relying on the solar coefficients, lighting has small but limited effects on academic outcomes. Therefore lighting alone may not be sufficient to boost educational outcomes without complementary academic inputs. The findings are robust to inclusion of private schools, exclusion of urban schools, and variation in clustering of standard errors. Overall, this paper finds weak evidence that electrification improves academic outcomes.

To the best of my knowledge this paper is the first to quantify the impact of electrification through lighting on education outcomes. In addition, I have not come across any study on education that jointly estimates the effects of solar and grid electrification. Finally, unlike many papers that focus on electrification at the household–level, this paper focuses on electrification at school. These contributions are important for several reasons. First, many papers do not attempt to isolate the channels through which electrification affect outcomes such as educational outcomes. Thus this paper attempts to tackle this missing part of analysis by attempting to isolate the effect of lighting. Second, the effects of grid and solar are likely to be different. Solar power at school level can only affect outcomes mostly through lighting and has no additional benefits outside of school. On the other hand, grid electricity at school can be an indicator of electrification outside of school. As noted in the literature below, electrification can have income effects which can ultimately affect education outcomes. Consequently, the solar coefficient will provide an ideal estimate for the effect of lighting. Jointly estimating the effects of solar and grid electricity allows for estimation of non–lighting effects of electrification. The underlying assumption is that, any differences between solar and grid electricity coefficients is a measure of additional effects of electricity outside of the lighting channel. One must, however, not push this idea too far because grid electrification may be more reliable and provide higher quality light than solar power. Thus, some of the results could be driven by these differences in quality and reliability of these power sources. Taking these and other caveats into consideration, the estimates of solar will provide lower bounds for the coefficients of interest. Household level studies, as reviewed below, do not attempt or are unable to easily isolate the mechanisms through which electricity affect education outcomes.

The remaining sections are organized as follows. Section 2 is a review of the existing literature. Section 3, is a brief description of the context and the data. Section 4, is a methodology section. This is followed by the results in section 5. Section 6 reports robustness checks, and finally section 7 is the conclusion.

2. LITERATURE REVIEW

In reviewing the existing literature, this paper splits the review into two major parts – grid and off-grid studies – and within each part provides literature on non-experimental and experimental studies. The first part begins with non-experimental followed by experimental studies on grid electrification. The bulk of the literature on grid use non-experimental methods given the difficulty in randomizing grid network. The second part focuses on off-grid electrification which is largely dominated by experimental methods. A common feature of these studies is that they are done at the household level. This paper diverges by focusing on electrification at school.

Several studies have investigated the impact of grid electrification on incomes and education outcomes. Comparing Vietnam communes with and without electricity, Khandker *et al*. (2009a) find that electricity has positive effect on both economic and educational outcomes. Electrification increases household's farm cash income by 30 percent, with no effect on non–farm income. Furthermore, it increases enrollment by about 10% for both boys and girls. The increase in years of schooling is limited to boys only with electricity increasing years of schooling by 0.52 (about 12% increase relative to year 2002 baseline). In related literature, Khandker *et al*. (2009 b), show electricity increases total household income by between 9 percent and 30 percent in rural Bangladesh. Educational outcomes also improve but the results are sensitive to the estimation approach. On the other hand, Dasso *et al*. (2015), find that grid electrification does not lead to substantial improvements in educational outcome. Taking advantage of a rapid expansion of electricity in rural Peru (Programa de Electrificación Rural) and relying household survey panel data, they find that rural electrification in Peru increases female enrollment but the effect does not translate to improved attendance. Surprisingly, using school–level panel data, electrification reduces learning in Math and Reading. However, longer exposure among treated schools increases scores in Reading among boys and girls but Math improvement is only observed among boys. This finding is consistent with the literature that show that technological innovations may take time before impacting student school outcomes (Kho, Lakdawala, and Nakasone, 2018)

Some studies rely on geographical influence on grid electrification process to overcome identification issues. Libscomb *et al*. (2013) exploit the heavy reliance of hydro power and the geographic considerations that influence the location of hydro–electricity dams to study the effect of electricity on development in Brazil. Using water flow and river gradients to instrument for electrification, they find large positive effects on income, and, educational literacy and school enrollment. Results show that going from no electricity to full electrification in a county leads to a reductions in the illiteracy rate of 8 percentage points (25 percent drop at the mean) and reduction in the proportion of the population with less than four years of education of 21 percentage points (32 percent decrease at the mean). However, the largest gains were experienced in years of schooling, which increased by two years (about a 72 percent increase at the mean). This suggests that more children obtained post–primary (or grade four) education, which may have ultimately led to labor productivity increases. In a similar spirit Dinkelman (2011) studies the impacts of electrification on employment in rural South Africa. Using land gradient as an instrument together with a fixed effects model, she finds that electricity increases female employment in treated areas.

Experimental evidence of impacts of electrification on educational outcomes are rare. This is largely driven by the fact that it is difficult to randomize grid electrification. Fortunately, certain policies and technological advancements have created opportunities for experimental interventions. For instance, Randomized Encouragement Designs (RED) can be employed to create exogenous variation in electricity access. Bernard and Torero (2013) are the first to implement this design on electrification in a developing country. Subsequently, it is employed by Barron and Torero (2014) in El Salvador. They find evidence of grid leading to increased time allocated to educational activities, increased participation in non-farm income generation activities but also children engaging more in household chores.

Technological innovations and desire for sustainable energy sources has also led to rise in use of portable sources of power such as solar panels and solar–powered devices including solar lamps. Consequently, there is a nascent literature that provide experimental and non–experimental evidence on the effects of solar power or solar–powered lanterns on education performance. Generally, except for a few studies, the findings tend to support the hypothesis that solar power leads to improvement in a number of measures of school outcomes. However, there is mixed evidence on the effects on academic performance. These papers include Furukawa (2014), Barron and Torero (2014), Arráiz and Calero (2015), Kudo and Takahashi (2017), Hassan and Lucchino (2017), Aevarsdottir, Barton, and Bold (2017).

Non-experimental studies on solar power included works by Arráiz and Calero (2015). Using household–level and individual–level data and employing propensity score matching techniques, Arráiz and Calero (2015) estimate that solar–powered home systems (SHSs) in rural Peru increases children study time, years of schooling (among elementary school students) and higher rates of enrollment (in secondary school). Specifically, enrollment increases by 12 percentage points for those enrolled in high/middle school. In addition, it leads to an increase in years of schooling by 0.4 from a base of 3.2 years, and increase in time spent studying by 9 minutes from a baseline of 84 minutes per day.

