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The Impact Of Access To Renewable Energy Technologies On Economic Development Of Remote Rural Areas In Developing Countries

A Case Study Approach.

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Abstract

Access to modern energy in rural areas of developing countries is critically low. This explains the associated poor levels of socio-economic development and extreme poverty conditions prevailing is some areas. Economic emancipation of these areas can be catalyzed by enhancing uptake of modern energy. Nonetheless, electrification through grid extension is not feasible due to isolated nature of most areas and financial constrains knocking at the door steps of their governments. This scenario had paved way renewable energy technologies as the feasible option to decentralize energy. Chipendeke rural community in Zimbabwe is a classic example of most rural areas in developing countries which, since time immemorial had lacked access to modern energy. A major mile stone was witnessed in 2010 in this community when a micro hydro power plant broke the long vicious cycles of seemingly perpetual dependency on traditional biomass energy. This paper interrogate the impact of renewable energy technologies on economic development under the null hypothesis that, "access to renewable energy makes a difference". Chipendeke community case study is presented where peasant farming is the main economic activity. Difference in Difference (DID) methodology had been employed to analyze agriculture output for two time periods, before and after electrification. This was done by dividing Chipendeke farmers into two groups which are, the treatment group comprised of 38 farmers with access to electricity and control group comprised of 77 randomly selected farmers without access to electricity. The product of the variables Time and Access was processed from the dataset to generate a new variable named "TAP". This variable is instrumental to the DID methodology because it shows the effect of treatment on the treatment group and compares it to control group for the two time periods. Results based on econometric modelling of crop harvests and income levels failed to reject the null hypothesis as farmers were found better off regarding harvest quantities and income levels in the second time point.

Keywords— Renewable Energy Technologies, Difference in Difference Methodology, Econometrics Models

I. INTRODUCTION

Enhanced access to modern energy is crucial for economic emancipation of remote rural communities in developing countries. Nearly 1,6 billion out of 6.5 billion of the total world population have no access to electricity and 2,5 billion depend on biomass, It is the poor who lack access and it has been argued that lack of access to modern energy is a contributory factor to the poor remaining poor, (OECD, 2006). Furthermore, according to (International Energy Agency, 2010 p 248) "…more than 1.4 billion people worldwide lack access to electricity, 585 million people in Sub Saharan Africa (including over 76 million in Nigeria and some 69 million in Ethiopia) and the rest in developing Asia (including 400 million in India and 96 million Bangladesh). Some 85% of those without access live in rural areas". Despite these statistics, frantic efforts to enhance access are underway in many countries. Although these countries bear the same logo "developing" they differ in many respects and the differences affects the dynamics of energy interventions. John & Otwin, (1995) stated that, some developing countries like Brazil, Nigeria or Myanmar have history of military interventions and rule, some like Somalia, Chad are poverty stricken while others like South Africa, South Korea and Singapore are developing economically. Some are governed by religious leaders such as Iran and Brunei while others Cuba, Vietnam are aggressively socialist and secular, moreover, political stability exist is some like Lesotho while others like Central Africa Republic are consistently on the brink of Chaos. These multifaceted differences affect the dynamics of energy access to the poor in remote rural areas. Kirubi et al, (2009), (Maher, Smith, & William, 2003) and (Khennas & Barnett, 2000) underscored that, studies on access to energy and rural development exist but, they focus mainly on geographic regions such as South and East Asian and Latin America. Empirical case studies from Sub-Saharan Africa are rare. Driven by this notion, this research contributes in filling this research gap by exploring a case study of Chipendeke rural community which is in sub Saharan Africa in the eastern highlands region of Zimbabwe. This paper posits that, access to modern energy is crucial for rural economies by presenting econometric models of crop harvests and income levels of farmers in Chipendeke community. The following null hypothesis had been constructed,

"Access to renewable energy technologies has no effect on economic development of remote rural communities"

This hypothesis will be tested and results will be analyzed using OLS multiple regression techniques. To achieve this objective, the paper is structured in sections. The first section is a description of the energy situation in African continent with specific reference to the Southern Africa Development Community (SADC) region. Then follows the theoretical framework, literature reviews and in-depth analysis of Chipendeke case study, Difference in Difference methodology, presentation of results and the conclusion.

II. Energy situation in the Southern Africa Development Community, (SADC) region

Austin (2010) posits that, in Africa, history shows that colonialism in most of Sub Saharan countries encouraged a non-inclusive type of development whereby areas which were not economically productive were deliberately sidelined by development. This resulted in infrastructure serving only areas which produce raw materials hence, most of the rural communities lacked basic infrastructure like tarred roads, tapped water and they had no access electricity which is a fundamental catalyst for development

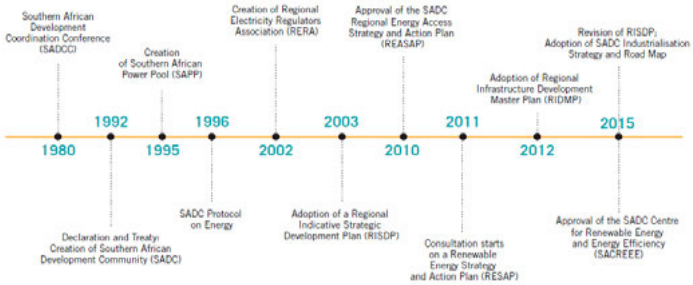
Moreover, postcolonial governments are failing to electrify rural by grid extension due to financial challenges (Austin, 2010). Decentralization of electricity is therefore a necessary adjunct to develop remote rural areas. To achieve decentralization of electricity to rural areas, renewable energy technologies offers the most feasible and affordable solution, (Karekezi & Kithyoma, 2002). The choice of particular technology to implement in an area depends on prevailing physical conditions in the area. For example, if an area receives adequate solar radiation, photovoltaics may be the best choice, if fast flowing rivers exists, micro hydro power will be the solution and if wind blows freely, wind turbines are competitive to generate energy. Out of the mix of renewable energy technologies, micro hydro technologies have more advantages because they their simple design, they offer low price per kilo watt, and they are easy to maintain once the initial investment has been made, (Fulford, Moseley, & Grill, 2000). Due to these advantages, small hydro projects are thus being widely used in many rural communities. In addition to providing heating and lighting for rural areas small hydropower is also a window of hope to accelerate rural economic development if the energy they produce is integrated with agriculture production and other income generating activities, (ESMAP, 2003)

Enhancing energy access is at the core SADC mandate since the bulk of the population in the region are in rural areas tied to traditional biomass as the primary form of energy. To liberated people from biomass, miles stones for energy cooperation started in 1980 where SADC in its original form called Southern African Development Coordination Conference, (SADCC) was formed to provide member states with means to coordinated infrastructure development. Figure 1 below the major miles stones made by the block.

III. Milestones for energy co-operation and integration in SADC

The miles stones for energy cooperation started in 1980 where SADC in its original form called Southern African Development Coordination Conference, (SADCC) was formed to provide member states with means to coordinated infrastructure development without including apartheid South Africa. Since its inception up to the present time major milestones have been taking place as indicated in figure 3.

