The Analysis of Determinants and Barriers of Household Sustainable Energy Transitions in Tanzania

By

Kevin Mutayebwa Rugaimukamu

Thesis Presented for the Degree of

DOCTOR OF PHILOSOPHY

in the School of Economics

UNIVERSITY OF CAPE TOWN

November 2021

Supervisors:

Prof. Edwin Muchapondwa

A/Prof. Djiby Thiam

Declaration

I, Kevin Rugaimukamu, do hereby declare that the work presented in this thesis is my own, except where acknowledged and that this thesis or any part of it has not been previously submitted for the award of a degree at any university.

Signed Signed by candidate

Candidate's signature: Date: 18/11/2021

Abstract

The Tanzanian energy policy is centered around improving access, reliability, and affordability of modern energy services. Up to the year 2018, Tanzania was among a small group of countries that dominated both the top 20 lists of countries in the world with electricity and modern cooking energy access deficits, respectively. The country's electricity access has since increased but the number of households connected to electricity has increased at an uneven rate, with higher connection rates observed in urban areas. Nevertheless, access to modern cooking energy has continued to increase at a very slow rate.

The country's household energy use portrays a heavy reliance on wood fuels (charcoal and firewood) for cooking with 90 percent of Tanzanian households using wood fuels for the activity. Nonetheless, it also depicts gradual and modest improvements in households' modern energy use, with regards to electrification and use of modern fuels for cooking particularly in urban areas (LPG and Electricity). This is despite the government's numerous initiatives put in place to spear head the transitions. The implementation of these initiatives has always been delayed and most of the time fallen short of the policy makers expectations, owing to both institutional and policy inefficiencies.

This thesis investigates the economics of household energy transition in Tanzania and adds to the literature by looking at the determinants of household adoption of modern cooking fuels (LPG and electricity), looking at the role of social capital in smoothing the adoption of modern cooking fuels. Moreover, we investigate the impacts of these household energy transitions on household welfare indicators, and, lastly, we investigate the institutional challenges in implementing household energy transition initiatives with regards to electrification particularly in rural areas. We do this in three separate but related chapters that form the key components of a thesis constituted of five

chapters, with the first and last chapter presenting the introduction and general conclusions of the thesis.

The second chapter investigates the determinants of adoption of modern cooking fuels (LPG and electricity) in Tanzania. We model household energy transition to modern cooking fuels with an emphasis on the role of social capital. We utilize membership into key community groups; Savings and Credit Co-Operative Societies (SACCOS) and other self-help groups as a measure of social capital. We make use of three waves of the 2008-2016 Tanzanian panel data set from a nationally representative household panel survey that collects information on a wide range of topics such as agricultural production, non-farm income generating activities, consumption expenditure, and a number of other social-economic characteristics of the households. We employed panel data techniques to ascertain the role of social capital on household energy transitions in Tanzania. For robustness purposes, we ran two regression analyses, one incorporating the social capital variable as a dummy variable and the other as a continuous variable to observe the stability of our results. Moreover, beyond the panel data model specifications, we ran alternative model specifications to check the stability of our results.

The third chapter investigates the impacts of household energy transitions on welfare indicators in Tanzania. We conducted two impact analyses, whereby we analyzed the impact of household's use of modern cooking fuels (LPG and electricity) on household welfare indicators (energy expenditure and health) and the impact of household use of electricity on household welfare indicators (energy expenditure, time use, study hours, acute respiratory health). We make use of two national representative data sets, that is the fourth wave of the national panel survey of 2014/15 and the 2015/16 Tanzanian Demographic and Health Survey and the Malaria Indicator Survey to analyze the impacts of household energy transitions on non-health and health related outcomes respectively. We used propensity score matching techniques to ascertain the impact of household energy transitions. We estimated the propensity scores, chose the appropriate matching algorithm to do the matching, assessed the matching quality and performed a sensitivity analysis of the results.

The fourth chapter looks at the institutional barriers in implementing household energy transition programs in Tanzania, with an emphasis on rural electrification in Tanzania. We investigate if the political clergy and energy sector governing entities in Tanzania constrain the smooth implementation of rural electrification projects. Moreover, we investigate whether the current rules, laws, and regulations in the electricity supply industry and supporting sectors attract investments in rural electrification projects. Furthermore, we review policies, strategies, and interventions within the energy sector with regards to rural electrification. We use primary data collected from key informants in the sector and augmented this with secondary data from official reports and periodicals from key government and non-government entities in the electricity supply industry sector. We used qualitative data techniques to ascertain the key institutional barriers to rural electrification in Tanzania.

The results of chapter two reveal that social capital plays an important role in household energy transitions. Households with membership in self-help groups or Savings and Credit Co-Operative Societies (SACCOS) were more likely to adopt modern cooking fuels (LPG and electricity). Membership in these groups help households raise awareness, gain technical information about, and bridge liquidity constraints on, new technologies including modern energy. Our results remained stable in the different specifications of the social capital variable and econometric models. The results also reveal that household income, household's head age, household size, and availability of biomass stoves and electricity connection to be important determinants of household's adoption of modern cooking fuels.

Chapter three results revealed significant impacts of household energy transitions on household welfare indicators. Household use of modern cooking fuels was found to significantly reduce charcoal expenditures, and consequently amount of charcoal used in urban areas. Moreover, the results revealed that use of modern cooking fuels was associated with a reduction of respiratory infection for children under five years old. On the other hand, electrification was found to improve study hours, years of schooling and consequently, schooling outcomes. Moreover, we find suggestive evidence that electrification smoothens information flows and augments social campaigns, thus facilitate promoting issues like family planning. The chapter also reveals an elongation of the working day due to electrification.

The results of the fourth chapter show institutional barriers pertaining to non-independence of institutions within the energy sector, deficiencies of the existing policies, strategies and interventions pertaining to rural electrification, the supporting framework's modus operandi not accustomed to serve the electricity supply sector, the uncertainties created by the laws and regulations governing the sector, and the institutional specific challenges such as financial constraints and shortage of staff facing the governing institutions in Tanzania formed some of the key bottlenecks hampering the timely implementation of and achieving of desired outcomes by rural electrification projects in Tanzania as perceived by the stakeholders in the Tanzanian electricity supply industry.

The revealed results point to key policy implications, including putting in place policies to enhance the use of modern cooking fuels to cut down the excessive use of charcoal. Furthermore, the government should enhance its efforts not only in increasing access to electricity but also increasing the number of connected households especially in rural areas, so as to reap the associated benefits with regards to schooling, labor and family planning. Thus, raising awareness about modern fuels of energy for cooking through promotions and easing liquidity constraints could go a long way in enhancing the use of modern cooking fuels and increasing households' electricity connections.

The best channel to enhance awareness and easing liquidity constraints is community-based groups. The government should promote financial inclusion through community groups to enhance among other things, household energy transitions by easing liquidity constraints. Moreover, encouraging the formation of such groups especially among women could amplify the dissemination of information about modern cooking fuels and heighten diffusion of new technologies, markedly in rural areas.

Nevertheless, to smoothen government's implementation of households' energy transition initiatives, institutional barriers must be nullified. The government should review its interventions to make sure they cover all the constraints with regards to hurdles associated with household's energy transitions. Moreover, as the energy sector is a capital-intensive sector, the government should iron out any prohibitive policies, rules, laws, and regulations deterring investments in the sector. One of the polices to advocate for in attracting investment in the electricity supply industry is to push for the use of more renewables. Lastly the government should allow the energy governing entities in the country to exercise their mandate professionally and independently to elicit the desired outcomes. Furthermore, these institutions should be strengthened financially, expertise wise and eliminate bureaucracies in service delivery.

Acknowledgment

I thank the almighty God, for giving me the gift of life to see through my PhD journey. This journey has been filled with positive testimonies because of the people I was blessed to interact with on a day-to-day basis, and occasionally from the day it began. The journey would have been harder to endure if it were not for the support and encouragement I received from these people. Firstly, I want to sincerely thank my academic advisors, Prof Edwin Muchapondwa and Prof Djiby Thiam who took on the humble task of supervising me. Their constructive ideas from the inception of this thesis, critics, encouragement, generosity, and persistence in pushing me towards the finish line resulted into the successful completion of this thesis. I am deeply indebted to them for their unwavering support despite my shortcomings as a student and a person. For this I owe them deeply.

Secondly, I would like to thank my sponsors SIDA and the Environment for Development initiative in Gothenburg. The financial support they gave me enabled me to concentrate more on my studies and worry less about the finances. Moreover, I thank them for their financial support that enabled my attendance of various conferences and workshops around the globe to get constructive inputs for my papers and exposed me to international academic communities such as the Sustainable Energy Transition Initiative (SETI) at Duke University. Analogously, I would like to thank the Environmental policy Research Unit (EPRU) at the University of Cape Town School of economics, for administering the scholarship exquisitely. Special thanks to Dr Jane Turpie and Prof Martine Visser who served as directors of the unit at different junctures, and sincere gratitude and thanks to Felicity Downes, whose emails always prompted a smile full of expectations. I thank EPRU for taking care of me as one of their own. Similarly, I would like to thank ECOCEP and Charles University, for sponsoring and hosting me to a 3-months fellowship that allowed me to work on part of my thesis as well as interact with their researchers.

I would like to thank my colleagues under the SIDA-EfD bursary scheme, Rebecca Klege, Chalmers Mulwa and Zachary Gitonga for their encouragement and special moments shared together. May the almighty God bless them for their generosity in all aspects of life during our academic journey. Special thanks to all the 2015 PhD classmates. Special thanks to Tamara Mugogo and Abel for their encouragement and inspiration. Special thanks to all my colleagues in the PhD lab at the UCT school of economics. I would also like to thank my friends and mentors; Sydney Chishimba, Lydia Chikumbi, Dr Mary Karumba, Dr Hebert Ntuli, Dr Francis, Dr Alfred Mukong, Dr Martin Chegere, Dr Remidius Ruhinduka and Dr, Gerald Kibira for their unwavering support and inputs towards the completion of my thesis.

I also thank the government of Tanzania and my employer the Mwalimu Nyerere memorial academy, for granting me the study leave and travel permit to enable me to undertake my studies at the university of Cape Town. Their understanding of my journey and its specifics warranted them to give me the necessary support needed to enable me to complete this journey successfully. Special thanks to Prof. Mwakalila (Rector of the academy), Prof kangalawe (Deputy Rector-Academics) and the whole administration of the academy for their unwavering support. Special mention to my colleagues and workmates Lilian Kapinga Mduma, Deusdetit Lemnge, Rugazia Nyombi, Ally Kibona, Binto Binto, Dr. Adilli Zella, Suzan Sylivester and Dr. Kamugisha Rwechungura, for always giving me a helping hand in my time of need during my study leave.

Finally, I would like to sincerely thank my family. To my late father who was the inspiration of it all, I say thank you. To my dearest mother, whose non seizing prayers and shoulder to cry on kept me going. To my dearest wife Magreth Maganga and lovely son Shawn Akushamulile for bearing the financial burden, their encouragement, and enduring lonely nights as I persisted to push my work, I am forever indebted to you. Special mention to my siblings Mathew and Ian for always being there for me.

Dedication

I dedicate this work to my late father, Dr Deogratias Matayo Rugaimukamu who inspired my career path, my mother Imelda Rugaimukamu, my wife Magreth Maganga and my dear son Shawn Akushamurile Mutayebwa.

List of Acronyms and Abbreviations

AFDB	-	African Development Bank
ATT	-	Average Treatment on the Treated
BLSS	-	Bhutan Living standard Survey
DARESCO	-	Dar-es-Salaam Electric Supply Company
DIE	-	Deutsches Institut für Entwicklungspolitik (German Development Institute)
EWURA	-	Energy and Water Utilities Regulatory Authority
FAO	-	Food and Agriculture Organization of the United Nations
GACC	-	Global Alliance for Clean Cookstoves
IADF	-	Institutional and Development Framework
ICS	-	Improved Cook Stoves
IEA	-	International Energy Agency
IEG	-	International Energy Group
IMF	-	International Monetary Fund
IRENA	-	International Renewable Energy Agency
JICA	-	Japan International Cooperation Agency
LPG	-	Liquified Petroleum Gas
MOE	-	Ministry of Energy
MOF	-	Ministry of Finance
MU	-	Mzumbe University
NBS	-	National Bureau of Statistics
NPS	-	National Panel Survey
REA	-	Rural Energy Agency

REB	-	Rural Energy Board
REF	-	Rural Energy Fund
SACCOS	-	Savings and Credit Co-operative Society
SDGs	-	Sustainable Development Goals
SUA	-	Sokoine University of Agriculture
TANESCO	-	Tanzania Electric Supply Company
THDS	-	Tanzania health and Demographic Survey
UDSM	-	University of Dar-es-Salaam
UNEP	-	United Nations Environment Program
URT	-	United Republic of Tanzania
USA	-	United States of America
USAID	-	United States Agency for International Development
USD	-	United States Dollar
WEO	-	World energy Outlook
WHO	-	World health Organization
WTP	-	Willingness to Pay

Table of Contents

List of tables

List of figures

Chapter One

General Introduction

1.1 Background

Tanzanian households derive domestic energy from various sources which include but not limited to firewood, charcoal, fossil fuels (kerosene, gas and coal), electricity, solar power as well as animal and plant residuals (National Bureau of Statistics, 2015a). According to the 2012 Tanzanian population and housing census, electricity and wood fuel (firewood and charcoal) are the main sources of energy for lighting and cooking respectively. There has been a consistent rise in the use of electricity for lighting over the years, from 13 percent of households in 2008/09 to 23.5 percent in 2014/15. Much of this increase hasbeen contributed by an increase in the use of electricity for lighting in urban areas, from 42.8 percent in 2008/09 to 54.7 percent in 2014/15 (URT, 2015). Although there has been a rise in the use of electricity invillages, access to electricity[1] remains very low at 7.1 percent (URT, 2015).

Nevertheless, the same cannot be said about the use of modern energy for cooking[2]. More than 90 percent of the Tanzanian population uses wood fuels (charcoal and firewood) for cooking. The most current population and housing census conducted in 2012 shows that firewood accounts for

[1] the electrification rates depicted in the study represents households that have been connected to electricity and use it primarily for lighting.

[2] The definition of modern cooking fuels used for the study is consistent with the definition provided by the international energy agency as adopted by the Tanzanian energy policy, that is the cooking fuels other than biomass, coal or kerosene for cooking. In our case the fuels of interest per the Tanzanian context were LPG and electricity.

90 percent of total energy used in rural areas while charcoal accounts for 62.1 percent of the population's energy use in urban areas. This is despite of an increase in the supply of modern cooking fuels such as LPG. According to the Energy and Water Utilities Regulatory Authority 2016 downstream petroleum subsector review report, the imports of LPG increased by 29% between the year 2015 and 2016. Further increases in LPG imports were observed in 2017, whereby a 50 percent increase in LPG imports was reported. The supply of LPG in Tanzania goes hand in hand with the demand. The country's imports are still very low because of the low consumption of LPG. The Energy and Water Utilities Regulatory Authority has planned to intensify its efforts to educate the public on the benefits of using LPG and the safety aspect regarding LPG operations. Furthermore, to ensure a regulated and assured supply of LPG in the future the authority, since the year 2016 adopted a bulk procurement system for LPG so as to ensure constant supply of LPG in the country and regulate its prices. On the other hand, Tanzania's electricity sector had been heavily dependent on hydropower energy whose energy cannot be depended upon in times of drought. Testament to this, effects of droughts faced during 1992/1993, 2005/2006, 2009/2010, 2010/2011 and 2011/2012, whereby the country faced a high frequency of power outages in the year 2012. Nevertheless, according to the 2017 annual report of the Energy and Water Utilities Regulatory Authority, since the commissioning of electricity generation using the country's natural gas reserves, which changed the electricity generation mix, from one dependent on hydro sources, the main problem the electricity sector has faced hasn't been one of power outages or load shedding, but rather frequent voltages and frequencies fluctuationsbecause of aged equipment and inadequate maintenance.. By the year 2015/16, the country's electricity generation mix constituted of 56 percent natural gas, 31 percent hydro and 13 percent other fossils fuels.

Although the use of wood fuels has remained above 90 percent from the year 2000, the country has observed a shuffle of the percentage composition of wood fuels, with more households shifting to the use of charcoal, especially in the urban areas. In Dar es Salaam, the largest urban city of Tanzania, the proportionof households using charcoal increased from 41 percent in 2001 to 71 percent in 2007, further increases were observed in 2012, with the rise having particularly reflected the increase in the price of petroleum products like kerosene, especially in 2007 (National Bureau of Statistics, 2015a).

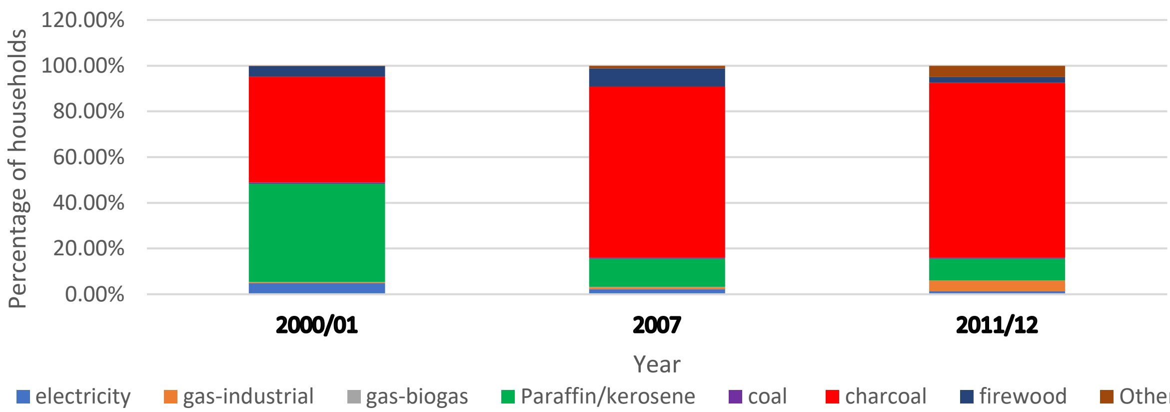


Figure 1: The use of various energy sources for cooking by year in Dar es Salaam

Source: National Bureau of Statistics

Although the percentage of households relying on wood fuels remains unchanged especially in rural areas, there have been signs of an increase of the proportion of households using modern cooking fuels. Though small, there are positive signs in the urban areas of households moving towards using modern cooking fuels other than wood fuels. The proportion of households using modern cooking fuels for cooking in urban areas increased from 4.0 percent in 2008 to 9.2 percent in 2014. The largest increases in usage of modern fuels for cooking were observed in Dar es

Salaam, where the proportion of households using modern fuels for cooking increased from 7.2 percent in 2008 to 12.5 percent in 2014.

The Tanzanian household energy use scenario portrays three key issues, one is the heavy reliance on wood fuels (charcoal and firewood) for cooking both in rural and urban areas, which poses several challenges to the environment. According to the National Bureau of Statistics (2015a), due to the rapid growth of the population and the absence of cheap alternative sources of energy, the demise of forest resources is inevitable. Indicators of such demise are already evident in large urban areas, such as the diminished forest cover along main roads from Dar es Salaam to Tunduma (919.6 Km) and Arusha (624.8 Km) due to firewood and charcoal production. Nevertheless, the small but gradual increases in the proportion of households using modern cooking fuels for cooking paves the way to sustainable use of wood fuels for cooking, particularly in urban areas. It is imperative that we understand the factors that determine these shifts towards the use of modern cooking fuels and thus act accordingly to enhance the adoption of such fuels. Studies have identified social demographic factors like age, education, gender of the household head and Income related factors[3] as important determinants of households' adoption of improved cook stoves and modern cooking fuels (Peng et al, 2010; Lee, 2013; Akpalu, 2011; Alem et al, 2014). Beyond these traditional determinants, households' choice of cooking fuels could be driven by other factors such as social capital (Fraser, 2020; Bernard and Torero, 2014). Social capital portrays the values that an individual derives from association with a group (either formal or

[3] Campbell et al., (2003) found that although of most of the literature in household energy transition attest to the energy ladder hypothesis, it's not usually the case that it's a straight forward conclusion, that when income rises, households would move towards the use of modern fuels in the higher ladders. The study provided evidence that this relationship sometimes postulates an inverted U shape, where, the transition always occurs initially with the rise of income, but at sometimes this transition is reversed, showing no differences in fuel choices among households with different incomes in the long run, pointing to other issues that affect a household's fuel choice beyond income.

informal) and social capital often influences the decisions of group members (Putnam, 1993; Grootaert et al., 2004; Grootaert, 1998). The adoption of sustainable cooking fuels such as electricity and LPG entails use of relatively more complex technologies than those of woody fuels and requires knowledge and financial investments. The underlying belief is that social capital affects adoption through knowledge sharing, peer-pressure towards adoption, fundraising, etc. This is often done by a sharing of agreed social norms. Our study wants to look at the extent to which social capital within given communities' drives adoption of modern, efficient, and sustainable cooking fuels, for asonly a handful of studies have been done for Africa (Fraser, 2020; Bernard and Torero, 2014).

Accounting for social capital allows us to disentangle causal effects related to socio-economic variables from the ones that are latent, formal, or informal, but highly influential when it comes to inducing behavioural change within a designated community. In the present context, this allows an evaluation of the extent to which interactions that take place between members of the same cooperatives, NGOs, formal or informal associations, community groups induce adoption of modern and more efficient cooking fuels (Putnam, 1993; Grootaert et al., 2004; Grootaert, 1998; Fraser, 2020; Bernard and Torero, 2014).

Secondly the energy scenario depicts improvements in modern energy access in terms of electricity, prominently in the urban areas and gradual improvements in the rural areas. The scenario also depicts modest increases of modern fuels use for cooking in urban areas. As energy access has been deemed crucial for sustainable development, as portrayed in in goal number 7 of the sustainable development goal agenda, it's important to establish the impacts of such transitions to establish linkages to economic development (Bonan et al, 2016) and provide evidence-based importance for household's energy transition. Household energy transitions are expected to improve household welfare indicators such as health and schooling. The transition to cleaner cooking can take the form of either improved biomass cook stoves or cook stoves that use cleaner fuels (e.g.biogas, LPG, solar and electricity). The use of improved cook stoves and/or modern cooking fuels ordinarily implies a reduction of the household's use of wood fuels and, consequently, a reduction of indoor air pollution, which has been linked to respiratory illnesses, especially for women and children. Moreover, the reduced use of wood fuels is naturally associated with a reduction of pressure on forests (Brook et al., 2016; Bensch and Peters, 2015; Bonan et al., 2017; Chaplin, 2017), which could make a significant contribution to carbon sequestration. Through the replacement of kerosene and other traditional sources of lighting, household electrification is also associated with a reduction of indoor air pollution and, thus, a reduction in respiratory illness. In addition, by providing better lighting, electrification positively affects schooling indicators such as the number of evening study hours, examination scores, and grade completion (Khandker et al., 2012; Bonan et al., 2017; Bos et al., 2018). Furthermore, household electrification has been linked to increased use of information technologies, which increases households' access to information on issues such as family planning.

Thirdly the scenario depicts that in totality, new initiatives must be put in place to improve access to modern energy, and thus enhance household energy transition in terms of lighting and cooking, particularly with regards to household energy transitions in rural areas. Despite having elaborate policies, plans, strategies, and Programs in place, most of the Tanzanian households in the rural areas have not transitioned to the use of modern energy services. Whereas overall access to electricity has increased over the years from 67.5 percent in the year 2016/17 to 78.4 percent in the year 2019/20 with access to electricity in urban and rural areas reaching 99.6 and 69.8 percent respectively in 2019/20, the proportions of households connected to electricity still stood at a mere

37.7 percent for the whole country, and 24.5 percent for the rural areas for the year 2019/20 (Rural Energy Agency, 2020). Moreover, household transition to modern energy services for cooking is only happening in the urban areas and at a moderate pace (National Bureau of Statistics, 2015b; Rural Energy Agency, 2020). The government and development partners had long seen the need to give rural energy transitions, specifically rural electrification a special emphasis by having an agency dedicated to rural energy projects, thus the establishment of REA in 2006. Although the country has managed to increase the number of new connections annually in rural areas to 30,357 by 2017 for both individual households and businesses, there have been delays in implementation of such projects to spear head the transitions to use of electricity. It is thus imperative that challenges attributed to such slow household energy transitions in rural areas are substantiated and addressed.

1.2 STATEMENT OF THE PROBLEM

Household energy choice has environmental (e.g., deforestation, climate change), health (e.g., pollution), social (e.g., gender disparity) and economic (e.g., welfare outcomes) consequences at the household and societal levels. The Tanzanian household energy use portrays three key issues:(i) the heavy reliance on wood fuels (charcoal and firewood) for cooking with the attendant effects on health, (ii) improvements in modern energy access in terms of electricity, prominently in the urban areas and gradual improvements in the rural areas that must be linked to household welfare to warrant the transitions, (iii) despite having elaborate policies, plans, strategies and programs in place, most of the Tanzanian households in the rural areas have not transitioned to the use of modern energy services.

In line with these issues, this thesis wants to add to a sparsely studied area of inquiry in household choice of cooking fuel literature, and thus investigates the extent to which social capital drives behavioral change to stimulate adoption of modern cooking stoves in Tanzania and thus reduce the heavy reliance on wood fuels. This paper not only adds to the few studies on social capital and household energy transitions in Africa, but also sheds light particularly on Tanzania. Whereas most previous studies looked into a select few aspects of social capital, namely social networks, social relations, and cognitive social capital. This paper, similar to a handful of papers, such as Das (2018) for India, looks into the role of structural social capital in adoption of modern cooking fuels. It leverages membership into special groups, namely self-help groups and Saving and Credit Co-operative Societies in Tanzania as a proxy for social capital, and investigates the role of social capital from a different dimension and adds additional channels through which social capital may bring about social development.