The most common experimental study on the effects of solar power involve the use of solar lamps. Furukawa (2014) conduct a randomized experiment involving 204 participants in Uganda where some participants received solar lamps among 5th and 7th grade students. After 5 months, the paper reports some evidence that the solar lamps increased daily study times by 30 minutes but surprisingly lowered academic performance. In particular, test scores for mathematics and English declined by 0.25 standard deviations, with high performing students (top quintile) experiences largest declines of 0.8 standard deviations. The author explains that these results could be driven by measurement error of study times as students lacked watches/clocks at home, inadequate charging of lamps leading to flickering lights, and possible intra–household factors that limited the use of the lamps for studying. These results are also limited by the small sample size, short observation time of 5 months, and also due to the adverse weather occasioned by the rainy season that minimize ability to charge solar lamps. While this study conducts the experiment at the school level, the use of solar lamps is not restricted to school. These solar lamps are available at home and are subject to be used for other purposes besides studying. Unlike Furukawa (2014), Hassan and Lucchino (2017) find positive effects and spillovers among 7th grade students in a similar experiment in Kenya. The authors report improved math scores of 0.88 standard deviations among treated students in a class with average treatment intensity (43%). In addition, there is evidence of spillovers as an increasing the share of treated students by 10% leads to a 0.22 standard deviation increase in scores of control students. The study provides some evidence suggesting that this spillover is largely driven by within–school interactions through co–studying after sunset. The co-studying spillovers are likely to be larger in a school setting than in households because schools provide larger avenues and central location for studying.

Small sample sizes are common in experiments due to logistical or funding constraints. Aevarsdottir, Barton and Bold (2017) conduct a solar lamp experiment with a large sample involving treating 1800 households with students in one of 60 schools in Tanzania. The experiment randomly provided full, partial, or no subsidies towards purchase of a solar lamp with the capability of charging mobile phones. They find that purchase of a solar lamp leads in a 25% increase in income. Adult labor participation on both the extensive and intensive margin rise by between 10% and 20%. Unlike in Barron and Torero (2014), improvement in labor force participation by adults does not lead to increase in child labor participation. Unfortunately, the study finds no evidence of improvement in education outcomes such as enrollment, attendance, and time spent studying. While the It is thus unlikely that the treatment would have had any positive effects on academic performance. These results are similar to those reported in an experimental setting in Bangladesh where outcomes were muted (Kudo, Shonchoy and Takahashi, 2017).

As evidenced by the literature above, most of the studies look at the impact of electrification at the household level. These studies document significant impact of electrification on incomes and labor demand which are likely to have also influenced the findings on educational outcomes. As such, these studies are unable to quantify the direct (non-monetary) impact of electrification on education and also cannot distinguish the channels through which electrification affects educational outcomes. In the latter experimental studies, the use of solar lamps limits the ability to isolate the impact of solar power as these lamps are portable and available for use outside of school. The use of solar lamps at home is subject to competing uses at home and may underestimate the true impacts of solar light on academic outcomes. Besides, if household chores are prioritized when the solar lamp is being used, and given that solar lamps typically provide power for a few hours, by the time students get the chance to study, the solar lamp light will likely be dimmer. In addition, solar lamps at home may lead to improvement in incomes either through charging of phones or through extended time engaging in income–generating activities (Aevarsdottir, Barton and Bold, 2017). This increased income can lead to more purchase of inputs for students. Finally, the solar lamps are likely to provide weaker lamination compared to both grid and photovoltaic solar panels (used in Kenyan schools). This paper on the other hand overcomes these challenges by studying presence of solar power that is used only at the school and by relying on solar photovoltaic power that provides higher quality lighting than solar lamps.

3. DATA DESCRIPTION

Context

The Kenyan education follows an 8-4-4 system. The 8-4-4 is designed so that ideally a student spends 8 years in primary school, 4 years in secondary school, and 4 years in university. Students start school in pre-school which lasts three years before the 8-4-4 system kicks in. Following the completion of pre-school, students enroll in primary schools for a period of eight years. Each school year is split into three semesters with school sessions starting in January and lasting three months with a one month intervening break. Primary school education culminates in the final national exam – the Kenya Certificate of Primary Education (KCPE). This is a very competitive standard national exam whose results are used to admit students to secondary school. Secondary school lasts four years. After four years, secondary school students must sit the national exam – Kenya Certificate of Secondary School (KCSE). This exam determines entry into university and the type of majors that student are eligible to pursue. This study focuses on the KCPE examination results for the 8^{th} grade students. This is because it is the only nationally representative examination results for primary school students. In addition, most secondary schools already have electricity, and hence has little variation in school electrification. Completion is defined as taking the KCPE exams while enrolment represents the number of 8^{th} grade students at the beginning of the year. The national examination scores and school completion data was provided by the Kenya National Examination Council. School completion is defined as having taken the 8^{th} grade national examination data. Examination covers five subjects, English, Kiswahili, Mathematics, Science, and Social Studies. The maximum score for each subject is 100 while the minimum score is 0. In the regression analysis the test scores are standardized to have a mean 0 and a standard deviation of 1.

This study uses data from all primary schools that had 8th grade students during the period of study (2014–2016). The unit of analysis is the school. Data on school electrification and school characteristics were obtained from the Ministry of Education Kenya which liaises with the school principals in collecting these data. The data is typically collected between October and November each year through a national primary school census. Data on school characteristics was gathered from the Ministry of Education. The school characteristics available include infrastructure – temporary and permanent classrooms, toilet facilities, primary sources of water, number of privately and publicly hired teachers, number of students (enrolment), school location (rural/urban), school ownership (private/public), school accommodation type (day, boarding or day and boarding), school gender (girls only, boys only, or mixed). Test score and school completion data is available from the Kenya National Examination Council (KNEC) which administers and grades the primary and secondary national exams. KNEC is an independent entity within the Ministry of Education.