Figure 1: Energy cooperation milestones in SADC region



Source: (SADC Renewable Energy and Energy Efficiency, Status Report, 2015)

SADC has developed two other organisations in the energy field, both of which are considered to be subsidiary components of the Secretariat, the Southern Africa Power Pool (SAPP) which was created in 1995 in response to concerns expressed by SADC member states that because of the lack of strong interconnections, the region was for practical purposes divided into a northern sector (Angola, the DRC, Malawi, Mozambique, Tanzania, Zambia and Zimbabwe), where base load was supplied primarily from hydropower, and a southern sector (Botswana, Lesotho, Namibia, South Africa and Swaziland), where base load was supplied primarily by thermal generation, (UNFCCC, 2015).

Second is the Regional Energy Regulators Association (RERA), was instituted in 2002 in response to the growing role of electricity/energy regulators in the region. In 1990, only three southern African countries had regulatory bodies, and these had little power to enforce action in such key areas as tariffs and capacity development. Today, 12 of the 15 SADC countries have either electricity or overall energy regulators in place (soon to include Botswana, which is developing a combined energy and water regulator). RERA's formal membership so far is limited to regulators in only 10 of the 12 countries (SADC Renewable Energy and Energy Efficiency, Status Report, 2015).

A third subsidiary organisation, the SADC Centre for Renewable Energy and Energy Efficiency (SACREEE) was approved by a meeting of the SADC energy ministers on 24 July 2015, during which the ministers also approved the selection of Namibia as the host country., It was subsequently endorsed by the SADC Council of Ministers, August 2015. The United Nations Industrial Development Organization (UNIDO) has provided support for SACREEE from the beginning, including completing a detailed preliminary study and roadmap

in 2013, (SADC Renewable Energy and Energy Efficiency, Status Report, 2015)

IV. THEORETICAL FRAMEWORK

A. The theory of sustainable agriculture intensification

The main form of economic activity in Chipendeke is farming hence, the community agriculture output will be accessed in this research. The theory of sustainable agriculture intensification focusing on, "Food Security, The Challenge of Feeding 9 Billion People" published by Godfray, et, al (2010) is the guiding theoretical framework in this research. Godfray et al, (2010) elucidates that, globally, growth in land for crop cultivation is outpaced by population growth. In the period 1961 to 2007 (total agricultural area has expanded 11% from 4.51 to 4.93 billion ha, and arable area 9% from 1.27 to 1.41 billion ha). Over the same period the human population grew at a faster rate than increase in agriculture land. It grew from 3 billion to 6.7 billion which is an increase of 123% and by 2050 world population is projected to reach 9 billion. Fitter, (2005) asserted that, these trajectories points to food crisis due to shortage in land to grow food crops. This land shortage is also being exacerbated by other factors such as climate change, urbanization, the processes of desertification, soil erosion, and other consequences of unsustainable land management, (Fitter , 2005). Pressure on land for food crop cultivation is increased due to recent policy decisions to produce bio fuels from plants such as Sugarcane and Jatropha seed which require good quality agricultural land. China, for example, has successfully acquired the rights to grow palm oil on 2.8 million (ha) of Congolese land, (The Royal Society, 2009) cited by (The Royal Society 2009).

Furthermore, recent studies have projected that the world will need 70-100% more food by 2050 thus, the challenging question emerging is, how can more food be produced sustainably? (Montegomery D, 2007). In the past the primary solution to produce more food was simply to bring more land into production or to exploit new fish stocks. This is no longer feasible due to land scarcity and new fishing grounds as the existing ones are already facing overfishing. Therefore, a practical approach to this inevitable food crisis to feed the projected 9 billion people by the year 2050 is sustainable agricultural intensification, Godfray et al, (2010) (Godfray et al, 2010).

Sustainable agricultural intensification is producing more crop harvest output from the same area of land while reducing the negative environmental impacts and at the same time increasing contributions to natural capital and the flow of environmental services, (Godfray et al, 2010). This is the solution to the impending food crisis to feed the projected 9 billion people by the year 2020. There is urgent need for the global agriculture system to be modelled under sustainable agriculture intensification where by yields are increased without adverse environmental impacts and without bringing more land to crop cultivation, (Royal Society 2009). The projected world population of 9 billion by 2050 is certain but, expanding agricultural land to contain the imminent food crisis is not feasible, sustainable agriculture intensification is a viable option for the world to mitigate food crisis in the face of critical shortage of farming land and a ballooning population. Further advantage of sustainable agriculture intensification is that it closes the yield gap, which is the difference between realized and achieved yields per hectare versus the highest quantity of yield which can be achieved from the same hectare if genetic engineering and other technologies are properly applied, (Godfray et al 2010).

Currently huge yield gaps exists for instance, it has been estimated that in some parts of South East Asia where irrigation is available, average maximum climate adjusted rice yields are 8.5 metric tons per hectare yet the average actually achieved is 60% of this figure. Similar yield gaps are found in rain fed wheat and in rain fed cereals in Brazil and Argentina, (Godfray et al, 2010). Technologies which facilitate closing the yield gap are necessary to be implemented as a means to abort the food crisis by closing the yield gap. If a technology such as crop genetic engineering improves production without adverse ecological consequences, then it is likely to contribute to the agriculture system's sustainability. As will be presented in this research renewable energy technologies constitute the technological mix in agriculture production which does not damage environment since energy produced is clean, no green house gases are emitted. Community access to this technology will be determined to see if it increase food crop production.

B. Review of studies on access to electricity and rural development.

(Annemarije et al, 2009) studies on impact of access to electricity conducted in rural Bolivia, Tanzania and Vietnan pointed out changes in income levels where, 172 of 182 (92%) households in Vang (Vietnam) considered that their income increased as a result of being able to use electric rather than manual tea drying machines. The increase in income was mainly related to increased efficiency, allowing more time spent on picking of tea leaves in the season where there is a shortage of labour. One electric tea drier owner (in Nho, Vietnam) reported that his annual income is US$494 which is almost double the income of other households (approximate average US$250). In this case, the difference in income can be explained by the fact that he not only uses the drier for his own tea, but also rents his drier to other villagers. Similarly, the grain millers in Tanzania indicated an increase in incomes due to a switch from diesel operation to electric operation due to faster operation and therefore being able to serve larger numbers of customers despite frequent electricity power cuts. I addition, the study shows that women have benefited from modern energy in their enterprises. Starting up an electric engine is much easier than a diesel engine, this benefited women especially in Vietnam, where women were strongly represented as owners of rice and rice mills, (Annemarije et al, 2009).

