Final report

Powering the powerless

Economic impact of rural electrification in Ghana

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POWERING THE POWERLESS: The economic impact of rural electrification in Ghana*

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Abstract

This paper examines the causal impact of rural electrification on household income and welfare, using the last two waves of Ghana Living Standards Survey (GLSS 5 and 6). Our identification strategy relies on exploiting temporal and spatial variation across rural households to measure their exposure to electricity. We find that rural households connected to electricity have significant improvement in their incomes and welfare compared with those without electricity. This effect is found to be significant at the 25th and median quantiles, with the magnitude of the effect increasing as one moves up on the income distribution. We further explore the mechanisms through which this effect may occur. We conclude that basic education of children, ownership of non-agricultural enterprises, and income from non-agricultural enterprises are some of the important channels through which electricity access affects income and welfare of rural households.

JEL codes: O12, O13, O18

Keywords: Rural electrification; economic outcomes; Ghana

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1 Introduction

Ghana has made significant progress in extending electricity access to greater parts of the country. By 1990, only 23.9% of Ghana's population had access to electricity SE4ALL database, IEA and World Bank (2011). In 1991, only 1.09% of rural population had access to electricity. In sharp contrast to this, 74.6% of the population living in urban areas had access to electricity in 1993. Figure 1 shows the rate of progress Ghana has made since the early 1990s to 2014 in the area of improving access to electricity. By 2014, electricity access rate in Ghana for the total, urban, and rural population respectively were 78.3%, 90.8%, and 63%. Despite the fact that current access rate among urban population is nearly 30% higher relative to rural population, the relative trends in the access rate shown in Figure 1 indicate that since the early 1990s rate of increase in access rate is comparatively higher among rural population. Thus, there seems to be some kind of 'convergence' in electricity access between rural and urban populations in Ghana. Further, Figure 1 reveals that Ghana has made a tremendous progress in extending electricity access to its rural areas. Also between 1992 and 2013, Ghana has made significant strides in reducing the national poverty level by more than half from 56.5% to 24.2% Ghana Poverty and Inequality Report (2016). A further disaggregation of poverty level analysis within the same period indicates that, rural (urban) poverty rates fell from 63.6% (27.7%) in 1991/92 to 37.9% (10.6%) in 2012/13.

A curious policy relevant question that lingers on the minds of many and still remains unanswered is: what has been the economic benefits of rural electrification projects? On the basis of the above statistics, there is still huge capital investment requirement that would be needed to be able to achieve a universal access to electricity by the year 2020. Strong evidence of the beneficial effects of the National Electrification Scheme is required in negotiating successful private sector participation, development partners' support, and government budget allocations towards improving electricity penetration into rural areas and electricity access by rural households.

The general objective of this study is to examine the socio-economic effects of rural electrification on rural households. First, we study the effect of rural electrification on households' income, by comparing households in rural areas with access to electricity with those without access to electricity. Second, using consumption and expenditure based measures of welfare (consumption/expenditure per household member) we examine the impact of access to electricity on household welfare within a "difference-in-differences" framework. Third, we examine the impact of penetration of electricity to rural areas on income and welfare redistribution using quantile regression techniques for those households with electricity access. Lastly,