School electrification variation is largely driven by the nationwide campaign to provide electricity to all public schools. This project started in an attempt to implement the government's Digital Learning Programme. The government intended to supply laptops to every first grade student in primary school and provided digital access of educational content. This was a major campaign promise that the president had pledged in the run up to the 2013 elections. Upon winning the elections the new administration embarked on an ambitious program to electrify schools to enable its digital learning program and also to improve access of households to electricity. Unlike in previous cases, the government intended to supply electricity specifically to schools and other public facilities. As of June 2013, out of a total of 21,222 primary schools in the country, 48% had access to electricity. However, by 2016, 80% of the 34,124 schools had electricity. Public schools largely drive the changes in electrification during this period. Specifically, by 2014, 8,522 public schools had grid electricity while 1,582 had solar. By 2015, the number of public schools with grid increased to 12,970 while solar schools doubled to 3,604. Finally by 2016, 16,403 public schools had grid electricity while the number with solar remains steady at 3,543. Meanwhile, the total number of public schools only rose by less than 2000 from 21,625 in 2014 to 23,439 in 2016. The rapid nature of the project reduces the likelihood of confounding policy factors that may affect academic outcomes. In determining routes for new electric transmission lines, the government "first looks at major corridors, such as existing utility lines, roads, and railroads before considering other areas" - according to the government-owned Kenya Electricity Transmission Company Limited (KETRACO). Most of these utility lines, roads, and railroads have been in existence for a long while before 2013. While the government has invested large sums on infrastructure, most of these funds are channeled towards upgrading or repairing of existing infrastructure. As a result, concurrent infrastructure are unlikely to have been completed in time to alter the existing network of utilities, roads, and railroads in a manner that affected the trajectory of the grid network. In addition, public schools do not have flexibility in choosing where to locate. Typically, the government and the community agree on a location of a school based on the population density. Generally speaking, in rural areas, new schools are built equidistantly from the nearest two or more schools to balance the distribution of schools across a geographic location. Given the speed of electricity rollout and these rigidities in infrastructure development and the location of public schools, the connection of schools to the grid is likely to have been exogenous. However, this paper takes additional steps to address potential endogeneity issues using panel fixed effects at the school level and by controlling for a number of school level observables. In addition, it includes variables to absorb school and regional time-varying unobservable. Electrification projects tend to be implemented regionally and as argued the main factors influencing electricity roll-out were likely fixed within the short period of 2014-2016. This paper argues that the factors that could have influenced electrification remain largely unchanged at the school level and thus the identifying assumption is that conditional on school fixed effects, electrification was largely exogenous.

Summary statistics

The data contains an unbalanced panel of three years from 2014 to 2016 for the main analysis. These were the only years in which the government had digitized records of school data. Table 1 below shows the summary statistics of the main variables of interest. The statistics are derived from the observations used in the panel analysis which restricts the sample to only public schools. Any observations not used in the regression analysis are excluded. This paper uses the universe of all 8^{th} grade schools that have all the data available. This summary is for the 2014 and 2016 which correspond to the beginning and the end of the study period.

The test scores shows that schools with grid electricity outperform those with off–grid and those without electricity. Similarly, schools with off–grid electricity generally outperform those without electricity though by a small margin and sometimes the difference is not statistically significant. Schools with grid electricity tend to have higher enrolment and completion while those with off–grid have slightly lower enrolment and completion compared to schools without electricity.

School inputs are reported in student-input ratio for easy comparability across schools. Schools with off-grid and without electricity have similar student-book ratio while grid schools sometimes has slightly has a better ratio. Generally, by subject, 3-4 students share a single book. Compared to the control schools off-grid schools have a higher student-teacher ratio while grid has a similar student-teacher ratio to the control schools. As shown by the student-classroom ratio, schools with either form of electricity initially are more crowded by about 2 extra students per class resulting in an average class size of 38 students. Water is useful for both consumption, cleaning and related sanitary conditions of the school. The statistics show that electrification is generally associated with access to better water sources (tap and borehole) with tap water being the largest predictor of electrification.

To highlight the importance of school ownership on electrification status, this paper includes statistics of private schools in the summary but not in the regression. Public schools account for 92% of schools without electricity in 2014 but this share declines to 77% by 2016, largely driven by increase in number of public schools receiving grid electrification. During this period, public schools accounts for 82% of schools with off-grid electricity in 2014 but this hare rises modestly to 85% by 2016. Further insights can be gleaned from looking at the distribution of schools with electricity within each school type. For instance, 72% of private schools are connected to the grid electricity compared to 44% of public schools in 2014. However, over time, the number of public schools rises and catches up with private schools by 2016. Initially, the same share (7%) of both private and public schools have off–grid electricity but the share of public schools rises to about 11% by 2016 with little change to the share of private schools.

Table 1: Summary statistics

Statistic	2014					2016				
	No light	Off-grid	Grid	Off-grid - No Light	Grid - No light	No light	Off-grid	Grid	Off-grid - No Light	Grid - No light
School Mean Score (out of 500)	238	241	248	*3****	*10****	236	235	245	*1.5*	*9****
Enrolment (Total)	367	376	499	*9*	*132****	349	335	431	*-14**	*81****
Enrolment (8th Grade)	33	31	51	*-2****	*18****	31	28	45	*-3****	*13.35****
Completion	32	30	50	*-1.88****	*18****	31	28	44	*-2.75****	*12.87****
Pupil-Books Ratio (4-8 grade)										
Math	2.99	2.97	2.97	*-0.02*	*-0.02*	2.97	2.8	2.77	*-0.17*	*-0.2*
English	2.8	2.84	2.69	*0.04*	*-0.11**	2.62	2.74	2.55	*0.12*	*-0.07*
Kiswahili	3.06	3.06	3	*0*	*-0.06*	2.66	2.83	2.65	*0.17*	*-0.01*
Science	4.28	4.36	4.39	*0.08*	*0.11*	4.35	4.41	3.75	*0.06*	*-0.6****
Social studies	4.08	4.34	3.87	*0.26*	*-0.21**	4.02	4.16	3.53	*0.14*	*-0.49***
Main Source of Water										
No water	10%	6%	4%	*-4%*	*-6%****	12%	8%	5%	*-4%****	*7%****
Rain	32%	28%	24%	*-4%*	*-8%****	31%	28%	25%	*-3%***	*-6%****
River	24%	25%	16%	*2%**	*-8%****	22%	27%	16%	*5%****	*-6%****
Tap	19%	17%	38%	*-2%*	*19%****	17%	14%	32%	*-3%***	*16%****
Borehole	16%	24%	18%	*8%****	*2%****	18%	24%	22%	*5%****	*3%****
Government Teachers	-	-	-	-	-	17.15	14.16	21.78	*-2.99****	*4.63****
Private Teachers	-	-	-	-	-	4.64	5.73	4.89	*1.09****	*0.25**
Total Teachers	-	-	-	-	-	20.03	18.32	24.73	*-1.71****	*4.7****
Students-Teacher Ratio	-	-	-	-	-	17.62	18.97	17.42	*1.35****	*-0.2*
Permanent Classrooms	8.3	7.76	11.4	*-0.54*	*3.1****	7.95	7.63	10.32	*-0.32****	*2.37****
Temporary Classrooms	2.26	2.35	2.07	*0.09*	*-0.19****	2.26	1.76	1.81	*-0.5****	*-0.45****
Total Classrooms	10.32	9.88	13.23	*-0.44*	*2.91****	9.32	8.84	11.23	*-0.48****	*1.91****
Students-Classrooms Ratio	36	38.28	37.63	*2.28****	*1.63****	37.5	37.23	37.6	*-0.27****	*0.1*
Teacher-Toilet Ratio						9.39	9.17	10.12	*-0.22**	*0.73****
Student-Toilet Ratio	38.9	46.13	34.82	*7.23****	*-4****	39.25	45.03	34.67	*5.78****	*-4.58****
Ownership										
Private	8%	18%	25%	*9.9%****	*17%****	23%	15%	21%	*-9%****	*-3%****
Public	92%	82%	75%	*-9.9%****	*-17%****	77%	85%	79%	*9%****	*3%****
Rural	98%	99%	91%	*1.2%****	*-7%****	99%	99%	94%	*1%****	*-4%****
Urban	2%	1%	9%	*-1%*	*7%****	1%	1%	6%	*-1%****	*4%****
Obs	8,655	1,241	7,794			1,883	1,978	14,024		