This thesis adds to the very few studies that look at the impacts of household energy transitions in Tanzania. It does this by helping link improvements in modern energy access in terms of electricity in the urban areas and gradual improvements in the rural areas to household welfare, thus consequently setting a stage thatwarrants intensive policies to smoothen household energy transitions. This thesis firstly it adds to the few studies on impact of household cooking energy transitions in Africa, especially Sub-Saharan Africa. As the impacts of such transitions differ in different contexts due to behavioral aspects and cooking habits, it is imperative to have more papers providing evidence of such impacts in Africa, specifically Tanzania. Furthermore, this thesis adds to the literature on the impacts of household’s use of electricity on schooling outcomes and health (especially fertility) by investigating these impacts in the context of Tanzania. To our knowledge, ours is among the first studies to comprehensively study the impact of electrification on several outcomes, including energy expenditures, fertility, schooling outcomes and time use for Tanzania.

Lastly the thesis investigates the institutional challenges facing the Rural Electrification Program in Tanzania, by dissecting the interactions of key players in the sector, the norms, rules, and regulations governing the sector and the resulting energy transitions outcomes. In particular, the analysis takes stock of the extent to which the rural electrification Program's demand and supply triggers household electrification and suggests institutional reforms that engender improved electrification outcomes. The paper adopts the Institutional and Development Framework (IDF) by Ostrom (2005) to systematically substantiate the institutional challenges. Whereas Alhborg and Hammar (2014) similarly looked at the challenges facing rural electrification in Mozambique and Tanzania within the confinement of 2003 Energy Policy, our analysis brings out challenges after the enactment of 2015 Energy Policy and expansion of the rural electrification Program in 2016 and thus provides a contemporary view of challenges facing rural electrification initiatives. Furthermore, unlike Aly et al. (2019) who only looked at challenges facing large scale solar power initiatives in Tanzania, our paper looks holistically at rural electrification, thereby giving a much wider picture of institutional challenges facing electrification initiatives in Tanzania. Thus, this thesis looks broadly at the political economy and institutional determinants of household energy transitions and its impacts in Tanzania.

1.3 Objectives of the study

The main objective of this thesis is to investigate the political economy and social economic determinants of household energy transitions and its impacts in Tanzania. and with the following three specific objectives as derived from the Tanzania energy scenario:

a) Analyze the role of social capital in the adoption of modern cooking fuels in Tanzania.
b) Analyze the impact of household energy transition on household welfare in Tanzania.
c) Analyze the institutional barriers to rural electrification in Tanzania.

1.4 Research questions

a) What is the role of social capital in household's adoption of modern cooking fuels in Tanzania?
b) What is the impact of household energy transition on household welfare in Tanzania?
c) What are the institutional barriers to rural electrification inTanzania?

1.5 Organization of the thesis

The thesis consists of five chapters. The first chapter presents the general introduction of the thesis, detailing the motivation and the objectives of the thesis with a corresponding chapter for each of the specific objective. Chapter two presents the analysis of the role of social capital on the adoption of modern cooking fuels in Tanzania while chapter three presents the impacts of household energy transition on household welfare in Tanzania. Chapter four presents the analysis of the institutional barriers to rural electrification in Tanzania. Lastly, chapter five presents the general conclusion and policy implications of the thesis.

Chapter Two

The Role of Social Capital in household's Transition towards Modern Cooking Fuels in Tanzania

Abstract

Tanzanian households rely heavily on wood fuel (firewood and charcoal) for cooking. This has far reaching implications on household and societal welfare due to the associated indoor air pollution and deforestation. Among other measures, social capital could catalyse greater transitions to clean and sustainable cooking fuels such as electricity and LPG. This paper uses panel data econometrics to investigate the role of social capital in households' transition towards modern cooking fuels in Tanzania. A key measure of social capital used for Tanzania is membership in Savings and Credit Co-Operative Societies (SACCOS) or self-help groups. The study found that households with membership in these groups were more likely to adopt modern cooking fuels. SACCOS and other self-help groups serve to spread awareness and technical information about, and bridge liquidity constraints on new technologies, including modern energy. Given the citizenry's general aversion to command and control by the government and the high levels of trust within SACCOS and other self-help groups, using these groups to drive the adoption of modern energy could be the panacea to the problem of continued unsustainable use of woody fuels in the country.

2.1 Introduction

Tanzanian households use various energy sources, including wood fuels (firewood and charcoal), fossil fuels (kerosene, gas, and coal), electricity, solar power as well as animal and plant residuals (National Bureau of Statistics, 2015a). Electricity and wood fuels are the main sources of energy for lighting and cooking, respectively (URT, 2016; Ministry of Finance and national Bureau of Statistics, 2019). Whereas there has been improvement in the proportion of households using electricity for lighting, that does not apply to cooking.[4] More than 90 percent of the Tanzanian population use woody fuels for cooking. Firewood accounts for 84. 4 percent of household's cooking energy use in rural areas while charcoal accounts for 60.5 percent of household cooking energy use in urban areas (Ministry of Finance and national Bureau of Statistics, 2019). In Dar es Salaam, the largest urban city of Tanzania, the proportions of households using charcoal for cooking increased from 41 percent to 71 percent between 2001 and 2007 but has decreased to 58.9 in 2019 (National bureau of Statistics, 2015a; Ministry of Finance and national Bureau of Statistics, 2019). This makes the use of woody fuels a common practice among Tanzanian households.

The overuse of wood fuels for cooking has been proven to generate negative impacts not only on households' health outcomes, but also on overall environment through air pollution, forest degradation and deforestation (Christophe and Huijie, 2016). Within the household, women and children are the most impacted members. This is because in low-income countries, such as

[4] The energy literature distinguishes between traditional (animal dung, agricultural residues, and fuelwood), intermediate (wood pellets, charcoal, briquettes, lignite, coal and kerosene) and modern (solar, LPG, biogas, natural gas, electricity, gel fuel, plant oils and dimethyl ether) types of energy sources. Additionally, one can distinguish between primary and secondary energy types. This distinction often depends on how the energy is produced, extracted, transported, and consumed. Primary energy types are energies that did not go through any transformation process, hence, energy obtained from fuelwood, agricultural waste, animal dungs, coal. Whereas secondary energy types are derived from primary energy sources after transformation (petroleum products (kerosene, LPG), crude oil, ethanol, biogases). In this paper, modern cooking fuels are LPG and electricity.

Tanzania, women and children are the ones who spend between 2 and 3 hours per day collecting firewood that is used for cooking, heating, and lighting (Christophe and Huijie, 2016; Link et al., 2012). Studies conducted by the World Bank (e.g., Malla and Govinda, 2014) show that this reduces the time that could have been spent by female household members to alternative income generating activities. This contributes to maintaining women in a poverty circle that exhibits long-term poverty trap and vulnerability. The impacts on children range from the opportunity cost of time not spent in education, to health-related respiratory problems that might lead to deaths (Bickton et al., 2020; Bonan et al., 2017). For instance, previous estimates listed around 450,000 deaths that were caused by outdoor air pollution from solid fuels use for cooking in Asia and Africa. Furthuremore in 2017 nearly 3.8 million premature deaths were also caused by household air pollution (WEO, 2017; Bickton et al., 2020). Therefore, to mitigate such devastating impacts a number of national and international initiatives have supported the government of Tanzania in its strategies[5] to promote transition to sustainable energy sources such as electricity and LPG. These strategies are expected to increase the share of modern energy sources into the overall country's energy supply and demand portfolio, including cooking, lighting, and heating.

The purpose of this paper is to investigate the factors that drive adoption of sustainable cooking fuels such as electricity and LPG in Tanzania. Having a good understanding of these factors should allow us to advocate for more targeted and tailored policy interventions that support and promote sustainable energy transition in the country. Reviews by Malla and Timilsina (2014), Bonan et al., (2017), Vigolo et al, (2018) along with more current studies (Paudel et al., 2018; Sana et al., 2020; Imran and Ozcatalbas, 2020) highlight a wide range of factors that influence households' cooking fuel choices and adoption of improved stoves, including socioeconomic (access and

[5] Initiatives range from Programs such as sustainable energy for all (SE4ALL), to Global Alliance for Clean Cookstoves (GACC) and Africa Clean Cooking Energy Solution

availability, collection costs and fuel prices, household income, education and awareness), behavioral (food tastes, lifestyle), and cultural and external factors (indoor air pollution, government policies). The current paper considers more factors that are likely to be more important in contexts such as the one found in Tanzania.

Most importantly, we look at the extent to which social capital within given communities' drive adoption of modern, efficient, and sustainable cooking fuels, with only a handful of studies having been done for Africa (Fraser, 2020; Bernard and Torero, 2014). Social capital portrays the values that an individual derives from association with a group (either formal or informal) and social capital often influences the decisions of group members (Putnam, 1993; Grootaert et al., 2004; Grootaert, 1998). The adoption of sustainable cooking fuels such as electricity and LPG entails use of relatively more complex technologies than those of woody fuels and requires knowledge and financial investments. The underlying belief is that social capital affects adoption through knowledge sharing, peer-pressure towards adoption, fundraising, etc. This is often done by a sharing of agreed social norms.

Accounting for social capital allows us to disentangle causal effects related to socio-economic variables from the ones that are latent, formal, or informal, but highly influential when it comes to inducing behavioural change within a designated community. In the present context, this allows an evaluation of the extent to which interactions that take place between members of the same cooperatives, NGOs, formal or informal associations, community groups induce adoption of modern and more efficient cooking fuels (Putnam, 1993; Grootaert et al., 2004; Grootaert, 1998; Fraser, 2020; Bernard and Torero, 2014). Due to its broad nature, social capital is usually measured by various indicators including group networks, (Bandiera and Rasul, 2002; Das, 2018). Following the same procedure, we use membership in ordinary self-help groups as well as Savings and Credit Co-Operative Societies (SACCOS)[6] as indicators of social capital. This enables us, to study the role of structural social capital in household energy transition in a similar way Das (2018) did for India, and go beyond the common aspects of social capital explored in household energy transitions, including social networks, peer effects and social learning (Fraser, 2020; Das, 2018; Srinivisan and Carattini, 2016; Graziano and Gillingam, 2015; Bollinger and Gillingam, 2012; McEachern and Hanson, 2008)

Our study contributes to the literature of sustainable energy transition, which is still heavily influenced by the energy ladder hypothesis (Peng et al., 2010; Lee, 2013; Alem et al., 2013; Rahut et al., 2015; Karimu, 2015; Karimu et al., 2016; Paudel et al., 2018; Sana et al., 2020; Imran and Ozcatalbas, 2020). The assumption made under such hypothesis is that households will move towards consumption of more efficient energy sources, as their income increase (Alem et al., 2013; Rahut et al., 2015; Karimu et al., 2016; Paudel et al., 2018; Sana et al., 2020; Imran and Ozcatalbas, 2020). A number of empirical studies have confirmed the energy ladder hypothesis, where households substitute traditional fuels with modern fuels as they get richer. However, there is also a different stream of literature that sees energy transition as a simultaneous combination of different stages when income increases: the energy stacking hypothesis. Households do not abandon completely the usage of traditional fuels as they get richer, but they combine them with modern fuel sources as their income grow (Masera et al., 2000; Van der Kroon et al., 2014;

[6] According to https://tanzaniasaccos.wordpress.com/ (accessed 19 June 2020), a SACCOS is a democratic, unique member driven, co-operative that operates according to the co-operative identity, values and principles, including honesty, openness, social responsibility and caring for others. It is owned, governed and managed by its members who have the same common bond: working for the same employer, belonging to the same church, labour union, social fraternity or living/working in the same community. These members save their money together and make loans to each other at reasonable rates of interest. The members are the owners and they decide how their money will be used for the benefit of each other.

Choumert, 2019). This is even more accurate in areas where energy switching behaviour remains heavily influenced by cultural factors. For instance, studies conducted in West Africa (Akpalu et al., 2011) and Asia (Jeuland et al., 2014) show that people continued to use wood fuel even when they could afford to use modern fuels, because they associate usage of traditional fuels with good taste and preferences on cooking practices.

Thus, this chapter adds to a few studies that have looked at the role of social capital in adoption of modern cooking fuels, which have mostly been fixated on Asia, Europe, and USA (Fraser, 2020; Das, 2018; Srinivisan and Carattini, 2016; Graziano and Gillingam, 2015; Miller and mobarak, 2015; Bollinger and Gillingam, 2012; McEachern and Hanson, 2008), with a handful of studies having been done for Africa (Fraser, 2020; Bernard and Torero, 2014). Furthermore, most of these studies have mostly looked into a select aspect of social capital, namely social networks and social (peer) relations. This paper, similar to a handful of papers, such as Das (2018) for India, looks into the role structural social capital plays in adoption of modern cooking fuels. By using membership into special groups namely self-help groups or Saving and Credit Co-operative Societies in Tanzania as a proxy for social capital, this paper investigates the role of social capital from a different dimension and adds additional channels through which social capital may bring about social development.

The paper makes use of three waves of a nationally representative panel survey data from Tanzania and thus comes up with more consistent estimates of factors that drive sustainable energy switching behaviour that account for social capital, which plays an important part in the African culture. We conduct this analysis by considering household heterogeneity over time, as suggested by Alem et al. (2013), Rahut et al. (2015) and Mensah and Adu (2015). This paper extends previous works (Kulindwa et al.,2018; Choumert et al., 2019; Alem and Ruhinduka, 2020) that investigated household energy switching behaviour in Tanzania but adds the social capital effects that may arise from people's interactions in explaining behavioural change in the energy sector.

The rest of the paper is structured as follows. Section 2.2 provides a literature review, whereas social capital in the Tanzanian context is presented in Section 2.3. Section 2.4 presents the methodology of the analysis. The results are presented in section 2.5. The last section 2.6 concludes the paper.

2.2 Literature Review

The literature on household choice of cooking fuel has grown over the last decade. Studies from various parts of the world have provided evidence of various determinants of household's choice of cooking fuels. These include a considerable number of studies from the African continent (Lee, 2013; Akpalu et al., 2011; Alem et al., 2013; Mwaura et al., 2014; Mensah and Adu, 2015; Karimu, 2015; Karimu et al., 2016; Hassen, 2015; Mutua and Kimuyu, 2015; Legesse et al., 2015; Benschet al., 2015; Berbard and Torero, 2014; Bonan et al.,2020; Vulturius and Wanjiru, 2017; D'Augustino et al., 2015; Choumert et al., 2019) and from the rest of the world, the majority being from Asia (Peng et al., 2010; Chen et al., 2016; ; Srinivasan and Carattini, 2016; Graziano and Gillingam, 2015; Miller and Mobarak, 2015;Das, 2018; Fraser, 2020; Bollinger and Gillingam, 2012; Paudel et al., 2018; Sana et al., 2020; Imran and Ozcatalbas, 2020).

Whereas most of these studies were cross sectional in nature, very few used longitudinal data to investigate the determinants of household choice of cooking fuels (Alem et al., 2013; Rahut et al., 2015; Mensah and Adu, 2015; D'Augustino et al., 2015; Choumert-Nkolo et al., 2019). These studies can be divided in two folds, those that look at a household's transition towards modern cooking technologies and fuels and those that look at transitions towards improved traditional technologies;that is improved cook stoves. Due to their importance with regards to household's shift from use of biomass, whose triggers are more or less the same,our discussion covers both aspects of the transition.

A key aspect of household energy transition that has been explored by only a handful of studies is social capital. Studies have explored the effects of social capital on household energy transitions in its different dimensions, including social networks, peer effects and social learning. Most of these studies have been conducted for Asia, Europe, and USA (Fraser, 2020; Das, 2018; Srinivisan and Carattini, 2016; Graziano and Gillingam, 2015; Bollinger and Gillingam, 2012; McEachern and Hanson, 2008), with only a handful of studies for Africa (Fraser, 2020; Bernard and Torero, 2014). These studies are diverse in terms of the data and methodologies used. w Whereas most studies have used a mixture of cross sectional and longitudinal data, analysed using a set of econometric techniques, dominated by panel econometric techniques supplemented by qualitative (Fraser, 2020;Srinivisan and Carattini, 2016 Graziano and Gillingam, 2015), others have employed cross sectional data in experimental design settings (Bernard and Torero, 2014).

Different conclusions have been drawn with regards to the role of social capital in household energy transitions. Most studies have ascertained the positive role of social capital in household energy transitions (Fraser, 2020; Das, 2018; Srinivisan and Carattini, 2016; Graziano and Gillingam, 2015; Bollinger and Gillingam, 2012; McEachern and Hanson, 2008; Bernard and Torero, 2014), but the channels through which it brings about household's energy transitions differs in different contexts. Graziano and Gillingam (2015) found that social interactions acted as a channel of spatial neighbour effects in household adoption of residential solar systems in Connecticut, with smaller clustered communities more likely to induce adoption of energy technologies compared to large communities. The authors found that those smaller urban areas, made of fewer inhabitants, experienced wider adoption than the larger urban centres. Srinivasan and Carattini (2016) further reiterated the role of social interactions coupled with spill over effects in the adoption of LPG in India as they found that households are more likely to adopt LPG if other households residing in the same village or urban block do so. This signals the influence of social interactions and spill over effects in influencing behavioural change.

The paper found divergence in the strength of this network and spill over effect between rural and urban households, with more persistent spill overs amongst rural households. Moreover, Miller and Mobarak (2014) examined how information sharing (learning) from opinion leaders and social networks influences demand for non-traditional cooking stoves. They conducted marketing interventions in rural Bangladesh to assess the extent to which adoption of non-traditional cooking stoves respond to (a) learning about the adoption choices from locally identified "opinion leaders" and (b) learning about stove attributes and performance through social networks. The results showed consumers appeared to rely on their social networks to learn about the attributes associated with modern cooking stoves.

Similarly, neighbour's connection behaviours were found to have large effects on a household's connection decision in Ethiopia, which was shown to decrease by distance (Beranard and Torero, 2014). Analogously, in the Californian context, Bollinger and Gillingam (2012) found that an additional installation of residential solar energy technologies by a household within a zip code increases the probability of adoption by other household within the zip code. Furthermore, social interaction embedded in ethnicity and political participation were reiterated to play a major role in the adoption of solar home systems in Sri Lanka (McEachern and Hanson, 2008).

Nevertheless, studies have pointed to the fact that different forms of social capital may have different effects on household energy transitions within the same or different community contexts. Das (2018) found that although bridging and linking social capital had a strong positive effect on household's adoption of LPG in India, political participation and bonding social capital had a negative effect on the same. In contrast, bridging social capital acted as an obstacle in the adoption of renewable technologies in several localities in South Africa, Germany, Japan, and several parts of the USA (Fraser, 2020).

Traditionally, income and fuel prices have been identified as the main determinants that influence household fuel choice, with an increase in income associated with household switching from using traditional to modern cooking fuels (Peng et al., 2010; Lee, 2013; Alem et al., 2013; Rahut et al., 2015; Karimu, 2015; D'Augustino et al., 2015; Karimu et al., 2016; Paudel, 2018; Kulindwa et al., 2018; Alemand Ruhinduka, 2020; Choumert et al., 2019). However, Peng et al. (2010) highlighted the need for income to rise substantially and reach a certain threshold for the use of biomass to fall in rural Hubei. This highlights the existence of a level of income threshold above which the energy switching behaviour from traditional to modern fuels is observed. Lee (2013) found that as household incomes increased, the use of traditional fuels evolved but following an inverse U curve shape while electricity showed a direct and positive relationship with income. Peng et al. (2010) also pointed to fuel price as a crucial determinant of household cooking fuel choice in Hubei.

Similarily, Alem et al. (2013) and Rahut et al. (2015) highlighted the important role of income and fuel prices on household energy choice in Ethiopia and Bhutan, respectively. Whereas Alem et al. (2013), using a random effects multinomial logit model, found that household's economic status -

captured by income - and fuel prices are important determinants of fuel choice in urban Ethiopia, Rahut et al. (2015) used data from three Bhutan Living Standard surveys (BLSS) for 2003, 2007 and 2012 and found that a household's choice of cleaner energy sources was driven by income level. Both studies argued that wealthier and more educated households relied more on clean sources of energy (i.e. electricity and LPG) while poorer households relied on dirtier fuels (i.e. fuelwood and kerosene).

Nevertheless, the availability of a clean and cost-effective source of energy within proximity to the household, education, age, household wealth, household size, distance to the market, gender and education of the household head, access to electricity, and location were also pointed as key determinants of household choice of cooking energy (Rahul et al., 2015; Alem et al., 2013; D'Augustino et al., 2015; Paudel et al, 2018; Choumert et al., 2019; Sana et al., 2020).

Karimu (2015) reiterated the role of household demographics, urbanization, income, and the supply (availability) of the fuels in influencing household choice for various fuel types. Increase in household income was likely to enhance the probability of choosing modern fuel (LPG and electricity) relative to solid (crop residue and fuelwood) and transition (kerosene and charcoal) fuel types. Karimu et al. (2016) used household-level data combined with a flexible semi-parametric specification and found socio-economic[7] and demographic factors, education, access to urban infrastructure, and location of household as key drivers of households' choice of LPG as main cooking energy source in Ghana. The influences of these factors were found to be stable across time, and with a strong price effect. Their findings show that urban households with higher socio-economic status were more likely to adopt LPG as the main

[7] These include factors like as income, employment, education and age.

cooking fuel compared to households in rural areas and households in urban areas but with poor socio-economic factors.

Furthermore, Mensah and Adu (2015) traced the dynamics of cooking fuel choice among Ghanaian households over the period 2005/6 and 2012/13 and further investigated the main forces driving households' choice of a cooking fuel. Their findings revealed a significant transition from wood fuel use towards LPG. Results revealed factors such as price, reliability in supply of LPG, income and other household attributes as significant factors influencing household's choice of a given energy type for cooking. Using a robust non-linear panel data and hazard models, Alem et al. (2013) found the price of electricity and firewood as well as access to credit as the major determinants of adoption and sustainable energy sources. Moreover, Mwaura et al. (2014) used a multinomial probit and found that consumption expenditure, whether residing in rural or urban areas, household size and education level were important determinants of energy choices in Uganda.

Although income and other key household attributes have been substantiated to play a major role in a household's choice of cooking fuels, tastes and preferences, and intra household bargaining power have also been identified as key determinants of household choice of cooking fuels (Akpalu et al., 2011;Choumert et al., 2019). For instance, Akpalu et al. (2011) found strong evidence that supports the claim that, for cooking purposes, most Ghanaians preferred LPG followed by charcoal and kerosene. On the other hand, Intra household bargaining was found to play a key role in the adoption of modern energy services in Tanzania, with the level of education of the spouse that was used as one of the proxies for intra household bargaining power, enhancing household's adoption of modern cooking fuels. This was reiterated for the case of Ouagadougou, with women's education attainment playing a key role in the adoption of modern cooking fuels (Sane et al., 2020).

The literature on household energy transition with regards to determinants of household choice of cooking fuels is not only limited to adoption of modern cooking fuels, but also embodies transition to efficient cooking technologies (improved cook stoves), which reduces the use of traditional cooking fuels (Charcoal and firewood) and associated impacts. Although these transitions do not present a complete shift from the use of traditional cooking fuels, they present the first stage of the transition, when a complete transition is not within the household's budget constraint and thus also provide us with triggers of transitions with regards to household energy cooking fuels.

Legesse et al., (2015) substantiated factors such as family size, age, energy sources, ownership of livestock, proximity to agricultural extension centre and market services as key factors that drive adoption of improved cook stoves in Ethiopia. Moreover, intra-household bargaining power was found to play a key role in the adoption of improved cook stoves in rural Ethiopia, highlighting the importance of empowering women and targeting this special group in improved cookstoves promotion (Hassen, 2015). Tastes and preferences also play a major role in the adoption of improved cook stoves, as reiterated by Jeuland et al., (2014), households in Northern India had strong preference for traditional stoves but were willing to pay (WTP) about $10 and $5 for realistic reductions in smoke emissions and fuel needs on average, respectively, or about half of the price of less expensive improved cooking stoves (ICS). Social perceptions were also deemed important in adoption of improved cooking stoves (Bielecki and Wingenbach, 2014).

Moreover, though studied scarcely, social capital in its various forms, has been shown to enhance the adoption of improved cook stoves (Bonan et al., 2020; Vulturius and Wanjiru, 2017; Beltramo et al, 2015; Bonan et al., 2020). Peer usage of improved cook stoves was found to enhance the adoption of such stoves among neighbours in Uganda, with the peer effects being channelled through opinions about the improved cook stoves (Beltramo et al., 2015). Moreover, Vulturius and Wanjiru (2017) also pointed to the role of social relations in the adoption of improved cookstoves in Kenya. Similarly, Bonan et al., (2020) showed that information about usage of improved cook stoves by a peer increased the likelihood of a household to adopt improved cook stoves.

Our literature review portrays a diverse number of studies in the household choice of cooking fuel literature. Nevertheless, one of the areas that have been sparsely looked at as portrayed in our review is the role of social capital in household's energy transition with regards to cooking. The few studies that have looked at the role of social capital in adoption of modern cooking fuels have mostly been conducted for Asia, Europe, and USA (Fraser, 2020; Das, 2018; Srinivisan and Carattini, 2016; Graziano and Gillingam, 2015; Miller and mobarak, 2015; Bollinger and Gillingam, 2012; McEachern and Hanson, 2008), with a handful of studies having been done for Africa (Fraser, 2020; Bernard and Torero, 2014). Furthermore, most of these studies have mostly looked into a select aspect of social capital, namely social networks and social (peer) relations.

This paper adds to this sparsely studied area of inquiry in household choice of cooking fuel literature, and thus investigates the extent to which social capital drives behavioural change to stimulate adoption of modern cooking stoves in Tanzania. This paper not only adds to the few studies on social capital and household energy transitions in Africa, but also sheds light particularly on Tanzania. Whereas most previous studies looked into a select few aspects of social capital, namely social networks, social relations, and cognitive social capital. This paper similar to a handful of papers, such as Das (2018) for India, looks into the role structural of social capital in adoption of modern cooking fuels. It leverages membership into special groups namely self-help groups and Saving and Credit Co-operative Societies in Tanzania as a proxy for social capital, and investigate the role of social capital from a different dimension and adds additional channels through which social capital may bring about social development.