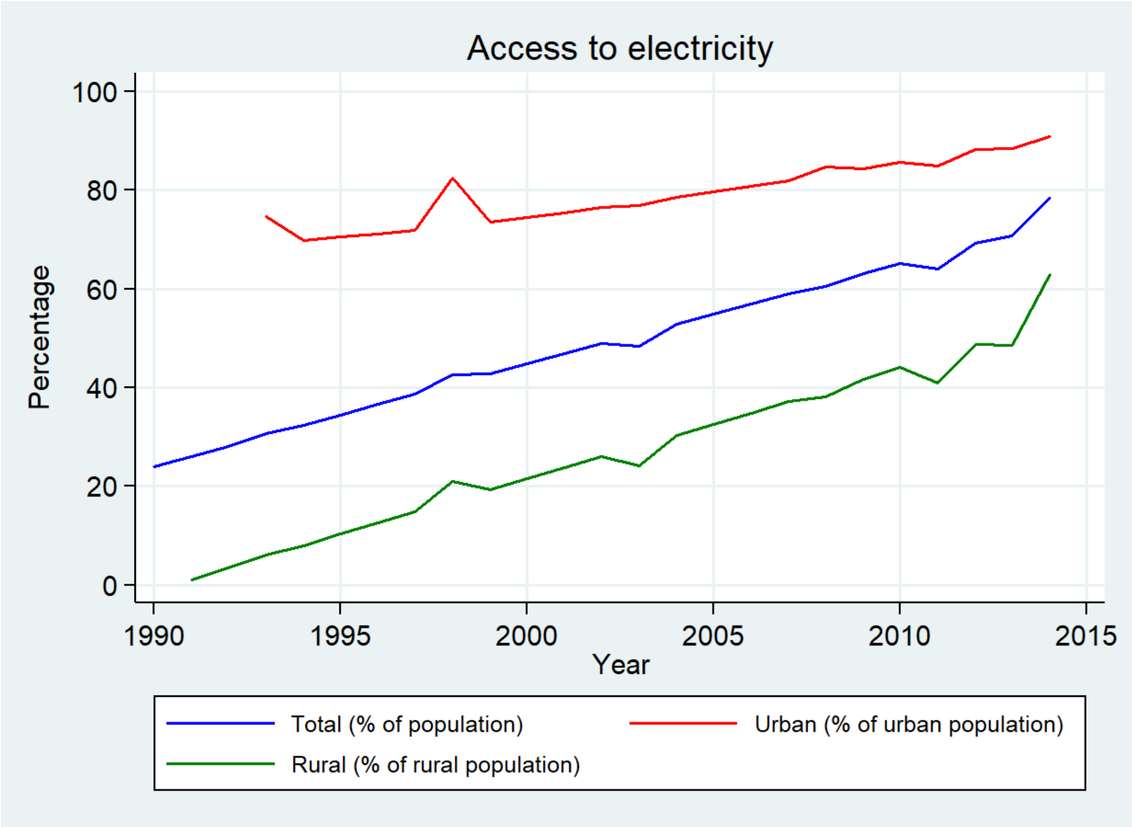

Figure 1: Electricity Access Rate: 1990–2014

we identify the potential pathways through which rural electrification affect household income and welfare. However, there are no proper assessments, particularly in Ghana on the impact of rural electrification on the welfare and income of rural communities making it difficult to for governments and donor agencies to appreciate the extent to which the objective of rural electrification has been achieved. Most of the extant studies in Ghana focused on the comparison between households with and without electricity at a particular point in time. For instance, National Rural Electric Cooperative Association (1981) revealed that rural electrification in Ghana has not been utilized for productive activities except for commercial purposes such as refrigeration and home lighting. Such studies are unable to measure the nature and magnitude of the benefits accrued, not to mention whether the identified benefits can be attributed to electrification projects. Similarly, Mensah et al. (2014) and Akpandjar and Kitchens (2017), used electricity as the only source for lightning in evaluating the direct effect of electricity access on welfare of rural households. However, there are many channels of transmission of the effects of rural electrification on welfare and income. This study fills both knowledge and policy gaps by evaluating the welfare and income effects of rural electrification projects in Ghana. Further, the paper assesses some of the potential channels of transmission from electricity access to income and household welfare.

Our identification strategy relies on both temporal and spatial variation across households in their exposure or access to electricity. While the lack of longitudinal data does not allow us to examine the income and welfare of the same households before and after their accessibility to electricity, we exploit cross-sectional variations in self-reported household income and expenditure levels in order to establish the mechanisms through which rural electrification may affect rural households. For the analysis, we use the 2005/2006 and 2012/2013 Ghana Living Standards Surveys (GLSS 5 and GLSS 6). These surveys provide rich information on households' accessibility to electricity which we use to construct their exposure into treatment. Specifically, we consider rural communities that did not have access to electricity during the 2005/2006 survey but gained access during the 2012/2013 survey as the treatment group. Rural households without electricity as at the time of any of the surveys constitute the control group. The assignment into treatment and control was made plausible by merging data from electricity gridded communities with the specific locations of communities (households) found in the survey data.

We find that electricity access is positively associated with gross incomes and welfare of households, conditioned on a set of controls at the household and community levels. For example, gross income and real household expenditure per capita are respectively about 64% and 63.7% higher for households with access to electricity relative to comparable households without electricity access. Further, we find that income and welfare gains from electricity access increase as one moves up on the income and welfare ladder, suggesting that richer households benefit more from electricity access. This implies that access to electricity has unequalizing effects. In addition, education (human capital accumulation), and non-agricultural enterprises have been validated to be among the pathways through which rural electrification improves income and welfare of rural households in Ghana. We supplement these results with a battery of robustness checks: providing an alternative definition of the treatment and control group, including non-linear term of age covariate and alternative specifications of additional covariates. Our results are robust to these tests and are suggestive of the indirect effect of electricity access on gross incomes. We find that our results hold up and that rural electrification project is an effective social intervention program in rural areas in Ghana, which could possibly be carried over to other developing countries with low electricity access rate in the rural areas.

The rest of the paper is structured as follows. Section 2 presents a brief review of the literature, whiles Section 3 presents our empirical model and identification strategy. In Section 4, we describe our dataset. Section 5 reports and discusses the main results of the paper, while Section 6 concludes the paper.

2 Related Literature

The effect of rural electrification on income and welfare enhancement are complex, with many potential transmission channels. Rural electrification program in Ghana has been accompanied by other public investment infrastructural development such as road, health facilities, educational facilities and water supply. This rural infrastructure together with rural electrification possess the potentials to contribute to higher education achievements, improved health care, higher income and greater business opportunities (Khandker et al., 2013).

2.1 Rural Electrification: Income and Welfare Improvements

Rural electrification affects households' socio-economic outcomes as well as the pattern of energy-usage and behaviour both directly and indirectly. For example, switching from kerosene to electricity provides direct benefits such as improved household lighting which is expected to increase the study hours of school children (Barkat et al., 2002, Khandker et al., 2013, Nieuwenhout et al., 1998). Similarly, communities connected to the national grid benefit indirectly with the provision of street lights which are expected to impart a high level of public security. In addition, rural electrification provides communities connected to the grid the opportunity to access information from radio and television which are expected to affect household behaviour and decision making. Associated with this is the spill-over effect to communities close to those that are connected. The use of refrigerator for preservation increases food safety through improved food storage. It also provides indirect benefits such as increase in productivity, income, employment, and health to household (Cabraal et al., 2005, Dinkelman, 2011, Khandker et al., 2013, Van de Walle et al., 2013). To the extent that there are interconnections among a wide collection of appliances, intermediate variables and outputs, the job of evaluating the direction of causality between rural electrification and welfare outcomes is justifiably complex.

The channels of transmission are equally complex. Communities connected to the grid begin by purchasing an assortment of appliances such as electric bulbs, television sets, refrigerators, fans, air conditioners, heaters, cooking equipment, washing machines and other small business equipment. These appliances then produce outputs and services such as increased quality of lightening, access to non-agricultural activities, modernization of agriculture, attraction of infrastructure (such as health facilities, roads, and water supply), access to information and knowledge (education), improved food preservation, higher-quality of comfort, productive motive power, healthy and improved cooking. All these activities would have been impossible without a connection to electricity (An, 2008).

The initial outputs, can in turn affect intermediate indicators such as longer hours for studies, extended time for home business operations, greater access to knowledge and information, improved health and business operations (Dinkelman, 2011, United Nations, 2010). In the medium to long term these intermediate outcomes have the potential to stimulate higher income and improvement in welfare. Access to electricity generates outcomes through multiple channels. For instance, extended hours of business operations can generate more sales, leading to high profits.