*Standard errors in parenthesis. * p<0.10, ** p<0.05, *** p<0.01.*

Overall, while there are some differences between schools based on electrification status there is no consistent pattern of differences between schools with electricity and those without. In addition, the differences in attributes tend to be minor particularly for school student-input ratios. In addition, schools without electricity and those with off–grid electricity are qualitatively similar in characteristics.

4. IDENTIFICATION STRATEGY

If the electrification process was random, the impacts could be estimated using the naïve OLS specified as follows:

$$Y_{sczt} = \beta_0 + \boldsymbol{ELEC}_{cszt}\boldsymbol{\beta_1} + \varepsilon_{sczt} \ (1)$$

where Y_{sczt} is the outcome of interest at school s, in county c, in zone z, and at time t. ELEC is a vector of electricity dummy variables for grid electricity and off–grid electricity. The counterfactual is having no electricity. The ε_{sczt} is the error term. In this model β_1 would be the coefficients of interest estimating the average treatment effects of electrification. However, electrification was not randomized and thus estimating equation (1) is likely to yield contaminated coefficients of interest due to omitted variables that are likely to be correlated with the electricity connection and also affect outcomes of interests. To address these issues, I add school–level controls and time and region fixed effects as follows:

$$Y_{sczt} = \beta_0 + \boldsymbol{ELEC}_{sczt}\boldsymbol{\beta_1} + \boldsymbol{X'}_{sczt}\boldsymbol{\beta_2} + \delta_z + \delta_t + \varepsilon_{sczt} \ (2)$$

where $\boldsymbol{X'}_{sczt}$ are observable school characteristics such as infrastructure, teacher and student demographics and characteristics. δ_z are zone fixed effects which capture factors that are common across schools within a zone that are fixed over time. δ_t are year fixed effects which control for factors that are fixed for all schools within time t.

Specification (2), however, does not address unobserved school-level fixed factors. Consequently, I use a panel fixed effects model as follows:

$$Y_{sczt} = \beta_0 + ELEC_{sczt}\boldsymbol{\beta_1} + \boldsymbol{X'}_{sczt}\boldsymbol{\beta_2} + \delta_s + \delta_t + \varepsilon_{sczt} \ (3)$$

where $\boldsymbol{X'}_{sczt}$ are observable school characteristics such as infrastructure, teacher and student demographics and characteristics. I include δ_s which are school fixed effects which capture time invariant characteristics of the school while δ_t are year fixed effects which control for factors that are fixed for all schools within time t.

The underlying identification assumption in specification (3) is that the omitted variables are time invariant at the school–level. While specification (3) addresses most of the endogeneity concerns raised previously, it does not address the issue of time–varying omitted factors that are likely to be correlated with electricity connection and the outcome of interest. Following, previous literature, I argue that the time variant characteristics are likely to be correlated with baseline school characteristics. The preferred specifications (4) therefore includes a linear time trend that allows baseline characteristics to differentially affect outcomes with time. Thus, the main identifying assumption of this paper is that, conditional on these set of controls, school electrification was exogenous.

$$Y_{sczt} = \beta_0 + \boldsymbol{ELEC}_{sczt}\boldsymbol{\beta_1} + \boldsymbol{X'}_{sczt}\boldsymbol{\beta_2} + \boldsymbol{X'}_{scz0} * \boldsymbol{t\beta_3} + \delta_s + \delta_t + \varepsilon_{sczt} \quad (4)$$

5. MAIN RESULTS

The preliminary findings based on panel fixed effects. The tables below report outcomes on test scores, attendance, and completion for 8th grade students in Kenya. The unit of observation is school. These regressions are based on variations of specification (4).

Part 1: School test scores

The general format of the tables starts with a simple panel fixed effects regression of the outcome variable on electrification variable and then proceeds with addition of controls and clustering of errors. In Table 2, specification (1) regresses test scores on electrification status only. To address potential omitted variable bias, specification (2) adds school level controls to specification (1). However, specifications (2) does not account for important omitted time varying school–level factors. There is no obvious or best method to address this issue. However, time varying confounding factors are likely to be correlated with the characteristics of the school. In line with