Turning to Kenya, a case study of impact of access to electricity at Mpeketoni rural community was conducted by (Kirubi, Jacobson, Kammen, & Mills, 2008). The study elaborates that, before electrification, farmers relied on traditional hand tools such as axe, hoe, and panga (machete) to clear the land and plough because tractors were limited and

very expensive. Also due to their high demand, farmers made reservations and payment for tractors a year in advance, yet within a few months of commissioning Mpeketoni mini grid electricity in 1994, over a dozen tractors were available for hire. Thus, the net effect of access to electricity was, increased access to tractors leading to improved agricultural productivity, which had a positive effect on the local economy. "Without electricity, very few entrepreneurs would dare bring their tractors at Mpeketoni because in the event of a major breakdown, welding repair services could only be obtained in Witu or Mombasa (100 km and 450 km away, respectively)", explained one of the farmers. Availability of electrical welding services for repairing tractors and other farm tools was the main mechanism through which electricity contributed to better exploitation of the agricultural potential in Mpeketoni. (Kirubi, Jacobson, Kammen, & Mills, 2008)

In South Korea, accession to power by General Park Chung Hee in 1961 through a coup led to electricity shortage being addressed by funding from USAID towards new energy generating facilities, (Amsden , 1989) and (Kim, 2011). A study by Terry Van Gevelt, (2014) on rural electrification between in South Korea from 1965 to 1979 shows positive economic and quality of life outcomes. Access to electricity in rural areas led to a dramatic increase in household income from an annual income of USD 249 in 1970 to USD 2172 in 1979. The late 1960s saw introduction of new high-yield varieties of rice and barley, the strengthening of extension services, land reclamation, and reforestation to improve soil fertility. Electricity contributed by significant increase in agriculture productivity as it powered water pumps and draining pumps which were used to irrigate rice fields and enabled cultivation of rice and barley, among other crops, in periods of drought, (Van Gevelt, 2014). Electricity made investment in livestock profitable for many rural households. For example, feed pulverisers enabled households to engage in larger scale ranch management and electric milking machines helped improve the productivity of milk production. Electrified chicken farms are also recorded to have seen a significant increase in egg production (Park, 1997) and (Yim, Park, & SW, 2012). Furthermore, electricity helped rural households capitalize on high market demand from an increasingly urban population and government guarantees of relatively high purchase prices for staple crops. It enabled crops to be processed and appropriately stored before being transported (Brandt, 1979; Ban et al., 1980). This reduced crop losses from the point of harvest to the point of consumption. Moreover, increased information on market structure and conditions through the television helped improve bargaining power of rural households with middlemen and traders, (Yim, Park, & SW, 2012) and Van Gevelt, 2014

Further economic benefits were felt throughout the wider economy with government estimates suggesting that investment in rural electrification and other rural infrastructure offered a three-fold return on investment costs (Kim, 2004). For example, (Brandt, 1979) reports that, as of 1979, more than 80% of children from rural areas were being sent to junior high school at private expense and the number of students continuing to senior high school, vocational schools, and university was approximately four times higher than that in 1970. Additionally, increased rural incomes created a new market for urban producers of consumable goods who consequently established rural distribution channels (Park, 1997)

However, amid these success stories of, anecdotal evidence presented by Brandt (1979) highlighted that, the benefits of electrification in South Korea were not captured by the poorest 25% of the rural population who could not afford the loans. This is supported by (Han , 1987) study of 209 households from28 villages in seven provinces, where Han's (1987) survey data found that 22.9% of respondent households did not benefit economically with 17.4% recording no change in income and 5.4% a decrease in income. Han (1987) also found a strong correlation between capital assets and increased income. Furthermore, given land reform and the dissolution of the more divisive class and clan barriers in the 1950s and 1960s, electrification helped create a new class division of the haves and have-nots, particularly with respect to household appliance ownership (Turner, Hesli, Bark, & Yu, 1993)

Furthermore, household debt increased significantly for both poorer and wealthier households. For poorer households, this was due to the loans taken out to finance internal wiring costs. For wealthier households, this was largely due to loans taken out to pay for electric appliances, such as televisions (Baek, Kim, & Lee, 2012). Han (1987), in his analysis of savings behaviour of households suggests that increased household debt became particularly burdensome on poorer households who lacked the assets to make economically productive use of electricity and increase their income. Taken together, this suggests that rural electrification disproportionately benefited more wealthy households at the expense of poorer households. This increase in income inequality was additionally solidified through the creation of a divisive class structure defined by ownership of electric household appliances.

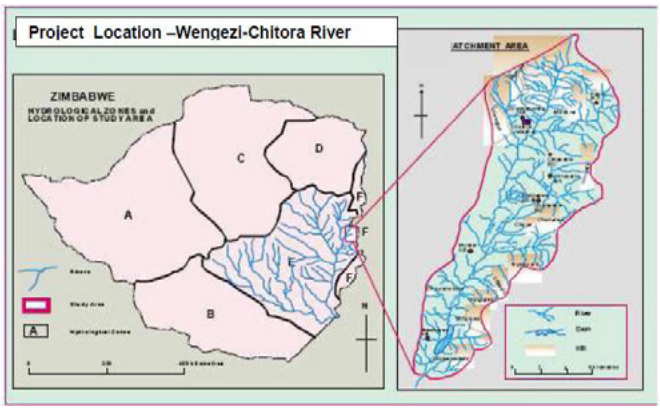
Lastly, despite improvements in income and quality of life, rural– urban migration accelerated during this period and into the 1980s, especially among wealthier households. Park (1997) stated that, it was television and the glamorous depiction of urban life that accelerated the migration of younger villages. (Chang, 2010) further asserted that, many of the more wealthy, older villagers who did not migrate, indirectly migrated through encouraging their children to migrate to cities. A survey of the literature on rural–urban migration in South Korea suggests that the key driver for the migration of the younger members of wealthier households was education as a good tertiary education was seen, and continues to be seen, as the most important determinant for 'a good life' (Turner, Hesli, Bark, & Yu, 1993) and (Soresen, 1994). Combined with the agglomeration of elite high schools and universities in urban centers, particularly Seoul, it seems that the improvements in rural living standards were not sufficient to stem rural–urban migration, but rather the increase in income accrued by wealthier households allowed for an increase in rural–urban migration.

V. BACKGROUND ABOUT CHIPENDEKE CASE STUDY

Chipendeke rural community is located in the eastern highlands region of Zimbabwe near the border with Mozambique. The region is mountainous and has the greatest hydro potential in the country owing to its high altitude. The community is situated along Wengezi River, a tributary of Chitora River in Save Catchment area. One of the notable features in the community is the gravity feed sprinkler irrigation which tapes water from the perennial Wengezi-Chitora river.

The community is largely engaged in cash crop farming. Major crops produced and sold are wheat, maize, sugar beans, Cassava, potatoes, tomatoes and small grains. Non-Governmental Organization called Practical Action Southern Africa was involved on a programme called "Catalyzing modern energy service delivery to marginalized communities in Southern Africa" covering Zimbabwe, Mozambique and Malawi. The goal of the programme is to increase uptake of renewable energy technologies in poor rural communities of Southern Africa. Chipendeke rural community is one of the beneficiary community of this project. Figure 2 below shows its location along Wengezi-Chitora River in Zimbabwe

Figure 2: MHP project location in Zimbabwe



Source: Practical Action Southern Africa, 2008

The demographics of Chipendeke are composed of a total population of 7284 with an average household size of 5.2 as show in the table 1 below.

