Electrification and Employment in Rural Africa

The case of the EARP in Rwanda

Sebastian Bielfeldt

A thesis presented for the degree of

Bachelor of Science

Environmental Economics

Frankfurt School of Finance & Management

Frankfurt, Germany

1. October 2018

Electrification and Employment in Rural Africa

The case of the EARP in Rwanda

Sebastian Bielfeldt

1. October 2018

Abstract

In this Bachelor Thesis, I look at the effects of a grid connection on remote rural households in Rwanda. Most of these households never before had any electricity. I find that both electricity and appliance ownership (independent from each other) are negatively correlated with how remote a given household is. This holds true after controlling for other investments and spending levels in general. Therefore, remote communities are underserved and would benefit from improved contact with the outside world.

The literature expects the gender gap in spending and time worked to be reduced by electricity. This does not seem to be the case in an environment with little-developed electricity markets. Women reap no additional benefits from electricity.

I find that small businesses are particularly quick to adopt electricity with higher usage and appliance ownership rates. Spending does not increase. It seems, however, as if they are saving more than the average household. They have both lower spending on micro-credits and higher rates of savings accounts.

Contents

1 Introduction

In the original Frankenstein novel, published exactly 200 years ago in 1818, Dr. Frankenstein used electricity to bring his creature to life. Back then, real-life applications of electricity were scarce, but its potential was considered to be so vast even containing the realm of the magical. The picture has changed drastically. Since then, the world has gone through several phases of mass electrification and the world has found use for electricity in almost every part of our lives. Indeed, while we have not yet created life as Dr. Frankenstein did, many things mankind accomplished using electricity might be considered magic 200 years ago. The effects of electricity enable so many devices, processes, and technologies and go through rapid and constant change. Therefore, up to this day, direct effects of its introduction remain heavily debated.

In this thesis, I investigate the effects of electricity on small business owners and the differences between gender in an environment with low ownership of most appliances. Furthermore, I look into how remoteness affects the rate of how many connect to the grid and the number of appliances owned.

In 1990 Rwanda had an electrification rate of 0% according to the World Bank [2016]. It has gone through its own first phase of mass electrification. In 2016 it had increased almost reached 30%. From this rapid progress, I try to draw lessons which can be applied to the 35 countries which still have electrification rates below 50%.

The data on which this thesis is based was taken from a study published by Lenz et al. [2017]. They collected data from the Electrification Access Roll-Out Program (EARP) in Rwanda collected. I apply linear regressions on cross-sectional data of rural Rwandans who recently connected (or did not connect) to the national grid. With this, I estimate the effects on women and small business owners as well as the impact of remoteness. I cross-check my findings with regressions on data before the connection to the grid.

This thesis aims to provide additional information for energy policy decisions in countries which still need to connect large parts of their population.

2 Literature Review

2.1 Providing Electricity

Not all ways of providing electricity are the same. There are three main ways discussed in academia how to provide electricity to the homes of those who still lack it. The traditional one is a connection to the national electricity grid. Its main advantage is that it can deliver a household almost any amount of electricity it could reasonably demand (regarding both wattage and total energy). Bos et al. [2018] point out the increased difficulty and cost to connect remote areas to the national power grid. This is because the fewer people live in a given area, the higher the costs per user have to be. Those costs have to be either borne by the ones receiving electricity (i.e. rural communities) or the ones providing it(i.e. the state). In areas where electrification rates are still low both of these groups are generally quite poor.

The two other options try to minimize the costs of energy transportation by moving the power generation closer to the community. In remote areas especially, government programs choose to focus on local solutions to combat the lack of electricity. They can thus forgo the high costs of providing energy infrastructure over hundreds of kilometres to supply relatively few communities. Currently, solar home systems are very popular especially in the regions around the equator. This is a (small) solar panel combined with a battery and a couple of power outlets. As the name implies each unit is for a single household.

The problem with most of the popular solar home systems is that they can only supply energy for low wattage appliances. This leaves users soon wanting for more(i.e. higher wattage appliances like refrigerators), which would require further investment. Solar home systems which provide such services remain prohibitively expensive [Lee et al., 2016].

The other local solution, the mini-grid, is bigger in scope, generating power on a village level. This is often comprised of a cheap source of energy in combination with a reliable one. For example, renewable energies such as solar energy in combination with a diesel generator. An advantage of this solution is the ability to later connect the local to the national grid at a reduced cost because of the existing infrastructure in the village. This is very important because currently, it is highly unlikely for local solutions to "leapfrog" grid electricity because of its higher energy serving capacity [Lee et al., 2016]. This means in the long run grid electricity is the aim.

2.2 General Benefits for First Time Electricity Users

Often noted in the literature among the immediate effects of electricity is the social side. Azimoh et al. [2015] sees improvement in the access to information and entertainment through a wider availability of phones, radios and television sets in remote regions of South Africa. Kirubi et al. [2009] found that electricity enables and improves (the delivery of) social activities and business services, especially after nightfall.

Another thing to note is the capability to save or "create" time through anything from lighting (e.g. performing tasks requiring good vision at night) to high-end appliances (e.g. time not spent on cleaning). It also increases the time kids study [Khandker et al., 2012b].

Hirmer and Guthrie [2017] looked at households using Solar Home Systems in Uganda and found that electricity brought benefits especially in the areas of comfort, food security and safety. They also found that electricity increased the overall attractiveness of a place to live, thus making it more appealing for skilled workers (such as health workers and teachers) to move and stay there.

Before moving to the discussion of the possible economic benefits, I will give an assessment of the benefits of the electric appliances most commonly found in rural households which recently got access to electricity for the first time.

2.3 Effects of Individual Appliances

Today most households which are electrified have (at least) lighting and cell phones. Electric lighting at home already enables a wide range of opportunities. More time of the day can be used efficiently. This means additional time to study and work as well as social events. Labour is saved as less fuel has to be collected and costs of lighting decrease. Additionally, health hazards are reduced (in the form of lower kerosene usage and better treatment of emergencies at night) and it is safer at night (through better lighting).

Cell phones offer a wide range of possible benefits from mobile banking over weather forecasts to communication and entertainment. They allow, among other things, for a faster emergency response, assist students, improve literacy and allows coordination with business partners [Hirmer and Guthrie, 2017].

It is possible to use both of the above without having electricity at home. The ability to charge them at home or power them straight from the outlet reduces costs drastically, making their use a lot more attractive and frequent. Furthermore, those are the devices even the simplest solar solutions can power.

The items purchased next (in the data of this Thesis at least) are radio and TV. Both are primarily used to gain information and entertainment. They can also be used productively, for example weather forecasts can help farmers to harvest more or a home cinema can be used as an additional source of income. They can also be used for educative purposes [Hirmer and Guthrie, 2017]. Radios can also be powered by batteries which can be recharged at low voltages. TVs, on the other hand, need higher voltages which means either more expensive electric solutions such as a more advanced set of solar home system or a grid connection would be needed (another solution to this would be the use of a diesel-powered generator or car battery) [Lee et al., 2016].

Other appliances purchased such as fridges improve food safety and dishwashers/laundry machines drastically reduce the time spent on certain chores. This time can be either spent on productive activities or for social/entertainment purposes. Then there are appliances whose main purpose is income generation such as mills and sewing machines [Hirmer and Guthrie, 2017]. Those are however less relevant for the data at hand as ownership rates are below 5%.

2.4 Economic Benefits of Electricity

Some studies find direct economic benefits like increases in income after the introduction of grid electricity [Chakravorty et al., 2014], [Khandker et al., 2012b] and [Rathi and Vermaak, 2018] (with the regions studied being in India and South Africa). Lipscomb et al. [2013] sees increases in labour productivity when communities in Brazil electrify. Those studies, however, were conducted in countries in which there were already mature markets of electricity and electricity available to a sizeable share of the population (at least since 1990 [World Bank, 2016]). Kirubi et al. [2009] found in Kenia that the introduction of micro-grids which enabled the use of electric equipment and tools led to a significant increase in productivity per worker as well as income growth.

Barnes and Binswanger [1986] observed (also in India, but 30 years earlier) that while some growth manifested in their study, it was a lot less than expected. Rathi and Vermaak [2018] argue that electricity is rather a pre-condition for continued economic development rather than a contributing factor. Foley [1992] describes electricity as "derived demand occurring only when an area has reached a certain economic level". A roll-out of electricity, for the sake of increasing economic output, will not reach its goal. Other inputs are needed to make efficient use of electricity and obtain growth [Rathi and Vermaak, 2018].

2.5 Humans Reduce Efficiency

Furthermore, many programs also fail for a range of reasons, many of which due to human shortcomings. Lack of training for the correct use of appliances or missing equipment for maintenance work were found to be reasons why photovoltaic powered appliances failed in health centers in Ethiopia [Berger, 2017]. The spread of stories of not/mal-functioning appliances (in part after wrongly using said appliance) led to distrust and reduction of use.

Not only do people need to know how to operate appliances, but they also have to be aware of the existence of said appliances and their possible benefits.

It cannot be expected that people who gain access to electricity for the first time know what they do. Training and business ideas should be presented to them instead of expecting them to figure them out by themselves [Hirmer and Guthrie, 2017].

Users and local officials increase the costs of such projects through incorrect use [Azimoh et al., 2015]. [1]

3 Hypotheses

3.1 Remoteness

[Manning et al., 2015] sees stark differences in the demand for electricity from village to village and recommends an analysis of preferences before offering the introduction of an electricity program to a certain region.

Being energy poor does not necessarily mean to be poor from an income perspective [Khandker et al., 2012a]. Villagers tend to prefer easy solutions to the best solutions in regards to energy. They tend to choose what they already know and like convenience very much like consumers all around the world. Many of the rural rich continue to use traditional energy sources [Mirza and Kemp, 2011].

When they do adopt new technologies, they do not disperse the old ones. Instead, they increase the total amount of energy options available so-called "energy stacking". They do this to have advantages of all sources and to reduce the risk of having no energy at all at a given point [Bisaga and Parikh, 2018].

The literature suggests that contact with electric appliances increases their acceptance. More contact also reduces the risk of misinformation dominating the conversation. In a village which before was not connected to electricity, this role would be taken by nearby dwellings which already have electricity. If a village is more remote than there should be less contact with electricity Also, as people are convenient, it is important that devices are in fact available. When they are only sold far away, their appeal is lower. This too should be correlated with remoteness. Electricity is only a means to power machines. With a lower expected rate of use of appliances, more users can be expected to not see a value in electricity. Therefore, I think connection rates, also, will go down with increasing distance.

This leads me to my first hypothesis.

1. *The appeal of electricity and access to electric appliances is reduced by the level of remoteness[2] of the household.*

[1] For example, Engie, a utility provider, observed as stated in an article in The Economist [2018] that they observed that many customers in rural Africa, confronted with electricity for the first time, unplugged their fridges at night in order to save energy.

[2] measured by the distance to the next main road

3.2 Women

Rural electrification has often been promoted as a boon to gender equality. Most regions with a lack of electricity are rather patriarchal societies, in which women carry the main burden of household chores, such as cooking and cleaning. With access to electricity, they should benefit because it could help reduce that burden. Household appliances save time primarily for those responsible for doing chores in the first place and light increases the time of the day which can be used effectively. Both of which would give women more time to use, of which some could be spent on working productively and thus increase family income.

There has already been a lot of research on the relationship between electricity consumption and its results on the labour market. Many of those studies indeed find that electrification is especially beneficial for women. [Mishra and Behera, 2016] find socioeconomic activities and standards of living improve for women in India. In South Africa, [Dinkelman, 2011] finds a significant increase in female employment, while male employment remains flat. Furthermore, both genders spend more time working. They observe that electricity releases women from home production and enables the creation of micro-enterprises.

In Bangladesh, [Chowdhury, 2009] is able to show that women due to electrification are more likely to be employed and at the same time the time spent on unpaid work is reduced. [Grogan and Sadanand, 2013] and [Grogan, 2015] find in Nicaragua and Colombia a similar trend of increasing female employment after connecting to the grid.