Table 2: Effects of School Electrification on School Mean Test Scores

	(1)	(2)	(3)	(4)
Off-Grid Electricity	-0.0210*	-0.0127	0.0020	0.0020
	(0.0121)	(0.0119)	(0.0122)	(0.0140)
Grid Electricity	-0.0230***	-0.0107	-0.0018	-0.0018
	(0.0069)	(0.0067)	(0.0078)	(0.0079)
Enrolment Boys (8th Grade)		-0.0075***	-0.0121***	-0.0121***
		(0.0003)	(0.0006)	(0.0012)
Enrolment Girls (8th Grade)		-0.0119***	-0.0092***	-0.0092***
		(0.0004)	(0.0006)	(0.0008)
Enrolment Boys (1st -7th Grade)		0.0002*	0.0006***	0.0006***
		(0.0001)	(0.0001)	(0.0002)
Enrolment Girls (1st -7th Grade)		0.0006***	0.0004**	0.0004*
		(0.0001)	(0.0002)	(0.0002)
Books 4-8th Grade (,00s)		-0.00002	-0.00008	-0.00008
		(0.0001)	(0.0001)	(0.0001)
Total Classrooms		-0.0004	-0.0007	-0.0007
		(0.0010)	(0.0012)	(0.0011)
Rain Water		0.0290**	0.0249	0.0249
		(0.0138)	(0.0186)	(0.0202)
River Water		0.0143	0.0353*	0.0353*
		(0.0142)	(0.0193)	(0.0208)
Tap Water		0.0283*	0.0319	0.0319
		(0.0156)	(0.0202)	(0.0216)
Borehole Water		-0.0031	0.0246	0.0246
		(0.0150)	(0.0203)	(0.0218)
Toilets - Boys		0.0000	0.0008	0.0008
		(0.0001)	(0.0012)	(0.0009)
Toilet - Girls		0.0004	-0.0002	-0.0002
		(0.0008)	(0.0012)	(0.0009)
Toilet - Male Teachers		-0.0071	-0.0045	-0.0045
		(0.0051)	(0.0072)	(0.0066)
Toilet - Female Teachers		0.0002	-0.0002	-0.0002
		(0.0011)	(0.0011)	(0.0005)
Constant	-0.229***	-0.0046	0.0098	0.0098
	(0.0051)	(0.0286)	(0.0318)	(0.0390)
N	52492	52492	52492	52492
R-Squared	0.00	0.05	0.06	0.06
School Fixed Effects	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y
Controls		Y	Y	Y
Initial controls x year			Y	Y
School Cluster				Y

*Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01.*

some existing literature, specification (3) includes an interaction of initial school characteristics and year. This will absorb some of the time varying confounders. Finally, specification (4) clusters standard errors at the school level since outcomes are likely to be correlated within the school over time. Failing to cluster will result in inflated/deflated standard errors leading to misleading p-values and inference interference. The remaining tables follow the same format. The “Y” in the tables indicates a “Yes”. All test-scores are standardized so that the national mean is 0 with a standard deviation of 1 every year. Thus all coefficients should be interpreted as changes in standard deviations.

Specification (1) indicates that electrification reduces school mean scores by 0.02 standard deviations. These estimates are statistically significant but they are also likely to suffer from omitted variable bias. Specification (2) confirms this suspicion as estimates increase by half to -0.01 and become statistically insignificant. Time varying confounders appear to also play a role in the estimates since estimates increase further when an interaction between 2014 school characteristics and time are included in the regression. Clustering of standard errors does not change the standard errors significantly. Taken together, the preferred specification (4) shows that off-grid electrification has a small positive but statistically insignificant effect on test scores while grid electrification has a small negative but statistically insignificant effect.

Quantitatively, these estimates are extremely small and hence the conclusion is that electrification has no effect on test scores at least within the short study period considered. Getting back to the mechanism of interest, lighting, this paper uses the estimates for off-grid to argue that the impact of lighting is positive but small. The negative effects of grid electrification may suggest that grid electrification may have negative impacts on test-scores outside of school. However, we cannot push this point too far as the estimates are quite small. These findings are surprising as one would expect electrification to improve school outcomes. One potential explanation could be that the effects take time and given the short nature of the panel data, observations within school are not sufficient to result in improved test scores. Kho, Lakdawala, and Nakasone (2018) provide evidence indicating that the effects of technological improvements may take time before affecting student performance. In summary, based on these results, grid and off–grid electrification have no differential impacts on test scores, at least in the short term.

Part 2: Enrolment

This part repeats the analysis of part 2 but focusing on enrolment as the outcome of interest. If electrification creates more study time and more study time results in improved performance, schools with electricity are likely to experience increases in enrolment. In addition, improved performance could lead to lower levels of dropping out. While Table 2 finds no effects on test scores, it is possible that anticipated improved test score by students following electrification can encourage students to enroll and stay at school. The estimates below test whether enrolment increases following electrification.

Table 3 reports panel fixed effects estimates. Unlike test scores, enrolment is in log forms. The format of the results is as in Table 2. Specification (1), which omits controls, indicates that both grid and non-grid electrification increases enrolment by 2.5%. Addition of school controls to the model increases estimates slightly to 2.6% and 2.8% for off-grid and grid electricity respectively. However, it appears that time varying confounders also affect enrolment in a significant manner. Once an interaction of initial school characteristics and time are included in specification (3), the coefficients shrink and become statistically insignificant. Specification (3) shows that electrification has a positive effect on enrolment of less than 1%. The results are robust to clustering of standard errors. Specification (4) indicates that off-grid electrification estimates are larger (0.7%) compared to grid electrification (0.3%). These estimates are in line with results from test scores. However, while off-grid electrification seems to have larger estimates than grid electrification, qualitatively, the estimates are similar for both types of electrification.

Part 3: Completion

Electrification can also affect completion. For instance, increased and better lighting hours from electrification can create conducive study environment for students. While we do not find any effect on test-scores, the results could be heterogeneous at the individual level. Thus if electrification increases test-scores for some individuals, it could also encourage staying at school. It is also important to note that student may stay longer in school if they have strong beliefs that electrification will positively affect their future performances. In the current context, the national exam (KCPE) is the ultimate exam that students study for, and if they believe that more study

Table 3: Effects of School Electrification on 8th Grade Enrolment (Dependent variable – log of enrolment)