2.3 Social Capital in Tanzania

This section elaborates on the social capital concept used in this study. The paper considers the two voluntary association groups, namely (1) ordinary self-help groups and (2) Savings and Credit Co-Operative Societies (SACCOS) as social networks that produce social capital capable of influencing members' adoption of modern cooking fuels in Tanzania. SACCOS and ordinary self-help groups are present in both urban and rural areas of Tanzania. Both organizations are run by their respective members who initiate and undertake frequent and personal meetings on a regular basis. These meetings are expected to strengthen the ties between members and help solve problems that members face. The main motivation in setting up these groups is to solve common problems (i.e., economic, social, or cultural) encountered by members. This is achieved by mobilizing financial, technical, and legal resources available to the members.

Beyond the direct assistances offered to its members, these social networks provide platforms that allow sharing of experience in order to stimulate participatory decision-making in the communities. They provide members with a space that can be used to convey important messages that trigger behavioural change. This can be, for instance, awareness and technical information related to new technologies. The themes can be as wide as usage of modern cooking fuels, climate change, deforestation, environmental degradation, income generating activities, etc.

Ordinary self-help groups are more informal gatherings of members from the same communities, where members are expected to help one another when they express some needs. The idea is to promote solidarity between members of the same community and make sure decisions taken within the community get supported by as many members as possible. This widespread support is expected to give more credibility to certain decisions made at village or community level.

Ordinary self-help groups' prominence can be traced back to the post IMF and World Bank structural adjustment Programs implemented in Sub-Saharan Africa in the mid-1980s (Ndumbaro and Kiondo, 2007; Bee, 2009). These groups were created to mitigate the shocks associated with the withdrawal of governmental agencies from the delivery of some crucial social services that were assisting many poor households. Self-help groups may be motivated by financial and non-financial considerations.

SACCOS operate under the Cooperative Societies Act of 1991 and their financial intermediary roles, in terms of soliciting savings and offering credit to members, are enshrined in the Banking and Financial Institutional Act of 1991. The Cooperatives Society Act rooted SACCOS' operation in volunteerism and self-regulation (Aikaruwa et al., 2014).

SACCOS have been around for much longer than the ordinary self-help groups. The existence of SACCOS can be traced back to 1938 and their prominence back in the 1960's. SACCOS emerged to respond to an increasing need to diversify the credit market in Tanzania, by making access to loans more affordable to the poor segment of the population. They primarily operate like microfinance institutions.

Although most SACCOS in urban areas are formed by wage earning individuals, in rural areas most of the SACCOS are community-based and enrooted in agricultural activities (Aikaruwa et al., 2014). Three forms of SACCOS are common: Community-based SACCOS mostly found in rural towns of the country; Employee-based SACCOS formed by employees of common firms in urban areas; Agricultural-based SACCOS comprising of farmers. All types of SACCOS offer credit facilities to their members.

2.4 Methodology

2.4.1 The empirical strategy

The paper makes use of a panel analysis to identify the factors that drive adoption of modern fuels such as electricity and LPG. The probability that a household uses modern energy as a primary cooking fuel is presented in Equation (1) below,

$$\Pr\,(CE_{it} = 1) = SC_{it}\alpha^{*} + X^{*}_{it}\beta^{*} + Y^{*}_{it}\delta^{*} + \varepsilon_{it} (1)$$

Where $i$represents households. CE_{it} is a dummy variable equivalent to one if the household has adopted LPG or Electricity as primary sources of cooking energy and zero otherwise. SC_{it} is the household's endowment of social capital, which is either a dummy variable indicating if a household has at least one of its members affiliated with a SACCOS/self-help group or a continuous variable indicating the number of household members affiliated with a SACCOS/self-help group; X is a set of observed household characteristics; Y is a set of observed characteristics from the household's locality (for example, the locality may have grid connections, the locality may have abundant supplies of LPG, etc). We control for geographical and household characteristics and use the longitudinal nature of the data set to control for the household unobserved heterogeneity.

2.4.2 The Data

The paper uses the 2008-2016 Tanzanian panel data set from a nationally representative household panel survey that collects information on a wide range of topics. For example, the data covers agricultural production, non-farm income generating activities, consumption expenditure, and a number of other socioeconomic characteristics of the households. The panel is currently made up of four waves. The first wave was collected from October 2008 to September 2009. The second wave started in October 2010 and finished in September 2011. The third and fourth waves took place between October 2012 and November 2013 and October 2014 and January 2016, respectively. The paper only uses the first three waves as the fourth wave used a replenished sample that did not track the original households interviewed in the previous waves.

The panel had an original sample size 3280 households for the whole country and 555 households for Dar es Salaam, with the samples constructed based on the National Master Sample frame which is a list of all populated enumeration areas in the country developed from the 2002 Population and Housing Census. In total, the target sample was 2,064 rural households and 1,216 urban households in 410 Enumeration Areas. The panel has a low rate of attrition, having a total of 4.87 percent of attrition up to wave three. The penetration of electricity and LPG is quite low in rural areas. Accordingly, this paper uses the data for Dar es Salaam to study the impact of social capital on transition to modern cooking fuels in Tanzania.

2.5 Results and Discussion

2.5.1 The Descriptive Statistics

Tables 1 and 2 show the descriptive statistics of the variables used in the empirical model for Dar es Salaam. Table 1 shows the descriptive statistics of the sample across the three waves while Table 2 shows the descriptive statistics specific to each wave. One can observe that 7.21 percent of the sampled households used modern energy (electricity and LPG) for cooking across the waves, and 93 percent of the sampled households owned a biomass cooking stove. Furthermore, across the waves, 10.4 percent of the households had a member affiliated to a SACCOS/self-help group and 60.7 percent had an electricity connection. Nearly 91 percent of the household heads have achieved at least primary level/adult education and 75.4 percent of the household heads are male. The mean household size and age of the household head are 5 and 43, respectively.

Table 1: Descriptive statistics of the pooled data across waves

VARIABLES	(1) N	(2) Mean	(3) sd	(4) min	(5) max
household size	1,484	4.743	2.772	1	22
household connected to electricity (Yes=1)	1,484	0.607	0.489	0	1
age of the head of the household	1,484	43.12	13.86	0	101
Household head is male (Yes=1)	1,484	0.754	0.431	0	1
Use of modern energy (Yes=1)	1,484	0.0721	0.259	0	1
HH has a member of a self-help/saccoss group (Yes=1)	1,484	0.104	0.305	0	1
Number of members of groups in a HH	1,484	0.104	0.322	0	2
household head is educated (yes=1)	1,481	0.909	0.288	0	1
household owns a biomass stove (yes=1)	1,484	0.930	0.255	0	1
household head owns a radio (yes=1)	1,484	0.724	0.447	0	1
household head own a telephone (yes=1)	1,484	0.902	0.298	0	1
real annual household consumption/1000	1,484	578.0	502.0	35.62	5,748

Table 2 shows the descriptive statistics by wave, with wave 1, 2 and 3 depicting the 2008, 2010 and 2012 surveys. The use of modern fuels for cooking has been increasing across the waves. In 2008, only 6.7 percent of sample used modern energy for cooking while it increased to 9.3 percent of the sample in 2012. Moreover, at least 92 percent of the sample owned biomass cook stoves throughout the sampling period. The proportion of households with at least a member affiliated to self-help groups or SACCOS has a gentle upward trend across the waves. About 10 percent of households have at least one member affiliated to self-help group or SACCOS. The percentage of household heads that achieved primary or adult education remained at 91 percent across the waves and household heads are pre-dominantly males (75 percent in 2008 and 2010, and 77 percent in 2012). The mean household size increased from 4 to 5 members, between 2008 and 2012. The percentage of households connected to electricity rose from 58 percent in 2008 to 62 percent in 2010 and 2012. This increase is consistent with the rise in the mean annual household consumption expenditure from 468 million in 2008 to 742 million Tanzanian shillings.

Table 2: Descriptive statistics by wave

	wave 1		wave 2		wave 3	
VARIABLES	N	mean	N	mean	N	mean
Household size	555	4.441	492	4.882	437	4.968
Household connected to electricity	555	0.582	492	0.622	437	0.622
Age of the head of the household	555	41.01	492	43.26	437	45.66
Household head is male	555	0.746	492	0.748	437	0.771
Use of modern energy	555	0.0595	492	0.0671	437	0.0938
HH has a member of a self-help/saccoss group	555	0.0973	492	0.112	437	0.103
Number of members of groups in a HH	555	0.105	492	0.114	437	0.0915
Household head is educated	555	0.912	491	0.908	435	0.906
Household owns a biomass stove	555	0.919	492	0.943	437	0.929
Household head owns a radio	555	0.753	492	0.776	437	0.627
Household head own a telephone	555	0.834	492	0.931	437	0.954
Real annual household consumption/1000	555	468.4	491	557.0	434	741.7

2.5.2 Empirical results

We estimated a logit random effects model. The random effects model was most appropriate because most of the variables used in our econometric model were either household characteristics that did not change much across the waves or measured as dummies, which would have resulted in them being differenced out if a fixed effects model was used

Table 3 presents the empirical results of the study. It presents the marginal effects with the social capital variable measured as a continuous variable of how many members of the household are members of self-help group or SACCOS.[8]

In Table 3, where the social capital variable is a dummy, the model was estimated stepwise. We first ran the dependent variable on the social capital variable without any other controls (column 1). We then controlled for the time and district dummies (column 2). Next, we introduced household characteristics: alone (column 3) and with time and district fixed effects (column 4).

[8] Table A3 (in the appendix) will present the marginal effects with the social capital variable measured as a dummy of whether any member of the household is a member of self-help groups or SACCOSS Tables A1 and A2 (in the appendix) present the coefficients of the logit random effects models for the dummy and continuous social capital specifications, respectively. The standard errors in the parentheses are clustered robust standard errors, clustered at the household level.

Table 3: Marginal effects from the logit random effects model with social capital (dummy)

DepVar: Use of modern cooking fuels VARIABLES	(1) marginal effects	(2) marginal effects	(3) marginal effects	(4) marginal effects
Social Capital (Continuous)	0.0387**	0.0407**	0.0405***	0.0402***
	(0.0165)	(0.0165)	(0.0148)	(0.0149)
Household head is male			-0.00896	-0.00906
			(0.0157)	(0.0158)
Age of the head of the household			0.00120*	0.00119*
			(0.000618)	(0.000622)
Real annual household consumption/1000			8.46e-05***	8.29e-05***
			(1.29e-05)	(1.36e-05)
Household size			-0.0138***	-0.0136***
			(0.00377)	(0.00381)
Household owns a biomass stove			-0.0732***	-0.0736***
			(0.0203)	(0.0205)
Household owns a telephone			0.0426	0.0412
			(0.0437)	(0.0439)
Household owns a radio			0.00566	0.00637
			(0.0144)	(0.0148)
Household connected to electricity			0.0799***	0.0814***
			(0.0228)	(0.0230)
Household head achieved primary or adult education			0.0253	0.0240
			(0.0432)	(0.0434)
Observations	1,484	1,484	1,484	1,484
District FE	No	Yes	No	Yes
Time dummies	No	Yes	No	Yes

Table 3 shows that households with an additional household member affiliated to self-help groups or SACCOS are more likely to adopt modern cooking fuels. The social capital variable is statistically significant at the 1 percent level of significance. The coefficient on social capital in the current formulation is slightly higher compared to the dummy variable version in appendix A but the marginal effect largely remains the same. The results from the continuous social capital variable suggest the importance of having more household members affiliated to social networks as that presumably leverage greater access to awareness and technical information on new technologies as well as financial intermediation services from these groups, which increase the likelihood of adoption of modern cooking fuels by the household.[9] This specification gives an added twist to the social capital variable effect, showing that the more household members that there are, who are members of self-help groups or SACCOS, the stronger and equally larger the social capital. This attests to the positive role played by the information sharing and financing services offered by these groups to their members.

The social networks' financial intermediation role allows members to acquire assets associated with the use of modern energy for cooking. Affiliated members can access loans with low interest rates. This provides credit-seeking households with the financial means to pay for gas cylinders, electrification and electric/gas stoves they would not have been able to afford under normal circumstances (Grootaert, 1998). Therefore, the resources mobilized through membership in these social networks contribute to mitigating liquidity constraints.[10]

Members become aware of new technologies and technical information around them through social networks or the media. Information from social networks is likely to be more influential on members as it is usually backed by lived experiences within the group. Awareness and information from social networks also come with peer-pressure effects. Our results are consistent with the peer pressure effect often observed among members of the same group regarding technology adoption (Kumar and Igdalsky (2019) observe the same in India). Our results suggest that other specific means of communication (i.e., a phone or radio), not based on face-to-face interactions, do not trigger the adoption of modern cooking fuels (Table 3). The only exchange of information that seems to work in stimulating behavioural change to induce adoption of modern cooking fuels

[9] Here also benefits can range from direct opportunities of households to finance household modern energy infrastructure and buy equipment required harnessing modern energy for cooking to acquisition of other income generating assets that would improve the household's prospects for adopting modern cooking fuels.

[10] Furthermore, members may acquire income generating assets that increase their likelihood of use of modern energy for cooking. These assets generally help improve household welfare (Atieno, 2017).

emanates from direct and physical interactions between members of the self-help groups and SACCOS.

Apart from our main variable of interest, social capital, other variables were also found to be significant in influencing the adoption of modern cooking fuels. The age of the household head was found to be positive and significant at the 10 percent level. This indicates that the older the household head the more likely adoption of modern cooking fuels would take place. This may be attributed to learning effects associated with age and this may increase the probability of adopting modern cooking fuels. Our results are similar to those of Kulindwa et al. (2018) and Brooks et al. (2016) who found that age positively influences adoption of modern cooking fuels in Tanzania and India, respectively. Our results differ however from other studies undertaken in other parts of Africa. Menasah and Adu (2015) found age to have a negative effect in influencing adoption of modern cooking fuels. They reasoned that people become more conservative as they grow older and are therefore more likely to refrain from the adoption of new technologies. The negative effect has also been associated with the tendency of old behaviours being hard to eradicate at older ages (Vigolo et al., 2018).

Household annual consumption expenditure was found to be positive and statistically significant at the 1 percent level of significance. Better off households are therefore more likely to adopt modern cooking fuels. The strong relationship between economic status and the adoption of modern cooking fuels has been extensively established in the literature (Alem et al., 2016). Householdsize was found to be negative and significant at the 1 percent level of significance. Larger households are less likely to adopt modern cooking fuels. This may be attributed to the higher cost associated with the amount of modern fuel needed to cater for a larger number of people within the household. In literature, the results with respect to household size have been mixed. Some studies have found similar results to ours with regards to household size in influencing adoption of modern cooking fuels (Vigolo et al., 2018).[11]Some studies found a positive and significant relationship between household size and the adoption of modern cooking fuels. They reasoned that larger households are more likely to adopt modern cooking technologies due to the less time it takes to prepare meals for large families and less fuel collection time (Alem et al., 2016; Vigolo et al., 2018). There are studies that found no effect of household size on the adoption of modern cooking fuels (Vigolo et al., 2018).

The availability of a biomass stove and an electricity connection were found to have statistically significant effects on households' adoption of modern cooking fuels. Household connection to electricity was found to have a statistically significant positive effect on the adoption of modern cooking fuels. This shows how availability of modern energy technologies influences their adoption for cooking. Conversely those households who had invested in biomass stoves were less likely to adopt modern fuels for cooking. The other variables included in the model (gender, education, owning a telephone, and owning a radio) were not found to be statistically significant.

[11] For some studies, in a village setting, larger households translate into more labour for the collection of traditional fuels (plant/animal waste, firewood and charcoal). This makes larger households lean towards the use of traditional fuels for cooking (Vigolo et al., 2018).

2.5.3 Robustness checks

To test the robustness of our measure of social capital, we further investigate its effect by specifying it as a dummy variable rather than a continuous variable: social capital is measured as a dummy of whether any member of the household is a member of self-help groups or SACCOSS. . Table A3 (in the appendix) presents the estimation results of the marginal effects from the random effects model.

Table A3 (in the appendix Shows that households with at least one member affiliated with a self-help groups or SACCOS are more likely to adopt modern cooking fuels. The social capital variable is statistically significant at the 5 percent level.

For further robustness checks, we used other model specifications: the pooled logit and linear probability models as presented in Tables A4 to A9 (in the appendix). The statistical significance and effects of our variables remain the same throughout all the econometric specifications.

2.6 Conclusion and Policy Implications

The main objective of the chapter was to look at the role of social capital on the households' adoption of modern cooking fuels in Tanzania, using Dar es Salaam as a case study. Affiliation to SACCOS/self-help groups was used as the measure of social capital. Three waves of the Tanzanian national panel data set for the years 2009, 2011 and 2013 were used.

The study estimated a logit random effects model of the households' adoption of modern cooking fuels on social capital and other variables. For robustness, social capital was measured both as a dummy variable (whether or not a household belonged to a social network) and a continuous variable (the number of household members affiliated to social networks). Furthermore, variant econometric specifications (the linear probability model and the pooled logit model) were explored. Our results suggest that social capital influences households' adoption of modern cooking fuels. The study also suggests that the more household members are affiliated with a social network, the more likely that a household will adopt modern cooking fuels. Members become aware of new technologies and technical information around them through social networks (the SACCOS/self-help groups). Information from social networks is more influential on members as it is backed by lived experiences within the group. Awareness and information from social networks also come with peer-pressure effects. The social networks' financial intermediation role allows members to acquire assets associated with the use of modern energy for cooking or other income generating activities as members can access loans at low interest rates.

Our study also substantiated other factors such as economic status (measured by consumption expenditure) as key in the adoption of modern cooking fuels. Household size was found to have a significant negative effect on the adoption of modern cooking fuels, confirming earlier results for Tanzania despite the general mixed results in literature. Furthermore, households' connection to electricity and households' ownership of traditional stoves had a positive and negative statistical effect on the adoption of modern cooking fuels, respectively. Whereas household head's age was found to positively impact the adoption of modern cooking fuels, education, gender of household head, and the ownership of a telephone and radio did not have a significant effect on the adoption of modern cooking fuels.

Our results point to a vital role that social capital may play in the adoption of modern cooking fuels. The structural nature of social capital amounting from household's group membership help leverage the cost associated barrier with regards to the adoption of modern cooking fuels. It is thus imperative for policies in the country to pinpoint the use of structural groups like self-help groups and SACCOS in Tanzania as a paramount strategy to aid household energy transitions in the country. This could be in the form of targeted credit facilities through these groups specifically for the financing of household modern energy infrastructure and the purchase of assets associated with the use of modern fuels for cooking.

Literature has shown that financial inclusion, especially for women for schemes that aim to empower women through household energy transitions. Thus, providing credit through groups like the ones explored in this paper goes a long way to ease access to credit for purchase of modern cooking fuels. Specific Programs that took this initiative on board such as Switch SA in Haiti have proven successful (ENERGIA, 2014). Nevertheless, these should be supported with awareness campaigns on the usefulness of modern cooking technologies, including their health associated benefits along with other incentives for adoption of modern cooking fuels (Vigolo et al., 2018).

Moreover, groups like these in the villages could potentially be used in the dissemination of information about modern cooking technologies and thus ease the diffusion of new technologies in the rural areas. In India, the use of self-help groups to aid the adoption of improved cook stoves was adopted as part of India's ninth government plan to bolster the microfinance programs in the country and bring about behavioural change with regards to cooking technologies using the strong social ties among the groups and their group leaders (Kumar and Igdalsky, 2019).

Chapter three

The Impact of Household Energy Transition on Household Welfare in Tanzania

Abstract

Household energy transitions are expected to improve household welfare indicators such as health and schooling. This paper looks at the impact of households' use of modern cooking fuels for cooking and electricity for lighting on health and schooling outcomes in Tanzania. The study employs propensity score matching techniques on two survey datasets. The results show a reduction in the incidence of respiratory diseases among children for households using modern cooking fuels, while the use of electricity for lighting was associated with improved evening study hours, examination scores and educational attainment. Moreover, electrification was found to affect household time use (encouraging more non-agricultural activities in rural areas) and reduce fertility (probably due to information access). The study provides the rationale for policies geared towards improving access to modern energy for cooking and lighting and easing the constraints towards full energy transitions by households to achieve several sustainable development goals.

3.1 Introduction

Over 70 percent of Tanzanian households use wood for cooking (National Bureau of Statistics, 2015a), with charcoal use being prominent in urban areas. Nevertheless, the use of modern fuels for cooking has increased in the urban areas, with the largest increases being observed in Dar es Salaam, where the proportion of households using modern fuels (LPG and electricity) for cooking increased from 7.2 percent in 2008 to 21.1 percent in 2019 (MOF and NBS, 2019). Moreover, the share of the population using electricity for lighting instead of kerosene and other fuels increased from 13 percent in 2008 to 37.7 percent and 24.5 percent in the year 2019/20 for the whole country and rural areas respectively, with access to electricity in urban and rural areas reaching 99.6 and 69.8 percent respectively in 2019/20 (Mokveld and Eije, 2018; Rural Energy Agency, 2020).

The Tanzanian household energy use scenario depicts a continued increase in annual household electrification and a slow but gradual shift to household use of modern fuels for cooking, with most of this shift taking place in urban areas. The government has been supporting household energy transition by putting in place a set of conducive polices. It is evident that more must be done to fast track and deepen the transition and providing evidence of the impacts of such transitions on household welfare can catalyze policy implementation. Bonan et al. (2017) points out the importance of establishing impacts of household energy transitions and linking them to the sustainable development goals (SDGs). On the basis of availability and nature of data, this study has zeroed in on a few selected welfare indicators as explained in the chapter.

Household energy transitions are expected to improve household welfare indicators such as health and schooling. The transition to cleaner cooking can take the form of either improved biomass cook stoves or cook stoves that use cleaner fuels (e.g. biogas, LPG, solar and electricity). The use of improved cook stoves and/or modern cooking fuels ordinarily implies a reduction of the household's use of wood fuels and, consequently, a reduction of indoor air pollution, which has been linked to respiratory illnesses, especially for women and children. Moreover, the reduced use of wood fuels is naturally associated with a reduction of pressure on forests (Brook et al., 2016; Bensch and Peters, 2015; Bonan et al., 2017; Chaplin, 2017), which could make a significant contribution to carbon sequestration. Through the replacement of kerosene and other traditional sources of lighting, household electrification is also associated with a reduction of indoor air pollution and, thus, a reduction in respiratory illness. In addition, by providing better lighting, electrification positively affects schooling indicators such as the number of evening study hours, examination scores, and grade completion (Khandker et al., 2012; Bonan et al., 2017; Bos et al., 2018). Furthermore, household electrification has been linked to increased use of information technologies, which increases households' access to information on issues such as family planning.

This study uses propensity score matching techniques on data from the 2014/15 Tanzania National Panel Survey and 2015/16 Tanzania Demographic and Health and Malaria Indicator Survey to isolate the health and schooling impacts of households' use of (a) modern cooking fuels (LPG and electricity) and clean cooking stoves and (b)modern lighting (electricity). To our knowledge, this is the first paper that has looked at the impact of household energy transitions comprehensively for both cooking and lighting for combined rural and urban Tanzania, adding to the few quantitative studies (e.g., Holmes 2010; Bwenge 2011; Alem et al. 2015; Aevarsdottir et al. 2017; Chaplin et al., 2017;Masatsugu and Pattanayak2017: Pueyo et al., 2020) on impacts of household energy transition in Tanzania.

Specifically, the chapter adds to the very few studies that look at the impacts of household cooking energy transitions in Africa, especially Tanzania. As the impacts of such transitions differ in different contexts due to behavioral aspects and cooking habits, it is imperative to have more papers providing evidence of such impacts in Africa, specifically Tanzania. Moreover, our study adds to the literature on the impacts of household's use of electricity on schooling outcomes and health (especially fertility) by investigating these impacts in the context of Tanzania. To our knowledge, ours is among the first studies to comprehensively study the impact of electrification on several outcomes, including energy expenditures, fertility, schooling outcomes and time use for Tanzania. In doing so, this paper adds to few studies that look at the impact of electrification on health and fertility. For example, although Aevarsdottiret al., (2017) made a similar attempt in Tanzania, their study focused on the impacts of electrification from solar lamps in rural areas. Our study looks at the use of electricity (both grid and off-grid) and studies its impacts not only for rural area, but for the whole sample and sub-samples in the urban and rural areas.

The results show a reduction in the incidence of respiratory diseases among children for households using modern cooking fuels, while the use of electricity for lighting was associated with improved evening study hours, examination scores and educational attainment. Moreover, electrification was found to affect household time use (promoting non-agricultural activities in rural areas) and to reduce fertility (probably due to access to information about family planning).

The paper is structured as follows. Section 2 offers an exhaustive review of the existing literature. The methodology and data are presented in Section 3. Section 4 presents the results and discussion, and section 5 concludes the paper.

3.2 Literature review

This section reviews the literature on the impact of transitions to cleaner cooking and electrification on household welfare.

3.2.1 Impact of transitions to cleaner cooking on household welfare

The energy transition to cleaner cooking is comprised of two different aspects which entail use of improved biomass cook stoves and use of cook stoves that take cleaner fuels (e.g.biogas, LPG, solar and electricity). Both aspects are important and therefore considered in this section[12].

Studies on the impact of transitions to cleaner cooking cover diverse regions around the world. However, studies from Asia have dominated the scene, e.g., Brooks (2014), Lewis (2015), Jain (2014), Brook et al. (2016), Lewis et al. (2017) and Hannah et al. (2016) in India; Andandari et al. (2014), Putra et al. (2017); Hnyine et al. (2015) in Indonesia; Yu (2011) in China and Vahlne and Ahlgren (2014) in Vietnam. Studies from Africa, particularly Sub-Saharan Africa, are still few, e.g.,Bruwen and Levine (2012) in Ghana; Beltramo and Levine (2013) in rural Senegal; Bensch and Peters (2015) in Burkina Faso; Yip et al. (2017) in Kenya; Masatsugu and Pattanayak (2017), Alem et al. (2015), Bwenge (2011) and Holmes (2010) in Tanzania.