In Peru, [Dasso and Fernandez, 2015] conclude that electrification leads to different decisions based on gender. Men tend to work more while at the same time reducing the likelihood of working two jobs. For women the likelihood to work increases as well as earnings. Furthermore, the likelihood to work outside of the agricultural sector increases and especially work as self-employed.

[Rathi and Vermaak, 2018] looked at the effects of electrification on employment, earnings and hours worked. In India they found both genders working fewer hours, suggesting higher productivity. In South Africa, employment stayed the same. In both countries, they saw increases in annual earnings for the already employed. They conclude that benefits accrue mainly due to gender roles, supporting policies and labour absorptive capacity of the labour market and not due to electricity in itself.

Less is written about the socioeconomic benefits of electrification on women or the effects on the gender gap in less developed countries. There are several studies about the opportunities and potential such as [Winther et al., 2018] and [Pascale et al., 2016].

Reports specifically about the socioeconomic impacts of PV programs are, however, harder to find. The present data primarily recorded the impacts of grid electricity. However, the appliances used (especially among female-led households) are similar to those available with solar home systems regarding their likely energy consumption. This data could be used as an indicator of the results of a study in such an environment.

As detailed in the literature review, electricity in itself was not found to be a promoter of economic growth. But rather required a certain level of economic growth to have occurred already. I want to look now whether this level is lower when focussing on effects on women. Since women have more unpaid duties (such as chores), they could make more efficient use of the effects of lighting for example. My data set does have low ownership rates of appliances, implying an underdeveloped market a relatively high share of female-led households (around 20%). Therefore it is a good choice to look at this question.

> *2. Electricity has an impact on the differences of income, employment and time spent working between genders in an environment with a little developed market for electric appliances.*

3.3 Small Business Owners

The question to be asked is: Who will first benefit from electricity? While the question of whether women benefit more from electricity already has been looked at in a number of studies, it is harder to find such studies looking at the breadwinning activities of people about to be connected.

In a rural community, there are roughly four groups of people. Farmers who make up the majority of villagers in rural Rwanda. Salaried workers paid by an outside entity such as government employees or priests [3]. And small private businesses which can be separated in the owners and their employees.

Electricity can enhance an existing business in two different ways. It can increase productivity by reducing the time (or materials) spent on creating a single end product. Also, it can increase the value of a produced good. This results in either increased returns or lower input costs (of either money or time).

Who will seek out such an opportunity? Two conditions need to be fulfilled. A person needs to be able to make decisions about how the work is done and income needs to be linked to performance. If someone cannot influence how things are done, they will not be able to include the use of electricity in the workflow. When their performance is not linked to their income they have little incentive to search for a more efficient way of doing things.

[3] To this group I would also count people employed by NGOs or bigger firms, but there is no indication any of those were present in the data set

Of course, it is possible to start a second job and work it on the side. Indeed, people do this, for example by charging phones for a payment or offering a home cinema. Income of such activities is in most cases rather limited however [Lenz et al., 2017].

I will, therefore, focus on the influence of electricity on the main activity of businesses.

Of the four groups presented, both salaried workers and employees of small businesses do not have the sufficient amount of agency to incorporate electricity into their jobs. Also, salaried workers pay is determined by people far away from the village and rises can occur due to external influences [4]. Farmers and small business owners remain as the two job categories which are incentivized to include electricity in their business.

As the country tries to move away from an agrarian economy, I am more interested in the latter. Does electricity make private businesses more appealing? This depends on how their owners fare and will determine whether more businesses are created. In my thesis, I want to look whether the EARP is able to kill two birds with one stone by electrifying the country and moving away from an agrarian economy.

> *3a. Electricity makes being a business owner become more appealing in the short and long run.*

The appeal in the short run I determine with the relative change in the employment figures. To see whether being a small business owner will become more appealing in the future, I look at how their spending and work time changes. Should those values move in a favourable direction in comparison to the average, they ought to be more attractive in the future.

I also want to look whether small business owners use electricity differently from the rest of the village. An outsize use of electricity and ownership of appliances would show that villagers see the business sense in connecting to electricity.

> *3b. Small business owners adopt electricity faster than the village at large.*

4 General Information

4.1 Rwanda

Rwanda is a relatively small African country with a size of about 26388 km^2, but also the most densely populated one with a total population of 11.5 million inhabitants [Central Intelligence Agency].

[4] which for government employees might even coincide with the launch of an electrification program

It was an independent kingdom when it was first colonized by Germany and later Belgium (a country of roughly the same size). In 1962, it gained independence from Belgium. Racial tensions resulted in a civil war in the 1990s, which climaxed in the genocidal killing of over a million people in 1994 [United Nations].

Nowadays the country is in peace and has seen economic growth which averaged at 7-8% between 2000 and 2015 [World Bank]. More recently there has been a reduction to around 6% [Central Intelligence Agency]. Nevertheless, the UN classifies Rwanda as a Least Developed Country having a GDP per capita at purchasing power of just $2,100 (and less than half that at the actual exchange rate) [Central Intelligence Agency]. 83% of Rwandans live in rural areas with more than 70% being subsistence farmers [World Economic Forum]. In total 39.1% (2015 est.) of the population are living below the poverty line [Central Intelligence Agency]. The government is still highly reliant on international aid, making up around 30-40% of the government budget [World Economic Forum].

Political power is concentrated around Paul Kagame, the current president, and his party, the Rwandan Patriotic Front. He has been in office since the year 2000 and has been considered Rwanda's de facto leader since 1994. He won another term in 2018 after a controversial change of the constitution and a disputed election (with him receiving well above 95% of the total vote) [Humans Rights Watch]. Since the civil war, Rwanda has seen political stability and seen an enforcement of accountable governance. Thus, on corruption indices, it outperforms most other African countries (and also some European countries such as Croatia or Italy) [Transparency International]. Its government can also point to substantial improvements in living standards, almost universal primary education and a steep drop in child mortality [World Bank].

The Rwandan Government formulated its long-term goals in its "Vision 2020" (which it published in 2000 and reaffirmed in 2012). In it, it says that it wants to transform Rwanda into a middle-income country by 2020 and raise GDP by a factor of 4 and shift away from an agriculture to a knowledge economy. Also, it wants to reduce poverty levels. One of the means of achieving those highly ambitious goals was the roll-out of the EARP [World Bank].

4.2 The Electrification Program

The Electricity Access Roll-Out Program (EARP) implemented by the government-controlled Rwanda Energy Group was started in 2009. Back then, only 6% of households and 1% of rural households were connected to the national grid. This was one of the lowest electrification rates in the world [Lenz et al., 2017]. [5]

[5] In 1990 (during the civil war), the country had reportedly an electricity rate of 0% [World Bank, 2016].

It managed to increase the capacity of the grid from 70 MW in 2007 to 190 MW in 2016. The Rwanda Energy Group is also the generator, transmitter, distributor of electricity in the country. The aim of connecting 16% of the population by 2013 was achieved, which is also the period covered by the presented data. The aim to connect all health facilities, administrative offices and half of all schools by 2012 was not met, with actual achievements being only 56%, 58% and 36% respectively [Lenz et al., 2017].

Nowadays 30% of the population has access to grid electricity, 11% to off-grid electricity with a total of 41% having access to electricity in general. Most of those live in cities, however, with 72% of the urban and 9% of the rural population enjoying access to electricity. The government now aims to connect all citizens until 2024 (half of them off-grid) [US AID].

5 Data

5.1 Data Selection

The data used for this Bachelor Thesis is taken from the paper of [Lenz et al., 2017] and consists of communities scheduled to be connected to the national grid for 2011-12 as part of the EARP. Another group of villages was scheduled for connection in 2013-2014. In fact, several communities selected to be connected in 2011-12, got connected only later. Those that did, in fact, connect are our treatment communities. The others make up the control group. Those communities were all selected after the same criteria, therefore they should be relatively similar. When no other village in proximity to the treatment village was due to be connected in the subsequent period, additional villages were selected in their proximity. Criteria for the selection process were road access, community size, number & type of businesses and prevailing agricultural activities.

In total there were 15 communities connected and 30 in the control group (15 to be connected communities + 15 additional control communities). More information about selection process can be found in the paper by Lenz et al. [2017]. The households were selected for the survey based on whether they would be able to connect to the grid without paying an additional connection fee when it became available. This means they needed to live in a distance of $50m$ from the village's principal street.

The cost of connecting to the grid of 65,000 RWF or 87 USD is highly subsidized, but nevertheless, it remains a big investment in comparison to the average yearly expenditure of 800,000 RWF in our data set. Villagers are allowed to spread out the payments being only required to pay 15,000 RWF immediately while the rest can be paid back later. To this came additional costs to install the electricity in the house. This was not recorded in most cases, but the lowest amount recorded was another 50,000 RWF. Total connection costs were, in some cases, above the aforementioned mean of yearly spending for the dataset.

At the time of the second survey in 2013, the average connection was at roughly one year five months. Virtually all who did not connect did this because of money issues. A small minority also cited concerns with the technology and a fear of health hazards in the household.

All in all, 974 households were interviewed twice. Of those, 288 were given the opportunity to connect. 62.5% or 180 had connected at the time of the follow-up survey. Most other households named money issues as the main reason why they did not connect. A minority also cited fears of the effects of electricity such as accidental electrocution. When separating between treatment and control group, I will only look at those that did connect (in the treatment group) because most effects of electricity should only materialize for households which actually connected.

5.2 General Overview

A typical household has 5 members (in adult equivalents). Its head of household has finished primary school, is 43 and works as a subsistence farmer. Before connecting, the average household spent around 1,000,000 RWF and works for around 750 hours a year (Table 3). The main farmed goods are manioc, potato, corn, coffee and tea. Most of it is consumed on a local level. In fact, less than half villages have any regular markets and only coffee and tea are produced to be sold on national markets. Some communities are only accessible during the dry season, with 20% of the treatment villages being difficult to access or not accessible during rainy season (45% in the control group). Most communities have a school and a minority also has a health center.

A typical household spends around 40% of its income on food, followed by ca. 20% on energy.

People have access to communication. Radio and mobile phone networks work everywhere. Even at the start of the study cell phones are already very common at over 60%, while other electric appliances were rather uncommon. In (more than) half of all communities, internet and TV access are not available. At the beginning of the study, a normal household has just 4.5 hours of artificial lighting a day. Of that virtually all came from using more traditional energy sources and was therefore of relatively low quality. Electric lighting is virtually non-existent at the beginning of the study.

At the second interview in 2013 ownership rates of some appliances were a lot higher (Table 1). The items most common are also rather cheap. Most of them do not require high wattages, with irons being a notable exception.

Looking at jobs (Table 5), before connecting to the grid the vast majority are subsistence farmers at 78%. This is followed by around 10% who own a private business. Another 4-5% work in the two remaining job categories, small business employees and civil servants. The rest (around 2.5%) are not working for various reasons such as studying, being retired or simply out of work. During the two years in between the two rounds of questioning one can see a highly statistically significant shift of around 10 percentage points away from subsistence farming in both treatment and control group, with many choosing dependent employment in private jobs. However, this trend does not seem to be connected to electricity as it is as strong in the control group as the treatment group. This could be an indicator that the country as a whole is taking small steps away from being an agrarian economy. The vast majority though chooses to remain active in farming.

All other occupations remain more or less stable. Unemployment does not change in a statistically significant manner over time for both the control and treatment group.

Interestingly, spending on candles rises in the followup. [Lenz et al., 2017] sees the reason for this in the grown demand for lighting after connecting. When the grid has a power outage the villagers nevertheless want to have lighting resulting in a higher usage of candles. Spending on food and as well as charcoal and firewood increases.

5.3 Remoteness

The average connected household is at 6.9km only half the distance from the next main road as are those who did not connect with 12.4 km.

5.4 Women

A quick glance at the data set reveals that 807 households are headed by a man and 167 by a woman. Women, therefore, represent 17% of all heads of households. This is narrowed down to 53 women and 235 men for the treatment group. Here, the percentage increases slightly to 18.5%. The rate of connection is virtually the same at 62.3% and 62.6% for women and men respectively. Regarding other investments, women seem more timid. Only 12.1% of women invested 50,000 RWF at least once in the last year, while 35.5% of men did.