	(1)	(2)	(3)	(4)
Off-Grid Electricity	0.0251***	0.0264***	0.0071	0.0071
	(0.0059)	(0.0059)	(0.0061)	(0.0069)
Grid Electricity	0.0246***	0.0281***	0.0026	0.0026
	(0.0034)	(0.0034)	(0.0039)	(0.0041)
Enrolment Boys (1-7th Grade)		0.0003***	0.0005***	0.0005***
		(0.0001)	(0.0001)	(0.0001)
Enrolment Girls (1-7th Grade)		0.0005***	0.0003***	0.0003***
		(0.0001)	(0.0001)	(0.0001)
Books 4-8th Grade (,00s)		-0.00001	-0.00001	-0.00001
		(0.0000)	(0.0001)	(0.0001)
Total Classrooms		0.0020***	0.0033***	0.0033***
		(0.0005)	(0.0006)	(0.0011)
Rain Water		-0.0108	-0.0151	-0.0151
		(0.0069)	(0.0093)	(0.0098)
River Water		-0.00321	-0.0189**	-0.0189*
		(0.0071)	(0.0096)	(0.0101)
Tap Water		-0.00659	-0.0139	-0.0139
		(0.0078)	(0.0101)	(0.0106)
Borehole Water		0.00792	-0.0172*	-0.0172
		(0.0075)	(0.0101)	(0.0107)
Toilets - Boys		0.0000	0.0006	0.0006
		(0.00003)	(0.0006)	(0.0008)
Toilet - Girls		0.0013***	0.0020***	0.0020***
		(0.0004)	(0.0006)	(0.0008)
Toilet - Male Teachers		0.0094***	0.0093***	0.0093**
		(0.0026)	(0.0036)	(0.0038)
Toilet - Female Teachers		-0.0001	-0.0001	-0.0001
		(0.0005)	(0.0006)	(0.0002)
Constant	3.515***	3.313***	3.304***	3.304***
	(0.0025)	(0.0140)	(0.0156)	(0.0251)
N	52366	52366	52366	52366
R-Squared	0.00	0.01	0.02	0.02
School Fixed Effects	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y
Controls		Y	Y	Y
Initial controls x year			Y	Y
School Cluster				Y

*Errors clustered at school level (specification 4). Standard errors in parenthesis. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.*

Table 4: Effects of School Electrification on 8th Grade Completion (Dependent: Log Completion)

	(1)	(2)	(3)	(4)
Off-Grid Electricity	0.0378***	0.0270***	0.0106**	0.0106**
	(0.0058)	(0.0044)	(0.0045)	(0.0053)
Grid Electricity	0.0286***	0.0145***	-0.0045	-0.0045
	(0.0033)	(0.0025)	(0.0029)	(0.0029)
Enrolment Boys (8th Grade)		0.0094***	0.0145***	0.0145***
		(0.0001)	(0.0002)	(0.0014)
Enrolment Girls (8th Grade)		0.0164***	0.0144***	0.0144***
		(0.0001)	(0.0002)	(0.0009)
Enrolment Boys (1st -7th Grade)		-0.0002***	-0.0006***	-0.0006***
		(0.0000)	(0.0001)	(0.0001)
Enrolment Girls (1st -7th Grade)		-0.0004***	-0.0001**	-0.0001
		(0.0000)	(0.0001)	(0.0001)
Books 4-8th Grade (,00s)		0.000003	0.000027	0.000027
		(0.0000)	(0.0000)	(0.0000)
Total Classrooms		-0.0001	0.0005	0.0005
		(0.0004)	(0.0004)	(0.0004)
Rain Water		-0.0025	-0.00954	-0.00954
		(0.0052)	(0.0068)	(0.0071)
River Water		-0.0031	-0.0186***	-0.0186**
		(0.0053)	(0.0071)	(0.0074)
Tap Water		-0.0034	-0.0219***	-0.0219***
		(0.0058)	(0.0074)	(0.0078)
Borehole Water		0.0021	-0.0143*	-0.0143*
		(0.0056)	(0.0075)	(0.0078)
Toilets - Boys		-0.000003	0.000468	0.000468
		(0.00002)	(0.00044)	(0.00062)
Toilet - Girls		0.0005	0.001**	0.001**
		(0.0003)	(0.0005)	(0.0005)
Toilet - Male Teachers		-0.00001	-0.00325	-0.00325
		(0.0019)	(0.0027)	(0.0023)
Toilet - Female Teachers		0.00005	-0.00013	-0.00013
		(0.0004)	(0.0004)	(0.0002)
Constant	3.490***	3.066***	3.045***	3.045***
	(0.0024)	(0.0107)	(0.0117)	(0.0311)
N	52492	52492	52492	52492
R-Squared	0.00	0.41	0.44	0.44
School Fixed Effects	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y
Controls		Y	Y	Y
Initial controls x year			Y	Y
School Cluster				

*Errors clustered at school level. Standard errors in parenthesis. * p<0.10, ** p<0.05, *** p<0.01.*

hours will translate to better final grade, they are likely to stay in school longer. In the spirit of the findings of Kho, Lakdawala and Nakasone (2018), students are also likely to have the same perspective about time invested studying leading to eventual positive results in the long-run. Finally, students may prefer co-studying and electrification increases opportunities for co-studying. This creates an attractive environment for students to learn and incentives to stay in school. On the other hand, it is possible that grid electrification outside of school may also have adverse effects on completion. For instance, jobs created from electrification can attract students leading to drop outs. Dinkleman (2011) find positive labor impacts of electrification for women in South Africa.

Table 4 above repeats the analysis of Table 3 but now with log of school completion as the dependent variable. Completion is defined as completing the 8th grade national exit exam (KCPE). Omitting school level controls, specification (1) shows positive and statistically significant impacts of electrification on completion. The off-grid estimates are slightly larger (3.8%) than grid estimates (2.9%). Specification (2) shows that estimates are biased from omitted school-level variables. Adding school-level controls decreases coefficients to 2.7% and 1.5% for off-grid and grid electrification respectively, but the estimates remain statistically significant. Specification (3) adds controls to remedy estimates from time-varying confounders. This results in estimates shrinking further. Specification (4) clusters standard errors at the school level but does not significantly affect outcomes. The preferred specification (4) indicates that off-grid electrification increases enrolment by 1% and this estimate is statistically significant. However, grid electrification has a small but negative coefficient.

The absence of positive effects for grid electrification on enrolment is surprising given that off-grid electrification has positive effects. One would expect that grid has stronger effects particularly since it is perhaps more reliable, might have better lighting quality, likely provides additional lighting and income opportunities outside of the school. One explanation of these results is that the completion estimates could be picking up some of the potentially negative effects of electrification outside of school. Presence of grid electricity at school implies that electricity is likely to be available in the areas near the school. If grid electrification encourages students to drop out of school to pursue jobs that come with electrification or distracts students (say through too much time spent on watching television), then electrification may result in more students dropping out of school. Alternatively, grid electrification may induce students at the margin of dropping out to stay in school longer but only temporarily – i.e. students may remain in school longer following electrification but not long enough to complete the national exit exam.