With regards to long run developmental outcomes, improved indoor air quality as households switch from biomass and kerosene to electricity will enhance health outcome and reduce mortality rate (Barron and Torero, 2014, Khandker et al., 2013). Greater access to reproductive programs through information transmission channels in electrified communities, can reduce fertility at lower cost. In addition, increased study hours for electrified communities can improve educational attainment leading to higher earnings and reduction in poverty (Barron and Torero, 2014, Samad et al., 2013). Further, improvements in the productivity of non-agricultural economic activities through increased revenue can raise the earnings of electrified communities. Similarly, the modernization of agriculture through the use of electric pumps for irrigation can also raise earnings (Aguirre, 2017, Torero, 2014). The modernization of agriculture and extended business hours can provide increased employment opportunities to electrified communities which can affect welfare (Aguirre, 2017, Barron and Torero, 2014, Samad et al., 2013). A shift from the use of biomass to the use of electric stoves allows the females to increase the supply of labour as they spend their extra labour time in micro enterprises as well as other self-employment which enhances welfare. The extended working hours further allows males to reduce off-farm hours (leisure) and increases time in other labour activities. Ceteris paribus, an increase in time reallocation to work increases household income. The expected higher income in electrified communities has the potential of increasing consumption expenditure per households which can improve welfare (Bensch et al., 2011, Khandker et al., 2013, Mensah et al., 2014). Rural electrification as part of the rural infrastructural development can generate a positive influence on rural welfare (Khandker et al., 2013). More importantly, the complementarity effect of household assets and the extended business hours can generate a positive and significant impact on welfare (Bernard, 2010).

Rural electrification, since its introduction in 1989 has been regarded and priced as a social service. Thus unit costs of service are not a major consideration in selecting the areas for rural electrification. More importantly, it is generally recognized as a very important resource for raising the standard of living of household and the promotion of economic development. Given the substantial welfare and development benefits of rural electrification, it was recognized as an important development tool for the accomplishment of the objectives of just ended UN Millennium Development Goals. To this end, some bilateral and multilateral donor organizations have supported the expansion of rural electrification projects in developing countries with the aim to improve welfare and income of rural communities.

3 Empirical strategy

3.1 Model specification

Our study aims to identify the effects of access to electricity on income and welfare of rural households. We use a difference-in-difference design, exploiting the geographic variation in electricity accessibility prior to being connected to the national electricity grid. We compare outcomes, at a point in time, for households in rural communities before and after their connection to the national grid. We take an approach that simply considers a household's accessibility to electricity if it resides in a community that has been connected to the grid power (not necessarily having electricity in the place of dwelling). With this definition of access, we are able to capture both the direct and spillover effects of access to electricity. We simply use a binary treatment variable to separate pre- and post-connected households.

The identification strategy relies on running regressions of the following form, for household i in community j and district d in time period $t = [0, 1]$:

$$y_{ijdt} = \alpha_0 + \alpha_1 t + \alpha_2 Electric_{ijdt} + +\delta D_{ijdt} + \beta_j + \lambda_d + \boldsymbol{x}'_{ijdt}\theta + \varepsilon_{ijdt}, \tag{1}$$

where y_{ijdt} is the outcome (for example gross income), $Electric_{ijdt}$ is the treatment indicator variable for whether a household in a community has been connected to the national electricity grid in a particular district; t is a dummy for the year they were connected unto the grid[1], D_{ijdt} is the product of $(Electric)_{ijdt}$ and t and $\boldsymbol{x}'_{ijdt}$ is a vector of household level controls which include: age, gender, marital status, migration status, level of education, sector of employment of the household head and household size as well as community level controls such as poverty rate, adult sex ratio and women with higher education.

Our coefficient of interest is δ, representing the difference-in-difference estimate of the effect of rural electrification.[2] We run equation 1 separately for different income quantiles in order to examine the distributional impact of rural electrification. We additionally run a number of robustness checks by including additional covariates and interacting them with the treatment.

[1] We define t equal to 1 if year of electrification is 2007 and beyond and zero otherwise.

[2] See appendix for the mathematical derivation of the differences-in-differences estimator.

3.2 Threats to identification

To identify the causal effect of rural electrification on the set of outcome variables requires that both assignment and selection to treatment are purely random process, making the treatment indicator in equation 1 truly exogenous. There are some reasons why both the assignment and selection into treatment may not be purely random, in the case of rural electrification in Ghana. First, we consider a possible non-randomness in treatment assignment. Communities in which the average income of households are high (or have "influential" persons residing in them) are more likely to be connected to the national grid. For instance, Ghana Self-Help Rural Electrification Program, where communities take part of the cost of extension of grid power. With regards to selection into treatment, electricity serves as a pull factor to residents in communities where there is grid power. High income households have the potential to relocate (migrate) compared with poor ones. These factors make the treatment indicator dummy potentially endogenous, and thus poses a major threat to identification of the causal impact of rural electrification on household income and welfare.

A powerful approach to deal with the endogenous selection/assignment without the need for instrumental-variables or additional distributional assumptions is the difference-in-difference (diff-in-diff) method (Cerulli et al., 2015). Whiles we are able to deal with time-invariant unobservable community and households' characteristics that can influence either treatment assignment or selection into treatment with the diff-in-diff estimator, a new challenge arises with its application. This is the assumption of parallel trends, which posits that the average change in the comparison group represents the counterfactual change in the treatment group if there were no treatment. When data on several pre-treatment periods exist, researchers like to check the parallel paths assumption by testing for differences in the pre-treatment trends of the treatment and comparison groups. In the present study, we are unable to test the common trend assumption between the treated and control group using pre-treatment data. Moreover, whereas equality of pre-treatment trends may lend confidence but this cannot directly test the identifying assumption; by construction that is untestable. Researchers also tend to explicitly model the "natural dynamics" of the outcome variable by including flexible time dummies for the control group and a parametric time trend differential between the control and the treated in the estimating specification. This is the approach we adopt in this study to deal with the hidden assumption of parallel trends. Moreover, given the relatively short period (about six years) covered, the trends between the two groups might not have undergone any significant change, to threaten the efficient identification of the treatment effect. Nonetheless, we perform an indirect placebo test by estimating OLS regressions of the outcome variables in households/areas that were electrified prior to 2007 on the full set of controls.