Female Heads of Household (HoH) in the data set are about 8 years older than male HoH as one can see in Table 3. This is largely due to the fact that female heads of households are less common when they are young. The ratio between female and male households changes from 12:1 at below 40 to 2:1 at above 60. In rural communities, due to traditional gender norms, most households are started with a man as the head of household. Over time various events can lead to the woman becoming the head of the household. Most are connected to the husband either disappearing and/or not being able to provide for the family. Women do not necessarily remain single for all too long. Throughout the whole data set 40 households changed from being female led to being male-led and 42 households did the reverse between the two interviews.

That female-led families are often missing a second spouse explains (in part) the big differences in family size. Another contributing factor is age, as households shrink when kids move out to start their own families. Both of these factors, in turn, lead to a lower spending level. However, even when controlling for those factors, female-led households are a lot worse off.

Mean spending levels at the beginning of the study are almost the same for both men and women with the difference being only around 30,000 RWF. The female average decreases in the followup by around 150,000 RWF while the male average increases by 600,000 RWF (largely driven by an increase in spending by mostly male civil servants). In the control group, there is a big difference of around 400,000 RWF between genders which grows larger over time.

Most women work in agriculture, just like men (Table 5). On a relative basis, even more, are employed in that area, with 90% of the female heads of household in the treatment group working there. 2% work as small business employees, 2% live off mother's help, 2% are housewives, retired or invalids and 3.9% are unemployed.

The share of unemployed women in the treatment group falls from 3.9% to 0. All other unemployment rates increase slightly. However, the share of retirees and invalids rises offsetting this effect almost completely. There are also insignificant shifts away from being a farmer and small business employee towards becoming small business owners and government employees[6].

5.5 Small Business Owners

As can be seen in Table 5 throughout the dataset business owners make up a bit less than 10% of the total population. They are a bit younger than the average and their family is about as big as the average male family in the first interview. This does diverge in the follow-up as some women in the control group switch profession or (re-)marry, reducing the female-led share of businesses in the control group. In the treatment group, on the other hand, both male- and female-led households open new businesses. This raises the average age by five years over a two year period. Even though there was an inflow of female-led families which are rather small, the family size of small business owners increases in absolute terms and in comparison to the average age of a HoH.

Total yearly spending is higher than average for both treatment and control group with the small business owners in the control group spending more in both periods (Table 3 and Table 4). Both

[6]The terms "government employee" and "civil servant" are used interchangeably throughout the thesis

control and treatment, increase by roughly 200,000 RWF between the two studies. Together with government employees, they are the highest spender. Time spent working is again a lot higher than average but trends diverge. While for the treatment group working hours of small business owners (SBOs) increase slightly (by insignificant 30 hours), SBOs in the control group decrease their workload by around 130 hours.

Connection rates are significantly higher among small business owners compared to the average with 82 % connecting. They own more electric appliances than the average at the beginning of the study (3.1 to 2.1) as well as the end (3.7 to 2.7)(Table 2). The difference is quite pronounced as the actual number of devices should be even bigger, since it is not unlikely to own two cell phones for example. Bank accounts are also more common among small business owners in both periods with almost all electrified SBOs having a savings account (Table 6). This is in contrast to the roughly 80 % of the treatment group in general as well as of SBOs in the control group.

6 Methodology

My analysis is entirely based on the data collected by [Lenz et al., 2017]. A lot of their variables regarding expenditures had to be imputed because many households were not able to provide exact information about their spending. Thus, information about habits and spending combined with local prices were used to infer spending levels. Whenever I am talking about currency, I mean the national currency of Rwanda (RWF), unless otherwise specified. All expenditure is on a monthly basis, except for total spending which is on a yearly basis.

I focus my view on a household level or the respective head of household. When mentioning groups of individuals like women or small business owner and similar groups, I will always refer to the Heads of Household. Connected, electrified and similar expressions are all supposed to mean households which connected to the national grid provided by EWSA. I disregard those who had the chance to connect but did not. I do this because I want to focus on the effects of those who did receive all the benefits of electricity.

The data set at hand labelled main activities/jobs differently. I decided to rename two categories. They were called "Other Activity (independent)" and "Other Activity (dependent)". There were only two other actual jobs (see Table 5), "Farmers (Independent)" and "Government Employees". The other two jobs are therefore all who neither farm or work for the state. This means they work for a private business, either as the owner or an employee. According to [Lenz et al., 2017] jobs include shop/bar owners as well as hairdressers.

Spending is used as a proxy for income. This is reasonable since most poor households spend about as much as they earn. There are some limitations specifically when people either begin saving significant amounts over longer time periods or when credit becomes available. Credit expenses would appear twice in a data set, once for the original investment and later as the repayment. This would make a household paying back such a loan seem richer compared to another one which paid it out of pocket, all else being equal.

In our dataset households did not have the high energy appliances required to cook with electricity. Therefore, Lenz et al. [2017] calculated a special variable for traditional energy excluding cooking.

I used linear regressions to estimate the effects of a connection to the electricity group on the whole data set and several subgroups, specifically I look at the groups of small business owners and women. I look at the effects on their yearly expenditure, total hours worked, expenditures on energy (as well as spending on traditional energy and electricity) and micro-credits. In the regressions, I marked binary variables with "(B)". I first look at the "raw" linear regression. I define the dependent variable d as above stated as one of the following: yearly expenditure, total hours worked, monthly expenditures on energy, monthly expenditures As independent variables, I introduce the grid connection e and either gender or small business owners f and the multiplication of the two ef which is the variable of most interest. Then there is the intercept I and the individual estimates a_i.

$$d = I + a_1 t + a_2 e + a_3 i + a_4 ei \tag{1}$$

After this, I introduce several control variables such as age, family size and gender (for SBOs). For everything but yearly expenditure and total time worked, I control for the time In a second regression, I introduce a further control in the form of control variables for the individual villages. Adding villages as a variable generally led to increases in adjusted R-squared and a reduction in F-statistic. They are omitted as otherwise the tables would have gotten too big and there is little value gained from studying them. The regression is structured the same way with more control variables as additional independent variables c_i added.

$$d = I + a_1 t + a_2 e + a_3 i + a_4 ei + \sum_{i=1}^{n} (a_{c,i} c_i) \tag{2}$$

All regressions are performed using linear regressions. The data is very scattered. This leads to very low values of R-squared. The variables I look at are of course only in part able to explain the fortunes of people in the particular group looked at. Many individual factors also determine this as well. Additionally, I compare it to the "raw" regression of the base sample and look at the

F-statistic and adjusted R-squared.

When looking at any energy-related spending, I excluded one value which heavily distorted values. When looking at spending on grid electricity I only look at those who connected.

Furthermore, I use regressions to see whether the distance from the next main road is a predictor of a grid connection or how many different appliances a household owns. For the latter, I created a variable from the data set combining individual binary variables for ownership of a given appliance. All the items in Table 2 (as well as some more with low ownership rates) are included, any sort of lighting is not.

Here too, I look first at the "raw" regression. I define the binary variable for grid connection/appliances owned as the dependent variable d and the independent variable r being the distance from the main road. Again, the intercept I and the individual estimates a_1 are added.

$$d = I + a_1 r \tag{3}$$

Then I introduce control variables. First I introduce control variables for spending (yearly expenditure, (grid connection) and other investments[7]) and later further variables which I found to influence the findings (civil servant, SBO, family size and gender).

$$d = I + a_1 r + \sum_{i=1}^{n} (a_{c,i} * c_i) \tag{4}$$

I do not control for the individual villages as this is could influence the effect on the distance to the next main road.

7 Results

7.1 Remoteness

Looking at the regressions in Table 7 determining whether someone has a grid connection, the distance to the next main road has a highly significant estimate with an estimate of -0.009 per km. I introduce two sets of control variables. First I try to see whether direct measures of wealth can explain this. While spending levels on its own are predictive, together only the investment in another project shows a significant (positive) estimate. Interestingly, both the significance and the estimate of the distance to the next main road increase in value. When introducing further controls I found none to have an influence, such as gender, profession and family size. Those

[7] Other investment is defined as the first investment above 50,000 RWF excluding the grid connection itself.

added controls do not influence the outcome a lot. Being a woman and family size are quite likely to not influence it at all. Nevertheless, the estimate for distance to the next main road is bigger still and more significant.

Now moving on to the factor of appliance ownership. In Table 8, I show the regressions. There is a high negative estimate for the distance to the next main road in the raw regression. When controlling for spending appliance ownership is also heavily influenced by the choice to connect (with a highly positive estimate). Other investment is also highly significant and has an even higher positive estimate than grid connection. Yearly Expenditure is not significant, however. The controls reduce the estimate a bit and it loses a lot of its significance (remaining borderline significant). When introducing further controls for groups of people who tend to own more or fewer devices, such as women, SBOs, and civil servants, the significance increases again. Levels of R-squared are comparatively high for all levels of controls.

7.2 Women

The simple regression of yearly total expenditure has significant estimates for the grid-connected with roughly 700,000 RWF and for women with almost -600,000 RWF. Being a woman with electricity results in a negative estimate but is not significant. When introducing first controls (household size and age of the HoH) the picture barely changes. Both estimates, being female and grid connection, shift a bit upward. The combination of the two continues to have no significant estimate. Further controls change the picture only slightly with the significance of most variables as well as the F-statistic decreasing by a lot and R-squared increasing a bit. In the baseline regression, there is also no statistically significant result (except for a lower estimate for spending on women). The estimate of connected women, however, is positive (Table 9).

When looking at the regressions on total time worked in Table 10, women work a lot less than men in the simple regression. Neither a grid connection nor female HoH with a grid connection experience a significant impact. When introducing first controls the trend does not change for women in general or women with an electric connection. Age shows a strong correlation at reducing time spent working. The controls add a bit to the estimate of being female (with and without electricity). The standard deviation remains flat for both. This trend is continued when introducing village dummies.

Energy expenditure does not change significantly for those who connected to the grid. This is not changed by introducing control variables. Family size, as well as total yearly expenditure, have a significant positive estimate in both regressions with control, age has a significant negative estimate only when including village dummies. Being grid connected has no effect. For both female and (later) grid-connected HoH are significant in the base sample with negative and positive estimates of around 1,000 RWF respectively. The overall energy expenditure increased over the two-year gap (Table 11).

Traditional energy in the simple regression is not influenced by any of the variables presented in the simple regression. When introducing first control variables, only family size can predict traditional energy consumption. When including village dummies, women seem to spend less on traditional sources. While both estimates are not significant, those of a grid connection (negative) and female with a grid connection (positive), cancel each other out. In the baseline scenario, grid-connected households spend more and women less. The estimate for the combination is not significant (Table 12).

The regression on expenditure on electricity does not yield any significant results and both adjusted R-squared and F-statistic show very insignificant results (Table 13).

Without any controls, it seems like being a woman leads to lower micro-credit expenditure. When introducing first controls, being female loses its predictive value, while the estimate for a grid connection increases in value and significance. This trend continues when including village dummies. A grid connection is strongly correlated with spending on micro-credits and highly significant. Being female as well as being female and grid-connected has no significant impact. In the baseline regression, micro-credits are less prevalent among female households with nothing else being statistically significant (Table 14).

7.3 Small Business Owners

The simple regression shows that the effects of being a small business owner and having electricity on yearly expenditure are roughly the same size totalling estimates of around 850,000 and around 1 million RWF respectively. However, small business owners who connect to the grid, seem to spend less than would be expected with a significant negative estimate of -1.3 million. When introducing first control variables, the picture barely changes. The effect of controlling for villages results in most values losing their significance (with R-squared increasing) such as a grid connection (reducing its mean of 473,000 RWF). Being a business owner is still highly significant as it increases spending by 750,000 RWF. The combination of both effects still yields a very negative 850,000 RWF. When looking at the baseline regression, it is visible that much of the effect on the (later) grid-connected business owners already exists at a negative estimate of 400,000 RWF. There is also an effect on the actual grid connection visible (it is a bit smaller) (Table 15).