Table 1: demographics of Chipendeke community

Males	Females	Total Population	Number of households	Average household size
3562	3722	7284	1390	5.2

Source: Practical Action Southern Africa, 2008

A. *Assessment of Micro Hydro Power in Chipendeke*

The feasibility assessment for a Micro Hydro Power generation was conducted from the 13th to the 17th of January 2009 by a team comprised of engineers from Practical Action Southern Africa, Ministry of Energy and Power Development and Zimbabwe National Water Authority. The purpose of the hydro assessment was to investigate if there was adequate water to sustain hydro-power generation for a long period of time. During the assessment, before any hydrological measurements were done the local leadership which was also accompanying the assessment team stated that the stream was flowing at its lowest level as compared to other times of the year. A thorough assessment of the site was conducted and it involved an investigation of the source of water, the potential site of the turbine and potential energy demand centers. A final report of the assessment findings was produced by the Ministry of Energy with details on the technical hydro potential of Wengezi Chitora River. A noted advantage is that the geology of the area which is mainly of granite rock offers scope for strong foundation to anchor the abstraction system, (Practical Action Southern Africa, 2008). The hydrological measurements conducted at the abstraction site showed that the river discharge was 25 liters per second. There is a significant drop in head of about 200 meters and "head" refers to the difference in altitude of weir location point and the point where the turbine is located. This gives the height or gradient at which the water flows to the turbine. The greater the head the faster the velocity at which the water flows and gravity of 9, 81 was measured on the head. The formula below show how the current potential power output was calculated using an average head of 120metres.

$$\text{Power} = 9.81*120*0.025$$
$$= 30\text{Kw}$$

The calculations above conducted by the Ministry of Energy showed that the site can generate power of 30KW despite the abstraction of water for irrigation and also there was high potential to generate more than these KW, (Practical Action Southern Africa, 2008). Given this situation where the head is good coupled with the fact that water for the hydropower is residual from irrigation and other upstream activities a 3 Jet Pelton turbine was recommended.

The Pelton turbine is very efficient and can operate even with small heads, Figure 3 below shows turbine with community workers manually opening two jets.

Figure 3: Three Jet Pelton Turbine with power house workers opening the jets

This picture was taken by the research team. As shown in the photography, the jets which divert water into the turbines can be adjusted and if all the jets are fully opened maximum power equivalent of 30KW, is produced by the turbines. After water had entered into the turbines, it is re-channeled back to join the mainstream of the river. Energy produced through this micro hydro technology is environmentally friendly (clean) no greenhouse gases are emitted. Moreover, this technology it

does not consume water but it just harness the energy in it and diverts it back to join the mainstream Wengezi- Chitora river.

Figure 4 below shows the mouth of the penstock where water from the river is diverted to generate power.

Figure 4: Mouth of the Penstock

Source: Practical Action Southern Africa, 2008

Shown above in figure 4 is part of Wengezi-Chitora River where the mouth of the penstock (pipes) is situated. Seen visibly is the civil construction work which was part of the community sweat equity contribution constructed under the supervision of engineers from Practical Action Southern Africa. This photography was taken by Practical Action in 2014 which was a normal year with no drought and this is evidenced by adequate amount of water flowing in the river course.

Furthermore, Figure 5 shows some of the workers at Chipendeke actively involved in sweat equity contribution.

Figure 5: Chipendeke Community members during sweat equity contribution

Source: Practical Action Southern Africa, 2008

Sweat equity contribution in the form of heavy construction manual work was male dominated as can be seen in figure 5. Females where mainly involved in gathering locally available materials such as quarry stones, pit sand, bricks and river sand and ensuring that they were available at the construction site.

Figure 6: Civil construction work diverging water from the mouth of penstock

Figure 6 is one of the outcomes of civil construction work performed under sweat equity contribution. This trench is diverting water from the mouth of the penstock to the turbines. The photography was taken by the research team in January 2016. This period was the peak of El Nino induced drought affecting Southern Africa as can be noted by little amount of water in the river course contrary to figure 4 which was taken in 2014. Nevertheless, during this drought stricken period, researchers noted that the community was still able to generate electricity by opening only one jet of the Pelton turbines.

Figure 7: Penstock, (Pipe) caring water to the turbine house

Source: Practical Action Southern Africa, 2008

The “head” refers to the vertical distance between the mouth of penstock (obstruction pipe) and the turbine location, (Dan, 2005). The head has a significant drop of about 200 miters where the water is being diverted from the river downhill to the 3 Jets Pelton turbine location. This high head increases the velocity of the water and results in more power being generated.

Figure 8: Turbine house before final completion

Source: Practical Action Southern Africa 2008

This picture figure 8 was taken by one the project donor, Practical Action towards the completion of the project in 2010.

Figure 9: Turbine house after completion

Figure 9 is the photography showing the current status of the turbine house. It was taken by the research team in January 2016. The house is securely locked to protect the turbines and other equipment inside.

Figure 10: Power house worker observing meter readings

Figure 10 is another photography taken by the research team in January 2016. It shows one of the community power house worker observing power output from the meter readings as the turbines are running.

Figure 11: Donors involved in funding the project

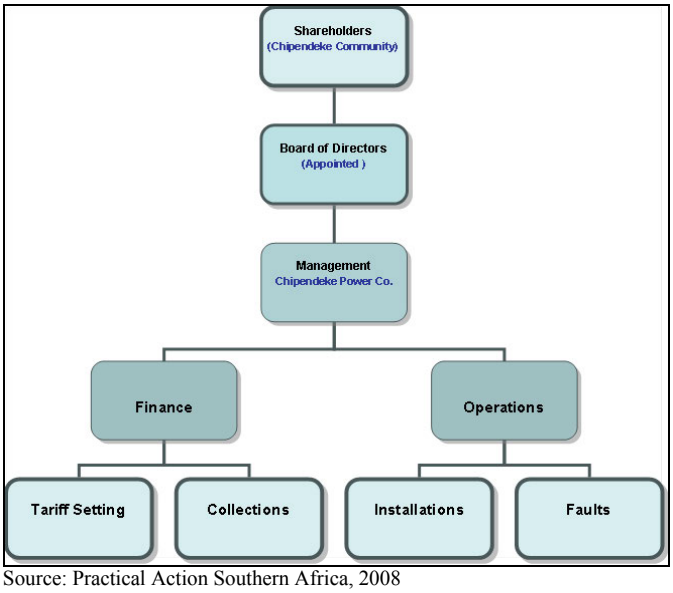
Figure 11 photographed by the research team. It shows the donors of the projects who are European Union Energy Facility and Practical Action. It also shows the date 27 June 2012 when the project was commissioned to the community by the resident Minister of Manicaland province which the community belongs to.