Most of these studied either used randomized control trials (Bruwen and Liven, 2012; Smith et al., 2011; Hannah et al., 2016; Bensch and Peters, 2015; Beltramo and Levine, 2013; Dresen et al., 2014; Alem et al., 2015) or quasi-experimental methods (Lewis et al., 2017; Brook et al., 2016; Adrianzen 2013; Yu 2011; Vahlne and Ahlgren 2014; Yip et al 2017; Tronsco et al., 2013; Jain,

[12] The chapter covers both aspects of energy transition with regards to cooking, as they all entail a shift from use of biomass, whose triggers are more or less the same. This is similarly depicted in most household energy transition studies with regards to cooking as depicted in Vigolo et al., (2018).

2014; Lewis, 2015; Andadari et al., 2014; Brooks, 2014; Masatsugu and Pattanayak, 2017). Nevertheless, a few studies have also done a qualitative exploratory impact analysis of improved and modern cooking stove use on households' welfare (Bwenge, 2011; Holmes, 2010).

An array of outcomes have been studied with regards to the impacts of cleaner cooking on household welfare, including fuel use, cooking time and time use for biomass collection (Bruwen and Levine, 2012; Lewis et al., 2017; Brook et al., 2016; Adrianzen, 2013; Lewis, 2015; Bensch and Peters, 2015; Beltramo and Levine, 2015; Hnyine et al., 2015; Putra et al., 2017; Jain, 2014; Dresen et al., 2014; Andadari et al., 2014; Alem et al., 2015; Holmes, 2010; Masatsugu and Pattanayak, 2017) and health related outcomes (Bruwen and Levine, 2012; Smith et al., 2011; Hannah et al., 2016; Lewis et al., 2017; Bensch and Peters, 2015; Yu, 2011; Yip et al., 2017; Beltramo and Levine, 2013;Lewis, 2015).

In this section, we are more concerned about the impact on health outcomes. This impact tends to be driven by the impact of transitions to cleaner cooking from usage of polluting fuels that are associated with indoor air pollution. Findings on the impact of transitions to cleaner cooking on fuel use have been mixed. Whereas most studies have ascertained significant decreases in the amount of traditional fuel used, both in terms of quantities and expenditures on wood fuels (Lewis et al., 2017; Brook et al., 2016; Bensch and Peters, 2015; Beltramo and Levine, 2015; Hnyine et al., 2015; Putra et al., 2017; Jain. 2014; Dresen et al., 2014; Alem et al., 2015; Holmes, 2010; Masatsugu and Pattanayak, 2017), others found that the decreases were not statistically significant, e.g.,Bruwen and Levin (2012), Andadari et al. (2014), and Beltramo and Levine (2013). Most papers have substantiated that, along with fuel saving, improved cook stoves and clean cooking fuel save cooking and fuel collection time, specifically time used to collect firewood (Lewis et al., 2017; Brook et al., 2016; Bensch and Peters, 2015; Jain, 2014). Lewis et al. (2017) ascertained that utilization of clean stoves (LPG, biogas, and electric cookers) is associated with substantial time savings for primary cooks, and Brook et al. (2016) reiterated that clean cook stoves not only reduced cooking time but also fuel wood collection time in India. Similarly, Jain (2014) stressed that the use of biogas in India was associated with women and children reducing their time spent on the drudgery of collection and carrying firewood, cooking, and cleaning utensils, while Bensch and Peters (2015) ascertained the impact of improved cook stoves and clean cook stoves on cooking time and fuel collection time, respectively, in Burkina Faso.

Closely linked to the impact on fuel use is the impact on health. The reduction of biomass fuel use in a household is associated with a reduction of indoor air pollution, which results in a reduction in incidences of self-reported acute respiratory and other health related outcomes associated with cooking such as burning eyes (Bruwen and Levin, 2012; Smith et al., 2011; Lewis et al., 2017; Bensch and Peters, 2015; Yu, 2011; Hannah et al., 2016). The results of impacts of improved cooked stoves and clean cooking fuels on health are also mixed. Whereas many studies have found significant reduction in the incidence of health problems, others have not found any significant effect (Hannah et al., 2016; Beltramo and Levine, 2013). In Ghana, Bruwen and Levin (2012) found significant impacts of improved cook stoves on self-reported symptoms associated with cooking, such as burning eyes and respiratory symptoms such as chest pains and runny nose. Similarly, Smith et al. (2011) found significant reductions in pneumonia in Guatemala associated with households' use of improved cook stoves, although the results were not significant for children under 18 months of age. In India, Lewis et al. (2017) found that the use of clean coking stoves was associated with substantial reduction in indoor pollutants and a significant reduction in visits to the hospital due to incidents of acute respiratory infection, as well as reduced blood pressure. Furthermore, Bensch and Peters (2015) pointed out that due to reduced firewood consumption by households, improved cook stoves also led to a reduction in smoke exposure and consequently smoke related disease symptoms. The results were attributed partly to behavioral change by households due to cooking outside of the household. Similarly, Yu (2011) showed that behavioral intervention coupled with stove interventions had significant impacts on incidences of acute respiratory infections for children aged five and under in rural China.

On the other hand, Hannah et al. (2016) found results contrary to what others had found with regards to reductions in incidences of acute respiratory infections in India. Using a randomized control trial , the authors found that although smoke exposure initially falls, the effect disappears in year two. They generally did not find any significant changes across health outcomes or greenhouse emissions. The study pointed out that human behavior may undermine the potential outcomes of improved cook stoves in the real world, as most households were found to have used the improved cook stoves irregularly and inappropriately. Similarly, Beltramo and Levine (2013) did not find any significant reductions in exposure to carbon monoxide nor self-reported respiratory symptoms such as coughs and sore throats.

Overall, our review of literature depicts positive impacts of improved and clean cook stoves on household welfare, specifically with regards to wood fuel consumption and health. Nevertheless, there are very few studies that look at the impacts of household cooking energy transitions in Africa, especially Sub-Saharan Africa. As the impacts of such transitions differ in different contexts due to behavioral aspects and cooking habits, it is imperative to have more papers providing evidence of such impacts in Africa, specifically Sub-Saharan Africa.

3.2.2 Impact of electrification on household welfare

The existing literature has looked at impacts of electrification on an array of welfare indicators. These include impacts on time allocation (Grimm et al., 2016; Arraiz and Calero, 2015; Samad et al., 2013; Khandkeret al., 2012; Benschet al., 2011; Barron and Torero, 2017; Aguirre, 2014; Furakawa, 2014; Aevarsdottir et al.,2017), employment and labor supply (Barron and Torero, 2015; Daso and Fernandez, 2015; Van de Walleet al., 2015), wages, earnings and income (Benschet al., 2011; Arraiz and Calero, 2015; Barron and Torero, 2015; Aevarsdottir et al.,2017), consumption and expenditure[13] (Van de walle et al., 2015; Bensch et al., 2011; Arraiz and Calero, 2014; Samad et al., 2013; Grimm et al., 2015), school performance (Van de Walleet al., 2015; Khandker et al., 2012; Arraiz and Calero, 2014; Furakawa, 2014) and health (Samad et al., 2013; Barron and Torero, 2017; Aevarsdottir et al.,2017).

In this section, our major focus is on the impact of electrification on schooling outcomes and health (especially fertility). This is because households adopt electricity primarily for lighting, which directly replaces other inefficient sources of lighting such as kerosene, candles and torch cells. The impact of electrification on schooling tends to be driven by the impact of electrification on household time allocation. Again, the impact of electrification on time allocation is mixed. Whereas Grimm et al. (2015) finds no effect on time allocation in Rwanda, other studies find significant effects (Arraiz and Calero, 2014; Samad et al., 2013; Khandker et al., 2012; Bensch et al., 2011; Bernard and Torero, 2015; Barron and Torero, 2015; Aguirre, 2014; Furakawa, 2014).

[13]The impact of electrification on energy expenditures is mixed; some studies find significant increases in energy expenditures (Bensch et al., 2011; Samad et al., 2013; Van de walle et al., 2015) other studies find statistically significant decreases in energy expenditures (Arraiz and Calero, 2014; Grimm et al., 2016; Karumba and Muchapondwa, 2018).

For example, Arraiza and Calero (2014) found that members of using traditional energy sources spent more time awake.[14]

Linked to time allocation due to time saved and an elongated working day is children's study hours. Samad et al. (2013) found significant increases in children's study time in Bangladesh. Not only did other studies find significant increases in children's study time but also found significant increases in time used by children in educational activities and household chores (Khandker et al., 2012; Bensch et al., 2011; Bernard and Torero, 2015; Barron and Torero, 2015; Aguirre, 2014; Furakawa, 2014).[15]

Closely linked to the impact on children's study hours is the impact on educational attainment and school performance (Van de Walle et al., 2015; Khandker et al., 2012; Arraiz and Calero, 2014; Furakawa, 2014). The results have also been mixed with regards to different contexts. Whereas most studies have substantiated a positive effect of electrification on education attainment (Van de Walle et al., 2015; Khandker et al., 2012; Arraiz and Calero, 2014), other studies have found negative and significant effects on school performance and education attainment (Furakawa, 2014; Squires, 2015).

14Furthermore, they stress that electrification decreases the time women spend on agricultural activities and increases the time they spend on household activities. As reiterated by Bonan et al. (2016), with the switch to household activities/non-agricultural activities, electricity contributes to the development of small businesses and firms' investment in electrical appliances that need non-agricultural labor. Similarly, Van da Walle et al. (2015) found significant time allocation from casual labor work to regular wage jobs and agricultural self-employment for men. Marginal effects were found for women. Furthermore, they found a significant increase in hours worked for men and the likelihood of men having more than one job. Such time allocation effects may also materialize due to time saved from traditional energy connected activities and extending the working day well beyond the sunset (Bonan et al., 2016).

15Nevertheless, other studies have found negative significant effects of electrification on children's study hours, citing the fact that children may use more of their time to watch television instead of studying (Karumba and Muchapondwa, 2018).

One of the least studied but key area of inquiry is the impact of electrification on fertility and health-related outcomes such as respiratory disease symptoms. Barron and Torero (2017) showed a reduction of indoor air pollution caused by traditional fuels for lighting and consequently a reduction in acute respiratory symptoms among children under six in El Salvador. Similarly, Samad et al. (2013) found significant reduction in respiratory disease symptoms for women in Bangladesh. On the other hand, studies have pointed out the impact of electrification on fertility. A 2008 World Bank study using cross-sectional data from Ghana, Peru, the Lao People's Democratic Republic and the Philippines substantiated a negative relationship between electrification and fertility due to improved access to technologies such as radios, mobile phones and televisions, which provide information about family planning (Arraiz and Calero, 2014).

Our study adds to the literature on the impacts of household's use of electricity on schooling outcomes and health (especially fertility) by investigating these impacts in the context of Tanzania. To our knowledge, ours is among the first studies to comprehensively study the impact of electrification on several outcomes, including energy expenditures, fertility, schooling outcomes and time use for Tanzania. In doing so, this paper adds to few studies that look at the impact of electrification on health and fertility. For example, although Aevarsdottiret al., (2017) made a similar attempt in Tanzania, their study focused on the impacts of electrification from solar lamps in rural areas. Our study looks at the use of electricity (both grid and off-grid) and studies its impacts not only for rural area, but for the whole sample and sub-samples in the urban and rural areas.

3.3 Methodology

3.3.1 Identification strategy

We use the counterfactual framework pioneered by Rubin (1974) and adopted by many previous studies, including Rosenbaum and Rubin (1983), Heckman (1992, 1997), Imbens and Angrist (1994), Heckman, Ichimura and Todd (1997) and Angrist (1998). We adopt this approach to determine (a) the impact of a household's use of modern cooking fuels and (b) the impact of household electrification on household welfare indicators in Tanzania. Our inferences hinge on modelling how a household would have performed had it not received the treatment.

As stipulated in Caliendo and Kopeinig (2008) for a binary treatment, the treatment indicator D_i for household i equals one (1) if a household receives a treatment and zero (0) otherwise. $Y_i(D_i)$defines the potential outcomes for each household i, where i = 1, 2, 3…, N, with N denoting the total population. The treatment effect for household i can be written as:

$$\tau_i = Y_i(1) - Y_i(0) \tag{1}$$

Nevertheless, as we can only observe one of the potential outcomes, estimating the household outcomes τ_i is not possible. Accordingly, using a counterfactual outcome which stipulates the unobserved outcome, we concentrate on estimating average treatment effects.

Furthermore, we estimate the average treatment effect on the treated (ATT), defined as:

$$\tau_{ATT} = E(\tau|D = 1) = E[Y(1)|D = 1] - E[Y(0)|D = 1] \tag{2}$$

The counterfactual mean for the treated $E[Y(0)|D = 1]$ is not observed. Thus, the fundamental problem becomes the choice of a proper substitute to estimate the average treatment effect on the treated (ATT). It is tempting to use the mean outcome of the untreated individual's$[Y(0)|D =$

0].However, in a non-random experiment such as ours; it is likely that factors that determine the treatment decision also determine the outcome. Hence, even without the treatment, the outcomes of treated and control households would differ, leading to self-selection bias. Rewriting Equation (2),

$$E[Y(1)|D=1] - E[Y(0)|D=0] = \tau_{ATT} + E[Y(0)|D=1] - E[Y(0)|D=0] \qquad (3)$$

Equations (2) and (3) only differ by the selection bias component. The true parameter τ_{ATT} is only identified if:

$$E[Y(0)|D=1] - E[Y(0)|D=0] = 0 \qquad (4)$$

The only way to ensure this is by random assignment of the treatment. We use the propensity score matching technique to reduce the selection bias problem.

3.3.2 Propensity Score Matching

Rosenbaum and Rubin (1983) define a propensity score as the conditional probability of receiving a treatment given pre-treatment characteristics. This can be represented by Equation (5) below, where X is a vector of pre-treatment characteristics.

$$P(X) \equiv \Pr(D=1|X) = E(D|X) \qquad (5)$$

Rosenbaum and Rubin (1983) proved that, if the treatment assignment is random within cells and defined by X, then it remains random within cells defined by $P(X)$. Hence, comparing mean outcomes of control and treated groups at the values of the score yields unbiased estimates. The unbiased average treatment on the treated, given the propensity score, can be estimated as shown in Equation (6) below.

$$\tau_{ATT}^{PSM} = E_{(P(X)|D=1)}\{E[Y(1)|D = 1, P(X)] - E[Y(0)|D = 0, P(X)]\} \qquad (6)$$

Propensity score matching hinges on two main assumptions for the estimation of unbiased estimates. The first is the conditional independence assumption: for a given set of observable covariates X, potential outcomes are independent of treatment assignment. This is a very strong assumption which most of the time is only introduced to address the quality of the data at hand. Based on a propensity score, this condition can be written as follows:

$$Y(0), Y(1) \perp D|P(X) \qquad (7)$$

The second assumption is common support, which rules out the phenomenon of perfect predictability. Thus, households with the same propensity scores have a positive probability of being in both treatment and comparison groups (Caliendo &Kopeinig, 2008; Heckman et al., 1999). This is expressed as follows:

$$0 < P(D = 1|X) < 1 \qquad (8)$$

With these assumptions, propensity score matching reduces the bias of the difference in the means of outcomes over the common support.

3.3.3 Theory of change

Modern cooking fuels

The use of modern cooking fuels (LPG and Electricity) is expected to have a direct impact on household energy expenditures. We expect the use of modern cooking fuels to replace the traditional cooking fuels, which can either be a total or partial replacement. The later means that a household continues using both modern and traditional cooking fuels, while the former means a household shifts to use of modern cooking fuels alone. We expect that households that use modern cooking fuels would on average spend less on wood fuels compared to households that use wood fuels only (Brooks et al, 2016; Bensch and Peters, 2015; Beltramo and Levine, 2013; Adriazen, 2013). As our analysis of the impact of modern cooking fuels is more centered in urban and peri-urban areas of Tanzania, where the prominent wood fuel used is charcoal, we expect on average a decrease in charcoal expenditures for households that use modern cooking fuels. Thus, in the long run this translates in lower physical quantities of charcoal consumed and thus reduced the pressure on forests.

The use of modern cooking fuels potentially reduces health associated risks of using wood fuels such as firewood and charcoal, (Burwen & Levine, 2012). The World Health Organization (WHO) has raised concern over severe health consequences of indoor air pollution caused by the use of wood fuels (firewood and charcoal), diseases like pneumonia and heart diseases are attributed to indoor air pollution, (Ezzati and Kammen, 2001). The adverse effects of indoor air pollution are more severe for women and children who spend most of their time around the kitchen. We expect households that use modern cooking fuels to have less incidences of under-five years and below that suffer from self-reported acute respiratory symptoms such as cough and shortness of breath.

Electrification

Once a household is connected to electricity, the immediate impact is observed in its expenditures, specifically those pertaining energy. Furthermore, our theory of change premise with regards to electrification also expect impact on education, time use and health. We expect a decrease in the household energy expenditure, specifically on kerosene. This is because electricity will first and foremost replace other lighting fuels, most prominently kerosene which is being used for lighting by 21 percent and 27 percent of the urban and rural households respectively in Tanzania.

Electrified households are expected on average to spend less on kerosene compared to non-electrified households, (Samad et al., 2013; Karumba and Muchapondwa, 2017; Grimm et al, (2015)).

Moreover, electrification impacts household welfare through changes in time allocation of household members. This results in welfare improvement through mechanisms like time saved from energy related activities (cooking and fuel collection), increase in the workday and a switch from agricultural to non-agricultural activities, (Bonan et al, 2016). Our paper considers the later mechanism of the switch from agricultural activities to non-agricultural activities that have resulted due to electrification. This may be in the form of small businesses and firms, which demand non-agricultural labour, (Bonan et al, 2016). We expect household members in electrified households to spend more time in non-agricultural activities compared to those from non-electrified households.

The quality of lighting from electricity is expected to increase children study hours. We expect that children in electrified households will study for longer hours in the evening relative to those in non-electrified households. Linked to longer hours of study, is education attainment and school performance thushildren in electrified households are expected to go further in terms of schooling, both in terms of test pass rates and study years, (Khandker et al, 2012). We thus expect that students in rural and urban areas in electrified households to be more educated and reach higher levels of schooling.

As electrification is expected to replace traditional sources of light specifically kerosene, which produces fumes that not only pollute the household but also lead to health problems, we expect electrified households to have low concentration of indoor air pollution and thus lead to a reduction in acute respiratory symptoms infections in the households, especially for children under the age of five, (Barron and Torero, 2017). Furthermore, linked to health outcomes, is the impact of electrification on fertility. Studies have shown that electrification may be attributed to decreased fertility due to improved access to family planning information. We hypothesize that as electrification increases, the use of appliances like radios, mobile phones and televisions, families in electrified households are more likely to get information on family planning and hence increase the number of women using modern family planning methods and lead to a decline in fertility, (Arraiz and Calero (2015), IEG (2008). Peters and Vance (2011)). Table 1 in the appendix summarizes the outcomes of interest in the study and how they are measured.

3.3.4 Empirical Strategy

We conducted two separate impact evaluation exercises to isolate health, schooling and other welfare indicators impacts of households' use of (a) modern cooking fuels (LPG and electricity) and clean cooking stoves and (b)modern lighting (electricity), Thus, household's use of modern cooking fuels and household's use of modern lighting (electricity) represented two distinct treatments for two distinct impact evaluation exercises for the study.

Specifically, the study evaluated the impact of household's use of modern cooking fuels on energy expenditures (total energy expenditures, modern energy expenditures, share of modern energy budget, charcoal expenditures, traditional energy expenditure and share of traditional energy budget) and health related outcomes (respiratory health of children aged five and below).

On the other hand, we also evaluated the impact of household's use of electricity on energy expenditures (total energy expenditures, kerosene expenditures, modern energy expenditures, share of modern energy budget, traditional energy expenditure and share of traditional energy budget), Schooling (study hours, years of education, standard seven results), time use (time used in non-agricultural activities), health and fertility (respiratory health of children aged five and below, the number of children aged five and below , the number of births in the last five years, the preferred waiting time before the next pregnancy and the use of contraceptives). Table B.1 (in the appendix) portrays how each of the outcome variable used for the study was measured.

The impact evaluation exercises employed propensity score matching techniques following four key steps as explained in detail in Caliendo and Kopeining (2008) to ensure precise and robust results, that is we first estimated the propensity scores, chose a suitable matching algorithm, assessed the matching quality was, and conducted a sensitivity analysis of our results. These steps are explained in detail below. The study adopted propensity score matching because of the type of data used. The study used two crosssectional data sets, that is the 2014/15 wave of the Tanzanian national Panel Survey and 2015/16 Tanzanian Demographic and Health and Malaria Indicator Survey. The impetus behind the study's use of two cross sections is firstly inability to use the 2014/15 wave of the panel data set to form a panel data set with the previous waves as it was a replenished wave, that used a new sampling frame different from the one used for the previous waves, thus, did not follow the original households, which ruled out the use of panel data techniques for impact analysis. Secondly, as we wanted to explore the impacts of household's energy transitions on both health related and non-health related outcomes, we opted to use a specialized data set on health outcomes, that is the most current demographic health survey for the country by the time the study was being carried out, as the panel data did not have explicit health outcomes. Thus, led to use of two national representative cross sectional data sets that had been collected around more or less the same time to get a picture of these impacts within a homogenous time period and for comparison purposes. Moreover, as the study made use of secondary data, finding suitable instruments for our study from data meant for broad purposes was an impossible task.

Estimating the propensity scores

This entails choosing the model for the estimation of the propensity scores and the variables to be included in the model. Any discrete choice model can be used: logit or probit. These are preferred over the linear probability model due to its well-known shortcomings (Caliendo and Kopeining, 2008). When the treatments are binary, as in our case, the probability of being treated versus not treated yields the same results, regardless of whether logit or probitis used. This paper used the logit model to estimate the propensity scores. The logit model that a household is treated is a linear function of X (observable characteristics) and represented by Equation (9) below:

$$logit(\theta_i) = F(X'\alpha) = X_i'\alpha \qquad (9)$$

Where α is a vector of coefficients and F(.) is the cumulative density function of the logistic distribution. The propensity scores are generated from the predicted probability based on model (9). The probability that a household is treated is given by Equation (10):

$$\theta_i = \frac{exp\{X_i'\}}{1 + exp\{X_i'\}} \qquad (10)$$

According to Caliendo and Kopeining (2008), matching hinges on choosing the most credible set of observables X, as omitting important variables can increase bias in resulting estimates. It is advisable to include only variables that simultaneously influence the treatment decision and outcome variables. This study takes that into consideration and chooses variables to be included in the participation models that are supported by economic theory and previous research on impacts of household energy transition.

Choosing a matching algorithm

Next, we choose the appropriate matching procedure to contrast the outcomes of treated and comparison households. There are five matching algorithms that we can chose from:(1) Nearest Neighborhood matching, (2) caliper and radius matching, (3) stratification and interval matching, (4) kernel and local linear matching and (5) weighting on propensity scores. These matching algorithms differ in how the neighborhoods for treated individuals are defined and how the common support problem is handled (Caliendo and Kopeining, 2008). Moreover, the choice between different algorithms entails a trade-off between bias and efficiency. Neither of the matching algorithms is superior to the other. Joint consideration of the matching algorithms serves as a good robustness check of the estimates.

The matching quality

As the matching is done based on propensity scores it's advised to check the quality of matching and assess if the matching procedure is able to balance the distribution of all the relevant variables in both the control and treatment group, (Caliendo and kopeining, 2008). All the approaches that assess the matching quality try to test if there any significant differences remaining between the treated and control groups after the matching, (Caliendo and kopeining, 2008). This is in line with the theorem suggested by Rosenbaum and Rubin (1983) that after conditioning on the propensity scores, additional conditioning on X should not provide new information about the treatment decision. Any dependence of the treatment decision on X after matching suggests a misspecification in the model used to estimate the propensity scores or a failure of the conditional independence assumption, (Caliendo and kopeining, 2008; Smith and Todd, 2005).

There are several approaches of assessing the matching quality, these include the standardised bias, which for any given covariate it's defined as the difference in the sample means in the treated and matched control subsamples as a percentage of the square root of the average of sample variances in both groups, (Caliendo and kopeining, 2008; Rosenbaum and Rubin, 1985). The standardized bias before and after matching are given by:

$$SB_{before} = 100.\frac{(\bar{X}_1 - \bar{X}_0)}{\sqrt{0.5(V_1(X) + V_0(X)}} \quad (12)$$

$$SB_{after} = 100.\frac{(\bar{X}_{1M} - \bar{X}_{0M})}{\sqrt{0.5(V_{1M}(X) + V_{0M}(X)}} \quad (13)$$

Where $\bar{X}_1$ and V_1 is means and variance respectively of the treatment group. $\bar{X}_0$ and V_0 is the mean and variance respectively for the control group before matching. Analogously $\bar{X}_{1M}\bar{X}_{0M}V_{1M}$ and V_{0M} are corresponding values for the matched samples. Thus, one of the common approaches in evaluation studies in assessing matching quality. In most studies a bias reduction below 3% or 5% is deemed enough. (Caliendo and kopeining, 2008). The other similar approach is a simple t-test, which uses a two-sample t-test to check if there are significant differences in covariates of means of the treated and control groups before and after matching, we expect to have no significant differences in covariates between the treated and control groups after matching if the matching in propensities was successful. The stratification test suggested Dehejia and Wahba (1999, 2002), implemented analogously as a simple t-test but the t-tests is conducted within strata based on the estimated propensity scores.

Sianesi (2004) suggested the use of the joint significance of the covariates and pseudo-R^2. The approach requires a re-estimation of the propensity score on the matched sample and compare the pseudo-R^2 after matching and before matching. After matching there shouldn't be any systematic differences between the groups and thus the pseud-R^2 should be very low. Moreover, the F-Test of the joint significant of the repressors should be rejected before matching and should not be rejected after matching. (Caliendo and kopeining, 2008). This study uses the standardised bias, the t-test and the Joint significance and Pseudo- R^2 to assess the matching quality.