In the raw regression, electricity does not seem to have an effect on time spent working. Business owners work with a significant, positive estimate of around 110 hours a year more than other professions. The combination of both effects (Electricity and SBO) is insignificant. Further controls don't change this. When controlling for villages, small business owners also lose their significance and a grid connection flips from having a p-value below above 0.90 to one below 0.01 with a positive estimate. Age always shows a negative correlation, being a woman, when not controlling for villages and family size when controlling for villages. In the baseline data households which would later connect have a significant and positive estimate (Table 16).

In the simple regression, neither small business owners nor electrified households have high or significant estimates regarding energy expenses. Being a small business owner with electricity has no significant effect. When introducing controls, only family size seems to be a strong predictor of expenses related to energy. This holds true, also when including village dummies. In the baseline data, however, being connected to the grid, being a business owner and the combination of the two, all have a positive, high and significant estimates (Table 17).

On traditional energy, the same can be observed as on energy overall (Table 18).

I look at spending on grid electricity. Small business owners are likely to consume a lot more electric energy than the rest (around 1,500 RWF) with the controls having little impact on the estimate or p-value. (The adjusted R-squared is quite low and decreases with more controls) (Table 19).

When looking at micro-credits, the regressions reveal that both a grid connection and being a small business owner have very significant and high estimates. On the other hand, the combination of the two is very negative and also very significant. Introducing controls doesn't change the outcome but increases the value of R-squared (Table 20).

8 Discussion

8.1 Limitations

One limitation is the control group which was not a perfect fit and not sufficiently controlled for. I filtered out only rudimentary differences when controlling for basic features such as age and gender. Especially in the case of small business owners, this became evident to not be sufficient as the two groups were already very different in the baseline sample. [Lenz et al., 2017] used a matching algorithm which helped reduce the differences between treatment and control.

I used only rudimentary linear regressions. This shows its weakness in the low R-squared values. The variance of the values is very high and other prediction methods could have accounted better for this. Possibly with more advanced regressions, clearer results could have been reached.

8.2 Remoteness

Both electricity, as well as the general level of appliances, are strongly influenced by the distance to the next main road with and without controls. I corrected for yearly total expenditure, since most, who did not connect said money was short. I also corrected for other investment decisions, to see whether the trend was specific to electricity or whether people preferred big investments in general when closer to the rest of society[8]. Interestingly, in both charts "Other Investment" was the more significant variable to control for spending. In the case of the level of appliances, I also controlled for access to electricity.

The results indicate that in remote areas fewer people chose to connect and those that connected owned fewer appliances. Especially for appliance ownership, the R-squared values are very high in comparison to the other regressions.

This shows that my findings are therefore very much in line with my hypothesis.

I presented two reasons as to why there might be fewer appliances in the region. On the one hand, the convenience of the villagers, not willing to travel far to buy an electric appliance. On the other hand, the lack of knowledge about or trust in a given appliance or both. In the data set several respondents cited fears of electricity as a reason for not buying a connection to the grid. Future research could look into which of those factors was the driving force behind this trend.

I consider the reduction of electric connection to be closely related to the lack of appliances. I think that the appeal of electricity itself is reduced by less knowledge about the opportunities regarding electric goods. Also some, already aware of scarce supply, might, therefore, decide to not connect to the grid.

These findings indicate that remote villagers satisfy only part of the demand they otherwise would have. For the roll-out of electricity to work better, the "remoteness" of communities should be reduced. Possible solutions to this would be to build more and better roads facilitating travel between communities. Another option would be to subsidize merchants to go to those areas to sell and inform about electric appliances. Any means of increasing contact between communities will be beneficial.

8.3 Women

My results show that women are in a financially worse situation than men. I find no significant effects of electricity on women regarding their spending habits or time spent working. Both

[8] A reason for this could be that components for any larger investment such as tiles for a new roof are more easily available closer to society.

when looking at averages and when looking at the regressions, the earnings of women seem to fall rather than rise with electricity while the average (i.e. men) seems to increase spending by a lot. I do not find any effects on women when looking at their spending on energy or their microcredit expenditure.

This is in part due to their position in society and the circumstances of how a female-led household comes into existence in the first place.

Changes in employment are not significant and can in part also be explained by the 80 households whose head of household was replaced by another one with a different gender.

Also, they had fewer other investments and lower rates of appliance ownership (which also increased by less in comparison to the year prior to connection). Not conform to this trend, is their connection to the grid, which is as high as that of men.

When looking at this, there was little which could save them time or make them more productive. Also, there was not more time spent working, due to improved lighting. Women do not work more than men overall. However, It is possible that women shifted tasks to the evening as the study of Lenz et al. [2017] suggests for the data set in general.

It seems, to achieve more balance between genders it is necessary to not only introduce electricity. The findings indicate that currently common solar home systems, too, will not be able to decrease the differences in income between genders. Further research could investigate at which level of available appliances an effect on women can be observed.

Also when looking at the effects on women, governments should not only present business ideas when giving the population electricity, but also offer them the access to appliances and training on how to use them, as well.

Regarding policy recommendation, I renew my call for the introduction of better options to purchase electric appliances. Governments or NGOs running an electrification program should do this also from a perspective of reducing the gender gap for income in such areas.

8.4 Small Business Owners

Effects on income for small business owners are ambiguous. Income measured in yearly expenditure has, in fact, a negative, significant estimate for small business owners with electricity. But a large portion of this change is already visible in the regression in the baseline data [9]. When subtracting the estimate of the baseline regression from the regression without controls, it only has a t-Value of roughly 1.5. This is on the border of being significant. Since the controls in the other regressions reduce the estimate but not the standard deviation, I consider the results for

[9] Here the problem of a not perfectly fitted control group was felt the most.

yearly total expenditure therefore ambiguous. Additionally, there was a big increase in spending by civil servants with electricity, further distorting the picture [10].

The regressions on time spent working did not yield any notable results.

The numbers of small business owners (or employees) do not rise in comparison to the control group (rising equally in both the control and treatment group). Electricity, therefore, does not seem to nudge people towards the creation of more private businesses in the short run.

There seems to be neither a strong incentive to become a small business owner in the short term nor do the incomes rise faster than was to be expected, reducing the incentive in the long run.

The results for energy spending and traditional energy spending are inconclusive for both business owner in control and treatment (having excluded one observation). Even when electrified most continue cooking with traditional energy sources. This means that energy prices do not drop by much after adopting electricity. On the other hand, spending on electric energy is indeed higher for business owners. They also own more electrical devices. Interestingly, connected business owner increase the number of types of appliances owned by a lot more than government employees even though they spend a lot more. They also have a higher rate of savings accounts and lower spending on micro-credits.

Small business owners show enthusiasm for electricity, as they use more of it and own more appliances. They also own most of the more advanced appliances in the data set. Among those are appliances such as mills and sewing machines whose main purpose is productive. They are also richer when looking at other factors than spending. Almost all of them have a savings account. Neither all business owners in the control group nor the rest of the treatment group have as high a share. Additionally, their microcredit expenditure is a lot lower, both when controlling for total spending and when not.

Therefore, I can affirm the part of the hypothesis. Small business owners are indeed quicker to adopt electricity. They also seem to save more than would be expected.

I call for more research in this area as I think that small businesses are a promising part of rural life that might drive growth and advancement in the long run. Further research could be done in a number of ways. First of all, a study should be done with a control group which is more comparable to the treatment group. Also, not all small business owners are the same and different subgroups might have differing impacts. A study could show how certain groups of small business owners benefit from different levels of electrification and electric appliances. This could show what business strategies should be taught when introducing villages to electricity.

[10] The spending of government employees almost doubled which could have been influenced by the roll-out of the electrification program itself.

9 Conclusion

All villages in the data set can be considered somewhat remote as they are miles away from the next main road and even more so from the next city. But even here the difference in distance to the next main road played a significant role. Remoteness has to be considered when connecting villages as the appeal of electricity and ownership of electric appliances are reduced. This was demonstrated by the clear negative correlation I found in my regressions.
Future electrification role out programmes should increase the availability of electric appliances and improve information regarding those devices in villages where they want to offer power. This could be done in several ways. For example by paying a salesman to pass through remote communities every couple of weeks to sell appliances as well as provide information about and training with those machines. Another, more costly possibility would be to improve the access by road. I agree with the demands of [Hirmer and Guthrie, 2017] to include pitches for business opportunities when presenting electric appliances. When it makes business sense to have electricity, more people will connect to the grid. With time those people would grow more comfortable with electricity and use it.

I did not observe a significant impact of electricity on women's income or time spent working. A wide gap remains between male- and female-led households. Most of the literature which identified a connection between a rise in economic growth or income in combination with electricity had a well-developed market for electrical goods. Most studies connecting a reduction in gender differences with electricity were carried out in countries with higher rates of electrification.
The electric devices available in this study are in fact mostly compatible with solar home systems (everything with ownership rates of more than 20%[11]). The findings of this study do not provide a definitive answer on the efficacy of programs which try to reduce income differences between genders with solar home systems. However, it indicates, that programs which only provide low voltage electronics might not see any change in the difference in income levels.
I call for a closer study of how ownership of certain appliances influences household income. Those which prove to increase income could be advertised/sold to villagers through the operator of the grid or any other point of contact with the villagers. When the economic advantages decrease if more people own it, an auction could be used to determine its fair value to the community.

The job of a small business owner does not seem to become more appealing in the short run

[11] TVs might need a more expensive solar solution then is currently common.

when presented with electricity. There are no changes in jobs relative to the control group. They are better off, but not the richest as civil servants spend a lot more. I cannot detect increases in income because of electricity. However, they do spend less on micro-credits [12] than would be expected. Also, they have a higher share of saving accounts than the average villager or small business owner in the control group.

Their spending does not seem to increase. It may be the case that they are able to save more, instead. Future research should investigate whether this is occurring under other circumstances as well.

However, small business owners do seem to be early adopters of electricity and they own a lot more devices and use them more than civil servants[13], as well. Therefore it seems business owners are more curious and friendly towards innovation. It may be that they regard investments in electricity to pay off in the long run. They own most of the few "productive" appliances (such as mills and sewing machines). A big obstacle to the increase in productivity (low rates of appliance ownership aside) is the bad connection to outside markets. Only few products are sent to bigger markets in the region (only coffee and tea). Here to better access to the outside world might be a remedy.

Basic applications of electricity do improve people's lives, as giving people more reliable lighting sources. Through phones, radios and TVs, people have a better access to both information and entertainment.

Lack of access to more appliances hindered the villagers to become a lot more efficient. Simply having more time to work at night does not increase productivity sufficiently to reduce gender inequality or increase incomes of small business owners of relatively isolated villages. After all, electricity is not magic.

[12] $\frac{1}{5}$ of the increase due to a grid connection

[13] their somewhat richer peers

10 Appendix

10.1 General Information

Appliances	% of all households in possesion	% of SBO households in possesion
Irons	38.3%	60.9%
Refrigerator	1.7%	4.3%
Mobile Phone	89.4%	100.0%
Radio	57.2%	47.8%
Cassette Recorder	9.4%	13.0%
CD-Player	3.3%	4.3%
TV	30.0%	47.8%
Video	3.9%	4.3%
DVD	19.4%	43.5%
Computer	5.0%	13.0%
Mills	1.1%	4.3%
Sewing Machine	4.4%	21.7%
Water heater	1.1%	4.3%
Coffee makers	3.3%	0.0%
N	180	23

Table 1: Appliances ownership among connected households, all appliances with more than 1% ownership, lighting not included

Ownership of types of appliances

	Treatment All	Treatment Woman	Treatment Men	Treatment Small Business Owner	Treatment Civil Servant	Control All
Base	2.06	1.47	2.18	3.11	3.00	1.58
Followup	2.69	2.03	2.84	3.70	3.36	1.74

Table 2: Ownership of different types of appliances per household; light not included; owning the same device twice did not count towards this indicator

Baseline Data: Basic Information

	Average	Women	Men	Small Business Owner	Civil Servant
Control					
Age of HoH	41.6	48.1	40.2	35.3	37.8
Size of Houshold (Adult Equiv.)	4.51	3.97	4.62	4.52	4.54
Total Yearly Expenditure in RWF	794,679	465,174	860,697	1,518,844	1,594,635
Total Hours Worked	693.7	590.6	711.9	938.5	803.6
Connected					
Age of HoH	43.0	50.9	41.3	40.0	36.9
Size of Houshold (Adult Equiv.)	5.21	4.77	5.31	5.34	4.72
Total Yearly Expenditure in RWF	1,016,028	994,996	1,020,607	1,195,599	1,248,735
Hours Worked	742.8	558.6	779.1	936.1	945.5
Connects in Followup	62.5%	62.3%	62.6%	82.1%	87.5%

Table 3: Basic Information about averages of selected subgroups before connecting.