4 Data and descriptive analysis

This study combines data from a geo-referenced household survey data with geo-referenced data on the locations with electricity in Ghana. Specifically, we utilize the two most recent waves of Ghana Living Standards Survey, GLSS 5 and GLSS 6 conducted in 2005/2006 and 2012/2013 respectively. These datasets are nationally representative repeated cross-sectional survey of households in Ghana, and conducted by the Ghana Statistical Service with support from the World Bank and other agencies. The sampling frame for the survey is the population living in private households in Ghana. The above sample frame is divided into two sampling units, a primary and secondary sampling unit. The primary sampling unit is defined as the census enumerated areas (EAs) that are stratified into the ten administrative regions of Ghana based on proportional allocation using the population in each of the ten regions. The secondary sampling unit on the other hand, is defined as the households living in each of the EAs. The sampling design for the survey is that of two-stage stratified random sampling approach, where in the first stage 550 EAs were considered, while in the second stage, 15 households per EA were considered. All the data in the two waves used in the study are geo-referenced, at the enumeration level or clusters. In other words, they contain the global positioning system (GPS) coordinates of the communities within which households are located rather than the exact location of the households. This is possibly due to the privacy issues related to the households interviewed. Thus our implicit assumption is that households in the same cluster share the same location. Nonetheless, this does not pose any serious limitation to our study in the sense that the use of the community location suffices in determining whether a household is located in a community connected to the national electricity grid or otherwise.

We also obtained data on electricity connections of communities in Ghana and their associated GPS coordinates from the Ghana Ministry of Energy and the Electricity Company of Ghana between 2005 and 2013. This information was then matched with the data extracted from the GLSS using geographic information system (GIS) software. Most importantly, we distinguish between those living in rural or urban areas within each cluster where electricity is connected and year of connection.

Table 1: Sample description

	Overall			Treated			Control		
	Mean	Std.Dev.	Obs	Mean	Std.Dev.	Obs	Mean	Std.Dev.	Obs
Household characteristics									
Sex of head	0.71	0.46	7931	0.63	0.48	3681	0.78	0.41	4250
Age of head	46.86	16.32	7931	47.60	16.91	3681	46.11	15.66	4250
None/kindergarten	0.56	0.50	7931	0.46	0.50	3681	0.65	0.48	4250
Basic	0.37	0.48	7931	0.44	0.50	3681	0.30	0.46	4250
Secondary	0.04	0.20	7931	0.06	0.23	3681	0.03	0.17	4250
Higher	0.03	0.18	7931	0.04	0.21	3681	0.02	0.15	4250
Marital status (Married=1)	0.94	0.24	7931	0.93	0.25	3681	0.94	0.23	4250
Migration status (Ever moved=1)	0.26	0.44	7931	0.34	0.47	3681	0.18	0.38	4250
Electricity (Main source)	0.37	0.48	7931	0.69	0.46	3681	0.05	0.21	4250
Household size	4.33	2.80	7931	4.03	2.58	3681	4.64	2.97	4250
Employment in non-agric enterprise	0.15	0.35	7931	0.19	0.39	3681	0.10	0.30	4250
Community characteristics									
Poverty rate	0.24	0.24	7931	0.19	0.20	3681	0.30	0.27	4250
Women with higher education	0.05	0.07	7931	0.06	0.07	3681	0.03	0.06	4250
Adult sex ratio ($N_{females}/N_{males}$)	0.55	0.61	7920	0.73	0.67	3681	0.35	0.47	4239
Outcomes									
Log Gross income	7.13	1.58	7931	7.20	1.60	3681	7.06	1.56	4250
Log Employment income	7.40	1.46	3787	7.49	1.42	2060	7.26	1.50	1727
Log Per capita Expenditure	1.39	1.17	7931	1.61	1.17	3681	1.17	1.13	4250

We collect information on the characteristics of the household including sex of household head which we define as binary and coded 1 if the individual is a male and zero otherwise. Other characteristics include the age of the head, marital status, and educational level of the head. Since the focal point of this study is to test the impact of rural electrification, we drop all urban samples from the data. Further, we create an indicator variable which takes a value of 1 if respondent lives in a community connected to the national grid and 0 otherwise. As a robustness check, we create another indicator variable which is coded 1 if the household indicates electricity as the main source of light and 0 otherwise.

Regarding the outcome variables, we consider total household income, gross labour income and real expenditure per capita. With respect to the latter, we correct for spatial differences in cost of living as well as changes in price over time.[3] Pooling across the surveys and after matching, the sample consists of 7931 households of which 3681 are treated and 4250 are not treated. Table 1 provides the descriptive statistics of the baseline variables for the full sample and separately by treatment status. Since these represent a sample of the population, the results are weighted.

Overall, 71% of the household heads are males and have an average age of approximately 47 years. 56% of household heads are not educated and 37% have only basic level of education whiles 4% and 3% have secondary and higher levels of education respectively. 37% indicated electricity as their main source of lighting. However, 46% of the treatment sample use electricity as their main source of lighting. The average household size in the sample is approximately 4 members. The table also indicates that 74% of the sample have never moved from the place of residence suggestive of increased likelihood of having in-depth knowledge about the area and hence providing accurate information. Additionally, the high immobility of the respondents subtly deals with the issue of selective migration into the sample areas which potentially can confound the estimated effects.[4] The distribution of the outcome variables particularly the income variables shows a marked variation in the overall sample. A similar distribution is witnessed when the sample is disaggregated by treatment status.[5]

To examine the pathways through which electricity can affect welfare of indi-

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[3]The real expenditures per capita were calculated as follows: (1) For GLSS 5, we calculate $\text{Real Expenditure} = \frac{\text{Gross Expenditure}}{\text{price index} \times 0.5871}$; and (2) For GLSS 6, we calculate $\text{Real Expenditure} = \frac{\text{Gross Expenditure}}{\text{price index} \times 1.3247}$. The price indices shown in the formula are all provided in the GLSS survey.