Since off-grid electrification is mainly benefiting students at school only, particularly through lighting, this paper argues that the off-grid coefficients provide lower bound estimates of effects of lighting from electrification. This paper argues that most of the off-grid electrification (1%) is coming through lighting.

6. HETEROGENEITY BY SUBJECT AND GENDER

In this section, the paper explores possibility of heterogeneous impacts of electrification on outcomes. For conciseness, the paper limits the analysis to test scores by subject and subsequently look at outcomes by gender. Studies in different countries have shown that treatment effects can vary by subject (Dasso *et al*., 2015; Furukawa, 2014; Hassan and Lucchino, 2017). One potential explanation for these findings is that students may choose to specialize on a few subjects when faced with time constraints. Lighting provides more study hours and this can allow students to increase study time dedicated to subjects that previously receiving less time. As a consequence, student performances may vary by subject. Gender has been shown to play an important role in different contexts. For instance, women generally have few economic opportunities globally in many sectors of the economy. In SSA, girls tend to have fewer education opportunities compared to boys due to cultural preferences for boys over girls. Studies on electrification and education have also documented gender differences in outcomes (Khandker *et al*., 2009a; Khandker *et al*., 2009b; Dasso *et al*., 2015).

Part 1: Test scores by subject

Table 5 reports the coefficient estimates of school test scores by subject. The subject test scores have been standardized to have a mean of 0, and a standard deviation of 1. Each column reports the preferred specification (4) used in the previous analysis.

Table 5: Effects of School Electrification on School Mean Test Scores by Subject

	English	Math	Kiswahili	Science	Social and Religious Studies
Off-Grid Electricity	0.0308**	0.0496***	-0.0500***	0.0039	0.0025
	(0.0122)	(0.0148)	(0.0150)	(0.0150)	(0.0138)
Grid Electricity	0.0057	0.0082	-0.0034	-0.0018	0.0061
	(0.0072)	(0.0081)	(0.0086)	(0.0087)	(0.0078)
Enrolment Boys (8th Grade)	-0.0100***	-0.0081***	-0.0116***	-0.0103***	-0.0091***
	(0.0009)	(0.0008)	(0.0013)	(0.0011)	(0.0010)
Enrolment Girls (8th Grade)	-0.0052***	-0.0097***	-0.0050***	-0.0161***	-0.0138***
	(0.0006)	(0.0007)	(0.0008)	(0.0010)	(0.0009)
Enrolment Boys (1st -7th Grade)	0.0004***	0.0002	0.0007***	0.0005***	0.0007***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Enrolment Girls (1st -7th Grade)	0.0004**	0.0007***	-0.0003	0.0008***	0.0006***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Books 4-8th Grade (,00s)	-0.00008*	-0.0002*	-0.00008	-0.00001	-0.00012*
	(0.0000)	(0.0000)	(0.0001)	(0.0000)	(0.0001)
Total Classrooms	-0.0004	-0.0009	-0.0005	-0.00228**	-0.0009
	(0.0009)	(0.0010)	(0.0012)	(0.0011)	(0.0010)
Rain Water	0.0358*	0.0005	-0.0089	0.0198	0.0160
	(0.0189)	(0.0199)	(0.0217)	(0.0220)	(0.0200)
River Water	0.0555***	0.0169	0.0249	0.0219	0.0254
	(0.0195)	(0.0207)	(0.0225)	(0.0228)	(0.0207)
Tap Water	0.0856***	0.0267	0.0369	0.00248	0.0172
	(0.0200)	(0.0214)	(0.0233)	(0.0235)	(0.0212)
Borehole Water	0.0356*	0.0070	-0.0115	0.0331	0.0221
	(0.0205)	(0.0215)	(0.0236)	(0.0240)	(0.0216)
Toilets - Boys	0.00003	0.00014	0.00049	-0.00030	-0.00215**
	(0.0008)	(0.0009)	(0.0010)	(0.0011)	(0.0010)
Toilet - Girls	0.0009	0.0025**	0.0011	-0.0019	-0.0002
	(0.0009)	(0.0012)	(0.0012)	(0.0012)	(0.0011)
Toilet - Male Teachers	0.0118**	0.0064	0.0044	-0.0026	-0.0083
	(0.0059)	(0.0064)	(0.0074)	(0.0072)	(0.0060)
Toilet - Female Teachers	0.0001	0.0010**	0.0000	-0.0004	-0.0006
	(0.0010)	(0.0004)	(0.0004)	(0.0007)	(0.0005)
Constant	-0.168***	-0.0218	0.0243	0.133***	0.0258
	(0.0332)	(0.0382)	(0.0422)	(0.0404)	(0.0377)
N	52492	52492	52369	52492	52492
R-Squared	0.05	0.06	0.04	0.08	0.07
School Fixed Effects	Y	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y
Initial controls x year	Y	Y	Y	Y	Y
School Cluster	Y	Y	Y	Y	Y

*Errors clustered at school level. Standard errors in parenthesis. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.*

Each estimates are from a panel fixed effects model with school-level controls, an interaction between initial school characteristics and time, as well as standard errors clustered at the school level. The results show evidence of heterogeneous treatment effects by subject both for grid and off-grid electrification. Grid electrification estimates positive for English, Math, and Social and Religious Studies but negative for Kiswahili and Science. However, these estimates are quantitatively small. Estimates are larger and statistically significant for off-grid electrification. Specifically, off-grid electrification increases test scores for English and Math by 0.03 and 0.05 standard deviations respectively. Kiswahili scores decrease by 0.05 standard deviations following off-grid electrification. The off-grid coefficient estimates for Science, and Social and Religious Studies are positive but small and statistically insignificant. Overall, this paper finds some evidence of heterogeneous treatment effects for off-grid electrification.

Part 2: Results by Gender

Table 6 explores heterogeneity by gender. For conciseness, this paper only reports the preferred full specification (4) which is a fixed effects panel with school controls and controls for time-varying confounders (the interaction between initial controls and time), in addition to standard errors clustered at the school level. Starting with test scores, electrification has a positive impacts for both boys and girls but the estimates are larger for girls. In addition, the estimates tend to be larger for off-grid than grid electrification. On the other hand, the estimates are not statistically significant. Consequently, this paper finds no evidence that the impact of electrification on test scores varies by gender.