Follow-up Data: Basic Information

	Average	Women	Men	Small Business Owner	Civil Servant
Control					
Age of HoH	43.8	51.5	42.3	39.4	39.0
Size of Houshold (Adult Equiv.)	4.72	3.55	4.95	4.83	4.71
Total Yearly Expenditure in RWF	836,818	346,347	925,127	1,764,028	1,959,043
Hours Worked	653.9	524.8	680.1	802.6	661.5
Connected					
Age of HoH	44.1	52.8	42.2	41.2	40.4
Size of Houshold (Adult Equiv.)	4.93	3.85	5.17	5.63	4.91
Total Yearly Expenditure in RWF	1,498,032	825,397	1,628,441	1,326,388	2,505,388
Hours Worked	679.6	546.9	710.1	960.1	575.0

Table 4: Basic Information about averages of selected subgroups after connecting (or not connecting)

Main Acitivity	Control 2011	Treatment 2011	Control 2013	Treatment 2013
Female				
1. Farmer (Ind.)	83.0%	90.2%	81.4%	87.0%
2. Civil Servant	0.9%	0.0%	0.0%	2.2%
3. Small Business Owner	8.0%	0.0%	2.0%	4.3%
4. Small Business Employee	3.6%	2.0%	3.9%	0.0%
5. Mother's Help	0.0%	2.0%	0.0%	0.0%
6. Studies	0.0%	0.0%	0.0%	0.0%
7. Housewife, Retired, Invalid	2.7%	2.0%	10.8%	6.5%
8. Unemployed	1.8%	3.9%	2.0%	0.0%
N	112	51	102	46
Male				
1. Farmer (Ind.)	76.0%	78.0%	68.0%	65.9%
2. Civil Servant	4.7%	5.3%	5.6%	7.0%
3. Small Business Owner	11.4%	10.1%	13.6%	12.1%
4. Small Business Employee	4.1%	4.0%	8.0%	8.9%
5. Mother's Help	1.5%	0.0%	0.0%	0.0%
6. Studies	0.9%	0.4%	0.2%	0.0%
7. Housewife, Retired, Invalid	0.8%	1.8%	3.3%	5.1%
8. Unemployed	0.6%	0.4%	1.3%	0.9%
N	533	227	538	214

Table 5: Relative main activities of groups seperated by gender, time and treatment status

Bank Account Ownership	Business Owner with electricity	Others with electricity	Business Owner Control	Others Control
No Savings Account	4.2%	16.4%	18.7%	38.6%
Bank Account	79.2%	59.6%	54.7%	36.1%
Savings Association	16.7%	17.1%	14.7%	22.5%
Both	0.0%	6.8%	12.0%	2.8%
Any Savings Account	95.8%	83.6%	81.3%	61.4%

Table 6: Relative ownership of savings accounts

10.2 Remoteness

Regression of Grid Connection

	Estimate	Std. Error	t-Value	p-Value
Without Controls				
(Intercept)	0.70	0.03	20.285	0.000 ***
Distance to next main Road	-0.009	0.002	-3.862	0.0001 ***
Adjusted R-squared: 0.04624 , F-statistic: 14.92 on 1 and 286 DF, p-Value: 0.0001391				
Controls for Spending				
(Intercept)	0.64	0.05	13.17	0.000 ***
Distance to next main Road	-0.010	0.002	-4.14	0.0001 ***
Other Investment (B)	0.22	0.08	2.81	0.0055 **
Yearly Expenditure	2.30E-08	1.52E-08	1.51	0.1327
Adjusted R-squared: 0.1151 , F-statistic: 13.22 on 2 and 186 DF, p-Value: 0.000004274				
Controls for Spending and other Factors				
(Intercept)	0.66	0.10	6.317	0.0000 ***
Distance to next main Road	-0.011	0.002	-4.536	0.0000 ***
Other Investment (B)	0.19	0.08	2.411	0.0170 *
Yearly Expenditure	1.98E-08	1.52E-08	1.3	0.1950
Female HoH (B)	-0.02	0.09	-0.16	0.8730 ~
Civil Servant (B)	0.15	0.14	1.034	0.3030
Small Business Owner (B)	0.10	0.11	0.923	0.3570
Family Size (Adult Equivalents)	0.00	0.02	-0.173	0.8630 ~
Adjusted R-squared: 0.1567 , F-statistic: 5.778 on 7 and 173 DF, p-Value: 0.00000498				

Table 7: Regressions on electricity status
Significance Levels: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '0.80 '~' 1

Regression of Appliances Owned per Household

	Estimate	Std. Error	t-Value	p-Value
Without Controls				
(Intercept)	2.37	0.12	19.648	0.000 ***
Distance to next main Road	-0.024	0.008	-2.938	0.0036 **
Adjusted R-squared: 0.0259 , F-statistic: 8.631 on 1 and 286 DF, p-Value: 0.003574				
Controls for Spending				
(Intercept)	1.51	0.22	6.804	0.0000 ***
Distance to next main Road	-0.016	0.008	-1.926	0.0557 .
Grid Connection (B)	0.96	0.24	3.931	0.0001 ***
Other Investment (B)	1.34	0.26	5.156	0.0000 ***
Yearly Expenditure	5.61E-08	5.06E-08	1.108	0.2694
Adjusted R-squared: 0.2887 , F-statistic: 20.07 on 4 and 184 DF, p-Value: 9.86e-14				
Controls for Spending and other Factors				
(Intercept)	1.60	0.24	6.562	0.0000 ***
Distance to next main Road	-0.018	0.009	-2.111	0.0362 *
Yearly Expenditure	4.84E-08	5.06E-08	0.956	0.3403
Other Investment (B)	1.14	0.27	4.245	0.0000 ***
Grid Connection (B)	0.85	0.25	3.385	0.0009 ***
Female HoH (B)	-0.32	0.30	-1.039	0.3003
Civil Servant (B)	0.71	0.47	1.507	0.1336
Small Business Owner (B)	0.81	0.35	2.293	0.0230 *
Adjusted R-squared: 0.3029 , F-statistic: 12.18 on 7 and 173 DF, p-Value: 1.308e-12				

Table 8: Regressions over amount of different types of electrical appliances owned
Significance Levels: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '0.80 '~' 1

10.3 Regressions regarding Gender

Regressions of Total Yearly Expenditure

	Estimate	Std. Error	t-Value	p-Value
Regression without Control				
(Intercept)	925,127	78,127	11.841	0.0000 ***
Grid Connection (B)	689,288	178,791	3.855	0.0001 ***
Female HoH (B)	-578,780	200,012	-2.894	0.0039 **
Female HoH with Grid Connection(B)	-210,238	444,862	-0.473	0.6367
Adjusted R-squared: 0.04 , F-statistic: 9.334 on 3 and 597 DF, p-Value: 0.00000488				
Regressions with Controls without village dummies)				
(Intercept)	963,032	249,871	3.854	0.000129 ***
Age of HoH	-3,664	4,144	-0.884	0.3770
Family Size (adj.)	23,333	35,371	0.66	0.5097
Grid Connection (B)	693,447	178,982	3.874	0.000119 ***
Female HoH (B)	-515,262	209,773	-2.456	0.014323 *
Female HoH with Grid Connection(B)	-183,566	445,922	-0.412	0.6807
Adjusted R-squared: 0.03859 , F-statistic: 5.817 on 5 and 595 DF, p-Value: 0.00002949				
Regressions with Controls without village dummies)				
(Intercept)	452,152	354,896	1.274	0.2032
Age of HoH	-2,907	4,116	-0.706	0.4803
Family Size (adj.)	28,213	34,797	0.811	0.4178
Grid Connection (B)	446,280	540,166	0.826	0.4091
Female HoH (B)	-394,930	208,579	-1.893	0.0588 .
Female HoH with Grid Connection(B)	-202,869	464,647	-0.437	0.6626
Adjusted R-squared: 0.125 , F-statistic: 2.904 on 45 and 555 DF, p-Value: 5.357e-09				
Regressions without Controls on data before connecting				
(Intercept)	860,496.0	57,821.0	14.882	<2e-16
Grid Connection (B)	160,111.0	127,699.0	1.254	0.2102
Female HoH (B)	-395,047.0	141,632.0	-2.789	0.0054 **
Female HoH with Grid Connection(B)	369,436.0	304,262.0	1.214	0.2250
Adjusted R-squared: 0.009693 , F-statistic: 3.812 on 3 and 859 DF, p-Value: 0.009891				

Table 9: Linear regressions on yearly total expenditure in RWF with a focus on the effects on gender
Significance Levels: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '0.80 '~' 1

Regressions of Total Time Worked

	Estimate	Std. Error	t-Value	p-Value
Regression without Control				
(Intercept)	680.1	17.0	39.912	0.0000 ***
Grid Connection (B)	14.1	39.7	0.356	0.7218
Female HoH (B)	-155.3	42.4	-3.667	0.0003 ***
Female HoH with Grid Connection(B)	-19.9	92.9	-0.215	0.8300 ~
Adjusted R-squared: 0.01806 , F-statistic: 5.99 on 3 and 811 DF, p-Value: 0.0004871				
Regressions with Controls without village dummies)				
(Intercept)	901.0	55.5	16.247	0.0000 ***
Age of HoH	-6.7	1.0	-6.697	0.0000 ***
Family Size (adj.)	12.5	7.5	1.676	0.0942 .
Grid Connection (B)	14.1	38.7	0.365	0.7150
Female HoH (B)	-88.8	43.5	-2.043	0.0414 *
Female HoH with Grid Connection(B)	19.5	90.7	0.215	0.8297 ~
Adjusted R-squared: 0.06825 , F-statistic: 12.93 on 5 and 809 DF, p-Value: 4.085e-12				
Regressions with Controls without village dummies)				
(Intercept)	781.2	87.6	8.923	0.0000 ***
Age of HoH	-6.7	1.0	-6.653	0.0000 ***
Family Size (adj.)	16.0	7.6	2.114	0.0348 *
Grid Connection (B)	543.5	392.9	1.383	0.1669
Female HoH (B)	-67.9	44.5	-1.526	0.1275
Female HoH with Grid Connection(B)	86.1	95.2	0.904	0.3664
Adjusted R-squared: 0.09164 , F-statistic: 2.785 on 46 and 768 DF, p-Value: 8.875e-09				
Regressions without Controls on data before connecting				
(Intercept)	712.4	14.4	49.465	0.0000 ***
Grid Connection (B)	65.2	31.8	2.051	0.0406 *
Female HoH (B)	-125.9	37.3	-3.372	0.0008 ***
Female HoH with Grid Connection(B)	-93.2	79.0	-1.179	0.2388
Adjusted R-squared: 0.02435 , F-statistic: 7.98 on 3 and 836 DF, p-Value: 0.00003003				

Table 10: Linear regressions on total time worked (hours per year) with a focus on the effects on gender
Significance Levels: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '0.80 '~' 1