[4]We later drop the sample that ever moved to check if indeed selection migration confounded with the outcomes.

[5]See Table A1 in the appendix for the mean difference test on the outcome variables.

viduals, we extracted information on years of education. Further, we create an indicator variable coded 1 if a household member owns non-agricultural enterprise and 0 otherwise.

5 Empirical Results

5.1 Difference-in-Difference Analysis

We now examine the effects of rural electrification using differences-in-differences (*diff-in-diff*) specification in equation 1. We test the hypothesis that, all else equal, incomes and welfare improve for households with access to electricity. We examine the effects on the overall sample as the baseline estimates presenting the results (see Table 2) with and without controls. We further examine the distributional impact of rural electrification on outcomes, using unconditional quantile *diff-in-diff* regressions. Here, our hypothesis is that high income households benefit more from rural electrifications relative to low income households. The reason is that, the high income households have the capacity to take full advantage of the economic opportunities that comes with electricity access, such as establishing non-agricultural enterprises, and acquisition of human capital through education. The results of this analysis are presented in Table 3. Lastly, we test whether the effect of rural electrification is significant depending on the year with which households were connected to the grid. Essentially, we expect that, the longer the years connected to the grid, the greater the impact. For instance, households connected to the grid in 2007 would have enjoyed electrification for about 5 years at the time of the survey compared with those connected in 2011 who would have just had one year. The results of this test are presented in Table 6

We further check the robustness of our estimates reported in Table 4 by estimating the effect of a household being electrified prior to 2007 on outcomes, after accounting for the full set of controls. Finally, we examine the transmission channels from rural electrification to economic outcomes of rural households. Due to data limitations, we are only able to examine two possible channels: education (years of schooling) as well as educational attainment, and non-agricultural enterprises. In the case of non-agricultural enterprises, we considered two alternative measures: (1) a binary indicator which is equal to one if a household owns a non-agricultural enterprise, and zero otherwise; (2) income (continuous variable) from non-agricultural enterprise. The results from this analysis are presented in Table 7.

Table 2: Rural Electrification and Household Economic Outcomes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent variable:	logY	logYL	logW	logY	logYL	logW	logY	logYL	logW
Electricity × Year	0.379***	0.318	0.433***	0.364***	0.403**	0.363***	0.436***	−0.105	0.367***
	(0.126)	(0.198)	(0.0834)	(0.116)	(0.189)	(0.0724)	(0.145)	(0.248)	(0.0841)
Controls	*No*	*No*	*No*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
District fixed effect	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*Yes*	*Yes*
Observations	7,931	3,787	7,931	7,920	3,784	7,920	7,920	3,784	7,920
R-squared	0.009	0.009	0.046	0.176	0.096	0.252	0.290	0.261	0.420

Notes: Robust standard errors clustered at the district level are in parentheses. Y is gross household income, YL denotes employment income and W is real household expenditure as a measure of welfare. All regressions are weighted by the sample weights in the survey. All regressions include district fixed effects, as well as demographic and community level covariates unless otherwise stated in the table. Demographic covariates include household size, age of the household head, sex and marital status of the head. Community level covariates include fraction of households living below the poverty line, share of female-headed households, and fraction of women with completed higher education. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Coefficients from the *diff-in-diff* regression are presented in Table 2. The table provides estimates coefficients and robust standard errors clustered at the district level. Columns (1)–(3) present the estimated coefficients without control variables and district fixed effects. Columns (4)–(6) present the results controlling for a set of household and community level variables but without district fixed effects while columns (7)–(9) includes both control variables and district fixed effects. The dependent variables in each of these specifications are the logarithms of gross income, employment income and per capita expenditure. Whether or not controls are included, the estimated average treatment effect of access to electricity is statistically significant for real gross income and real household expenditure per capita. However, the estimated average treatment effect is not significant in the case of gross employment income. This means that there is no significant difference between gross employment income of households with access to electricity and those without access. This is not very surprising since agriculture is the main source of wage employment in rural areas. Farming activities are generally not affected by access to electric power since significant chunk of farms are not mechanised. The story is not the same for gross income and real expenditure per capita. In the case of the former, the point estimate implies that gross income is about 41% points higher for households with access to electricity relative to those without access. Similarly, households being electrified increases per capita expenditure (welfare) by approximately 33% points compared with those without. It is also worth mentioning the sensitivity of the results to the inclusion of district fixed effects. This reflects the fact that differences in exposure to electricity are larger across districts than within districts, particularly with regard to gross income outcome. Since incomes differ across districts, including district fixed effects allows for the identification of rural electrification by comparing households within the same income category. The implication of these findings is that electricity access improves incomes and welfare of rural households. Policy makers can achieve substantial reduction in rural poverty and reduce inequality in the distribution of income and welfare between rural and urban households through rural electrification projects.

As pointed out in section 3, there are some reasons which could potentially make our estimates invalid. For example, if connection to the national grid is determined by the economic strength of a particular rural area, then assignment to treatment is endogenous and thus may invalidate the causal impact of electrification on household income and welfare. We are constrained to check this directly because of the number of years of electrification we consider in this study. Howbeit, we implement an indirect placebo test by estimating OLS regressions of the outcomes on the treatment sample before 2007 and the full set of controls. Table 4 presents the results of the placebo test. The coefficients are imprecisely estimated suggesting that there is no evidence of a relationship between the outcomes and being electrified already in the beginning of the sample period (in this case, periods before 2007). Thus, concerns about the invalidity of our research design is minimal.