B. Chipendeke Power Company, (Pvt Ltd)

The Micro Hydro Power project is being operated as a community owned private company called as Chipendeke Power Company, (Pvt Ltd). Figure 12 below shows the company management structure. A business model or shares for dividends model which promotes sustainability through community investment in the form of sweat equity contribution is being used. Sweaty equity contribution refers to all labour and locally available material include sand, quarry stones, excavation of trenches, building and general labour of carrying water for building, cement and pipes which the community did. Community contribution was valued based on the prevailing market worth of the task and came to a total of €18 340.00, (Practical Action Southern Africa, 2008). This became the dividends shares or the sweat equity contribution of the community to the company.

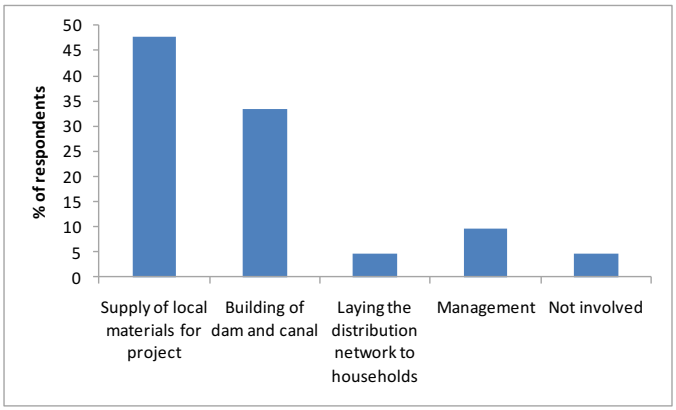
Chipendeke Power Company scheme is a grant co funded by European Commission (EC) Energy facility and Practical Action to the total of €68 903.00 and 25% of this amount was sweat equity contribution by the Chipendeke community in the form of labour and locally available materials valued at €18 340.00. The life span of the project was estimated to be about twenty years after which the installed turbine would have undergone enough wear and tear thus, in need of a replacement. (Practical Action 2008). Figure 13 shows the various activities which the community members were involved in during the construction phase.

Figure 12: Chipendeke Power Company management structure



Source: Practical Action Southern Africa, 2008

Figure 13: Various activities where the community sweat equity contribution



Source: (Zinamwe, Sibanda, & Mbengo, 2010)

From the graph, it shows that supplying of locally available materials for the civil construction works is the greatest community contribution followed by the technical expertise of building the canal which was done by trained local builders under the supervision of engineers from Practical Action. This was followed by the task of laying the poles and installing cables which were connected to different households, the clinic, local school and the business center. The community was also involved in some managerial decision during the construction and the percentage of the work which the community was not involved is very small as can be noted from the graph and this was in the form of highly technical task such as surveying of the site and some electrical engineering roles such as deciding which type of turbine can fit the area for maximum power generation.

The project at the time of research was connected to 38 households and has a potential of connecting 100 additional households. Electricity bills are settled through the prepayment system, a system provided by Conlog-Sneider Electric, Private Limited, which is a company based in South Africa. A tariff structure has been designed which shows a breakeven tariff of US$0.04 cents in the first year, thereafter inflation adjusted by 1.5%annual inflation rate. There are no charge penalties for late payments because all services are prepaid.

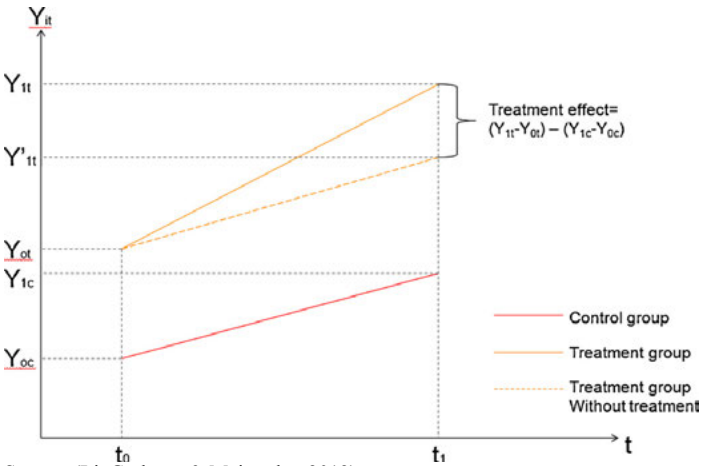
VI. Difference in Difference, (DID) Methodology

To assess the impact of access to electricity through renewable energy from a community owned Chipendeke Micro Hydro Power Plant, this research make use of Difference in Difference methodology in conjunction with logit and ordinal logistic regression models. The difference in difference will be used as an evaluation tool to make causal inferences regarding community access to renewable energy and quantity of agriculture output which is the main indicator of economic development in Chipendeke community. This approach is most appropriate since observations on crop harvest output are being made for two time periods which are the year 2010 when the micro hydro power plant started to operate and the year 2015

A. Description of Difference in Difference methodology

The basic idea embedded in the DID methodology is that observations are collected for two groups for two time periods. One group is the treatment group which is exposed to the treatment in one period. The other group is the control group which receives no treatment during both time periods. In the case where the same units within a group are observed in each time period, the average gain over time in the non-exposed (control) group is extracted from the gain over time in the exposed (treatment) group. This double differencing is called "difference-in-difference", it removes biases in the second comparison time period between the treatment and control groups such that the results will be due to permanent differences between those groups. It also removes biases from comparison over time in the treatment group that could be the result of time trends unrelated to the treatment (Abadie, 2005), (Finkelstein, 2002), (Card & Krueger, 1994). In order to provide an unbiased consistent estimate of the treatment effect, the DID approach strongly relies on parallel trend assumption. This assumption states that, average outcomes for the treatment and control groups follow the same trend over time in the absence of treatment as graphically illustrated below.

Figure 14: Graphic Illustration of DID methodology



Source: (Li, Graham, & Majumdar, 2012)

- To grasp how the DID methodology works, practical interpretation of the above graph is applied to the Chipendeke case study. In Chipendeke community, 115 farming households were observed in two time periods, t = 0, 1 where 0 indicates the pre-treatment phase, the year 2010 which is a time period before the treatment group receives treatment or put simply, before electrified farming households has access to electricity and 1 is the post-treatment phase which is a time period after the treatment group receives treatment, put simply this is the year 2011 to the present time when some farming households had access to electricity.
- Every group is indexed by the letter i = T, C where T indicates the treatment group which farmers with access to electricity, and C indicates the control group which are farmers without access to electricity.
- Let Y0T and Y1T be the outcome for the treatment group before and after treatment respectively, and let Y0C and Y1C be the corresponding outcome for the control group.