Regressions of Monthly Expenditure on Energy

	Estimate	Std. Error	t-Value	p-Value
Regression without Control				
(Intercept)	3,912.9	482.6	8.107	0.0000 ***
Grid Connection (B)	-1,424.6	1,111.2	-1.282	0.2002
Female HoH (B)	-2,542.4	1,192.7	-2.132	0.0333 *
Female HoH with Grid Connection(B)	1,403.0	2,620.3	0.535	0.5925
Adjusted R-squared: 0.003824 , F-statistic: 2.083 on 3 and 843 DF, p-Value: 0.101				
Regressions with Controls without village dummies)				
(Intercept)	631.4	1,541.2	0.41	0.6822
Yearly Expenditure	1.02E-03	2.50E-04	4.103	0.0000 ***
Age of HoH	-11.8	25.3	-0.467	0.6405
Family Size (adj.)	523.1	215.6	2.427	0.0155 *
Grid Connection (B)	-1,567.3	1,104.1	-1.42	0.1563
Female HoH (B)	-662.7	1,284.5	-0.516	0.6061
Female HoH with Grid Connection(B)	1,184.7	2,717.2	0.436	0.6630
Adjusted R-squared: 0.0342 , F-statistic: 4.541 on 6 and 594 DF, p-Value: 0.0001628				
Regressions with Controls without village dummies)				
(Intercept)	-383.6	2,230.1	-0.172	0.8635 ~
Yearly Expenditure	1.02E-03	2.66E-04	3.836	0.0001 ***
Age of HoH	1.8	25.8	0.068	0.9457 ~
Family Size (adj.)	517.6	218.5	2.369	0.0182 *
Grid Connection (B)	-1,724.3	3,391.4	-0.508	0.6113
Female HoH (B)	-1,407.3	1,313.0	-1.072	0.2843
Female HoH with Grid Connection(B)	2,186.4	2,916.0	0.75	0.4537
Adjusted R-squared: 0.06763 , F-statistic: 1.946 on 46 and 554 DF, p-Value: 0.0003019				
Regressions without Controls on data before connecting				
(Intercept)	2,532.9	103.5	24.466	0.0000 ***
Grid Connection (B)	1,014.7	228.6	4.438	0.0000 ***
Female HoH (B)	-824.1	252.7	-3.262	0.0012 **
Female HoH with Grid Connection(B)	154.9	544.3	0.285	0.7761
Adjusted R-squared: 0.0383 , F-statistic: 12.46 on 3 and 860 DF, p-Value: 5.577e-08				

Table 11: Linear regressions on monthly expenditure on energy in RWF with a focus on the effects on gender
Significance Levels: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '0.80 '~' 1

Regressions of Monthly Expenses on traditional Energy Sources (ex. Cooking)

	Estimate	Std. Error	t-Value	p-Value
Regression without Control				
(Intercept)	3,842.5	475.9	8.075	0.0000 ***
Grid Connection (B)	-2,996.0	1,095.6	-2.735	0.0064 **
Female HoH (B)	-2,472.0	1,176.0	-2.102	0.0358 *
Female HoH with Grid Connection(B)	2,089.9	2,583.5	0.809	0.4188
Adjusted R-squared: 0.01012 , F-statistic: 3.882 on 3 and 843 DF, p-Value: 0.009001				
Regressions with Controls without village dummies)				
(Intercept)	792.8	1,501.5	0.528	0.5977
Yearly Expenditure	9.58E-04	2.43E-04	3.939	0.0001 ***
Age of HoH	-13.5	24.6	-0.547	0.5848
Family Size (adj.)	506.3	210.0	2.411	0.0162 *
Grid Connection (B)	-3,283.9	1,075.7	-3.053	0.0024 **
Female HoH (B)	-656.5	1,251.4	-0.525	0.6001
Female HoH with Grid Connection(B)	1,936.0	2,647.2	0.731	0.4649
Adjusted R-squared: 0.0403 , F-statistic: 5.199 on 6 and 594 DF, p-Value: 0.0000315				
Regressions with Controls without village dummies)				
(Intercept)	-366.5	2,173.2	-0.169	0.8661 ~
Yearly Expenditure	9.49E-04	2.60E-04	3.655	0.0003 ***
Age of HoH	1.0	25.2	0.041	0.9672 ~
Family Size (adj.)	501.0	212.9	2.353	0.0190 *
Grid Connection (B)	-2,671.8	3,304.9	-0.808	0.4192
Female HoH (B)	-1,400.5	1,279.5	-1.095	0.2742
Female HoH with Grid Connection(B)	2,531.3	2,841.6	0.891	0.3734
Adjusted R-squared: 0.07308 , F-statistic: 2.028 on 46 and 554 DF, p-Value: 0.0001259				
Regressions without Controls on data before connecting				
(Intercept)	2,474.4	88.6	27.92	0.0000 ***
Grid Connection (B)	736.4	195.7	3.762	0.0002 ***
Female HoH (B)	-800.4	216.3	-3.7	0.0002 ***
Female HoH with Grid Connection(B)	468.0	466.0	1.004	0.3155
Adjusted R-squared: 0.03598 , F-statistic: 11.74 on 3 and 860 DF, p-Value: 0.0000001534				

Table 12: Linear regressions on monthly expenditure on traditional energy sources in RWF with a focus on the effects on gender
Significance Levels: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '0.80 '~' 1

Regressions of Monthly Expenses on Electricity

	Estimate	Std. Error	t-Value	p-Value
Regression without Control				
(Intercept)	1,608.7	259.5	6.199	0.0000 ***
Female HoH (B)	-724.1	604.9	-1.197	0.2330
Adjusted R-squared: 0.002665 , F-statistic: 1.433 on 1 and 161 DF, p-Value: 0.2331				
Regressions with Controls without village dummies)				
(Intercept)	283.4	1,423.4	0.199	0.8430 ~
Yearly Expenditure	9.61E-05	1.14E-04	0.845	0.4000
Age of HoH	18.5	27.2	0.679	0.4990
Family Size (adj.)	107.3	176.0	0.61	0.5430
Female HoH (B)	-772.9	1,007.7	-0.767	0.4450
Adjusted R-squared: -0.01334 , F-statistic: 0.6215 on 4 and 111 DF, p-Value: 0.6481				
Regressions with Controls without village dummies)				
(Intercept)	97.4	1,633.5	0.06	0.9530 ~
Yearly Expenditure	1.04E-04	1.20E-04	0.87	0.3860
Age of HoH	8.4	29.3	0.286	0.7750
Family Size (adj.)	119.8	184.9	0.648	0.5190
Female HoH (B)	-220.6	1,114.7	-0.198	0.8440 ~
Adjusted R-squared: -0.04885 , F-statistic: 0.6174 on 14 and 101 DF, p-Value: 0.8451				

Table 13: Linear regressions on monthly expenditure on electricity from the national grid operator EWSA in RWF with a focus on the effects on gender
Significance Levels: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '0.80 '~' 1

Regressions of Monthly Expenses on Micro Credits

	Estimate	Std. Error	t-Value	p-Value
Regression without Control				
(Intercept)	5,814.1	535.4	10.86	0.0000 ***
Grid Connection (B)	794.9	1,232.6	0.645	0.5192
Female HoH (B)	-4,032.9	1,323.0	-3.048	0.0024 **
Female HoH with Grid Connection(B)	1,033.9	2,906.5	0.356	0.7221
Adjusted R-squared: 0.009703 , F-statistic: 3.763 on 3 and 843 DF, p-Value: 0.01059				
Regressions with Controls without village dummies)				
(Intercept)	4,584.9	2,050.4	2.236	0.0257 *
Yearly Expenditure	2.78E-03	3.32E-04	8.366	0.0000 ***
Age of HoH	-18.0	33.6	-0.535	0.5928
Family Size (adj.)	30.7	286.8	0.107	0.9149 ~
Grid Connection (B)	-1,978.8	1,468.9	-1.347	0.1784
Female HoH (B)	-2,806.6	1,708.9	-1.642	0.1010
Female HoH with Grid Connection(B)	818.0	3,614.8	0.226	0.8211 ~
Adjusted R-squared: 0.1108 , F-statistic: 13.46 on 6 and 594 DF, p-Value: 2.394e-14				
Regressions with Controls without village dummies)				
(Intercept)	2,435.0	2,966.0	0.821	0.4120
Yearly Expenditure	2.72E-03	3.54E-04	7.682	0.0000 ***
Age of HoH	-11.4	34.4	-0.332	0.7398
Family Size (adj.)	118.5	290.5	0.408	0.6836
Grid Connection (B)	9,772.0	4,510.0	2.167	0.0307 *
Female HoH (B)	-2,081.0	1,746.0	-1.192	0.2339
Female HoH with Grid Connection(B)	797.1	3,878.0	0.206	0.8372 ~
Adjusted R-squared: 0.1423 , F-statistic: 3.165 on 46 and 554 DF, p-Value: 1.437e-10				
Regressions without Controls on data before connecting				
(Intercept)	3,883.4	501.1	7.749	0.0000 ***
Grid Connection (B)	612.3	1,106.8	0.553	0.5803
Female HoH (B)	-2,385.6	1,223.1	-1.95	0.0514 .
Female HoH with Grid Connection(B)	431.1	2,635.0	0.164	0.8701 ~
Adjusted R-squared: 0.002245 , F-statistic: 1.647 on 3 and 860 DF, p-Value: 0.177				

Table 14: Linear regressions on monthly expenditure on micro credits in RWF with a focus on the effects on gender
Significance Levels: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '0.80 '~' 1

10.4 Regressions regarding Small Business Owner

Regressions of Total Yearly Expenditure	**Estimate**	**Std. Error**	**t-Value**	**p-Value**
Without Controls				
(Intercept)	720,410	77,473	9.299	0.0000 ***
Grid Connection (B)	835,209	178,859	4.67	0.0000 ***
Small Business Owner (B)	1,043,618	229,532	4.547	0.0000 ***
SBO with Grid Connection (B)	-1,383,687	496,649	-2.786	0.0055 **
Adjusted R-squared: 0.05619 , F-statistic: 12.63 on 3 and 583 DF				
Regressions with Controls (without village dummies)				
(Intercept)	666,833.0	255,012.0	2.615	0.0092 **
Age of HoH	-2,214.0	4,186.0	-0.529	0.5971
Family Size (adj.)	30,949.0	35,389.0	0.875	0.3822
Female HoH (B)	-386,834.0	193,532.0	-1.999	0.0461 *
Grid Connection (B)	802,507.0	175,832.0	4.564	0.0000 ***
Civil Servant	1,164,932.0	278,975.0	4.176	0.0000 ***
Small Business Owner (B)	1,050,264.0	227,818.0	4.61	0.0000 ***
SBO with Grid Connection (B)	-1,247,359.0	477,727.0	-2.611	0.0093 **
Adjusted R-squared: 0.09295 , F-statistic: 9.578 on 7 and 579 DF				
Regressions with Controls (including village dummies)				
(Intercept)	425,235.0	357,940.0	1.188	0.2354
Age of HoH	-2,979.0	4,249.0	-0.701	0.4835
Family Size (Adult Equivalents)	28,902.0	35,540.0	0.813	0.4165
Female HoH (B)	-395,325.0	196,800.0	-2.009	0.0451 *
Grid Connection (B)	473,172.0	545,114.0	0.868	0.3858
Small Business Owner (B)	752,556.0	235,827.0	3.191	0.0015 **
SBO with Grid Connection (B)	-856,595.0	496,388.0	-1.726	0.0850 .
Adjusted R-squared: 0.141 , F-statistic: 3.091 on 46 and 540 DF, p-Value: 3.998e-10				
Regressions without Controls on data before connecting				
(Intercept)	684,412	57,695	11.863	0.000 ***
Grid Connected	288,642	125,678	2.297	0.0219 *
Small Business Owner (B)	834,432	174,861	4.772	0.0000 ***
SBO with Grid Connection (B)	-611,887	386,013	-1.585	0.1133
Adjusted R-squared: 0.02827 , F-statistic: 8.885 on 3 and 810 DF, p-Value: 0.000008484				

Table 15: Linear regressions on Yearly Total Expenditure in RWF with a focus on the effects on small business owner
Significance Levels: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '0.80 '~' 1