5.2 Distributional impacts of rural electrification

The results presented above indicate that electricity access improves the income and welfare of rural households which is robust to the various control specification. We now turn to examine whether the effect of electricity access in income varies across different quantiles of income and welfare. To address this issue, we use unconditional difference-in-difference quantile regression to evaluate possible variation in the effect of electricity on income and welfare across different socio-economic groups. The results presented in Section 5.1 indicated that the effect of electricity access improves incomes through some other means rather than opportunities for wage employment. The implication is that, the income of a household at the time of exposure to electricity will determine the effect on income and welfare. Our expectation is that high income households will benefit more since they have the capacity to take advantage of the economic opportunities that come with electricity access. The quantile regression estimates for the first, second (median), and third quartiles are presented in Table 3.

Consistent with the main results and our a priori expectations, the effect of electricity access on income and welfare increases as one moves up on the income/welfare distribution, based on the results from the unconditional quantile regression estimates. Firpo (2007) and Firpo et al. (2009) have interesting discussion on the preference for unconditional over conditional quantile regressions especially when one is looking to isolate the impact of a particular variable (electricity access), as it is in our case. In the case of (log) of real gross income, the estimated *diff-in-diff* coefficient (average treatment effect) is positive and significant at 1% significant level for the first and second quartiles. The estimated average treatment effects are 0.564 and 0.578 for the first and second quartiles respectively. This result implies that: (1) electricity access improves the gross income of households up to the middle quartile, irrespective of initial level of income at the time they are exposed to electricity, (2) high income households, do not benefit from electricity access compared to poorer households. Stated alternately, higher income households do not realise significant improvement in their incomes and welfare as a consequence of their being exposed to electricity access. A possible reason could be that such households could already be using engine or electric generator (GENSETS).

Table 3: Electricity Connection and Household Outcomes-Quantile Treatment Effect

	(1)	(2)	(3)	(4)
Dependent variable:	logY	logW	logY	logW
Panel A: Quantile=0.25				
Electricity × Year	0.690***	0.603***	0.564***	0.183*
	(0.215)	(0.155)	(0.182)	(0.108)
Panel B: Quantile=0.5				
Electricity × Year	0.766***	0.290*	0.578***	0.314**
	(0.175)	(0.161)	(0.165)	(0.157)
Panel C: Quantile=0.75				
Electricity × Year	0.0.180	0.0138	0.258	−0.051
	(0.200)	(0.173)	(0.179)	(0.0914)
Controls	*No*	*No*	*Yes*	*Yes*
District fixed effect	*No*	*No*	*Yes*	*Yes*
Observations	7,931	7,931	7,920	7,920

Notes: Y is gross household income, YL denotes employment income and W is real household expenditure as a measure of welfare. All regressions are weighted by the sample weights in the survey. All regressions include district fixed effects, as well as demographic and community level covariates unless otherwise stated in the table. Demographic covariates include household size, age of the household head, sex and marital status of the head. Community level covariates include fraction of households living below the poverty line, share of female-headed households, and fraction of women with completed higher education. *** p<0.01, ** p<0.05, * p<0.1

Considering the results for the first quartile, the estimated average treatment effect implies that gross income of households living in rural communities with electricity and occupying the bottom 25% of income distribution is about 56% higher than households occupying the bottom 25% of income in rural areas without electricity access. The median regression show that gross income of households at the 50th percentile of the income ladder is about 58% higher for households with access to electricity in comparison with households occupying same income percentile but without access to electricity. This results implies that access to electricity has the potential to widen the income gap among rural populations, and to reduce the income gap between urban and rural households.

With regards to welfare (real household expenditure per capita), the estimated average treatment effect for the first, second and third quartile, respectively, are 0.183, 0.314, and -0.051, with the latter been imprecisely estimated. This implies that real per capita expenditure of households living in rural communities with electricity and occupying the bottom 25% of welfare distribution is about 18% higher than households occupying the bottom 25% of welfare in rural areas without electricity access. The median regression shows that real expenditure per capita of households at the 50th percentile of the welfare ladder is about 31% higher for households with access to electricity in comparison with households occupying same welfare percentile but without access to electricity. Finally, the estimated average treatment effect at the third quartile by per capita expenditure implies that real welfare of households in the upper quartile in rural communities with electricity comparable households in rural communities without electricity access is about the same. Similar to the case of real gross income, this result implies that access to electricity has the potential of widening the welfare gap among rural populations, and to reduce the welfare gap between urban and rural households. The immediate corollary of our results is that rural electrification project could serve very well as a social intervention program in Ghana and the rest of sub-Saharan Africa.

5.3 Robustness analysis

We check the sensitivity of our estimated average treatment effect of electricity access on households and welfare in rural communities in two ways. First, to be sure if our results are not confounded by selective migration of households, we restrict the sample to those households who have never migrated from their locations since birth. Second, we interact the exposure to electricity with the literacy status of household heads in defining the treatment status. Table 5 presents the results of these analyses and indicates that the results are robust to these alternative specifications.

Table 4: Placebo test

	(1) Log Gross income	(2) Log Per capita expenditure
Electric	−0.257	−0.232
	(0.317)	(0.168)
Observations	733	733
R-squared	0.399	0.528

Notes: Sample is restricted to households that were connected to the national grid prior to 2007. The regressions include all controls as in Table 2. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Electricity Connection and Outcomes: Robustness

	(1) LogY	(2) LogYL	(3) LogW
	Panel A: Never-migrated sample		
Electric ×Year	0.525***	−0.247	0.497***
	(0.175)	(0.286)	(0.104)
Observations	5,959	2,889	5,959
R-squared	0.305	0.273	0.418
	Panel B: Treatment × Literacy		
Electric ×Year	0.383***	0.241***	0.368***
	(0.0593)	(0.0778)	(0.0374)
Observations	7,920	3,784	7,920
R-squared	0.280	0.254	0.409