Therefore, according to Card and Kruger (1994), under the basic DID approach, the outcome Y_it which is the crop harvest quantity of farmers with access to electricity, is modelled by the following equation

$$Y_{it} = \alpha + \beta T_{it} + \gamma G_{it} + \delta(T_{it} \cdot G_{it}) + \boldsymbol{\pi X_{it}} + \varepsilon_{it}$$

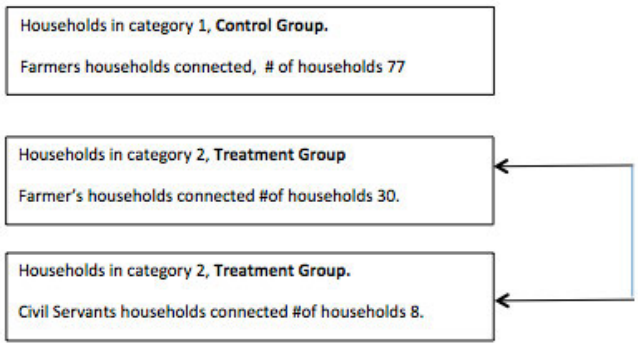
whereby,

- α is the constant term,
- β is the time trend,
- Y is the specific group effect.
- δ is the treatment effect we are interested in
- ε_{it} is a random, unobserved term which contains the error caused by omitted covariates.
- X_it is the vector of covariates uncorrelated with ε_{it}
- π is the vector of coefficients, the point is parallel trend assumption will how but will be now conditional to χ .
- T_it is the time-specific component, which takes the value 1, if Y_it is observed in the post-treatment period and 0 otherwise.
- G_it is a group-specific component, which is 1, if Y_it is an observation from the treatment group and 0 otherwise.
- T_(it).G_it is an interaction term which indicates a treated individual after the intervention.

B. Research design for the DID estimator

Table 2 below shows the research design of how household were sampled to constitute the treatment and control groups in Chipendeke rural community. 38 households from three villages which are accessing electricity were purposefully sampled as the treatment group while other 77 farming households randomly selected from villages which are not yet accessing electricity constituted the control group. Observation on the harvest output will be made for two time periods which are the year 2010 and the 2015 will be used.

Table 2; DID Estimator design



This design above shows that Chipendeke community will be divided into two categories which are, households category one, which is the control group composed of 77 households which are not connected to electricity, household category two, which is the treatment group composed of 38 households which are connected to electricity. Currently, 38 households, rural health center, primary school, and business center with three shops and a grinding mill are also connected to electricity.

C. Study design

The study area Chipendeke community falls under ward 31 of Mutare Rural District Council, (MRDC). The area is fairly big, it has a total population of 7 284 and 1390 households which are sparsely populated, (Practical Action, 2008). Data collection was conducted by a team of 6 enumerators during the month of December 2015. Due to the size of the area, random sampling of households was done to ensure that all the households in the community have an equal and independent chance to be selected in the study. However, since the focus was on access to electricity in this community, purposively sampling of 38 households which are currently benefiting from the micro hydro project was done because information from these households was critical for the research hence it was inevitable to include them. Before the final research was conducted the structured questionnaire was tested with a sample of 10 households target population. After this testing adjustment was done to some questions to make them more relevant to the context in Chipendeke. Using the adjusted questionnaire, a pilot survey was conducted where by 20 household randomly sampled participated and the results of this pilot survey were analyzed on Stata version 12 software.

Based on the results of the pilot survey the researchers were convinced that the questionnaire can be used for the actual survey to the sample population. On the 5th to the 9th of January 2016, the actual survey was the conducted and the set target for the research was to cover 200 households because the bigger the sample the better the quality of the results. Some information obtained through key informant interviews with community leaders. However, due to some challenges experienced in the field 115 instead of 200 households were eventually covered. Two major challenges which contributed

for the failure to attain the set target of households during the two days of the survey as follow as,

- Erratic rainfalls were experienced every day and researchers were at times forced to stop because the questionnaires could be spoiled by the showers hence making it difficult to read during the data leaning and analysis process.
- Households in Chipendeke community especially those in the control group are sparsely populated and sometime distances from one household to another can be a 500 meters. Researchers ended up with fatigue as they moved from one household to another following the random sampling strategy.

VII. Results

Field data collected was entered in Stata version 12 and a data set called Chipendeke Energy Survey, 2016 was produced. This dataset is comprised of 115 observations across 21 variables. Following the DID methodological approach, the dataset was structured in a manner that observations for the first time period, the year 2010 before access to electricity is represented by the dummy variable 0 and for the second time period which is 2015 when there was access to electricity it was represented by the dummy variable 1. Observations numbered 1-38 are households in the treatment group which have access to electricity while observations numbered 39-115 are households with no access to electricity which forms the control group. A variable of interest named "TAP" was generated from the dataset, this variable is a product of the variables Time, (which are the two time periods before and after electrification) and the variable Access. This new variable TAP, according to the DID methodology is the most important because it shows the treatment effect. Results presented here shows a summary statistics of 21 variables in the research, modelling of maize, beans wheat and tomatoes crop harvest. Subsequently, an ologit model of farmer's income levels performed followed by conclusion.

Table 3: Summary of variables in the research

. summarize

Variable	Obs	Mean	Std. Dev.	Min	Max
HHNumber	230	58.34783	33.45545	1	116
Labour	230	4.513043	.7803842	3	6
Education	230	1.86087	.8755481	1	4
Irrigation	230	.7217391	.44912	0	1
FamilySize	230	5.6	1.352985	4	9
Access	230	.326087	.469802	0	1
Time	230	.5	.5010905	0	1
Gender	230	.4434783	.4978785	0	1
Pfarming	230	.2217391	.4163226	0	1
Age	230	4.026087	.9930841	2	5
IncomeLevel	230	3.052174	1.245733	1	6
Soiltype	230	.3043478	.4611342	0	1
Extension	230	1	0	1	1
MaizeHarvest	230	5.956522	1.811614	2	9
WheatHarvest	230	4.247826	1.393801	1	8
BeansHarvest	230	3.26087	1.106448	1	8
TomatoHarv~t	230	2.304348	1.352171	1	7
MaizeAcreage	230	4.952174	1.338829	2	9
WheatAcreage	230	3.804348	1.01988	2	8
BeansAcreage	230	2.995652	.795719	1	6
TomatoAcre~e	230	2.247826	.9365782	1	4
V	0				
W	0				
TAP	230	.1608696	.3682119	0	1

The summary of variables in table 2 is showing that the research had 230 observations across 26 variables. The mean and standard deviation of each variable is indicated. On the extreme left is the min max which shows how the survey instrument was structured in collecting data on each variable.