Regressions of Total Time Worked

	Estimate	Std. Error	t-Value	p-Value
Without Controls				
(Intercept)	648.2	17.5	37.128	0.0000 ***
Grid Connection (B)	-10.2	40.2	-0.254	0.7998
Small Business Owner (B)	154.5	50.8	3.041	0.0024 **
SBO with Grid Connection (B)	116.4	116.9	0.996	0.3197
Adjusted R-squared: 0.01664 , F-statistic: 5.292 on 3 and 758 DF, p-Value: 0.001294				
Regressions with Controls (without village dummies)				
(Intercept)	926.78	58.70	15.789	0.0000 ***
Age of HoH	-7.248	1.044	-6.941	0.0000 ***
Family Size (adj.)	11.67	7.80	1.496	0.1351
Female HoH (B)	-69.79	41.85	-1.668	0.0958 .
HoH chose to connect (B)	2.99	38.75	0.077	0.9384 °
Small Business Owner (B)	108.50	49.34	2.199	0.0282 *
SBO with Grid Connection (B)	117.91	112.55	1.048	0.2951
Adjusted R-squared: 0.08947 , F-statistic: 13.46 on 6 and 755 DF, p-Value: 1.528e-14				
Regressions with Controls (including village dummies)				
(Intercept)	808.38	88.97	9.086	0.0000 ***
Age of HoH	-7.516	1.063	-7.07	0.0000 ***
Family Size (adj.)	15.78	7.91	1.995	0.0464 *
Female HoH (B)	-44.87	42.97	-1.044	0.2967
HoH chose to connect (B)	385.76	134.43	2.87	0.0042 **
Small Business Owner (B)	72.91	51.12	1.426	0.1542
SBO with Grid Connection (B)	118.93	115.09	1.033	0.3018
Adjusted R-squared: 0.1176 , F-statistic: 3.206 on 46 and 715 DF, p-Value: 3.832e-11				
Regressions without Controls on data before connecting				
(Intercept)	655.8	14.0	47.028	0.0000 ***
Grid Connected	59.5	30.3	1.967	0.0495 *
Small Business Owner (B)	282.6	43.2	6.536	0.0000 ***
SBO with Grid Connection (B)	-61.9	93.0	-0.666	0.5058
Adjusted R-squared: 0.0598 , F-statistic: 17.81 on 3 and 790 DF, p-Value: 3.403e-11				

Table 16: Linear regressions on Total Time Worked (hours per year) with a focus on the effects on small business owner
Significance Levels: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '0.80 '~' 1

Regressions of Monthly Expenses on Energy				
	Estimate	**Std. Error**	**t-Value**	**p-Value**
Without Controls				
(Intercept)	3,454.5	502.6	6.874	0.0000 ***
Grid Connection (B)	-1,478.7	1,143.6	-1.293	0.1960
Small Business Owner (B)	1,188.4	1,467.0	0.81	0.4180
SBO with Grid Connection (B)	1,291.8	3,404.1	0.379	0.7040
Adjusted R-squared: -0.0001804 , F-statistic: 0.9525 on 3 and 787 DF, p-Value: 0.4147				
Regressions with Controls (without village dummies)				
(Intercept)	611.80	1595.00	0.384	0.7010
Yearly Expendiutre (B)	0.001	0.000	4.089	0.0000 ***
Age of HoH	-14.93	26.18	-0.571	0.5690
Family Size (adj.)	5.46E+02	2.22E+02	2.464	0.0140 *
Female HoH (B)	-356.80	1210.00	-0.295	0.7680
HoH chose to connect (B)	-1765.00	1120.00	-1.576	0.1160
Small Business Owner (B)	-211.20	1441.00	-0.147	0.8840 °
SBO with Grid Connection (B)	2612.00	3075.00	0.85	0.3960
Adjusted R-squared: 0.0353 , F-statistic: 4.058 on 7 and 578 DF, p-Value: 0.0002341				
Regressions with Controls (including village dummies)				
(Intercept)	-309.7	2,264.0	-0.137	0.8912 ~
Yearly Expenditure	1.03E-03	2.72E-04	3.786	0.0002 ***
Age of HoH	-2.5	26.9	-0.091	0.9273 ~
Family Size (adj.)	528.9	224.6	2.355	0.0189 *
Female HoH (B)	-943.4	1,247.9	-0.756	0.4500
Grid Connection (B)	-1,989.3	3,448.0	-0.577	0.5642
Small Business Owner (B)	219.4	1,503.7	0.146	0.8841 ~
SBO with Grid Connection (B)	2,247.2	3,212.7	0.699	0.4846
Adjusted R-squared: 0.06909 , F-statistic: 1.924 on 47 and 538 DF, p-Value: 0.0003489				
Regressions without Controls on data before connecting				
(Intercept)	2,261.1	101.4	22.292	0.0000 ***
Grid Connected	669.6	221.1	3.028	0.0025 **
Small Business Owner (B)	878.5	307.7	2.855	0.0044 **
SBO with Grid Connection (B)	3,655.0	679.2	5.381	0.0000 ***
Adjusted R-squared: 0.09604 , F-statistic: 29.83 on 3 and 811 DF, p-Value: < 2.2e-16				

Table 17: Linear regressions on monthly expenditure on energy in RWF with a focus on the effects on small business owner
Significance Levels: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '0.80 '~' 1

Regressions of Monthly Expenses on traditional Energy Sources (ex. Cooking)	Estimate	Std. Error	t-Value	p-Value
Without Controls				
(Intercept)	3,398.8	495.8	6.856	0.0000 ***
Grid Connection (B)	-2,652.1	1,128.1	-2.351	0.0190 *
Small Business Owner (B)	1,126.8	1,447.1	0.779	0.4360
SBO with Grid Connection (B)	-555.4	3,357.9	-0.165	0.8690 ~
Adjusted R-squared: -0.0001804 , F-statistic: 0.9525 on 3 and 787 DF, p-Value: 0.4147				
Regressions with Controls without village dummies)				
(Intercept)	723.0	1,555.3	0.465	0.6422
Yearly Expenditure	9.70E-04	2.50E-04	3.878	0.0001 ***
Age of HoH	-16.9	25.5	-0.662	0.5085
Family Size (adj.)	537.0	216.0	2.487	0.0132 *
Female HoH (B)	-203.4	1,180.2	-0.172	0.8632 ~
Grid Connection (B)	-3,060.1	1,091.8	-2.803	0.0052 **
Small Business Owner (B)	-111.9	1,405.3	-0.08	0.9366 ~
SBO with Grid Connection (B)	504.9	2,998.2	0.168	0.8663 ~
Adjusted R-squared: 0.03905 , F-statistic: 4.396 on 7 and 578 DF, p-Value: 0.00009074				
Regressions with Controls without village dummies)				
(Intercept)	-338.1	2,207.8	-0.153	0.8784 ~
Yearly Expenditure	9.50E-04	2.65E-04	3.58	0.0004 ***
Age of HoH	-3.4	26.2	-0.131	0.8957 ~
Family Size (adj.)	524.4	219.1	2.394	0.0170 *
Female HoH (B)	-873.4	1,217.0	-0.718	0.4733
Grid Connection (B)	-2,476.9	3,362.5	-0.737	0.4617
Small Business Owner (B)	295.5	1,466.4	0.201	0.8404 ~
SBO with Grid Connection (B)	-201.3	3,133.0	-0.064	0.9488 ~
Adjusted R-squared: 0.07238 , F-statistic: 1.971 on 47 and 538 DF, p-Value: 0.0002107				
Regressions without Controls on data before connecting				
(Intercept)	2,220.2	88.3	25.146	0.0000 ***
Grid Connected	650.0	192.5	3.377	0.0008 ***
Small Business Owner (B)	781.1	267.8	2.917	0.0036 **
SBO with Grid Connection (B)	1,640.7	591.2	2.775	0.0056 **
Adjusted R-squared: 0.04539, F-statistic: 1.799 on 47 and 743 DF, p-Value: 0.001061				

Table 18: Linear regressions on monthly expenditure traditional energy (excluding cooking) in RWF with a focus on the effects on small business owner
Significance Levels: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '0.80 '~' 1

Regressions of Monthly Expenses on Electricity

	Estimate	Std. Error	t-Value	p-Value
Without Controls				
(Intercept)	1229.2	257.0	4.784	0.0000 ***
Small Business Owner (B)	1649.9	768.4	2.147	0.0334 *
Adjusted R-squared: 0.02335, F-statistic: 4.611 on 1 and 150 DF, p-Value: 0.03338				
Regressions with Controls without village dummies)				
(Intercept)	-44.5	1,457.8	-0.031	0.9757 ~
Yearly Expenditure	1.08E-04	1.15E-04	0.938	0.3501
Age of HoH	24.1	27.7	0.867	0.3876
Family Size (adj.)	70.6	180.3	0.391	0.6963
Female HoH (B)	-902.0	1,058.6	-0.852	0.3961
Small Business Owner (B)	1,678.7	979.3	1.714	0.0894 .
Adjusted R-squared: 0.006261 , F-statistic: 1.14 on 5 and 106 DF, p-Value: 0.344				
Regressions with Controls without village dummies)				
(Intercept)	-176.4	1,662.0	-0.106	0.9157 ~
Yearly Expenditure	1.15E-04	1.21E-04	0.956	0.3412
Age of HoH	12.1	29.9	0.407	0.6852
Family Size (adj.)	69.5	190.5	0.365	0.7159
Female HoH (B)	-314.1	1,177.0	-0.267	0.7902
Small Business Owner (B)	1,903.9	1,029.9	1.849	0.0676 .
Adjusted R-squared: -0.02421 , F-statistic: 0.8251 on 15 and 96 DF, p-Value: 0.6477				

Table 19: Linear regressions on monthly expenditure on electricity from the national grid operator EWSAin RWF with a focus on the effects on small business owner
Significance Levels: 0 ’***’ 0.001 ’**’ 0.01 ’*’ 0.05 ’.’ 0.1 ’ ’0.80 ’~’ 1

Regressions of Monthly Expenses on Micro Credits

	Estimate	Std. Error	t-Value	p-Value
Without Controls				
(Intercept)	4,185.3	540.3	7.746	0.0000 ***
Grid Connection (B)	2,528.7	1,229.4	2.057	0.0400 *
Small Business Owner (B)	9,096.4	1,577.1	5.768	0.0000 ***
SBO with Grid Connection (B)	-14,139.9	3,659.4	-3.864	0.0001 ***
Adjusted R-squared: 0.04033 , F-statistic: 12.07 on 3 and 787 DF, p-Value: 9.948e-08				
Regressions with Controls without village dummies)				
(Intercept)	3,553.0	2,069.0	1.717	0.0864 .
Yearly Expenditure	2.48E-03	3.33E-04	7.466	0.0000 ***
Age of HoH	-15.7	34.0	-0.463	0.6434
Family Size (adj.)	57.7	287.3	0.201	0.8410 ~
Female HoH (B)	-2,148.0	1,570.0	-1.368	0.1718
Grid Connection (B)	-232.6	1,452.0	-0.16	0.8728 ~
Small Business Owner (B)	7,574.0	1,870.0	4.051	0.0001 ***
SBO with Grid Connection (B)	-11,660.0	3,989.0	-2.924	0.0036 **
Adjusted R-squared: 0.1345 , F-statistic: 13.98 on 7 and 578 DF, p-Value: < 2.2e-16				
Regressions with Controls without village dummies)				
(Intercept)	2,235.0	2,953.0	0.757	0.4495
Yearly Expenditure	2.51E-03	3.55E-04	7.061	0.0000 ***
Age of HoH	-10.4	35.0	-0.297	0.7665
Family Size (adj.)	116.4	293.0	0.397	0.6912
Female HoH (B)	-1,708.0	1,627.0	-1.05	0.2943
Grid Connection (B)	11,120.0	4,497.0	2.474	0.0137 *
Small Business Owner (B)	6,577.0	1,961.0	3.354	0.0009 ***
SBO with Grid Connection (B)	-11,830.0	4,190.0	-2.822	0.0049 **
Adjusted R-squared: 0.1558 , F-statistic: 3.297 on 47 and 538 DF, p-Value: 1.98e-11				
Regressions without Controls on data before connecting				
(Intercept)	2,823.1	473.9	5.958	0.0000 ***
Grid Connection (B)	1,329.3	1,031.0	1.289	0.1976
Small Business Owner (B)	4,205.4	1,438.4	2.924	0.0036 **
SBO with Grid Connection (B)	-2,746.8	3,174.9	-0.865	0.3872
Adjusted R-squared: 0.008409 , F-statistic: 3.307 on 3 and 813 DF, p-Value: 0.01974				