Sensitivity analysis

As propensity score matching estimates treatment effects based on the conditional independence assumption that is conditioning on observable characteristics, if there are unobservable variables which simultaneously affect treatment assignment and the outcome variable a hidden bias may arise, (Caliendo and kopeining, 2008). The magnitude of this selection bias cannot be estimated with non-experimental data. To address this problem Rosenbaum (2002) proposed a bounding approach that tries to check if inference may be altered by unobservable factors. As Caliendo and kopeining (2008) put it, the bounds determine how strongly an unmeasured variable may influence the selection process and thus, undermine the implications of the matching analysis. If the participation probability is:

$$P(X_i) = P(D_i = 1|X_i) = F(\beta X_i + \gamma\mu_i) \quad (14)$$

Where X_i are observed characteristics for household i, μ_i is the unobserved variable and γ is the effect of μ_i on the participation decision of the household. If a study is free of hidden bias, γ will be zero and thus the participation probability of the household. The presence of a hidden bias means two households with similar observable characteristics may have different chances of receiving treatment, (Caliendo and kopeining, 2008). Rosenbaum (2002) shows that the odds ratio of the odds that two matched households i and j receive treatment imply the following bounds:

$$\frac{1}{e^{\gamma}} \leq \frac{P(X_i)\left(1-P(X_j)\right)}{P(X_j)\left(1-P(X_i)\right)} \leq e^{\gamma} \qquad (15)$$

Where e^{γ} measures the extent to which a study has deviated from a study that is free of hidden bias, (Caliendo and kopeining, 2008; Rosenbaum, 2002).

3.3.5 The data

The study makes use of two data sets: the 2014/2015 Tanzania National Panel Survey and the 2015/2016 Tanzanian Demographic and Health and Malaria Indicator Survey. Specifically, the 2014/15 National Panel Survey was used to estimate the impacts of adoption of modern cooking fuels and household electrification on non-health outcomes, while the 2015/2016 Tanzanian Demographic and Health and Malaria Indicator Survey was used to ascertain the impacts on health-related outcomes.

The 2014/2015 Tanzania National Panel Survey is the fourth wave in a series of nationally representative household panel surveys that collect data on various social and economic characteristics (National Bureau of Statistics, 2016). The survey collected data at the individual, household and community levels. The survey used four survey instruments:(1) the household questionnaire, (2) the agriculture questionnaire, (3) the livestock/fishery questionnaire and (4) a community questionnaire. The wave used a revised sample, where only a sub-sample of the National panel survey (NPS) was selected to continue as an extended panel and an entirely new "refreshed" sample was added to represent the national and sub-national domains, (NBS, 2016). The wave used a multi-stage clustered sampling design, with four analytical strata of Dar-es-Salaam; other urban areas in mainland; rural mainland and Zanzibar. Clusters were chosen at random from each stratum, with the probability of selection proportional to their population size. From the selected primary sampling units, 8 households were chosen at random from each cluster. The study used 3344 and 1094 households for the country (full sample) and the urban areas (urban sample) analyses, respectively.

The 2015/16 Tanzanian Demographic and Health and Malaria Indicator Survey is the sixth in the series of demographic and health surveys conducted in Tanzania. Its main objective was to obtain up to date information on demographic and health indicators including fertility, family planning and acute respiratory health for children under 5. The survey used four survey instruments: (1) household questionnaire, (2) women's questionnaire, (3) men's questionnaire and (4) biomarker questionnaire. The survey adopted a two-stage sampling design designed to provide estimates that are country representative that is urban and rural areas in Tanzania mainland, and for Zanzibar, (NBS, 2016). Nevertheless, for specific indicators like contraceptive use the sampling design allowed the estimation for indicator for all the 30 regions in the country. The first stage of the sampling sampled clusters and the second stage selected 22 households from each sampled cluster and resulting in a sample of 13,376. The 2012 Tanzanian population census was used as the master sampling frame. The study used 5557 and 1522 households for the country (full sample) and urban areas (urban sample) analyses, respectively.

3.4 Results and Discussion

This section presents the results in two subsections. The first subsection presents the results on the impact of use of modern cooking fuels on household welfare indicators and the subsequent subsection presents the results of the impact of use of electricity for lighting on household welfare indicators.

3.4.1 The impact of modern cooking fuels on household welfare

Data description

The use of modern cooking fuels in Tanzania is still very low. As seen in Table B.2 in the appendix, only 3.34 percent of households in the used sample utilised modern cooking fuels (LPG and Electricity), that is 112 households out of the 3344 households. The use of modern cooking fuels is more prominent in urban areas, with about 8.3 % of the households using them. Conversely, the use of modern cooking fuels in rural areas is negligible, with only three households (0.17%) out of the 1776 rural households sampled for the 2014/15 national panel survey using modern cooking fuels. Owing to the distribution of use of modern cooking fuels, our analysis was restricted to the full sample (Country level) and the urban sample.

As stated earlier, we used the 2014/15 Tanzania national panel survey to investigate the impact of household's use of modern cooking fuels on household's energy expenditures. The study used 3344 and 1094 households for the country (full sample) and the urban areas (urban sample) analyses, respectively. Before matching, based on the simple t-test, the treated and control households adopted in the full sample analysis were statistically similar in only three out of the eight characteristics used as balancing covariates in the full sample analytical model while in the urban sample the households were similar in only two of the nine characteristics used as balancing covariates in the urban sample analytical model (see table B.3 and B.4 in the appendix).

Similarly, the study used the 2015/16 Tanzanian Demographic and health survey and malaria indicator survey to study the impact of household modern cooking fuel use on health for children that are five years of age and under and fertility of women. The study used 5557 and 1522 households for the country (full sample) and urban areas (urban sample) analyses, respectively. Before matching, based on the simple t-test, the treated and control households used in the full sample analysis were statistically similar in only three out of the eleven characteristics used as balancing covariates in the full sample analytical model while in the urban sample the households were similar in only two of the seven characteristics used as balancing covariates in the urban sample analytical model (see table B.5 and B.6 in the appendix). The statistical difference in the covariate means before matching in both data sets is largely expected (Caliendo and Kopeining, 2008), and thus comparing these group's outcomes of interest will result in biased results as these characteristics may simultaneously influence a household's treatment status and the outcomes of interest. To reduce such biases the study used propensity score matching to establish the best counterfactuals for our analyses.

Estimating the propensity scores

Tables B.4 and B.5 in appendix B show the results of the logit models used to estimate the propensity scores for household use of modern cooking fuels on expenditures and health-related outcomes, respectively. The covariates included in the models were based on the theory and literature of household cooking fuel choice. Moreover, as suggested in Caliendo and Kopeining (2008), only those variables that simultaneously affect the treatment status of the households and the outcome variables of interest were included in the models. Household income, education level of the household head, age of the household head, and the household's ownership of various assets like a house, mobile phones and televisions were among the variables that were used to estimate the propensity scores for the full sample and the urban samples of the respective data sets.

The common support and matching quality

The study checked if the overlap condition was satisfied. Furthermore, the matching quality was assessed for the sub samples, within the individual data sets that were used for the analysis of the impact of household use of modern cooking fuels on energy expenditures and health related outcomes, respectively. Firstly, the common support and the matching quality was assessed for the fourth wave of the Tanzania national panel data set which was used for the analysis of the impact of household use of modern cooking fuels on household energy expenditures. As the analysis was done for both the full sample and the urban sample within the data set, we accordingly start with the full sample assessment. The easiest way to assess the common support is by looking at the distribution of propensity scores of the treatment and the control group. The distribution of the propensity scores and the common support region for the full sample analysis is presented in figure B.1(see in the appendix). Out of the 3344 households used for the full sample analysis, 3340 were on the common support. The four households that were not on the common support were from the treatment group, which constituted of 112 households. The kernel (Epanechnikov) matching with a bandwidth of 0.06 was the one that gave the best matching quality in terms of the mean of the standardized biases and the standardized biases of the individual covariates used in the estimation of the propensity scores, whereby almost all the covariates after matching had standardized biases of 5% and below (See Table B.3 in the appendix) and the mean standardized bias stood at 3.1%. Similarly, for the urban sample, the common support and the distribution of the propensity scores are presented in figure B.2 (see in the appendix). Out of the 1094 households used for the urban sample analysis, 1081 were on the common support. The thirteen households that were not on the common support were from the treatment group, which constituted of 91 households. The kernel (Epanechnikov) matching with a bandwidth of 0.06 was the one that gave the best matching quality in terms of the mean of the standardized biases and the standardized biases of the individual covariates used in the estimation of the propensity scores, whereby almost all the covariates after matching had standardized biases below 5% (See Table B.4 in the appendix) and the mean standardized stood at 2.7%. Furthermore, the Pseudo-R2 after matching for both the sub samples (see Table B.9 in the appendix) was considerably lower, meaning that there are no systematic differences in the distribution of the covariates between the treatment and the control groups of the respective samples. This is further ascertained by the joint significance test of the covariates after matching (see Table B.9 in the appendix).

Secondly, the common support and the matching quality was assessed for the 2015/16 Tanzania demographic household survey, used for the analysis of the impact of household use of modern cooking fuels on health and fertility. Similarly, the analysis was done for the full sample and the urban sample within the data set. Starting with the full sample, the study assessed the common support by looking at the distribution of propensity scores of the treatment and the control group. The distribution of the propensity scores and the common support region for the full sample analysis are presented in figure B.3 (see in the appendix). Out of the 5557 households used for the full sample analysis, 5,555 were on the common support. The two households that were not on the common support were from the treatment group, which constituted of 87 households. The kernel (Epanechnikov) matching with a bandwidth of 0.02 was the one that gave the best matching quality in terms of the mean of the standardized biases and the standardized biases of the individual covariates used in the estimation of the propensity scores, whereby almost all the covariates after matching had standardized biases of 5% and below (See Table B.5 in the appendix) and the mean standardized bias stood at 2%. Similarly, for the urban sample, the common support and the distribution of the propensity scores are presented in figure B.4 (see in the appendix). Out of the

1522 households used for the urban sample analysis, 1,519 were on the common support. The three households that were not on the common support were from the treatment group, which constituted of 75 households. The kernel (Epanechnikov) matching with a bandwidth of 0.02, is the one that gave the best matching quality in terms of the mean of the standardized biases and the standardized biases of the individual covariates used in the estimation of the propensity scores, whereby almost all the covariates after matching had standardized biases below 5% (See Table B.6 in the appendix) and the mean standardized stood at 3%. Furthermore, the Pseudo-R2 after matching for both the sub samples (see Table B.9 in the appendix) was considerably lower, meaning that there are no systematic differences in the distribution of the covariates between the treatment and the control groups of the respective samples. This is further ascertained by the joint significance test of the covariates after matching (see Table B.9 in the appendix).

The impact of household's use of modern cooking fuels on energy expenditures

The study found that a household's use of modern cooking fuel had a positive effect on its energy spending per month for both the country as whole (full sample) and in the urban sample as shown in table 4. We looked at the effects on the household's (i) total energy expenditure, (ii) modern energy expenditures, (iii) modern energy budget share, (iv) charcoal expenditures, (V) traditional energy expenditure, and (vi) traditional energy budget share. The total energy expenditures constitute the household's expenditures on electricity, LPG, kerosene, and charcoal per month. Modern energy expenditures consist of the household's expenditures on electricity and LPG per month. Charcoal expenditures comprise a household's expenditures on charcoal per month while the traditional energy expenditures comprise the household's expenditures on charcoal and kerosene per month. The traditional and modern energy budget shares represent the share of the household's total energy expenditure allotted to traditional and modern energy fuels per month, respectively.

Table 4: The impact of Household's use of modern cooking fuels on energy expenditures

Outcome variable	Full Sample		Urban sample	
	ATT	Critical Γ hidden bias	ATT	Critical Γ hidden bias
Total energy expenditure	11208.7 (6934.113)	n.s	11439.47 (6262.8)	n.s
Modern energy budget expenditure	26473.74*** (6452.638)	(+)>2	29028.22 *** (7510.3)	(+) >2
Charcoal expenditure	-14021.79*** (2143.328)	(-)>2	-16317.63*** (2893.87)	(-)>2
Modern energy budget share	0.319066*** (0.0382703)	(+)>2	0.3071832*** (0.0415919)	(+)>2
Traditional energy expenditure	-15265.04*** (2657.838)	(-)>2	-17588.75*** (2780.49)	(-)>2
Traditional energy share	-0.338059*** (0.0378087)	(-)>2	-0.3408712*** (0.0434521)	(-)>2

*, ** and *** represent 10, 5 and 1 percent level of significance respectively

A household's use of modern cooking fuels had a significant effect on a household's charcoal expenditures, modern fuel expenditures, traditional fuel expenditures and the proportions of energy expenditures on traditional and modern fuels. Starting with the country level (full sample) analysis, using data from 3340 households after matching, of which 108 were treated and 3232 were controls, households that use modern cooking fuels (treated) were found to spend more on modern fuels and consequently allocate a higher proportion of their energy expenditures to modern fuels (LPG and electricity) compared to households that did not use modern cooking fuels as their major cooking fuels (controls). On average, the treated households spend 26,474 (USD 11.68[16]) Tanzanian shillings more per month on modern fuels than the control households. Furthermore, on average, treated households spend 30 percentage points more of their energy budget on modern fuels per month than the control households. These differences in the amounts used on modern fuels by treated and control fuels households are significant at the 1% level of significance. On the other hand, treated households spend 14022 (USD 6.2) Tanzanian shillings less on charcoal per month compared to control households. This difference is significant at the 1% level of significance. In an environment where multiple fuel use is dominant, such savings are substantial and help cover part of the modern cooking fuel budget. On average, the treated and control households still spend 8523 and 22545 Tanzanian shillings on charcoal, respectively. Based on the 2016 charcoal price depicted in Ishengoma and Abdallah (2016), the cost of a 1 Kg bag of charcoal is around 500 to 1500[17] Tanzanian shillings. Thus, the 14022 Tanzanian shillings savings are equivalent to around 14 kg to 28 kg reduction in charcoal consumption per month. Our findings are similar to Yonas et al. (2015) in Tanzania, where they found that LPG adoption reduced charcoal consumption and expenditures by 6 Kg and 3800 Tanzanian shillings per week. Furthermore, treated households spend less on traditional energy fuels (charcoal and kerosene) overall; they spend 15,265 (USD 6.7) Tanzanian shillings less compared to control households. Consequently, treated households spend a lesser share of their energy budget on traditional energy fuels; they spend thirty-three percentage points less of their energy budget on traditional energy fuels. The differences in expenditure and expenditure shares are significant at the 1% level of significance. Nevertheless, the study did not find any significant difference in total energy expenditures between treated and control households.

The results for the urban sample are similar to what we observed for the full sample. The urban areas analysis used 1081 households after matching, of which 1003 were controls and 78 were

[17] The cost of charcoal remained relatively the same through to the year 2020, the deflated prices that take into account inflation brough about relatively the same prices experienced in 2016, that is 500 to 1000 Tshs per kg.

treated households. Households that use modern cooking fuels as their main cooking fuels were found to spend more on modern energy fuels in terms of actual expenditures and energy budget shares of such expenditures compared to control households. Not only do treated households spend 29028 (USD 12.8) Tanzanian shillings more on modern energy fuels per month, but they also spend 31 percentage points more of their energy budget on modern energy fuels compared to control households. These differences in expenditures and budget shares were significant at the 1% level of significance. Treated households in urban areas also spend less on charcoal, and on traditional fuels. Households that use modern cooking fuels as their major fuels for cooking spend 16318 (USD 7.2) Tanzania shillings less on charcoal per month compared to control households. Based on the 2016 charcoal price depicted in Ishengoma and Abdallah (2016), the cost of a 1 Kg bag of charcoal is around 500 to 1500 Tanzanian shillings. Thus, the 16318 Tanzanian shillings savings are equivalent to around 16 kg to 33 kg reduction in charcoal consumption per month in urban areas. The study does not find any significant differences in total energy expenditures in urban areas between the treated and control households.

The impact of household's use of modern cooking fuels on health

We further looked at the impact of household use of modern cooking fuels on households' health and fertility using the 2015/16 Tanzanian Demographic and Health survey and Malaria indicator survey. We specifically looked at the impact of households' use of modern cooking fuels on the respiratory health of children aged five and below. We investigated these impacts for the full sample and the urban sample.

The impact of household's use of modern cooking fuels on the children's respiratory health was explored by looking at the incidence of acute respiratory disease symptoms such as cough, fever and shortness of breath accompanied by chest problems. The full sample analysis used data from

5555 households with at least one child aged five or below where 85 and 5470 households out of the 5555 households were treated and control households, respectively. The results of the impacts of household's use of modern cooking fuels on health are presented in Table 5.

Table 5 : The impact of household's use of modern cooking fuels on health

Outcome variable	Full sample		Urban sample	
	ATT	Critical Γ hidden bias	ATT	Critical Γ hidden bias
Respiratory disease symptoms (either of the symptoms)	0.0889674 (0.0665996)	n.s	0.0482069 (0.0658801)	n.s
Respiratory disease symptoms (all symptoms)	-0.0215508** (0.0101316)	>2	-0.0240931** (0.0115776)	>2
Has cough	0.0615478 (0.0667622)	n.s	0.0511097 (0.0589013)	n.s
Has fever	0.0323645 (0.0487019)	n.s	-0.0196987 (0.0562317)	n.s
Has shortness of breath and chest problem	-0.007846 (0.0234023)	n.s	-0.0073439 (0.026283)	n.s
Cough and shortness of breath	-0.0137449 (0.0173658)	n.s	-0.014523 (0.0235643)	n.s
Fever and cough	-0.0255522** (0.0098592)	>2	-0.0276492 ** (0.0119801)	>2
Fever and shortness of breath	0.0058143 (0.0422442)	n.s	0.000789 (0.0308697)	n.s

*, ** and *** represent 10, 5 and 1 percent level of significance respectively

We did not find any significant differences between the treated households and control households in the proportion of households with a child aged five years or below with at least one of the acute respiratory disease symptoms, nor did we find any significant difference in the incidence of each individual symptom between the treated households and the control households. Nevertheless, we found a significant difference between the treated households and control households in the proportion of households with children with all the self-reported respiratory symptoms, whereby a household's use of modern cooking fuels reduces the proportion of households with children with all the self-reported acute respiratory symptoms by 2.1 percentage points. Furthermore, the study found a significant difference between treatment and control groups in the proportion of households with children with cough and fever, whereby a household's use of modern cooking fuels reduced the proportion of households with children with fever and cough by 2.5 percentage points. The differences were significant at the 5 percent level. The fact that we could not isolate between households that use modern cooking fuels onlythose that use multiple cooking fuels, and those using traditional cooking fuels only, nor measure the incidence with which the traditional fuels are used in multiple fuel use scenarios, may explain why there are no significant differences in the individual symptoms. This is probably an indication of the difference in the incidences of already manifested acute respiratory infections such as pneumonia, whose diagnosis may be attributed partly to a combination of symptoms such as a deep cough, fever, chest tightness and pleuritic chest pains (Short et al., 2017). Thus, our results are similar to other studies in two ways. First, we mirror previous studies (Bruwen and Levin, 2012; Smith et al., 2011; Lewis et al., 2017; Bensch and Peters, 2015) and have ascertained the positive impact modern and improved cooking stoves have on health-related outcomes. Second, the fact that we could not find any significant effect for the individual symptoms reflects the importance of the intensity with which these modern cooking fuels are used in a multiple fuel use scenario.

The results in the urban area are consistent with what we found for the whole sample. The urban analysis used data from 1518 households with at least one child aged five years or younger. Out of the 1518 households, 71 and 1447 were treated and control households, respectively. Similarly, the study did not find any significant differences between the treated households and control households in the proportion of households with a child aged five years or below with at least one of the acute respiratory disease symptoms. Nor did we find any significant difference between the treated households and the control households in the incidence of each individual symptom.

Nevertheless, we found a significant difference between the treated households and control households in the proportion of households with children with all the self-reported respiratory symptoms. For instance, a household's use of modern cooking fuels reduces the proportion of households with children with all the self-reported acute respiratory symptoms by 2.4 percentage points. Furthermore, we found a significant difference between treated and control groups in the proportion of households with children with cough and fever, whereby a household's use of modern cooking fuels reduced the proportion of households with children with fever and cough by 2.7 percentage points. The significant differences were significant at 5 percent level

Sensitivity Analysis

As the propensity score matching only controls for the observables, if there exist unobservable variables that affect assignment of households into treatment and the outcome variables simultaneously, a hidden bias may occur (Caliendo and Kopeining, 2008). Using the Rosenbaum (2002) bounding approach, the study checked the magnitude with which the selection process may be influenced by unobserved/unmeasured variables to alter the implications of the impact analysis. The study conducts a sensitivity analysis of all significant outcomes. The sensitivity analysis for the results of the impact of household use of modern cooking fuels on energy expenditures and child health shows that all our results are robust to any possible hidden selection bias The results indicate that the confidence intervals for the various significant effects would not include zero if unobserved variables caused the odds ratio of treatment assignment between the treatment and control households to differ by as much as 2.

3.4.2 The impact of electrification on household welfare

Data description

The use of electricity in Tanzania as the main source for lighting has improved dramatically over recent years. Although the use of electricity for lighting is still very low in the rural areas, more than 50 percent of the urban population uses electricity as the main fuel for lighting. As seen in Table B.10 in the appendix, for the country, 38.40 percent of households use electricity as their main fuel for lighting that is 1284 households out of the 3344 households. The use electricity for lighting is more prominent in urban areas, with about 64.35 percent of the households using electricity as their main fuel for lighting. The use of electricity in rural areas is still very low, with only 325 households (18.36%) out of the 1770 rural households sampled for the 2014/15 Tanzania national panel survey using electricity as main fuel for lighting. Based on the prominence of use of electricity, our analysis was restricted to the full sample (Country level), the urban sample and the rural sample.

The study used the 2014/15 wave of the Tanzanian national panel survey to investigate the impact of household's use of electricity on household's energy expenditures. The study used 3344, 1094 and 1770 households for the country (full sample), urban areas (urban sample) and the rural areas (rural sample) analyses, respectively. Before matching, on the basis of the simple t-test, the treated and control households used for the full sample analysis were not statistically similar in any of the ten characteristics used as balancing covariates in the full sample analytical model (see tableB.11 in the appendix) while in the urban and rural sample the households were similar in only one of the characteristics used as balancing covariates in the urban and rural sample analytical models respectively (see table B.12 and B.13 in the appendix).

Similarly, the study used 2015/16 Tanzanian Demographic and health survey and malaria indicator survey to study the impact of household use of electricity on children's health and women's fertility. The study used 5557, 4170 and 1386 households for the country (full sample), rural areas (rural sample) and urban areas (urban sample) analyses, respectively. Before matching, based on the simple t-test, the treated and control households used in the full sample analysis were statistically similar in only two out of the seven characteristics used as balancing covariates in the full sample analytical model while households were similar in one and two characteristics for the urban and rural sample respectively used as balancing covariates in the urban sample analytical model (see table B.14, B.15 and B.16 in the appendix). The statistical difference in the covariate means before matching in both data sets is largely expected (Caliendo and Kopeining, 2008), and thus comparing these group's outcomes of interest will result in biased results as these characteristics may simultaneously influence a household's treatment status and the outcomes of interest. To reduce such biases the study used propensity score matching to ascertain the best counterfactuals for our analyses.

The common support and matching quality

The study checked if the overlap condition was satisfied. Moreover, the matching quality was assessed for the sub samples, within the individual data sets that were used for the analysis of the impact of household use of electricity on non-health and health related outcomes, respectively. The study thus assessed the common support and the matching quality for the fourth wave of the Tanzania national panel data set, used for the analysis of the impact of household use of electricity on energy expenditures, schooling and time use. As the analysis was done for the full sample, we accordingly start with the full sample assessment. The easiest way to assess the common support is by looking at the distribution of propensity scores of the treatment and the control group. The distribution of the propensity scores and the common support region for the full sample analysis are presented in figure B.5(see in the appendix). Out of the 3344 households used for the full sample analysis, 3258 were on the common support. The eighty-six households that were not on the common support were from the treatment group, which constituted of 1284 households. The (Epanechnikov) matching with a bandwidth of 0.06 was the one that gave the best matching quality in terms of the mean of the standardized biases and the standardized biases of the individual covariates used in the estimation of the propensity scores, whereby almost all the covariates after matching had standardized biases of 5 percent and below (See Table B.11 in the appendix) and the mean standardized bias stood at 1.6 percent. Similarly, for the rural and urban sample, the common support and the distribution of the propensity scores are presented in figure B.6 and B.7 (see in the appendix). Out of the 1094 and 1770 households used for the urban and rural sample analysis respectively, 990 and 1767 were on the common support for the urban and rural sample, respectively. The 104 and 3 households that were not on the common support for the urban and rural sample respectively, were from the treatment groups, which constituted of 704 and 325 households for the urban and rural sample, respectively. The kernel (Epanechnikov) matching with a bandwidth of 0.06 was the one that gave the best matching quality in terms of the mean of the standardized biases and the standardized biases of the individual covariates used in the estimation of the propensity scores for both the urban and the rural sample, whereby almost all the covariates after matching had standardized biases below 5% (See Table B.12 and B.13 in the appendix). The mean standardized biases stood at 2.8 and 2.3 percent for the urban and rural samples. Furthermore, the Pseudo-R2 after matching for all the sub samples (see Table B.19in the appendix) were considerably lower, meaning that there were no systematic differences in the distribution of the covariates between the treatment and the control groups of the respective samples. This was further ascertained by the joint significance test of the covariates after matching (see Table B.19 in the appendix).