Notes: Y is gross household income, YL denotes employment income and W is real household expenditure as a measure of welfare. All regressions are weighted by the sample weights in the survey. All regressions include district fixed effects, as well as demographic and community level covariates unless otherwise stated in the table. Demographic covariates include household size, age of the household head, sex and marital status of the head. Community level covariates include fraction of households living below the poverty line, share of female-headed households, and fraction of women with completed higher education. Panel A restricts the sample to never-migrated households. Panel B interacts electricity access with literacy status of the household head. *** p<0.01, ** p<0.05, * p<0.1

Table 6: Electricity Connection and Outcomes: Year-on-Year effect

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent variable:	Log(Gross income)					Log(Real Expenditure)				
Year of Electrification:	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
Electricity × Year	0.532**	0.312**	0.207	0.950***	0.522***	0.459***	0.317***	0.187	0.850***	0.298**
	(0.248)	(0.151)	(0.215)	(0.235)	(0.189)	(0.169)	(0.0899)	(0.139)	(0.147)	(0.119)
Controls	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
District fixed effect	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	1,307	4,335	1,911	1,060	2,239	1,307	4,335	1,911	1,060	2,239
R-squared	0.370	0.333	0.372	0.437	0.365	0.440	0.494	0.499	0.536	0.534

Notes: Y is gross household income, YL denotes employment income and W is real household expenditure as a measure of welfare. All regressions are weighted by the sample weights in the survey. All regressions include district fixed effects, as well as demographic and community level covariates unless otherwise stated in the table. Demographic covariates include household size, age of the household head, sex and marital status of the head. Community level covariates include fraction of households living below the poverty line, share of female-headed households, and fraction of women with completed higher education. *** p<0.01, ** p<0.05, * p<0.1

As further robustness checks, we estimated the average treatment effect for each year to see how the effect varies with the year of connection. All things being equal, the average treatment effect is expected to decline monotonically as we move from 2007 (those who got connection just after the baseline survey) to 2011 (the year preceding the 6th round of the GLSS survey). The reason is that it takes time for the economic effect of electricity access to affect economic outcomes, hence the effect is expected to be stronger for those who got connected earlier. In the case of the log of real gross-income of the household, we found the estimated effects to be positive and significant for all the years, except for the 2009. Similar results was obtained for the log of real expenditure per capita (see Table 6). Though the estimated effects are significant, except 2009, for both the gross-income and welfare, we did not find evidence of monotonically declining average treatment effect. The reason behind this deviation from our initial conjecture is not far fetched. The communities connected each year may be quite dissimilar in terms of their initial endowments, which affect the degree to which they benefit from electrification, as our quantile regressions reported earlier suggest.

5.4 Exploring the potential mechanisms

We now study the possible channels of transmission through which electricity access could affect income and welfare. In doing so, we consider potential differences between the control and the treated groups in terms of ownership of non-agricultural enterprises, and income from non-agricultural enterprises. We also examine whether there are differences in school attainment for children within households, between the treated and control groups. Including education here allows us to access the long-term effects of electricity access on income and welfare, rather than explain the current differences observed in the data. Second, education is an important objective of public policy, hence, identifying the effect of electricity access on education is an end in its own right. The results of this analysis are presented in Table 7.

The results show that ownership of non-agricultural enterprises, and income from non-agricultural enterprises are important pathways through which access to electricity may improve economic outcomes of rural households with electricity access relative to comparable households who live in communities without electricity. Non-agricultural enterprise in column (3) is an indicator variable, which takes the value of 1, if at least one member of a household owns/operates a non-agricultural enterprise, and zero otherwise. The coefficient indicates that households electrified are about 3% points more likely to engage in non-agricultural enterprise than those without electrification. Incomes obtained from such non-agricultural enterprises are significantly higher for this same group. This suggests that establishment and operation of non-agricultural enterprises constitute an important channel through which rural electrification affect the economic outcomes (income and welfare) of rural households in Ghana. The analysis here also quite explains why income from employment was found not to be statistically different between the treatment and control group. The reason is that in rural areas, non-agricultural enterprises mainly relies on unpaid household labour. The implication is that rural electrification has limited scope for generating wage employment, which is consistent with the results from our baseline estimations.

In the case of educational attainment, we focus on children's completion of basic and secondary school in households and how electrification affects them. It is evident that, children from electrified households are about 28% points more likely to complete basic education compared with those without. However, there is no statistically significant difference between treated and untreated households when we consider secondary school completion. This notwithstanding, our results could be treated as an end in itself since increasing educational attainment is national priority in its own right, and its long-run effect on income and poverty reduction is potentially substantial.

Table 7: Impact of Rural Electrification-Mechanisms

	(1) Basic school completion	(2) Secondary completion	(3) Non-Agric Enterprise	(4) Income Non-Agric Enterprise
Electric × Year	0.275***	0.017	0.029**	1.521***
	(0.036)	(0.012)	(0.012)	(0.431)
Mean of dep variable	0.33	0.04	0.13	3.05
Observations	19694	19694	36561	14289

Notes: Robust standard errors clustered at the district level are in parentheses. Columns (1) and (2) are samples of children in the household aged less than 20 years who have completed basic and secondary school respectively. The regressions include all controls at the household and community levels. *** p<0.01, ** p<0.05, * p<0.1

6 Conclusion

This paper examines the impact of rural electrification on a household's income and welfare, using the last two waves of Ghana Living Standards Survey (GLSS 5 and 6). These surveys provide rich information on households' accessibility to electricity which we use to construct their exposure into treatment. Our identification strategy relies on both temporal and spatial variation across households in their exposure or access to electricity. Specifically, we consider rural communities that did not have access to electricity during the 2005/2006 survey but gained access during the

2012/2013 survey as the treatment group. Rural households without electricity as at the time of any of the surveys constitute the control group. The assignment into treatment and control was made plausible by merging data from electricity gridded communities with the specific locations of communities (households) found in the survey data.