Similarly, enrolment results shows a positive effect of electrification that are larger for girls than for boys and larger for off-grid than grid. However, these estimates are small and statistically insignificant. Turning to completion, off-grid electrification continues to have larger impacts, though quantitatively small, relative to grid electrification. Off-grid has positive effects while grid has negative effects. The impacts on girls tend to be larger but statistically insignificant. The only statistically significant result in this analysis is that grid electrification decreases enrolment of boys by 0.8%.

In summary, while there appear small differences in outcomes between boys and girls, the difference tend to be statistically insignificant. However, there is some suggestive evidence that grid electrification may draw boys away from school and hence decreasing enrolment. This can occur if electrification improves economic outcomes that require low skills.

Table 6. Heterogeneous Impacts by Gender - Test scores, Enrolment, and Completion

	Test Scores		Log Enrolment		Log Completion	
	Boys	Girls	Boys	Girls	Boys	Girls
Off-Grid Electricity	0.0060	0.0166	0.0050	0.0069	0.0086	0.01
	(0.0133)	(0.0136)	(0.0089)	(0.0104)	(0.0072)	(0.0081)
Grid Electricity	0.0018	0.0074	0.00205	0.0024	-0.0078*	-0.0028
	(0.0078)	(0.0074)	(0.0056)	(0.0059)	(0.0044)	(0.0044)
Enrolment Boys (8th Grade)	-0.0133***	-0.0107***	-	-	0.0291***	-0.0001
	(0.0013)	(0.0011)	-	-	(0.0028)	(0.0007)
Enrolment Girls (8th Grade)	-0.0086***	-0.0095***	-	-	-0.0021*	0.0319***
	(0.0008)	(0.0007)	-	-	(0.0012)	(0.0015)
Enrolment Boys (1st -7th Grade	0.0007***	0.0004***	0.000138	0.0007***	-0.0014***	0.0001
	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0003)	(0.0001)
Enrolment Girls (1st -7th Grade	0.0003*	0.0005***	0.0007***	-0.00003	0.0006***	-0.0008***
	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0002)	(0.0002)
Books 4-8th Grade (,00s)	-0.00007**	-0.0001***	0.00002	-0.00005	0.00002	0.000028
	(0.0000)	(0.0000)	(0.0000)	(0.0001)	(0.0001)	(0.0000)
Total Classrooms	-0.0015	-0.0004	0.0030**	0.0036***	0.0001	0.0008
	(0.0010)	(0.0008)	(0.0012)	(0.0012)	(0.0006)	(0.0005)
Rain Water	0.00483	0.0235	-0.0176	-0.00459	-0.0035	-0.0056
	(0.0199)	(0.0193)	(0.0135)	(0.0142)	(0.0105)	(0.0108)
River Water	0.0286	0.0347*	-0.0218	-0.00587	-0.0102	-0.0159
	(0.0205)	(0.0198)	(0.0141)	(0.0146)	(0.0111)	(0.0113)
Tap Water	0.0353*	0.0394*	-0.0076	-0.0146	-0.0171	-0.0197*
	(0.0213)	(0.0205)	(0.0144)	(0.0153)	(0.0115)	(0.0116)
Borehole Water	0.0165	0.0195	-0.0134	-0.0122	-0.0103	-0.0117
	(0.0212)	(0.0207)	(0.0144)	(0.0153)	(0.0112)	(0.0119)
Toilets - Boys	-0.0010	0.0008	0.0003	0.0008	0.00066	0.00026
	(0.0008)	(0.0008)	(0.0013)	(0.0009)	(0.00107)	(0.00052)
Toilet - Girls	0.0006	0.0006	0.0024***	0.00174*	0.0012*	0.0009
	(0.0009)	(0.0010)	(0.0010)	(0.0010)	(0.0008)	(0.0006)
Toilet - Male Teachers	0.0023	0.0031	0.0108**	0.0122**	-0.00179	-0.0023
	(0.0065)	(0.0060)	(0.0050)	(0.0048)	(0.0040)	(0.0036)
Toilet - Female Teachers	-0.0001	0.0004	-0.0003	0.0002	-0.00049	0.0004
	(0.0006)	(0.0005)	(0.0003)	(0.0004)	(0.0004)	(0.0003)
Constant	0.029	-0.0314	2.592***	2.571***	2.387***	2.233***
	(0.0400)	(0.0358)	(0.0293)	(0.0300)	(0.0553)	(0.0282)
N	52492	52492	52202	52229	52323	52364
R-Squared	0.07	0.06	0.01	0.01	0.31	0.41
School Fixed Effects	Y	Y	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y
Initial controls x year	Y	Y	Y	Y	Y	Y
School Cluster	Y	Y	Y	Y	Y	Y

*Errors clustered at school level. Standard errors in parenthesis. * p<0.10, ** p<0.05, *** p<0.01.*

7. CONCLUSION

This paper sought to quantify the effects of electrification on primary school test scores, enrolment, and completion for students in Kenya. Using the national examination data and school administrative data, the paper relied on panel fixed effects models. The estimates showed that grid and off–grid electrification have no statistically significant effects on the outcomes of interest – test scores and enrolment. However, off–grid electricity was found to increase completion by approximately 1%. In addition, there was no evidence that grid and off–grid estimates differ in magnitudes except for the positive impact of off–grid electricity on completion (1%). Taken together these estimates show that, in a short term period, electrification may not have any significant impacts on academic outcomes.

Since this paper relies on the off–grid estimates to identify the mechanism of interest –lighting – the findings above suggest that lighting alone may not be sufficient to induce improved test scores and enrolment both in the short–term. This is consistent with previous empirical work such as Kho, Lakdawala, and Nakasone (2018) and Dasso *et al*. (2015). On the other hand, the panel estimates suggesting positive and statistically significant impact on completion is encouraging and warrants more scrutiny. This paper finds that, relying on the off-grid estimates, lighting only has a statistically significant positive impact on completion which increases by 1% following electrification.

This study documents heterogeneity in results by subject indicating that provision of electricity may affect student or teacher behavior. As such measures have to be taken to ensure that students do not skew their studies in favor of particular subjects at the expense of others. However, there is no evidence of difference by in impacts by gender. The location of a school in urban or rural area has little effect on the impact of electrification. Finally, inclusion of private schools in the analysis does not qualitatively affect the results.

The policy implication for these findings is that while electrification may not improve academic outcomes in the short run, positive changes can be experienced in the long run and thus investment in electrification is encouraged. However, to reap the benefits on the electrification, additional short-term and long-run investments in complementary academic inputs such as books, teachers, and infrastructure should be made. Providing additional lighting at school may not be sufficient.

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