Secondly, the common support and the matching quality was assessed for the 2015/16 Tanzania demographic household survey, used for the analysis of the impact of household use of electricity on children's health and women's fertility. Similarly, the analysis was done for the full sample, rural sample, and the urban sample within the data set. The study, starting with the full sample assessed the common support by looking at the distribution of propensity scores of the treatment and the control group. The distribution of the propensity scores and the common support region for the full sample analysis are presented in figure B.8 (see in the appendix). All the 5556 households used for the full sample analysis were on the common support. Whereby 2236 were treated households and 3320 were control households. The kernel (Epanechnikov) matching with a bandwidth of 0.06 was the one that gave the best matching quality in terms of the mean of the standardized biases and the standardized biases of the individual covariates used in the estimation of the propensity scores, whereby almost all the covariates after matching had standardized biases of 5% and below (See Table B.14 in the appendix) and the mean standardized bias stood at 2.1 percent. Similarly, for the rural and urban samples, the common support and the distribution of the propensity scores are presented in figure B.9 and B.10 (see in the appendix). Out of the 1386 and 4170 households used for the urban and rural sample analysis respectively, 1351 and 4168 were on the common support for the urban and rural sample, respectively. The 35 and 2 households that were not on the common support for the urban and rural sample respectively, were from the treatment groups, which constituted of 912 and 1324 households for the urban and rural sample, respectively. The kernel (Epanechnikov) matching with a bandwidth of 0.06 and 0.02 were the ones that gave the best matching quality in terms of the mean of the standardized biases and the standardized biases of the individual covariates used in the estimation of the propensity scores for the urban and rural samples, respectively. Whereby almost all the covariates after matching had standardized biases below 5% (See Table B.15 and B.16 in the appendix) and the mean standardized stood at 2.8 and 2.3 for the rural and urban sample, respectively. Furthermore, the Pseudo-R2 after matching for all the sub samples (see Table B.19 in the appendix) was considerably lower, meaning that there were no systematic differences in the distribution of the covariates between the treatment and the control groups of the respective samples. This was further ascertained by the joint significance test of the covariates after matching (see Table B.19 in the appendix).

Estimating the propensity scores

The study estimated the propensity scores for the individual samples in the respective data sets used. The study used the logit model to estimate the propensity scores. tables B.17 and B.18 in appendix B show the logit models used to estimate the propensity scores for households for the impact of household use of electricity on expenditures, schooling, time use and health-related outcomes. Household income, education level of the household head, age of the household head, household's ownership of various assets like a house, mobile phones and televisions were among the variables that were included in the logit models used to estimate the propensity scores for the full sample, the rural sample, and the urban samples of the respective data sets to analyses the impact of households' use of electricity on household welfare indicators in Tanzania.

The impact of household electrification on energy expenditures

Table 6 presents the results of the impact of household electrification on energy expenditures. The use of electricity was found to have a significant effect on household energy expenditures. Starting with the full sample analysis, we found a significant impact of household use of electricity on the household's total energy expenditures. Treated households spend 9894 (USD 4.36) Tanzanian shillings more on household energy expenditures per month compared to control households. This difference in total energy expenditures was significant at the 1 percent level. The study's findings are similar to what other impact studies have ascertained: that household use of electricity, particularly on-grid connection, leads to an increase in total energy expenditures (Bonan et al., 2016; Bensch et al., 2011; van de Walle et al., 2015). Although some of these studies highlighted that the use of electricity from other sources, such as solar PV, may lead to lower energy expenditures (Arraiza and Calero, 2014; Samad et al., 2013), the global consensus is that acquisition of new electrical appliances and intensive use of lighting overcompensates the efficiency gains from a household's switch from traditional sources of lighting to electricity (Bensch et al., 2011). As a result, treated households were found to spend more on modern fuels in terms of expenditures and budget shares. For example, treated households spend 12558 (USD 5.54) Tanzanian shillings and 32.5 percentage point more per month on modern fuel expenditures and budget shares, respectively. This difference was significant at the 1 percent level.

Table 6: The impact of Household electrification on energy expenditures

Variable	Full sample		Rural sample		Urban sample	
	ATT	Critical Γ hidden bias	ATT	Critical Γ hidden bias	ATT	Critical Γ hidden bias
Total energy expenditure	9893.955*** (1165.712)	>2	1422.522 (932.8858)	n.s	10138.22*** (2148.402)	(+)1.9-2
Kerosene expenditure	-2584.472*** (419.283)	>2	-1332.175*** (244.8063)	>2	-2593.641*** (629.1626)	>2
Traditional energy expenditure	-2663.905 ** (1067.379)	(-) 1.5-1.6	-1472.504** (688.1512)	>2	-4155.893** (1655.772)	(-) 1.4-1.5
Modern energy budget	12557.86*** (623.516)	>2	2895.026*** (527.3982)	(+)1-1.1	14228.05*** (812.6543)	>2
Modern energy budget share	0.3254351*** (0.0099871)	>2	0.1418945*** (0.0212963)	(+)1-1.1	0.3587903*** (0.012536)	>2
Traditional energy budget share	-0.342115*** (0.016201)	>2	-0.265999*** (0.0315396)	>2	-0.332957*** (0.0190764)	>2

*, ** and *** represent 10, 5 and 1 percent level of significance respectively

On the other hand, a household's use of electricity was found to decrease household kerosene expenditures. Electricity replaces kerosene, which is used as the main lighting fuel for 27 percent of Tanzanian households. On average, treated households were found to spend 2584 (USD 1.14) Tanzanian shillings less on kerosene per month compared to control households. The difference in kerosene expenditures between the treated and control groups is significant at the 1 percent level. Our findings are similar to what Karumba and Muchapondwa (2017) and Grimm et al. (2015) found for the case of Kenya and Rwanda, respectively. The continued use of kerosene by treated households may be for lighting in times of power outages and for cooking, as our sample shows that 2.8 percent of the households use kerosene for cooking. Treated households were found to spend less on traditional energy fuels both in terms of expenditures and budget shares. Treated households spend 2664 (USD 1.18) Tanzanian shillings and 34 percentage points less per month on traditional fuel expenditures and budget shares, respectively. This difference was significant at the 1 percent level.

Furthermore, we investigated whether the impacts on the various energy expenditures were any different in the rural and urban sub-samples. We found that all but one of the results remained the same in terms of signs and significance for both rural and urban samples. There were significant differences in modern energy expenditures, modern energy budget shares, traditional energy expenditures, traditional energy budget shares and kerosene expenditures between the treated and control households in both the urban and rural samples. Nevertheless, whereas the study found significant increases in total energy expenditures for the urban sample (as in the full sample), corresponding increases in the rural sample were not statistically significant. It is highly probable that this is because the majority (73 percent) of rural households are electrified through solar.

The impact of household electrification on schooling

We further found evidence of the impact of a household's use of electricity on schooling as presented in Table 7. We looked at various schooling indicators: study hours, education years and passing of national "standard seven exams". The analysis was done for households that had children whose age ranges fell in the Tanzanian school-going age (5 and 20 years of age) who were attending or had attended school. This comprised 1814 households in the full sample. However, we looked at 1263 and 1262 households that had at least one male child and one female child, respectively. This allowed us to study the impact of household electrification on schooling outcomes for both boys and girls.

Table 7: Impact of household electrification on education outcomes

Variable	Full sample		Rural sample		Urban sample	
	ATT	Critical Γ hidden bias	ATT	Critical Γ hidden bias	ATT	Critical Γ hidden bias
Study hours	1.223128*** (0.3837315)	(+) 1-1.1	0.6913118* (.3809661)	(+)1-1.1	2.4149 *** (0.5623059)	(+)1.8-1.9
Study hours (boys)	1.129013** (0.4787241)	(+) 1-1.1	0.5569739 (0.4753587)	n.s	1.955508** (0.7395021)	(+) 1.3-1.4
Study hours (girls)	1.456541*** (0.3401197)	(+) 1-1.1	0.7090958 (.592498)	n.s	2.748634** (0.7162748)	(+)1.3-1.4
Education years	0.3773642** (0.1743501)	(+) 1-1.1	0.4681123** (0.2323217)	(+)1.1-1.2	0.1882237 (0.2970063)	n.s
Education years (boys)	0.1084777 (0.2009645)	n.s	0.1307921 (0.2678974)	n.s	-0.2805175 (0.4037532)	n.s
Education years (girls)	0.790234** (0.2867365)	(+) 1.3-1.4	0.445853 (0.2928733)	n.s	0.8642235** (0.4250708)	(+) 1.2-1.3
Standard seven results	0.0461815 (0.0345554)	n.s	0.0448727 (0.0398655)	n.s	0.0041256 (0.0367256)	n.s
Standard seven result (boys)	0.0575483** (0.0200828)	(+) 1-1.1	0.0562661* (0.0330455)	1-1.1	0.0032038 (0.0323413)	n.s
Standard seven result (girls)	0.0136894 (0.0313936)	n.s	0.0170192 (0.0430219)	n.s	0.0290464 (0.0254471)	n.s

*, ** and *** represent 10, 5 and 1 percent level of significance respectively

We found significant differences in study hours between the treated and control groups. Children in treated households study an hour more per week than children in control households. Furthermore, we find significant differences in study hours among male and female children in the full samples. Both male and female children in treatment households study an hour more per week compared to their counterparts in the control households. Our findings are similar to what other studies found in Bangladesh and Peru (Samad et al., 2013; Arraiz and Calero, 2015).

We further investigated whether a connection to electricity by a given household influenced the years of schooling of children aged between 5 and 20, attending school. We found a significant difference in the years of schooling between children in treated and control households. The difference are significant at the 5 percent level. Furthermore, we found significant differences in schooling years between female children in the treated and control group but did not find any significant differences in years of schooling for male children in control and treated households. The significant difference in years of schooling is suggestive evidence that more study hours for children in electrified household's translates to better schooling outcomes and thus children moving further in education attainment. Similarly, Arraiz and Calero (2015) and Khandker et al. (2013) found significant effects on schooling in Peru and Vietnam, respectively. Nevertheless, we did not find any significant difference in the proportion of households with at least one child that sat for and passed the standard seven examinations. We found significant differences for boys but not girls

We found that the impact of electrification manifests itself differently in different contexts as portrayed by our results for the rural and urban sub-samples. We found significant differences in study hours between children in treatment and control groups for both the rural and urban samples. Nevertheless, we did not find any significant differences in study hours among either male or female children in the treatment and control households in the rural sample. On the other hand, these differences were significant for the urban sample. In urban areas, household connection to electricity is associated with longer study hours of approximately 2 and 3 hours a week for male and female children respectively, compared to children in control households. These differences were found to be significant at the 5 percent level. The fact that girls study longer than boys when the household has an electricity connection may be indicative of the girl child's day being made longer after having spent other hours in doing domestic chores, thus having to study for longer hours in the evening to compensate those hours (United Republic of Tanzania, 2016).

Furthermore, whereas there are no any significant differences in years of schooling between children in the treated and control households in the urban sample, these differences are significant for the rural sample. We found significant differences in years of schooling between female children in the treated and control households in the urban sample but not for the rural sample. This may be because electricity makes a day for the girl child longer. Access to electricity may allow girls to be able to study longer in the evenings after their chores and this manifests in more years of schooling (United Republic of Tanzania, 2016). This may not manifest in the rural areas due to different priorities for the girl child in the villages. On the other hand, we did not find any significant differences in years of schooling between male children in treated and control households in the rural areas. We do not find any significant effect of a household's electricity connection on overall passing of standard seven examinations for the rural and urban samples. Nevertheless, the study finds significant differences for female children passing in standard seven exams in the rural sample.

The impact of household electrification on time use

We also looked for evidence of time use changes by households due to electricity connection. Table 8 presents the results of the impact of household electrification on time use. Starting with the full sample, we did not find any significant differences between the treatment and control households in the proportion of households whose members spent most of their time in non-agricultural activities. Furthermore, we did not find any significant differences between the treatment and control households in the proportion of households whose male household members spent most of their time in non-agricultural activities nor in the proportion of households whose female household members spent most of their time in non-agricultural activities. Similarly, we did not find any significant time-use differences in the urban sample.

Table 8: Impact of household electrification on time use

Variable	Full sample		Rural sample		Urban sample	
	ATT	Critical Γ hidden bias	ATT	Critical Γ hidden bias	ATT	Critical Γ hidden bias
Households with members that spent most time in non-agricultural activities	0.0220952 (0.0149526)	n.s	0. 0659021* (0. 0359631)	1.2-1.3	0.0034423 (0.0232322)	n.s
Households with members (**males**) that spent most time in non-agricultural activities	0.0079506 (0.0244616)	n.s	0.0460192 (0.0359359)	n.s	-0.0052356 (0.0471116)	n.s
Households with members (**females**) that spent most time in non-agricultural activities	-0.0154152 (0.0322714)	n.s	0.0334557 (0.0330912)	n.s	-0.0224913 (0.0433133)	n.s

*, ** and *** represent 10, 5 and 1 percent level of significance respectively

Nevertheless, we found significant differences in the proportion of households whose members spend most of their time in non-agricultural activities in rural areas. There was a seven percentage point difference between the treatment and control households in members engaged in non-agricultural activities. Our results are consistent with the theory that electricity contributes to shifts from agricultural to non-agricultural activities, especially in rural areas. Our findings are similar to what Aevarsdottir et al. (2017) found in rural Tanzania. Their study substantiated that household use of electricity in rural areas increased labour supply by eight percentage points. Our results support findings in other studies that find a significant impact on time use and labour supply (Arraiz and Calero, 2015; Samad et al., 2013; Khandker et al., 2012; Benschet al., 2011; Bernard and Torero, 2015; Barron and Torero, 2015; Aguirre, 2014). Nevertheless, these impacts differ in different contexts; whereas some studies find an overall significant impact on time spent in non-agricultural activities (Aevarsdottir et al., 2017), others find these effects are significant for either males or females (Arraiz and Calero, 2015; van de Walle et al., 2015).

The impact of household electrification on health and fertility

We investigated whether a household's use of electricity had an impact on the incidence of various individual symptoms (cough, fever and shortness of breath accompanied by chest problems) and various combinations of such symptoms on children aged five and below. Table 9 presents the results of the impact of household electrification on health and fertility. Starting with the full sample, we did not find any significant effect of households' use of electricity on respiratory symptoms for children aged five and below. There were also no significant differences between the treated and the control households in the incidence of neither the individual symptoms nor various combinations of the symptoms.

Table 9: The impact of household electrification on health

Variable	Full sample		Rural sample		Urban sample	
	ATT	Critical Γ hidden bias	ATT	Critical Γ hidden bias	ATT	Critical Γ hidden bias
Respiratory disease symptoms (all symptoms)	-0.003393452 (0.0042342)	n.s	-0.0021 (0.0038931)	n.s	-0.0140607 (0.011516)	n.s
Cough and shortness of breath	0.003008062 (0.005459)	n.s	-0.003002 (0.0052821)	n.s	0.0041833 (0.0171726)	n.s
Fever and cough	-0.00147335 (0.0046904)	n.s	-0.000796196 (0.004394)	n.s	-0.0105669 (0.0171649)	n.s
Fever and shortness of breath	-0.000142111 (0.0141709)	n.s	0.009648216 (0.0129775)	n.s	-0.0658699 (0.0401211)	n.s
Has cough	0.000715273 (0.0161367)	n.s	-0.002358233 (0.0161817)	n.s	-0.0307068 (0.050841)	n.s
Has fever	-0.001882035 (0.0182442)	n.s	-0.002135854 (0.0184388)	n.s	-0.0327933 (0.0497409)	n.s
Has shortness of breath and chest problem	0.005763224 (0.0057896)	n.s	-0.00224566 (0.0055556)	n.s	0.0107004 (0.0149089)	n.s
Respiratory disease symptoms (any of the symptoms)	-0.00227678 (0.0182748)	n.s	-0.015833108 (0.0157848)	n.s	-0.0006148 (0.0610377)	n.s

*, ** and *** represent 10, 5 and 1 percent level of significance respectively

Our results are contrary to what a few studies have found. For instance, Barron and Torero (2017) found significant improvement of air quality and a reduction of acute respiratory infections among children aged six and below in El Salvador. The context of their study differs from ours in the sense that, for a country like Tanzania, where biomass fuel accounts for 70 percent of household cooking (MOF and NBS, 2019), and over 30 percent of households cook inside the house, the payoffs of electrification with regards to health may be hard to substantiate for children aged five years and below. Although Aevarsdottir et al. (2017) substantiates such effects on health in Tanzania for all household members, their results depend on whether households use multiple fuels, and whether the cooking takes place inside or outside. Our results for the separate rural and urban samples also show no significant differences between the treated and control households in the incidence of respiratory symptoms in children aged five and below.

We also investigated the impact of electrification on fertility. Table 10 presents the results of the impact of electrification on fertility. We used the number of children aged five and below per woman in a household, the number of births in the last five years, the preferred waiting time before the next pregnancy and the use of contraceptives as indicators of fertility in the households. The analysis was done for the full sample and the rural and urban samples.

Table 10: Impact of household electrification on fertility

Variable	Full sample		Rural sample		Urban sample	
	ATT	Critical Γ hidden bias	ATT	Critical Γ hidden bias	ATT	Critical Γ hidden bias
Number of children under five	-0.04459 (0.0324771)	n.s	-0.0281987 (.0405474)	n.s	-0.0266878 (0.0776173)	n.s
Number of births in last five years	-0.0299082 (0.024246)	n.s	-0.0192053 (0.0213274)	n.s	-0.0491348 (0.0615992)	n.s
Preferred waiting time before next pregnancy	0.0295344 (0.0220463)	n.s	0.029057* (.0161902)	(+) 1.4-1.5	-0.0060244 (0.0530191)	n.s
Use of contraceptives	0.0442699 ** (0.0199879)	(+) >2	0.0061785 (0.0190849)	n.s	0.0959578 * (0.0490053)	(+) 1.4-1.5

The full sample analysis showed no significant difference between the treated and control households in the number of children aged five and below in the households, number of births in the last five years and the preferred waiting time before the next pregnancy. However, the full sample showed a significant difference in the proportion of households with women who use contraceptives. There was a 4.4 percentage point difference between treated and control households for women who use contraceptives. A household's connection to electricity may induce such impacts through improved access to information, as argued by Arraiz and Calero, (2015). According to the Tanzania Demographic health survey 2015/2016, the use of contraceptives has increased from 27 percent in 2010 to 32 percent in 2015. One of the challenges organizations have always faced in promoting family planning is getting information to the population, especially in remote rural areas (USAID, 2017). National mass media campaigns are among the interventions used to raise awareness and use of family planning services (USAID, 2017).

We also find a significant effect of households' use of electricity on contraceptive use in urban areas, as well as on the preferred waiting time before the next pregnancy. There was a three-percentage point difference in women who prefer to wait at least two years before their next pregnancy. The result in urban but not rural areas can be explained as follows. Although information may be helpful in increasing the awareness of family planning, it can only work if modern family planning service centers are available; such services are less likely to exist in remote areas.

Sensitivity analysis

As the propensity score matching only controls for the observables, if there exist unobservable variables that affect assignment of households into treatment and the outcome variables simultaneously, a hidden bias may occur (Caliendo and Kopeining, 2008). Using the Rosenbaum (2002) bounding approach to check the magnitude with which the selection process may be influenced by unobserved/unmeasured variables to alter the implications of the impact analysis. Similarly, the study conducted a sensitivity analysis of all significant outcomes due to a household's use of electricity as done in the previous section for impacts of household's use of modern cooking fuels. The sensitivity analysis for the results of the impact of household use of electricity on energy expenditures results show that most of our results are robust to any possible hidden selection bias. The results indicate that the confidence intervals for the various significant effects would not include zero if unobserved variables caused the odds ratio of treatment assignment between the treatment and control households to differ by 2.

Nevertheless, our results on the impact of household's use of electricity on traditional energy expenditures for the full sample and urban sample, modern energy budget and modern energy expenditures share for the rural sample are sensitive to possible deviations from unconfoundedness assumptions due to unobservable factors. The lowest critical values at which these results are sensitive to possible deviation is 1-1.1 for modern energy expenditures and modern energy budget shares outcomes, while the largest critical values are for traditional energy expenditures for the full sample 1.5-1.6. Our results on schooling for all the sub samples are also sensitive to possible deviations from unconfoundedness assumptions. The lowest critical value at which our results are sensitive is 1-1.1 and the highest being 1.8-1.9. Furthermore, our results on time use are also sensitive at a critical value of 1.2-1.3. Nevertheless, our results on fertility are robust to any possible deviations from unconfoundedness assumptions, except for outcomes in the rural and urban samples that were sensitive at critical values of 1.4-1.5.

It is of note that, a sensitivity analysis assesses the strength unmeasured confounders would require changing inferences about the treatment effects, thus the critical values are gradually increased to a point which inference about the treatment effect might change. Thus, these are worst case scenarios and do not imply unobserved heterogeneity (Caliendo et al., 2005). These results only state that the confidence intervals for the various significant effects that are sensitive to possible deviations from unconfoundedness assumptions may include zero if unobserved variables caused the odds ratio of treatment assignment between the treatment and control households to differ by a certain critical value. Additionally, our results are relatively robust, as most of them are not sensitive to possible deviation from unconfoundedness assumptions. Those that are sensitive, require a big differential in odds for inferences about treatment effects to change. Nevertheless, those that are sensitive at low critical levels of 1-1.1 does not mean they are not robust enough, but rather should be interpreted within those restrictions (Caliendo et al., 2005).

3.5 Conclusion

The main objective of this study was to look at the impacts of household energy transition on household welfare indicators in Tanzania. We looked at the impact of households' use of modern cooking fuels and electricity on household welfare. We used two nationally representative data sets: the fourth wave of the Tanzanian National Panel Survey 2014/2015 and the Tanzanian Demographic and Health Survey and Malaria indicator survey 2015/2016. We employed propensity score techniques to come up with suitable counterfactuals for treated households based on observable characteristics. Propensity scores were estimated using logit models that constituted covariates that simultaneously affect the treatment status and outcomes of interest. The treated and control households were matched based on the estimated propensity scores. A sensitivity analysis showed that our results are relatively robust to possible deviations from unconfoundedness assumptions.

We find significant impacts of households' use of modern cooking fuels on charcoal expenditures. Thus, the promotion and use of modern cooking fuels may help cut down on the amount of charcoal consumed, especially in urban areas. With the rolling out of natural gas for home consumption in the test phase, households should be made more aware of such ventures, to help cut back on charcoal consumption. Policies advocating a reduction in excessive use of charcoal and other traditional cooking by shifting to modern cooking fuels may go a long way in reducing hospital visits by children due to respiratory infections.

Households' use of electricity was found to improve schooling outcomes. The increase in study hours also translates to an increase in years of schooling. Although schooling outcomes may not be attributed to electricity alone, our study suggests that electricity may be important in augmenting other factors in improving schooling outcomes. Moreover, our study provides suggestive evidence that electricity may promote the information flow in rural and urban areas and augment various social campaigns like family planning. Furthermore, the benefits that electrification may bring in rural areas, by supporting small businesses and elongating the working day, may go a long way toward improving household welfare. Thus, the government should enhance electrification programs to enable communities to extract such payoffs.

Further research is needed to elicit differential impacts among households that use modern cooking fuels alone and those that use multiple fuels. A multiple treatment type of study that looks at where the food is cooked by a household (indoors or outdoors) and the type of fuel used may elicit more precise impacts of modern cooking fuels on household welfare. In addition, further research may be of interest to differentiate the benefits of electrification from various sources of electricity, such as grid electricity and renewable sources of electricity like solar power, which may be useful only for lighting. It is important to note that while this is correct in terms of the potential effects, actual effects may not differ as long as grid electricity is used by most people only for lighting.

Chapter Four

The political economy analysis of institutional barriers to rural electrification in Tanzania

Abstract

Institutions may play a great role in the smooth implementation of development programs in any sector. They affect how players within the policy space act and affect the policy outcomes of the designated programs. This paper investigates the institutional barriers to rural electrification in Tanzania. We investigate if the political clergy and energy sector governing entities in Tanzania constrain the smooth implementation of rural electrification projects. Moreover, we investigate if the current rules, laws, and regulations in the electricity industry and supporting sectors attract investments in rural electrification projects. Furthermore, we review policies, strategies, and interventions within the energy sector with regards to rural electrification. We use primary data collected from key informants in the sector, augmented with secondary data from official reports and periodicals from key government and non-government entities in the electricity sector. Qualitative data analysis techniques were used to ascertain the key institutional barriers to rural electrification in Tanzania. Institutional barriers pertaining to non-independence of institutions within the energy sector, deficiencies of the existing policies, strategies and interventions pertaining to rural electrification, the supporting framework's modus operandi not accustomed to serve the electricity sector, the uncertainties created by the laws and regulations governing the sector, and the institutional specific challenges facing the governing institutions in Tanzania formed some of the key bottlenecks hampering the timely implementation of and achieving of desired outcomes by rural electrification projects in Tanzania as perceived by the stakeholders in the Tanzanian electricity industry.

4.1 Introduction

Access to modern energy services is necessary for any country's economic transformation as enshrined in goal number 7 of the United Nations 'Sustainable Development Goals and prioritized in the Tanzanian 2015 Energy Policy (United Republic of Tanzania, 2015; African Development Bank, 2016).Tanzania influences household energy transitions in accordance with its energy policy that promotes the provision of reliable, affordable and access to modern energy services and ensuring full participation of Tanzanians in the sector. This contributes to the economic growth of the country and, subsequently, the welfare of the Tanzanian households (United Republic of Tanzania, 2015). The Tanzanian 2015 Energy Policy covers issues such as electricity (generation, transmission, distribution, rural and urban electrification); renewable energy; energy conservation; energy efficiency; petroleum and gas activities; institutional set up within the energy sector; and the corresponding legal and regulatory framework (United Republic of Tanzania, 2015).