We find that electricity access is positively associated with gross incomes and welfare of households, conditioned on a set of controls at the household and community levels. For example, gross income and real household expenditure per capita are respectively about 44% and 37% higher for households with access to electricity relative to comparable households without electricity access. Further, we find that income and welfare gains from electricity access increase as one moves up on the income and welfare ladder, suggesting that relatively richer households benefit more from electricity access. This implies that access to electricity has unequalizing effects at two levels. First, electricity access increases the income gap between the households at the bottom of the income ladder relative to high income households. Second, the income gaps between households in communities with electricity access and those without increases in favour of those with access.

As a final step in our investigations, we attempted to identify some of the potential channels through which electricity access transmit to real income and welfare of rural households. Due to data limitations, we were able to test the education and expansion in economic opportunities channel. With regards to economic opportunities channel, we considered differences in ownership of non-agricultural enterprises and income from non-agricultural enterprises. All the three measures proved to be very important channels of transmission of electricity access on income and welfare. On the average, we found educational attainment, in basic school completion rates of children living in the household, is about 28% higher among households living in communities with electricity access relative to comparable households without access. The likelihood of a household owning a non-agricultural enterprises was also found to be 3% higher among rural households with access compared to similar households without access. Consistent with this, we also find a significant differences in income from non-agricultural enterprises for rural households with electricity access relative to households without access. Specifically, income from non-agricultural enterprises is about 152% higher for households with electricity access relative to households without access.

From the foregoing, we conclude that: (1) electricity access improve income and welfare of rural households; (2) the effect gets strong as one moves up on the income ladder, suggesting potential unequalizing effects; and (3) education, ownership of non-agricultural enterprises, and income from non-agricultural enterprises are some of the potential channels through which electricity access affect income and welfare at the household level.

Given the similarities in the structure of rural economies in the developing worlds, and similarities in the electricity access rates (which is generally low), the policy implications of the findings of this study can be generalized to cover other developing countries. First, the positive link between rural electrification and welfare has been clearly established by this paper. This implies that the economic justification for investment in rural electrification in any developing country has been proven. Even though the positive impact of rural electrification is higher for wealthier households than the poorer ones, it has the potential to reduce poverty through the promotion of not just access but utilization. This implies rural electrification can benefit the poor more if other complementary actions (subsidize the connections and appliance costs) are implemented together with grid extension process since access is only a necessary but not a sufficient condition for the improvement of welfare and income by stakeholders.

The findings on income indicate that there are good prospects in developing non-farm economic ventures in rural communities with electricity than relying on agriculture. Therefore, International Development Institutions, governments and other development agencies who are interested in using rural electrification to reduce poverty, should target developing off-farm ventures concurrently with rural electrification projects in rural areas. In addition, enterprise development programs should be designed to spur end-users to utilize electricity. This will offer the rural communities the opportunity to put electricity to productive use. The increase in non-farm income has the potential of further increasing demand for electricity which can support cost recovery.

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Appendices

A Tables

Table A1: Mean difference test

	(1)	(2)	(3)
		Panel A: GLSS 5	
	logY	logYL	logW
Control	6.276	6.083	0.391
Treated	6.231	6.311	0.640
t statistic	1.015	-2.339^{*}	-10.056^{***}
p value	0.310	0.020	0.000
Observations	4570	3227	4570
		Panel B: GLSS 6	
Control	8.243	7.586	2.184
Treated	8.181	7.799	2.489
t statistic	1.711	-4.516^{***}	-12.964^{***}
p value	0.087	0.000	0.000
Observations	4570	3227	4570
		Panel C: Combined	
Control	7.311	7.347	1.334
Treated	7.467	7.594	1.813
t statistic	-4.420^{***}	-5.354^{*}	-18.132^{***}
p value	0.000	0.022	0.000
Observations	7931	37873	7931

B Derivation of the Differences-in-Differences estimator

Our dataset is made of repeated cross sections of N different households situated in rural areas. These households are observed at time periods t_0 and t_1. Time is an indicator variable for the period when the locality was connected to the national grid. Thus, t_1 covers the period 2007-2011 whiles t_0 covers the period before 2007 since the two surveys were collected in 2005/2006 and 2012/2013 respectively.

We define a binary treatment variable *Electric* which is equal to 1 if a household in a community has been connected to the national grid and 0 otherwise. Additionally, we define a time dummy variable t taking the values $t_i = t_1$ if household i is observed after their location was being connected to the national grid, and $t_i = t_0$ if household i is observed before they were connected. Finally, we let y_i indicate the outcome of interest of household i after they had been connected. We can write the model without controls as:

$$y_{ijdt} = \alpha_0 + \alpha_1 t_i + \alpha_2 Electric_{ijdt} + \delta(Electric \times t) + \varepsilon_{ijdt} \tag{A1}$$

which is equivalently written as:

$$y_i = \alpha_0 + \alpha_1 t_i + \alpha_2 T_i + \delta D_{it} + \varepsilon_i \tag{A2}$$

where $D_{it} = 1$ if household is connected for the period between 2007-2011 and 0 otherwise. Thus for the samples not connected to the national grid, we have:

$$E[y_{ijdt}|t = t_1] - E[y_{ijdt}|t = t_0]$$

$$= (\alpha_0 + \alpha_1) - (\alpha_0)$$

$$= \alpha_1 \tag{A3}$$

and for the samples connected to the national grid, we have:

$$E[y_{ijdt}|t = t_1] - E[y_{ijdt}|t = t_0]$$

$$= (\alpha_0 + \alpha_1 + \alpha_2 + \delta) - (\alpha_0 + \alpha_2)$$

$$= \alpha_1 + \delta \tag{A4}$$

Combining equations (A3) and (A4), we have,

$$E[y_{ijdt}|t = t_1] - E[y_{ijdt}|t = t_0]\} - \{E[y_{ijdt}|t = t_1] - E[y_{ijdt}|t = t_0]\}$$

$$= (\alpha_1 + \delta) - (\alpha_1) = \delta \tag{A5}$$

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