Table 20: Linear regressions on monthly expenditure on micro credits in RWF with a focus on the effects on small business owner
Significance Levels: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '0.80 '~' 1

Variables in Dataset	Name
Dependent Variables	
yearlytotalexp_imp	Total Yearly Expenditure
TOTAL_time_work_hoh	Total Hours Worked
hexp_en_nc_imp	Monthly Expenditure on Energy
hexp_en_tradnc_imp	Monthly Expenditure on Traditional Energy (ex. Cooking)
hexp_ewsa	Monthly Expenditure on Electricity
hexp_en_kwhewsa	Monthly Use Electricity in KWH
hexp_micro_imp	Monthly Expenditure on Micro Credits
$\sum_{i=1}^{17}$ h47_ix	Types of Appliances Owned
Independent Variables	
hdum_ewsa	Grid Connected (B)
h17_hoh	Age of HoH
h26adeq	Family Size (adj.)
h20dumhoh3	Small Business Owner (B)
h16a	Female HoH (B)
followup2	Time (Followup) (B)
treat	Treatment Group (B)
followup2:hdum_ewsa	Grid Connected Household (B)
h16a:followup2:hdum_ewsa	Female HoH with Grid Connection(B)
h20dumhoh3:followup2:hdum_ewsa	SBO with Grid Connection (B)
hdum_ewsa:h20dumhoh3	SBO with Grid Connection (B)
hdum_ewsa:h16a	Female HoH with Grid Connection(B)
h20dumhoh2	Civil Servant (B)
invest1	Other Investment (B)
yearlytotalexp_imp	Yearly Expenditure
h14z11	Distance to next main Road
Other	
h20_cathoh	Main activity of Head of Household
h117	Bank account
h47_ix	Individual Household appliance (i=1 to 17)
$\sum_{i=1}^{17}$ h47_ix	Types of Appliances Owned

Table 21: The names of the variables in the dataset of Lenz et al. [2017] used throughout this thesis

Bibliography

Chukwuma Leonard Azimoh, Patrik Klintenberg, Fredrik Wallin, and Björn Karlsson. Illuminated but not electrified: An assessment of the impact of solar home system on rural households in south africa. *Applied Energy*, 155:354 – 364, 2015. ISSN 0306-2619. doi: https://doi.org/10.1016/j.apenergy.2015.05.120. URL http://www.sciencedirect.com/science/article/pii/S030626191500759X.

Douglas F. Barnes and Hans P. Binswanger. Impact of rural electrification and infrastructure on agricultural changes, 1966-1980. *Economic and Political Weekly*, 21(1):26–34, 1986. ISSN 00129976, 23498846. URL http://www.jstor.org/stable/4375175.

Tania Berger. Practical constraints for photovoltaic appliances in rural areas of developing countries: Lessons learnt from monitoring of stand-alone systems in remote health posts of north gondar zone, ethiopia. *Energy for Sustainable Development*, 40:68 – 76, 2017. ISSN 0973-0826. doi: https://doi.org/10.1016/j.esd.2017.07.001. URL http://www.sciencedirect.com/science/article/pii/S0973082617304490.

Iwona Bisaga and Priti Parikh. To climb or not to climb? investigating energy use behaviour among solar home system adopters through energy ladder and social practice lens. *Energy Research and Social Science*, 44:293 – 303, 2018. ISSN 2214-6296. doi: https://doi.org/10.1016/j.erss.2018.05.019. URL http://www.sciencedirect.com/science/article/pii/S2214629618304961.

Kristine Bos, Duncan Chaplin, and Arif Mamun. Benefits and challenges of expanding grid electricity in africa: A review of rigorous evidence on household impacts in developing countries. *Energy for Sustainable Development*, 44:64 – 77, 2018. ISSN 0973-0826. doi: https://doi.org/10.1016/j.esd.2018.02.007. URL http://www.sciencedirect.com/science/article/pii/S0973082617308074.

Central Intelligence Agency. CIA world factbook: Rwanda. https://www.cia.gov/library/publications/the-world-factbook/geos/rw.html. Accessed: 30.08.2018.

Ujjayant Chakravorty, Martino Pelli, and Beyza Ural Marchand. Does the quality of electricity matter? evidence from rural india. *Journal of Economic Behavior & Organization*, 107:228–247, 2014.

Shyamal K. Chowdhury. Impact of infrastructures on paid work opportunities and unpaid work burdens on rural women in bangladesh. *Journal of International Development*, 22(7):

997–1017, 2009. doi: 10.1002/jid.1607. URL https://onlinelibrary.wiley.com/doi/abs/10.1002/jid.1607.

Rosamaría Dasso and Fernando Fernandez. The effects of electrification on employment in rural peru. *IZA Journal of Labor & Development*, 4(1):6, 2015.

Taryn Dinkelman. The effects of rural electrification on employment: New evidence from south africa. *American Economic Review*, 101(7):3078–3108, December 2011. doi: 10.1257/aer.101.7.3078. URL http://www.aeaweb.org/articles?id=10.1257/aer.101.7.3078.

Gerald Foley. Rural electrification in the developing world. *Energy Policy*, 20(2):145 – 152, 1992. ISSN 0301-4215. doi: https://doi.org/10.1016/0301-4215(92)90108-E. URL http://www.sciencedirect.com/science/article/pii/030142159290108E. Energy and the Third World.

Louise Grogan. Household electrification, fertility and employment: Evidence from the colombian censuses. 2015.

Louise Grogan and Asha Sadanand. Rural electrification and employment in poor countries: Evidence from nicaragua. *World Development*, 43:252 – 265, 2013. ISSN 0305-750X. doi: https://doi.org/10.1016/j.worlddev.2012.09.002. URL http://www.sciencedirect.com/science/article/pii/S0305750X1200215X.

Stephanie Hirmer and Peter Guthrie. The benefits of energy appliances in the off-grid energy sector based on seven off-grid initiatives in rural uganda. *Renewable and Sustainable Energy Reviews*, 79:924 – 934, 2017. ISSN 1364-0321. doi: https://doi.org/10.1016/j.rser.2017.05.152. URL http://www.sciencedirect.com/science/article/pii/S1364032117307797.

Humans Rights Watch. Rwanda: Politically closed elections. https://www.hrw.org/news/2017/08/18/rwanda-politically-closed-elections. Accessed: 03.09.2018.

Shahidur R. Khandker, Douglas F. Barnes, and Hussain A. Samad. Are the energy poor also income poor? evidence from india. *Energy Policy*, 47:1 – 12, 2012a. ISSN 0301-4215. doi: https://doi.org/10.1016/j.enpol.2012.02.028. URL http://www.sciencedirect.com/science/article/pii/S0301421512001450.

Shahidur R Khandker, Hussain A Samad, Rubaba Ali, and Douglas F Barnes. *Who benefits most from rural electrification? Evidence in India.* The World Bank, 2012b.

Charles Kirubi, Arne Jacobson, Daniel M. Kammen, and Andrew Mills. Community-based electric micro-grids can contribute to rural development: Evidence from kenya. *World*

Development, 37(7):1208 – 1221, 2009. ISSN 0305-750X. doi: https://doi.org/10.1016/j.worlddev.2008.11.005. URL http://www.sciencedirect.com/science/article/pii/S0305750X08003288.

Kenneth Lee, Edward Miguel, and Catherine Wolfram. Appliance ownership and aspirations among electric grid and home solar households in rural kenya. *American Economic Review*, 106(5):89–94, 2016.

Luciane Lenz, Anicet Munyehirwe, Jörg Peters, and Maximiliane Sievert. Does large-scale infrastructure investment alleviate poverty? impacts of rwanda's electricity access roll-out program. *World Development*, 89:88 – 110, 2017. ISSN 0305-750X. doi: https://doi.org/10.1016/j.worlddev.2016.08.003. URL http://www.sciencedirect.com/science/article/pii/S0305750X16304387.

Molly Lipscomb, A. Mushfiq Mobarak, and Tania Barham. Development effects of electrification: Evidence from the topographic placement of hydropower plants in brazil. *American Economic Journal: Applied Economics*, 5(2):200–231, April 2013. doi: 10.1257/app.5.2.200. URL http://www.aeaweb.org/articles?id=10.1257/app.5.2.200.

Dale T. Manning, Peter Means, Daniel Zimmerle, Kathleen Galvin, John Loomis, and Keith Paustian. Using contingent behavior analysis to measure benefits from rural electrification in developing countries: an example from rwanda. *Energy Policy*, 86:393 – 401, 2015. ISSN 0301-4215. doi: https://doi.org/10.1016/j.enpol.2015.06.032. URL http://www.sciencedirect.com/science/article/pii/S0301421515002505.

Bilal Mirza and René Kemp. Why the rural rich remain energy poor. *Consilience*, (6):133–156, 2011.

Pulak Mishra and Bhagirath Behera. Socio-economic and environmental implications of solar electrification: Experience of rural odisha. *Renewable and Sustainable Energy Reviews*, 56:953 – 964, 2016. ISSN 1364-0321. doi: https://doi.org/10.1016/j.rser.2015.11.075. URL http://www.sciencedirect.com/science/article/pii/S1364032115013428.

Andrew Pascale, Tania Urmee, Jonathan Whale, and S. Kumar. Examining the potential for developing women-led solar pv enterprises in rural myanmar. *Renewable and Sustainable Energy Reviews*, 57:576 – 583, 2016. ISSN 1364-0321. doi: https://doi.org/10.1016/j.rser.2015.12.077. URL http://www.sciencedirect.com/science/article/pii/S1364032115014604.

Sambhu Singh Rathi and Claire Vermaak. Rural electrification, gender and the labor market: A cross-country study of india and south africa. *World Development*, 109:346 – 359, 2018.

ISSN 0305-750X. doi: https://doi.org/10.1016/j.worlddev.2018.05.016. URL http://www.sciencedirect.com/science/article/pii/S0305750X18301645.

The Economist. Empowering villages. https://www.economist.com/finance-and-economics/2018/07/12/mini-grids-could-be-a-boon-to-poor-people-in-africa-a 2018. Accessed: 30.08.2018.

Transparency International. Corruption perceptions index 2014: Results. https://www.transparency.org/cpi2014/results. Accessed: 03.09.2018.

United Nations. Brief history of rwanda. http://www.un.org/en/preventgenocide/rwanda/education/rwandagenocide.shtml. Accessed:03.09.2018.

US AID. Rwanda: Africa fact sheet(power). https://www.usaid.gov/powerafrica/rwanda. Accessed: 03.09.2018.

Tanja Winther, Kirsten Ulsrud, and Anjali Saini. Solar powered electricity access: Implications for women's empowerment in rural kenya. *Energy Research & Social Science*, 44:61 – 74, 2018. ISSN 2214-6296. doi: https://doi.org/10.1016/j.erss.2018.04.017. URL http://www.sciencedirect.com/science/article/pii/S2214629618303694.

World Bank. The world bank in rwanda. http://www.worldbank.org/en/country/rwanda/overview. Accessed: 03.09.2018.

World Bank. Access to Electricity (% of population). https://data.worldbank.org/indicator/eg.elc.accs.zs, 2016. Accessed: 04.09.2018.

World Economic Forum. Things to know about Rwanda's economy. https://www.weforum.org/agenda/2016/04/5-things-to-know-about-rwanda-s-economy/. Accesed: 01.09.2018.