Subsequently, the country has incorporated the energy transition agenda in both its national long term and mid-term plans including the Tanzanian Development Vision 2025 and National Strategy for Growth and Reduction of Poverty II. Moreover, the country has sector specific plans and strategies with regards to the energy sector, which include the Power Systems Master Plan of 2012, the Biomass Energy Strategy of 2014, the Electricity Supply Industry Reform Strategy and Roadmap 2014-2025 and the National Electrification Program (United Republic of Tanzania, 2015). These strategies and plans within the energy sector are implemented in accordance with the national energy policy under the guidance of the Ministry of Energy (MOE) and autonomous entities under its stewardship including the Tanzania Electric Supply Company (TANESCO), the Energy and Water Utilities Regulatory Authority (EWURA) and the Rural Energy Authority (REA). Whereas the government plays a pivotal role in the actualization of the energy policy objectives with regards to household energy transitions, in terms of providing ease of access, reliability of supply and affordability of modern energy services, the private sector also plays a key role in terms of provision of capital and market-oriented products to aid household energy transition.

Nevertheless, despite having elaborate policies, plans, strategies, and Programs in place, most of the Tanzanian households especially in the rural areas have not transitioned to the use of modern energy services. Whereas overall access to electricity has increased over the years from 67.5 percent in the year 2016/17 to 78.4 percent in the year 2019/20 with access to electricity in urban and rural areas reaching 99.6 and 69.8 percent respectively in 2019/20, the proportions of households connected to electricity still stood at a mere 37.7 percent for the whole country, and 24.5 percent for the rural areas for the year 2019/20 (Rural Energy Agency, 2020). Moreover, household transition to modern energy sources for cooking is only happening in the urban areas at a moderate pace (National Bureau of Statistics, 2015b; Rural Energy Agency, 2020). The government and development partners had long seen the need to give rural energy transitions, specifically rural electrification a special emphasis by having an agency dedicated to rural energy projects, thus the establishment of REA in 2006.

According to REA reports, since the year 2007, the agency had implemented 42 rural energy projects comprising of grid and off-grid electrification projects, solar systems, and trainings to project developers (United Republic of Tanzania, 2018). The agency, although autonomous in its mandate, works together with other government institutions (TANESCO, MOE and EWURA) and donors to solicit funds for rural electrification projects, pave a good investment environment in the sector to warrant the participation of the private entities in rural electrification and render expertise necessary for the implementation of projects (United Republic of Tanzania, 2014).

Although the country has managed to increase the number of new connections annually in rural areas to 30,357 by 2017 for both individual households and businesses, there have been delays in implementation of such projects to spear head the transitions to use of electricity. Moreover, whereas these projects were meant to bring grid electricity to the villages and subsidize household connections, agencies report that village's connectivity does not translate to more individual household connections (United Republic of Tanzania, 2018). Furthermore, the slow-paced implementations of projects have been compounded with a limited participation of the private sector, with investment in the rural electrification sector still seemingly risky (United Republic of Tanzania, 2014).

Moreover, these impediments have been coupled with an increasing demand for electricity and unreliable power supply to cater for the connected villages (African Development Bank, 2015).The aforementioned shortcomings of the rural electrification programs usually spur political debate due to their foreseen economic importance, as portrayed in a not far distant past in 2018, when members of parliament aired their grievances regarding delays of implementation, number of villages covered by the electrification program and the number of households connected to electricity (Pengying, 2018). It is thus imperative that challenges attributed to such slow household energy transitions are substantiated and addressed.

The shortcomings of the rural electrification programs in Tanzania, in a scenario of well stipulated policies, plans and strategies may be susceptible to two key issues. The first being the institutional paradigm within which the Program is implemented. As defined by Polski and Ostrom (1999), institutions entail understood rules or strategies that affect behavior in repetitive scenarios. Whereas these institutions may be formally set up, they sometimes exist as informal sets of rules or habits that affect how players within the policy space act and thus affect the policy outcomes or smoothness of implementation of policies via the designated Programs (Polski and Ostrom, 1999). Thus, the rules and strategies of key players in different scenarios within the energy sector affect the political economic behavior of the key players (Polski and Ostrom, 1999). It is thus important that in analyzing the scenario of elaborate policies accompanied with slow household energy transitions that we take a firm interest on how institutional set up spear heading the transitions, the politics and the laws within the sector shape interactions in the sector and ultimately the policy outcomes resulting from such interactions.

On the other hand, and equally important, these shortcomings of the rural electrification Program in Tanzania may be a case of policies, plans and strategies not incorporating fully the key determinants of change with regards to the policy objectives. As substantiated by Rugaimukamu et al. 2020a, Rugaimukamu et al. 2020b and others, factors such as social capital, social networks, income and price of modern energy fuels and technologies are key determinants of household transition to use of modern energy services (Bernard and Torero, 2015; Alemet al., 2013; Bonanet al., 2016; Miller and Mobarak, 2014;). Hence, it is imperative to analyze if such key factors have been embedded in the rural electrification Program to facilitate the transition by households.

Moreover, whereas electrification has been linked to household welfare improvements with regards to children’s respiratory health, study hours, schooling outcomes, time use and household energy expenditures (Van de Walleet al., 2015; Benschet al., 2011; Bensch et al., 2015; Arraiz and Calero, 2014; Barron and Torero, 2016), in some cases, as indicated by Rugaimukamu et al. 2020a, Rugaimukamu et al. 2020b these impacts are sometimes difficult to substantiate perhaps due to a partial transitions by households. Whereas some households may have made a transition to electricity in the initial stages due to policy and government initiatives that supported the transition at the time, new connections and perpetuating the use of electricity may have been unattainable for some households post the intervention period. Nevertheless, this could also be because of the dwindling supply of electricity. Thus, not only should the policy, plans and strategies incorporate the demand side triggers of the transition but also the supply side factors to sustain the transition and manifest the foreseen impacts of the transition. As encapsulated in literature, a successful energy policy should encompass issues of availability, reliability, affordability, and sustainability (African Development Bank, 2016).

Hence, this paper investigates the institutional challenges facing the rural electrification Programs in Tanzania, by dissecting the interactions of key players in the sector, the norms, rules, and regulations governing the sector and the resulting energy transitions outcomes. In particular, the analysis takes stock of the extent to which the rural electrification Program's demand and supply triggers household electrification and suggests institutional reforms that engender improved electrification outcomes. The paper adopts the Institutional and Development Framework (IDF) by Ostrom (2005) to systematically substantiate the institutional challenges. Thus, the paper used qualitative research techniques, and conducted 30 in depth stakeholder interviews, which constituted of experts within the electricity supply industry, from government institutions, donors, and academia. These in-depth interviews were supplemented by literature from peer reviewed articles and official institutional reports from government and private institutions.

The IDF provides a systematic way of doing policy analysis. Although in most recent studies, the IDF has largely been used in the analysis of common-pool resources (Berthelemy, 2016; Koster 2013), it has also been used in other areas of research to analyze systematically how the key actors in a particular policy space influence key decision within the confinements of the existing rules and regulations governing the policy space. These areas include delivery of human health services, infrastructure, federal public services, and international relations (Polski and Ostrom, 1999). The framework has also been used on a few occasions to study energy transitions and electricity supply (Berthelemy, 2016; Koster, 2013). Its broad application in other fields of expertise other than its famed use in the analysis of common pool resources shows how the framework generally facilitates institutional analyses.

Moreover, whereas Alhborg and Hammar (2014) similarly looked at the challenges facing rural electrification in Mozambique and Tanzania within the confinement of 2003 Energy Policy, our analysis brings out challenges after the enactment of 2015 Energy Policy and expansion of the rural electrification Program in 2016 and thus provides a contemporary view of challenges facing rural electrification initiatives. Furthermore, unlike Aly et al. (2019) who only looked at challenges facing large scale solar power initiatives in Tanzania, our paper looks holistically at rural electrification, thereby giving a much wider picture of institutional challenges facing electrification initiatives in Tanzania. The paper specifically answers the following research questions

i. Do interactions between the energy sector and political clergy delay the implementation of rural electrification projects?
ii. Do the current rules and regulations that govern the electricity industry act as barriers to rural electrification in Tanzania?
iii. Do the current policy, Programs and strategy designs cover all the important drivers of household connection to electricity to incentive rural electrification?

The paper has six sections. Section 1 presented the introduction and research questions of the study; Section 2 presents the literature review on challenges facing electrification initiatives in Africa. The methodology of the study is presented in Section 3 while the data collection and analysis techniques are presented in Section 4. The discussion of results are presented in Section 5 while the conclusions and recommendations of the study are presented in Section 6.

4.2 Challenges facing electrification initiatives in Africa

Literature has stressed on several challenges prohibiting the success of electrification initiatives in Africa. As most of these initiatives differ structurally in different contexts and different countries, most of the papers have substantiated program and country specific challenges (Abdullahi, 2017; Aly et al., 2019; Ahlborg and Hammar, 2014; Sergi et al., 2018; Mawhood and Gross, 2014). Nevertheless, as some of the challenges are inherently common regardless of the contexts at hand, a handful of papers have provided a snapshot of challenges that most of these initiatives face in Africa (Peters et al., 2019). The vast literature in this area has substantiated these challenges as institutional, technical, political, economic, and social challenges. Most of these papers used stakeholder interviews supported with literature analysis and qualitative techniques to substantiate these challenges (Abdullahi, 2017; Aly et al., 2019; Ahlborg and Hammar, 2014; Sergi et al., 2018; Mawhood and Gross, 2014; Peters et al., 2019).

Political and institutional challenges have been substantiated in different forms in various contexts. In Nigeria, the legal and regulatory framework within the energy sector, non-participation of the private sector, non-integration of energy mix and lack of political will in investing in clean energy technologies were among the institutional and political barriers to the development of solar energy initiatives. This led to uncertainties with regards to solar energy, induced negative lobbying against solar energy initiatives and created a disconnect between the solar energy developers and law makers in the country, thus slowing down solar energy and in turn slowing down electrification initiatives (Abdullahi, 2017). In Tanzania and Mozambique, the institutional and political challenges are in the form of political priorities of the regimes, corruption, politically motivated and economically unviable plans and over reliance on donor funding to implement electrification initiatives (Ahlborg and Hammar, 2014).

Furthermore, Aly et al. (2019) adds on the institutional challenges facing electrification initiatives in Tanzania. They put to bear the lack of political will and commitments towards electrification projects as one of the institutional challenges that face the development of large-scale solar power initiatives. They further reiterated challenges with regards to non-independence of autonomous government institutions within the energy sector and unconducive business environment (Aly et al., 2019). Similarly, the lack of political support and politicization of electrification initiatives were cited as institutional barriers to rural electrification initiatives in Senegal (Mawhood and Gross, 2014). Nevertheless, institutional barriers may sometimes manifest in terms of misalignment of priorities and policy direction with regards to electrification initiatives between the donors and recipient governments (Sergi et al., 2018). This has been reiterated for the case of Kenya and Tanzania, whereby although development agencies have focused on funding off-grid electrification initiatives, the Kenyan and Tanzanian governments still favor grid electrification initiatives, and thus slowing down the electrification process due to lack of funding to pursue their objectives (Sergi et al., 2018).

The technical challenges to electrification initiatives in Africa substantiated in literature include lack of skilled personnel for the initiatives, lack of data and studies to support clean energy initiatives, lack of training facilities, and the unreliability of power supply (Abdullahi, 2017; Aly et al., 2019; Mawhood and Gross, 2014). These challenges have amounted to poor plans, constrained markets, uninformed decisions with regards to technology risk and acceptance ultimately slowing and prohibiting the implementation of electrification initiatives (Abdullahi, 2017; Aly et al., 2019; Mawhood and Gross, 2014). On the other hand, financial challenges have hampered implementation of electricity initiatives in most African countries. The lack of access to capital, consumer credit and proper lending financial instruments hampered the adoption and investments in solar systems in Nigeria (Abdullahi, 2017). Similarly, in Tanzania, poor financing conditions and financial weaknesses of the main utility company have hampered the development of large-scale solar power projects (Aly et al., 2019).

As stipulated by literature, these challenges that hinder the smooth implementation of electrification initiatives differ in varying contexts, as they manifest differently due to the polices in place and the institutional framework governing the sector (Abdullahi, 2017; Aly et al., 2019; Ahlborg and Hammar, 2014; Sergiet al., 2018; Mawhood and Gross, 2014; Peters et al., 2019). It is thus important to understand the root of these challenges by comprehending the policies, rules, regulations governing the energy sector in different contexts, and the powers in play, the resulting interaction and policy outcomes with regards to the electrification initiatives at hand. This paper investigates the institutional challenges facing rural electrification initiatives in Tanzania and adopts the Institutional and Development framework by Elinor Ostrom (2005) to substantiate the institutional challenges systematically and qualitatively. The framework's systematic way of policy analysis renders to a detailed analysis of the policy space at hand.

Although in most recent studies, the Institutional and development framework has largely been used in the analysis of common-pool resources (Berthelemy, 2016; Koster 2013), it has also be used in other areas of research so to analyse systematically how the key actors in a particular policy space influence key decisions within the confinements of the existing rules and regulations governing the policy space.

Moreover, whereas the paper by Alhborg and Hammar (2014) similarly looked at the challenges facing rural electrification in Tanzania and Mozambique with the confinement of 2003 energy policy, our analysis brings out challenges after the enactment of 2015 Energy Policy and expansion of the rural electrification Program in 2016 and thus bringing in a more current outlook of challenges facing the rural electrification initiatives. Furthermore, as our paper takes a holistic look of rural electrification in Tanzania, it gives a much wider picture of institutional challenges facing electrification initiatives in Tanzania, and thus goes beyond what Aly et al. (2019) did for the case of Tanzania, who only looked at challenges facing large scale solar power initiatives in Tanzania.

4.3 The Methodology

4.3.1 The conceptual framework

The paper borrows conceptually from the Institutional and Development framework (IADF) by Ostrom (2005). The IADF is a useful conceptual framework to organize policy analysis and concentrates attention of the analysis on actors involved in policy manifestation (Polisk and Ostrom, 1999; Koster, 2013). It is a systematic way of breaking down a complex policy scenario into manageable multiple sub-scenarios. Its multiple scenarios nature allows for a detailed analysis which results in policy solutions that encompass the entire policy space (Polski and Ostrom, 1999).

Figure 1 presents the diagrammatic schematic of the IADF as portrayed in Polski and Ostrom (1999), Ostrom (2007) and Ostrom et al. (1994). The current paper adapts it for the context of rural electrification in Tanzania.

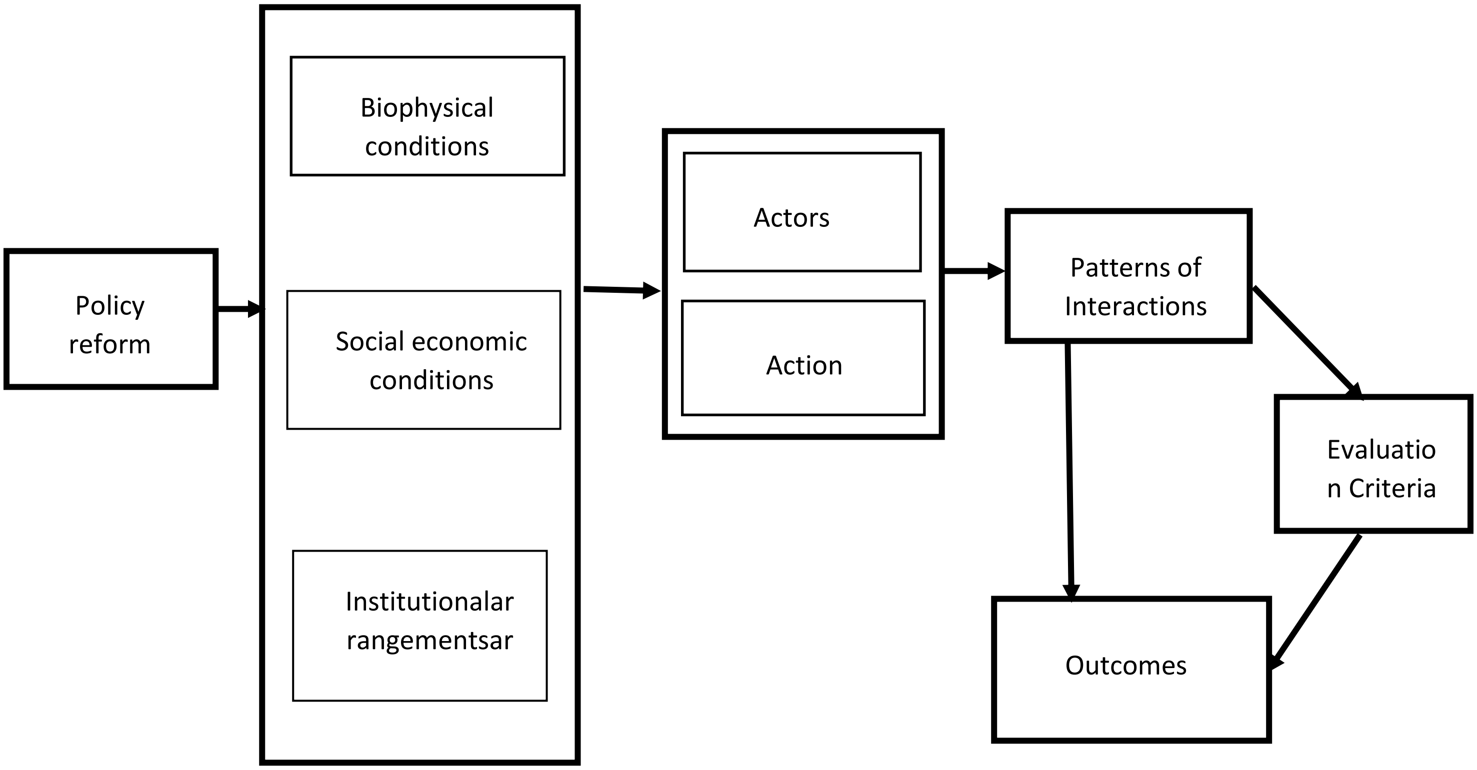


Figure 2: The schematic presentation of the IAD framework

Source: Polski and Ostrom (1999)

The action arena, which constitutes of the actors and the action situations, is at the heart of the IADF; actors within the energy sector interact there to shape the outcomes in the energy sector e.g., rural electrification (Ostrom etal., 1994; Polski and Ostrom, 1999; Nigussie et al., 2018). The IADF also entails the analysis of the physical and material conditions, which are comprised of the physical and human resources used in the production and provision of goods and services (Polski and Ostrom, 1999). In our context, these will comprise of the domestic resources used in the generation of electricity and the skills and capabilities of the personnel and the institutional arrangements in the electricity supply industry. Moreover, the IADF also brings to the fore the analysis of the rules-in-use in the policy arena; according to Polski and Ostrom (1999), these refer to both formal and informal rules that affect behaviour in the action arena. In our study, we investigate the rules and regulations articulated and those that have become part of the *modus operandi* in the sector and the sources of these rules and how they affect the speed and timely implementation of rural electrification projects in Tanzania.

This paper takes a keen focus on the electricity industry and its policy space and portray the key actors in the Tanzanian electricity sector, the functions of the various actors in the sector, the rules and regulations governing the sector and thus analyze the structure of interactions within the IADF and how the behavior of the actors is affected by the prevalent structure and accompanying rules and regulations. To accomplish this, we use a modified and customized IADF befitting our context as depicted in figure 2.

The customized framework portrays the main actors in the policy arena, which include the Ministry of Energy, politicians, EWURA, TANESCO, REA, the development partners (donors), the Independent Power Producers, Small Power Producers (SPPs), standalone systems service providers, the banking sector, and customers. In Section 4.3.3, we describe in detail the actors in the action arena depicted in the figure 2 in terms of their functions and authority in the sector.

4.3.2 The resource endowments of the sector

Tanzania has been endowed with diverse electricity generation resources, including hydro, coal, natural gas, wind, solar, (National Bureau of Statistics, 2017; National Bureau of Statistics, 2015a; United Republic of Tanzania, 2014). Whereas the country has exploited extensively its hydro resources, some of the abundant renewable energy resources such as wind and solar power have not been extensively explored. The country has just recently started using its natural gas reserves discovered offshore in the deep sea off the coast of Tanzania, along Lindi and Mtwara regions, and onshore in Mnazi bay, Songosongo, Mkuranga, Kiliwani and Mtoryaintensively for electricity generation activities. On the other hand, the country's massive coal reserves offer another avenue for electricity generation expansion. It is estimated that the country has about 1.9 billion tons of coal reserves, of which 25 percent are proven (National Bureau of Statistics, 2017; National Bureau of Statistics, 2015a; United Republic of Tanzania, 2014). Furthermore, the country has uranium reserves that have not been used (National Bureau of Statistics, 2017). As of 2016, of the installed 1474 MW generation capacity, 38 percent was hydro power, 49 percent natural gas fired power plants and 12 percent fuel power plants (Eberhard et al., 2018).

4.3.3 The key actors of the electricity sector

The Ministry of Energy (MOE)

The ministry of energy is the pivot of the electricity supply industry in Tanzania. Not only does it give the policy direction but also sets up and shapes the agenda of the electricity industry by enacting and overseeing laws and strategies for the fruition of policy objectives (IRENA, 2017). The ministry is envisioned to bring about social economic development and improvement in the quality of life of the Tanzanian citizens through the provision of reliable and affordable modern energy services, most prominently electricity (IRENA, 2017; United Republic of Tanzania, 2015). All institutions that oversee the electricity supply industry in various capacities are under the stewardship of the ministry. It is within the ministry's mandate and guidance, that TANESCO, REA and EWURA work in tandem to pave and implement electrification projects, create an enabling environment for the sustainability of such projects and attract private investments in the electricity supply industry (World Bank, 2016; United Republic of Tanzania, 2014; African Development Bank, 2015).

The Energy and Water Utilities Regulatory Authority (EWURA)

EWURA was enacted in 2006 and accorded an autonomous mandate to regulate the energy and water utilities in Tanzania; this was five years after its creation under the Energy and Water Utilities Regulatory Authority Act in 2001 (IRENA, 2017; World Bank, 2016; United Republic of Tanzania, 2014; African Development Bank, 2015). Its mandate within the electricity supply industry spans from licensing, enforcement and monitoring of technical standards within the industry, regulation of consumer tariffs and facilitate access to modern energy services for all, particularly the low-income group (IRENA. 2017; World Bank, 2016; African Development Bank, 2015; United Republic of Tanzania, 2014). In its regulatory capacity, EWURA has been key in setting up regulations that are compatible with and friendly to prospective investors in rural electrification. Regulations that allowed for setting of own tariffs for standalone systems that sell power to customers directly, exemption of licensing to entities producing less than one megawatt and feed-in tariffs for Small Power Producers (SPPs – producing power under 10 megawatts), are the few incentives that EWURA has deployed to attract the private sector into rural electrification initiatives in Tanzania (United Republic of Tanzania, 2014; African Development Bank, 2015).

The Tanzania Electric Supply Company Ltd. (TANESCO)

TANESCO is as state-owned company with the sole mandate of electricity generation, transmission, distribution, and sale in Tanzania. Etymologically, the company was formed in 1975 upon the merger of the Tanganyika Electric Supply Company (previous TANESCO) and the Dares Salaam Electric Supply Company (DARESCO) with the government becoming the sole shareholder. It is the only electricity utility company with such a holistic mandate in the electricity sector in Tanzania; guided by its mission to generate, transmit and supply electricity in the most effective, competitive and sustainable manner possible (IRENA, 2017; World Bank, 2016; African

Development Bank, 2015; United Republic of Tanzania, 2014b). Nevertheless, after the liberalization of the Tanzanian electricity supply industry, the company is going through the first stages of reforms of unbundling the company to make it more efficient and attract greater participation by the private sector. Currently, the electricity sector allows for private power generation through Independent Power Production Agreements and Small Power Producer Agreements (African Development Bank, 2015; United Republic of Tanzania, 2014b). Whereas TANESCO is at the forefront when it comes to urban electrification, it plays a supervisory, quality assurance, performance monitoring role, together with overseeing the commissioning of infrastructure whose construction had been procured by the REA when it comes to rural electrification (World Bank, 2016).

The Rural Energy Agency (REA)

REA is an autonomous body that was enacted together with the Rural Energy Fund (REF) under the provisions of the 2005 Rural Energy Act and operationalized in 2006, with the mandate to accelerate access to modern energy services in rural mainland Tanzania (IRENA, 2017; World Bank, 2016; United Republic of Tanzania, 2014). REA plays a key role in realizing the goal of modern energy access to all with regards to rural electrification, as it supports extension of electrification services to areas that may not be priority niches for TANESCO. REA supports rural electrification processes in various ways, first by offering subsidies for rural electrification projects, which it does under the supervision of the Rural Energy Board (REB) which administers the REF. The REF gets its resources from various sources including but not limited to the government, development partners, levies and fees as stipulated in section 19(3) of the Rural Energy Act no. 8 of 2005(World Bank, 2016; United Republic of Tanzania, 2016; United Republic of Tanzania, 2012; African Development Bank, 2015). Nevertheless, not all resources that finance

REA's initiatives go through the REF, sometimes, special purpose vehicles are set up to support specific projects whose fund disbursements must adhere to special rules and regulations agreed with the financer. REA provides technical know-how through capacity building initiatives for private power developers e.g., technical assistance and training on rural electrification project management (World Bank, 2016; United Republic of Tanzania, 2016; United Republic of Tanzania, 2012; African Development Bank, 2015).

The Emergency Power Producers (EPPs) and Independent Power Producers (IPPs)

EPPs and IPPs are privately owned generation companies that each produce more than 10 MW. They currently contribute to about 40 percent of the country's generation capacity. Most of these privately-owned generation stations are diesel, gas or heavy fuel operated; nevertheless, new IPPs that make use of renewables such as hydro, wind and solar power are in the pipeline (IRENA, 2017; African Development Bank, 2015). According to the Africa Development Bank (2015), by the year 2015, about six IPPs and EPPs were operational in the country; these included Symbion (Arusha, Ubungo and Dodoma), Songas, Independent Power Tanzania Limited and Aggreko (Tegeta and Ubungo). The IPPs sell the power they produce to TANESCO under IPPA's (IRENA, 2017; African Development Bank, 2015). Nevertheless, according to Eberhard et al. (2018), some of the EPPs have since been retired, these include Aggreko Tegeta, Aggreko Ubungo, Symbion Arusha and Symbion Dodoma.