Table 4: Maize crop harvest model

Source	SS	df	MS
Model	262.698452	11	23.8816775
Residual	488.866765	218	2.2425081
Total	751.565217	229	3.28194418

Number of obs =	230
F(11, 218) =	10.65
Prob > F =	0.0000
R-squared =	0.3495
Adj R-squared =	0.3167
Root MSE =	1.4975

MaizeHarvest	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
WheatAcreage	-.2308542	.123878	-1.86	0.064	-.475006	.0132976
Labour	-.0769033	.1319866	-0.58	0.561	-.3370364	.1832297
Education	-.0557036	.1170126	-0.48	0.635	-.2863244	.1749172
FamilySize	.0143024	.0766013	0.19	0.852	-.1366717	.1652764
Access	-1.670568	.3728286	-4.48	0.000	-2.405378	-.9357575
Time	1.119696	.2550426	4.39	0.000	.6170308	1.622361
Gender	.0980134	.2103315	0.47	0.642	-.3165301	.5125569
Pfarming	.3294259	.3279152	1.00	0.316	-.3168641	.9757159
Age	-.0947654	.1050166	-0.90	0.368	-.3017432	.1122125
IncomeLevel	.2117931	.1101699	1.92	0.056	-.0053413	.4289275
TAP	1.340408	.4994399	2.68	0.008	.3560589	2.324757
_cons	6.593266	1.162779	5.67	0.000	4.301538	8.884994

A. Coefficient TAP in the Maize crop model

The coefficient for TAP in table 4 informs us about the treatment group which are the 38 farming households with access to electricity in 2015, and the group which it is compared to is the control group which are the 77 farming households which had no access to electricity in both time periods, in 2010 and in 2015 time period. Farmers maize harvest is explained in kilograms hence, in this model, the P value 0,000 and coefficient 2,16789 for TAP means that, the treatment group had 2,2 units or 2,2 tons more of Maize harvest quantity compared to the control group thus, access to

electricity in the treatment group increases maize harvest by 2,2 tons more than the control group.

Table 5: Wheat crop harvest model

Source	SS	df	MS
Model	141.193302	11	12.8357547
Residual	303.680611	218	1.39303033
Total	444.873913	229	1.94268084

Number of obs =	230
F(11, 218) =	9.21
Prob > F =	0.0000
R-squared =	0.3174
Adj R-squared =	0.2829
Root MSE =	1.1803

WheatHarvest	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
WheatAcreage	.4187881	.0976354	4.29	0.000	.2263579	.6112183
Labour	-.109409	.1040263	-1.05	0.294	-.314435	.0956169
Education	-.0105483	.0922244	-0.11	0.909	-.1923139	.1712174
FamilySize	-.1126876	.060374	-1.87	0.063	-.231679	.0063038
Access	-.3890944	.2938479	-1.32	0.187	-.9682409	.190052
Time	.427086	.2010138	2.12	0.035	.0309067	.8232653
Gender	.0854638	.1657744	0.52	0.607	-.241262	.4121895
Pfarming	.5040945	.258449	1.95	0.052	-.0052841	1.013473
Age	-.2390083	.0827697	-2.89	0.004	-.4021396	-.0758771
IncomeLevel	-.0634851	.0868313	-0.73	0.465	-.2346213	.1076511
TAP	1.301018	.3936375	3.31	0.001	.5251953	2.07684
_cons	4.509456	.9164537	4.92	0.000	2.703212	6.3157

B. Coefficient for the variable TAP in Wheat crop model

Table 5 shows the coefficient for TAP which informs us about the treatment group which are the 38 farming households with access to electricity in 2015, and the group which it is compared to compared to is the control group which are the 77 farming households which had no access to electricity in both time periods, in 2010 and in 2015 time period. Wheat harvest is expressed in kilograms hence, the P value 0.000 and coefficient 1,644987 for the coefficient TAP means that treatment group has 1,6 tons of Wheat harvest quantity more than the control group thus, access to electricity in the treatment group increases Wheat harvest quantities by 1,6 tons more than in the control group.

Table 6: Beans crop harvest model

Source	SS	df	MS
Model	75.9802626	11	6.9072966
Residual	204.367564	218	.937465888
Total	280.347826	229	1.22422631

Number of obs =	230
F(11, 218) =	7.37
Prob > F =	0.0000
R-squared =	0.2710
Adj R-squared =	0.2342
Root MSE =	.96823

BeansHarvest	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
BeansAcreage	.1868983	.0858797	2.18	0.031	.0176376	.3561591
Labour	.0747692	.0849219	0.88	0.380	-.092604	.2421423
Education	-.0553625	.0755084	-0.73	0.464	-.2041824	.0934574
FamilySize	-.0211658	.0500951	-0.42	0.673	-.1198985	.0775668
Access	.0080855	.209839	0.04	0.969	-.4054873	.4216584
Time	.7618596	.1629014	4.68	0.000	.4407963	1.082923
Gender	-.0417118	.1366585	-0.31	0.760	-.3110528	.2276292
Pfarming	.5169505	.2120349	2.44	0.016	.0990496	.9348513
Age	.0169769	.0677793	0.25	0.802	-.1166096	.1505635
IncomeLevel	-.1992091	.0711615	-2.80	0.006	-.3394616	-.0589566
TAP	.6818067	.3219719	2.12	0.035	.0472305	1.316383
_cons	2.535394	.6534577	3.88	0.000	1.247491	3.823297

C. Coefficient for the variable TAP in Bens crop models.

The coefficient for TAP in table 6 informs us about the treatment group which are 38 farming households with access to electricity in 2015, and the group which it is compared to is the control group which are the 77 farming households which had no access to electricity in both time periods, in 2010 and in 2015 time period. Beans harvest was expressed in kilograms, hence the P value 0.000 and coefficient 1,291441 means that, treatment group has 1,3 tons of Wheat harvest quantities more than the control group thus, access to electricity in the treatment group increases Beans harvest quantity by 1,3 tons more than in the control group.

Table 7: Tomatoes crop harvest model

Source	SS	df	MS
Model	111.783686	11	10.1621533
Residual	306.911966	218	1.40785306
Total	418.695652	229	1.82836529

Number of obs =	230
F(11, 218) =	7.22
Prob > F =	0.0000
R-squared =	0.2670
Adj R-squared =	0.2300
Root MSE =	1.1865

TomatoHarvest	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
TomatoAcreage	.2190176	.0910751	2.40	0.017	.0395171	.398518
Labour	.0048541	.1051929	0.05	0.963	-.2024711	.2121793
Education	.0239606	.0934117	0.26	0.798	-.160145	.2080662
FamilySize	.0226094	.060682	0.37	0.710	-.0969891	.1422078
Access	-.0202342	.2506736	-0.08	0.936	-.5142881	.4738197
Time	1.422879	.1986133	7.16	0.000	1.031431	1.814327
Gender	-.0222227	.1671966	-0.13	0.894	-.3517515	.3073062
Pfarming	.2331256	.2597913	0.90	0.371	-.2788985	.7451497
Age	.0192775	.083233	0.23	0.817	-.1447669	.1833219
IncomeLevel	-.1316351	.0868194	-1.52	0.131	-.302748	.0394778
TAP	-.7483118	.3926257	-1.91	0.058	-1.52214	.0255165
_cons	1.31679	.7799872	1.69	0.093	-.2204912	2.854071

D. Coefficient variable TAP in Tomatoes crop model

The coefficient for TAP in table 7 informs us about the treatment group which are the 38 farming households with access to electricity in 2015, and the group which is compared to the control group which are the 77 farming households which had no access to electricity in both time periods, in 2010 and in 2015 time period. The P value 0,058 and coefficient -7483118 means that, treatment group has -0,75 tons less harvest quantities than the control group.

E. Summary of the variable TAP from the four models.

To determine the effect of treatment on the treatment the variable TAP is instrumental to the DID methodology as it informs us about the effect of treatment. For the four econometrics models presented above, shows the treatment effect increase Maize harvest by 1,3 tons, Wheat 1,3 tons and Beans 0,7 tons. It is only in the tomatoes model were the control treatment has -0,7 tons less than the control group. Therefore, given this outcome we fail to reject the null hypothesis that access to renewable energy makes a difference for maize, wheat and beans crop models but the hypothesis is rejected for the Tomatoes crop harvest model. In the four models where the variable TAP is significant the variable access is also significant but with a negative coefficient. Since the variable "access" represents the treatment group in 2010, this means that in these three models the treatment group always had less harvest quantity in 2010 than in 2015.

Table 7: Ordinal logit model for farmers income levels

Ordered logistic regression

Number of obs	=	230
LR chi2(12)	=	150.33
Prob > chi2	=	0.0000
Pseudo R2	=	0.2035

Log likelihood = -294.22192

IncomeLevel	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Labour	.0393229	.161624	0.24	0.808	-.2774543	.3561002
Education	.161959	.1450616	1.12	0.264	-.1223565	.4462744
FamilySize	.1094288	.0966599	1.13	0.258	-.0800212	.2988788
Access	1.097251	.3853485	2.85	0.004	.341982	1.85252
Time	1.684746	.3579418	4.71	0.000	.9831932	2.386299
Gender	-.3523396	.2574957	-1.37	0.171	-.8570219	.1523428
Pfarming	.4740463	.4260483	1.11	0.266	-.360993	1.309085
Age	.1248418	.1314685	0.95	0.342	-.1328319	.3825154
WheatHarvest	.0124568	.1020928	0.12	0.903	-.1876415	.212555
BeansHarvest	-.3651222	.128205	-2.85	0.004	-.6163994	-.113845
TomatoHarvest	-.1703621	.1114758	-1.53	0.126	-.3888506	.0481264
TAP	2.982667	.7383962	4.04	0.000	1.535438	4.429897
/cut1	-1.323828	1.413771			-4.094769	1.447113
/cut2	.4847647	1.40955			-2.277902	3.247432
/cut3	2.315124	1.421385			-.4707402	5.100988
/cut4	4.850617	1.478642			1.952532	7.748703
/cut5	7.276786	1.541416			4.255667	10.29791

F. Income levels

Income levels for farmers are ordered from the least income of less than 700 US$ per annum to the maximum of more than 2000 US$ per annum. Due to this categorical ordering of incomes, ordered logistic regression provides subtle interpretation as elaborated by table 7 above which an ologit model of farmers' incomes. The variable TAP in the model shows the income levels of the treatment group in the year 2015 and compares it to the incomes of the control group. P value of 0,000 shows that TAP is significant and it coefficient of 2,982667 means that the incomes of farmers in the treatment group were 3 units higher than incomes of farmers in the control group. With such figures, it can be summed up that the treatment effect had significantly increased incomes from farming activities. The variable Access which represents the treatment group in 2010 has a coefficient of 1,097251 which is less than the coefficient of variable TAP hence this further confirms that, the treatment group had more income in 2015 compared to 2010.

G. Other impacts

Apart from improving crop harvest output as shown in by the constructed four econometrics models, other related impacts such as storage of fresh farm produce, use of Information and Communication technology (ICT), environmental gains and improved transportation were also experience in Chipendeke community. Regarding farm produce, electricity enabled farmers to store for a couple of days fresh farm produce such as meat, milk and perishables products which they bought from the nearby city. This had been facilitated by some farmer's households and entrepreneurs at the business center who had purchased refrigerators. Quality of life was also improved through the use of Information and Communication Technology on daily basis. Purchased some electrical appliance like radio, television and cell phones had enabled to be efficient in communication with the outside world. Farmers can now listens to news and farming programmes on radio and television where they get advice on issues such as climate change, drought, planting timing and onset of the rain season. This information is widely shared to other community members without radio and television. Furthermore, on days where interesting programs are aired on radio and television other households without radio and television are welcomed with neighboring household with these gadgets to listen to programmes. This combined with their indigenous knowledge systems of interpreting whether conditions and farming activities had greatly improved life in the community.

On the environmental arena, the energy produced from Chipendeke Micro Hydro Power plant is clean, no greenhouse gases are emitted hence, it is contributing to the worldwide efforts to fight climate change which had been exacerbate by the use of fossil fuels. The Wengezi-Chitora River is major form of livelihood for communities located downstream from where the Micro-Hydro power station is located. Irrigation, laundry, livestock drinking water are some major uses of the river which are not affected by the MHP because the technology simply diverts waste from the river, harness the hydro energy, then rechanneled it back to the main stream of the river. Even aquatic life in the river is not affected by this process hence it is contributing to environment sustainability.

Improved transportation with the advent of electricity was applauded by the farmers. Before electrification, it was impossible to travel to and fro within a day to the nearby city of Mutare. This journey could take about one week as there was no transport for people to reach the highway that goes to the city of Mutare. People had to walk these long journeys but with the advent of electricity there were one commuter omnibus introduced to ply route to the city to and fro once a day. In addition, due to electrification, the once remote rural Chipendeke community had been transformed into a look and learn visitors center. It is now frequently hosting academic visitors mainly students from universities and technical college in the country studying sustainability related disciplines and are learning from its experience.

VIII. CONCLUSION

The use of difference in difference estimator in this case study had implicitly shown the treatment effect when average gain over time in the non-exposed control group was extracted from the gain over time in the exposed treatment. This double differencing is called "difference-in-difference", removed biases in the second comparison time period (the year 2015) between the treatment and control groups such that the results obtained with the coefficient of TAP were due to permanent differences between the two groups. Employing this methodology had removed biases in the treatment group from comparison over time that could be the result of time trends unrelated to the treatment. Moreover, to provide an unbiased consistent estimate of the treatment effect, the DID methodological approach which had strongly relied on the parallel trend assumption which states that, average outcomes for the treatment and control groups follow the same trend over time in the absence of treatment.

Conclusively, the overall research outcome is that, we failed to reject the null hypothesis that, "access to electricity through renewable energy technologies has an effect on remote rural areas economic development". Why? the is answer is

partly attributed to more time to concentrate on farming activities had been created by elimination of some tasks as gathering firewood wood and walking long distances to the diesel powered grinding mill to process maize meal which is a staple food for the community. Reduction of drudgery from cooking smoke and kerosene lambs used for lighting had contributed to farmer's health hence, good health is positively correlated to high agriculture output. However, some sentiments echoed by farmers were that, there is still need to connect more households to electricity since the maximum of 100 can be connected. I addition, there is also need to upgrade the capacity of the micro hydropower plant to generate more than 30 KW. Lastly, Chipendeke community represent typical remote rural communities in developing countries therefore, results in this research can be generalized.

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