The Small Power Producers (SPPs)

SPPs constitute of privately-owned power generation systems that produce up to 10 MW. Most of these systems are characterized by the fact that they are not solely power producing systems but rather part of a structure such as tea, sisal, tannin, and sugar business entities (IRENA, 2017; World

Bank, 2016; African Development Bank, 2015). These production systems were first piloted and supported by World Bank through REA. Whereas they sell the power produced to TANESCO via SPPAs, they have also been licensed to sell power directly to individual customers and communities at large (World Bank, 2016; African Development Bank, 2015). Some of the SPPs in Tanzania include Mwenga Hydro Power, Mufindi Paper Mills, TANWATT, Texpol Company, Ngombezi (IRENA, 2017; World Bank, 2016; African Development Bank, 2015).

Development Partners and Banks

Development partners and the banking sector are also important players in the electricity sector in Tanzania. Whereas development partners have supported the electricity sector and rural electrification initiatives through donations made to the REF or special purpose vehicles, grants and concessionary loans, the banking sector has liaised with the development partners as channels for access of much needed liquidity for investment in the electricity sector by the private sector (African Development Bank, 2015; United Republic of Tanzania, 2014). Most development partners in Tanzania have preferred using special purpose vehicles, grants and credit lines rather than donating into the REF to support rural electrification initiatives. Donor's support towards rural electrification initiatives have not only covered the generation, transmission and distribution costs but also studies and capacity building pertaining to the implementation of rural electrification projects in Tanzania (African Development Bank, 2015; United Republic of Tanzania, 2014). Nevertheless, most of the funding from donors has been directed to support grid expansion initiatives, having committed a chunk of their donations to the sector towards grid-based projects, with only a reportedly 8 percent of foreign aid committed to off-grid projects (Aly et al., 2018; Serge et al., 2018). Furthermore, the types of grid energy projects funded by donors have depicted the paths different donors 'desire for the Tanzanian energy sector. Whereas the European Union has looked to support renewable energy-based projects, the African Development Bank and Japan International Cooperation Agency (JICA) have supported and/or committed to support Tanzanian's coal and gas-powered energy initiatives (Aly et al., 2018). The magnitude of donor support for the Tanzanian electricity sector has been massive on an annual basis, exemplified by the 1.5 trillion Tanzanian shillings (646,776,420,000 USD) of commitments recorded for the year 2016/17. The World Bank has been the major player in financing electrification initiatives in Tanzania, with the development agencies of France, Japan, Norway, Sweden and USA, the African Development Bank, and the European Union being the other main donors for the sector (African Development Bank, 2015; Serge et al., 2018).

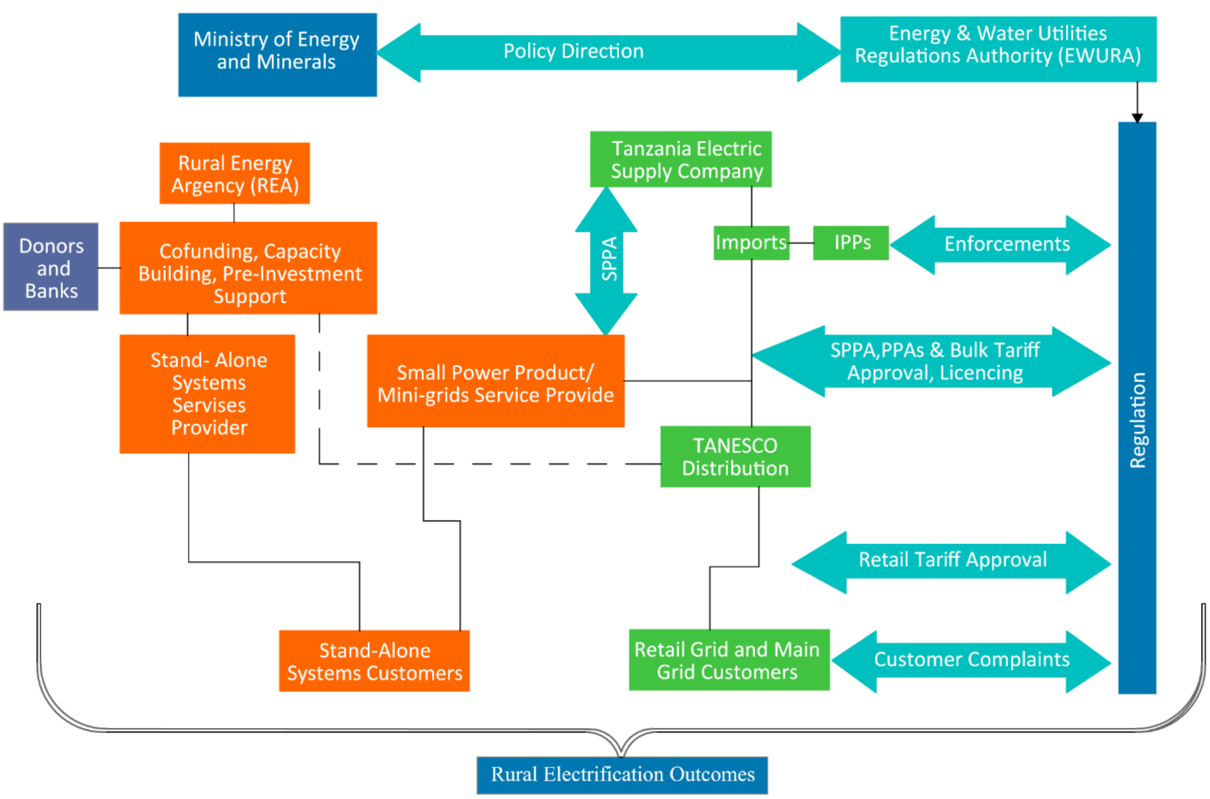


Figure 3: Customized IADF for the Tanzanian electricity sector

Source: IRENA (2017)

4.3.4 Policies, laws, rules, and regulations governing the sector

Table C1 (in the appendix) presents a list of key policies, laws, rules and regulations governing the Tanzanian energy sector. Tanzania's energy policy has always given a general direction of the whole energy sector. The most current policy is the 2015 Energy Policy, which was brought in to address challenges in the sector and shortcomings of the 2003 Energy Policy which ushered the era of liberalization for the electricity supply industry in Tanzania. The 2015 Energy Policy is anchored in access to affordable and reliable modern energy services by all Tanzanians and provides a comprehensive institutional, legal and regulatory framework for electrification initiatives (World Bank, 2016; United Republic of Tanzania, 2015). The policy not only gears towards the creation of a business environment conducive for private investment, but also anchors its goals in sustainability of resource use in the electricity supply industry by increasing the share of renewables in the total electricity generation mix of the country (World Bank, 2016; United Republic of Tanzania, 2015; African Development Bank, 2015). Nevertheless, the electricity supply industry is also dependent on policies of supporting sectors for the manifestation and fruition of itsplans, strategies and policy outcomes. Some of the key polices supporting the sector include the 1997 National Environment Policy and the 1997 National Land Policy (United Republic of Tanzania, 2015; African Development Bank, 2015).

Whereas the energy policy informs the general direction taken by Tanzania's energy and electricity sectors, the country has similarly put in place specific plans, strategies, and a prospectus for the electricity sector, which give a snapshot of actions and programs within the electricity supply industry. The Tanzanian 2016 Power Master Plan is one of such plans that streamlines the general objectives of the energy policy and other development plans in the country in the context of the electricity sector. The plan is pivoted on attainment of sustainable power supply. It provides a detailed assessment of generation, transmission and distribution requirements to optimally use the available resources in an efficient and cost effective manner, so as to bring about reliable power supply and thus spurring economic development, bring about energy security and ensuring environmental protection. Furthermore, the connection of off-grid regions is also at the heart of the plan, with the aim of deriving social-economic development through electricity access to all Tanzanians (United Republic, 2016; Pryavarat and Shweta,2018).

Additionally, the electricity supply industry reform strategy and road map (2014-2025) provides a framework and road map for reforms of the electricity supply industry in line with the energy policy and more broadly with the Tanzania's Development Vision 2025 (United Republic of Tanzania, 2014b). The strategy entails the step by step restructuring the sector must go through. Key issues stressed by the strategy is restructuring the market and electricity sub sector, risk mitigation within the sector and the timelines associated with the respective restructuring processes, with the road map providing the implementation plan (United Republic of Tanzania, 2014b). The creation of a financially sound sector, improved access and increased electricity connections, optimal use of energy resources and improved reliability of power supply are at the center of the reforms (United Republic of Tanzania, 2014b).

On the other hand, the national electrification program prospectus depicts a strategy to support the national electrification program for the period between 2013-2022. At the heart of the strategy is the advancement of electrification using the least cost path, and suggests a framework in terms of institutions, regulations and capacity of human resources needed for the smooth implementation of the strategy. The strategy covers both urban and rural electrification, with the viability of grid and off grid solutions assessed for different population densities in different parts of the country.

Nevertheless, the prospectus proposes grid-based electrification for settlements close to the grid, densely populated and large. Off-grid solutions have been proposed for remote low-density areas (United Republic of Tanzania, 2014; United Republic of Tanzania, 2013). If the prospectus is realized, the country's electrification rates are projected to be 31%, 57% and 20% for the overall country, urban areas, and rural areas respectively (United Republic of Tanzania, 2014; United Republic of Tanzania, 2013).

To support the implementation and realization of the energy policy and other supporting sector policies within the provided institutional setups, the country has passed several legislationproviding for the establishments of various institutions in the sector and their respective functions. The most encompassing legislation of the Tanzanian electricity supply industry is the Electricity Act of 2008. It stipulates the mandate of the Ministry of Energy and the respective minister. It also stipulates the role of EWURA with regards to tariffs setting, its regulatory mandate with regards to licensing, monitoring, enforcement of standards pertaining to rural electrification and sets outs procedures for the reorganization of the electricity supply industry (United Republic of Tanzania, 2012; African Development Bank, 2015). Other more specific legislations in the sector include the Energy and Water Utilities Acts of 2001, 2006 and its regulations which provided for the establishment of EWURA as the regulator of the energy and water utilities sectors. To give priority and facilitate rural electrification, the Rural Energy Act no. 8 was passed in 2005 to provide for the establishment of REA. It stipulates funding channels and procedures for disbursement of such funds for rural energy projects (United Republic of Tanzania, 2012; African Development Bank, 2015).

On the other hand, there are other overlapping or general legislations, that not only provide for the smooth functioning of the electricity supply industry, but also the smooth functioning of other sectors. One important legislation of such nature is the Public Private Partnership Act of 2010, which provides for the regulation of public-private-partnership projects in Tanzania. Not only does it stipulate the responsibilities of all parties involved in private-public-partnership projects with regards to penalties, remedies and financial controls, it also provides for dispute resolutions procedures in case of disputes between parties. It provided for the establishment of the public-private-partnerships coordination units under the Tanzania Investment Centre in conjunction with the Tanzania Investment Act of 1997, which provides provisions for investments and leeway to make them prosper in various sector, the electricity supply industry being one of them, with regards to rural energy projects (United Republic of Tanzania, 2012; African Development Bank, 2015). Moreover, the most recent Contract Review Act of 2017, provides provisions for renegotiations of contracts if the country deems the contracts to have unconscionable terms (Aly et al., 2019).

Other general legislations of the same importance to the electricity supply industry, include the Land Act of 1999 which stipulates the provisions for land ownership by investors in various sectors, be it individuals or corporate, which works hand in hand with the Village Land Act of 1999, which stipulates the procedural priors for acquisition of village land for investment in Tanzania (United Republic of Tanzania, 2012). Moreover, legislation most relevant for rural energy projects developers that access grantsand make use of public funds isthe Public Finance Act of 2001 which provides provisions for access of such funds and required audits to be adhered to and institutions responsible for such audits. On the other hand, the Public Procurement Act of 2011, and its regulations, provides for the disbursements of grants for development projects (United Republic of Tanzania, 2012). As most projects in the electricity supply industry involve the use of natural resources in one way or the other, legislations pertaining to the use, acquisition of such resources and sustainable use of the resource also provide a framework in which these projects operate. These legislations include the Water Resources Management Act of 2009, which provides for the management of water resources with regards to protection of catchment areas and pollution. Furthermore, the Environment Management Act of 2004,stipulates the responsibilities and regulations that rural energy projects developers will have to bear and adhere to with regards to environmental sustention. On the other hand, the Petroleum Act of 2008, provides for the licensing requirements and regulations with regards to acquiring, processing and use of petroleum products which national and rural energy projects developers that make use of petroleum products must adhere to.

4.4 Empirical Methodology and Data

Following from the IADF, the study engaged stakeholders to gather their perceptions onthe electricity sector with regards to rural electrification in Tanzania. This was done on thebasis of their mandate, influence, authority, expertise, and their overall role within the sector. The paper collected data from different stakeholders within the electricity supply industry in Tanzania through key informants' interviews from the 25th March 2019 to 25th April 2019 in Dar es Salaam, which was complimented with data from literature and official institutional reports (Government and non-government institutions).

The data from stakeholders was collected through semi structured interviews. Questions were posed in an open-ended modalitys, and the stakeholders were given an opportunity to give their answers and explain them in detail, to get an ample story surrounding the issues of interest. The questioning was tailored in the context of the the stakeholder institution's work and their overall areas of expertise in the electricity subsector. The stakeholders that were interviewed were experts and people working in the electricity subsector that acted as key informants on the issues of interest in an expertise capacity. The snowballing technique was used to identify the key stakeholders in the sector.

The semi structured questions addressed five areas based on a literature review guided by the IADF; these areas were(i) the characterization of scope of electricity access in Tanzanian rural areas (ii) the pros and cons of the institutional set up in the electricity supply industry and their respective reforms (iii) the clarity and effectiveness of rules and regulations governing the electricity supply industry (iv) the role of donors in financing of the electricity supply industry, the pull and push factors for such support (v) the opportunities for improving electricity access in rural Tanzania.

We interviewed stakeholders from government institutions within the electricity subsector, like TANESCO, EWURA, REA, Ministry of Energy; we also interviewed the international and academic community including the African Development Bank (AfDB), the World Bank office in Tanzania, the Swedish International Development Agency in Tanzania, and researchers in academic institutions. Thus, in total we conducted 30 key informant interviews. Whereas the government and international institutions provided one key informant each, we interviewed three key informants from academic institutions. The key informants were chosen by institutions based on their expertise in the study pertaining to their institutional mandate and role in the sector.

Table 15: Stakeholders interviewed for the study

The stakeholder	**The number of interviewees**
Tanzania National Electricity Supply Company (TANESCO)	3
Energy and Water Utilities Regulatory Authority (EWURA)	3

Rural Energy Agency (REA)	3
Ministry of Energy	3
The World Bank group, Tanzania	3
The Swedish International Development Agency (Sida)	3
The African Development Bank (AfDB)	3
Research institutions: University of Dar-es-Salaam (UDSM), Environment for Development (EfD)-Tanzania, Mzumbe university (MU), Sokoine University of Agriculture (SUA).	9
Total	**30**

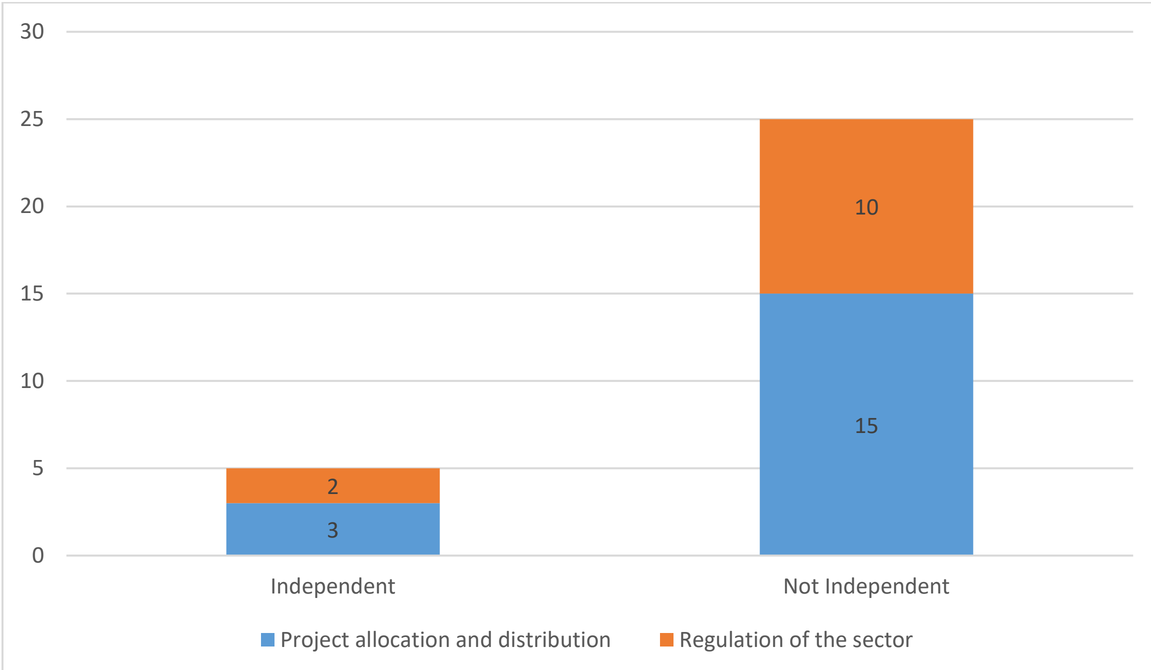
Nevertheless, due to time, bureaucracies, and financial constraints, we could not get stakeholders from the private sector. This was one of the main reasons that propelled us to speak to more representatives in the academic community who had worked closely with the private sector in consultancy and research capacity in the electricity supply industry. Prior to the research, ethics and clearance was obtained from the University of Cape Town along with permission and consent from the relevant authorities, institutions, and individuals.

4.5 Discussion

This section presents a discussion of the stakeholder's perceptions pertaining to the electricity supply industry, with regards to institutional barriers of rural electrification in Tanzania. More specifically the stakeholders pointed to the barriers impeding successful and timely implementation of rural electrification projects and increased participation of the private sector in thisrural electrification endeavour. The study elicited these perceptions based on the mandates/authority of individual stakeholders within the sector, expertise of the individual respondents, rules and regulations within the sector, resource use and investments within the sector and the interactions of various stakeholders within the policy space in accordance with the conceptual framework adopted for the study. The results from the stakeholder's interviews can be grouped into five main themes, namely constraints pertaining to (i) non-independence of institutions within the energy sector (ii) the current energy policy direction, strategies, and rules of operations (iii) the supporting sectors framework's *modus operandi* (iv) social and community inherent barriers and (v) problems inherent within the energy sector governing institutions.

The non-independency of most of the governing institutions in the sector was one of the issues that was brought to the fore. Over 80 percent of the stakeholders interviewed stressed that the institutions that govern the sector, particularly TANESCO and REA were not independent enough in their operations and decision making, as interference from politicians and board of directors of these institutions lead to the delay of implementation of electrification projects, as portrayed in figure 4.

Figure 4: Independence of institutions in the Tanzanian energy sector

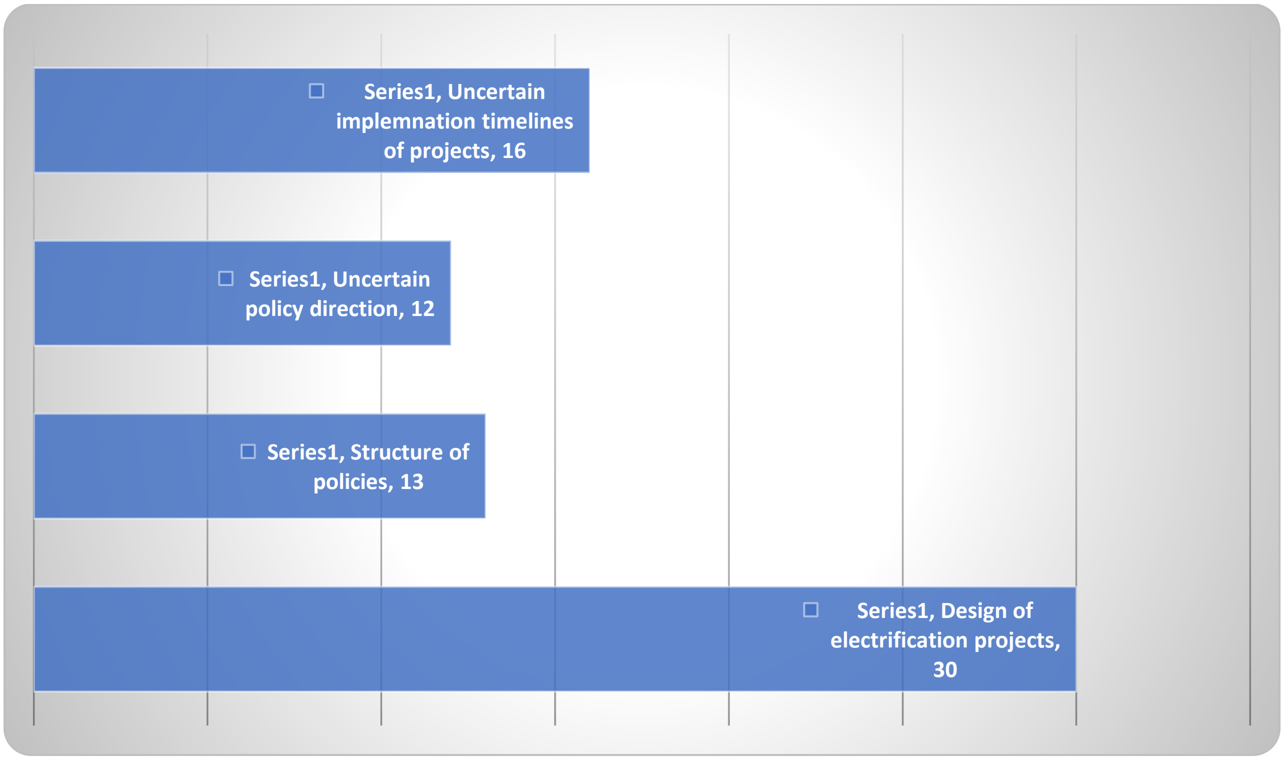


One area where such interferences were of prominence according to the stakeholders was in deciding areas and the number of villages to be electrified under rolled out rural electrification projects, with over 50 percent of the stakeholders that cited non-independence of institutions, pointing it as an area of concern as portrayed in figure 4. Stakeholders elaborated that as electrification is a key campaign issue, most politicians try to lobby and put pressure on the project implementing institutions to either include big portions or the whole of their constituencies within the planned projects, which is usually beyond the project's budget and the contractual obligations of the contactors on site. This is something that the Ministry of Energy has taken note of in the National Electrification Program Prospectus 2013-2022, which has highlighted the need to have a transparent process in determining households that would be covered by the electrification projects (United Republic of Tanzania, 2014).This has been a challenge that rural electrification projects in Tanzania under various donors have faced as reiterated by Miller et al. (2015), whereby the consensus among beneficiaries of the Millennium Corporation Challenge electrification projects in Tanzania was that there was no known criteria for determining the benefiting communities, which translated into feelings of unfairness by adjacent communities as projects are deemed a political game by the communities, thus putting pressure on their political representatives whose lobbying lead to delays of project implementation and over commissioning household connections beyond the projects budget scope.

On other hand, 40 percent of stakeholders that had cited non independence of governing institutions as a problem, were more particular on non-independence with regards to regulation of the sector as shown in figure 4. The non-independence with regards to the regulation of the sector provides loopholes for political meddling in the running of the sector, and thus threatening the sustainability of private investments and the general attraction of such investments in the electricity sector, particularly in off-grid generation systems which have provided a platform for the electrification of remote areas. For instance, stakeholders stressed that although the Energy and Water Utilities Regulatory Authority (EWURA) had put in policies that allowed for flexible consumption tariffs that allowed cost recovery by off-grid investors (Sergiet al., 2018), the political pressure from some members of parliament and community leaders to lower tariffs charged by off-grid power producers so as to be at par as those charged by TANESCO for grid electricity which are financially unviable (Ahlborg and Hammar, 2011) may deter such investments and plunge the existing ones in uncertainties. While grid-based electricity projects may survive on non-cost reflective tariffs due to mostly being, on the one hand, subsidized by governments and, on the other hand, supported by a tariff system that sees urban dwellers cross-subsidize rural dwellers, such scenarios do not apply to off-grid private investments (Peters et al., 2019).Such political and community pressures culminate when off-grid served communities and grid-served communities are adjacent to each other or through communication by community members in the respective communities (Peters et al., 2019).

Nevertheless, apart from political interferences in the running of the energy sector, stakeholders pointed to the shortcomings of the existing policies, strategies and plans for the energy sector which either result in partial achievement of policy outcomes, creating uncertainties in the sector or missing out on funding opportunities for rural electrification in Tanzania. Several shortcomings were brought to the fore by stakeholders, the prominent one being the design of rural electrification projects through the REA and the least cited being the uncertainty of policy direction in the sector as shown in figure 5. By design, these projects subsidize the household's connection fees which have been a stumbling block to household's overall connection to electricity. Households under REA projects are required to only pay 27,000 Tshs (11.64 USD) flat fees for them to be connected. Nevertheless, the experience has shown that there are more less salient costs facing households beyond the connection fees when it comes to connecting the household to electricity. These costs include wiring costs which have been deemed expensive for low-income households in the rural areas and thus act as a barrier for household's connection to electricity. This has been substantiated in recent literature, whereby not only have wiring and other electricity fixture costs been deemed a barrier to household's connection to electricity, but it has also been pointed out that even the subsidized fee of 27,000 Tshs that households are supposed to pay is still not affordable to some households (United Republic of Tanzania, 2018: World Bank, 2016). Furthermore, Chaplin et al. (2018) reiterated that not only were the wiring and other electric fixture costs expensive for rural households but also these costs were much greater or equivalent to the standard connection fees that are being subsidized by rural electrification projects.

Figure 5: Barriers pertaining to policy direction, strategies, and rules of operation



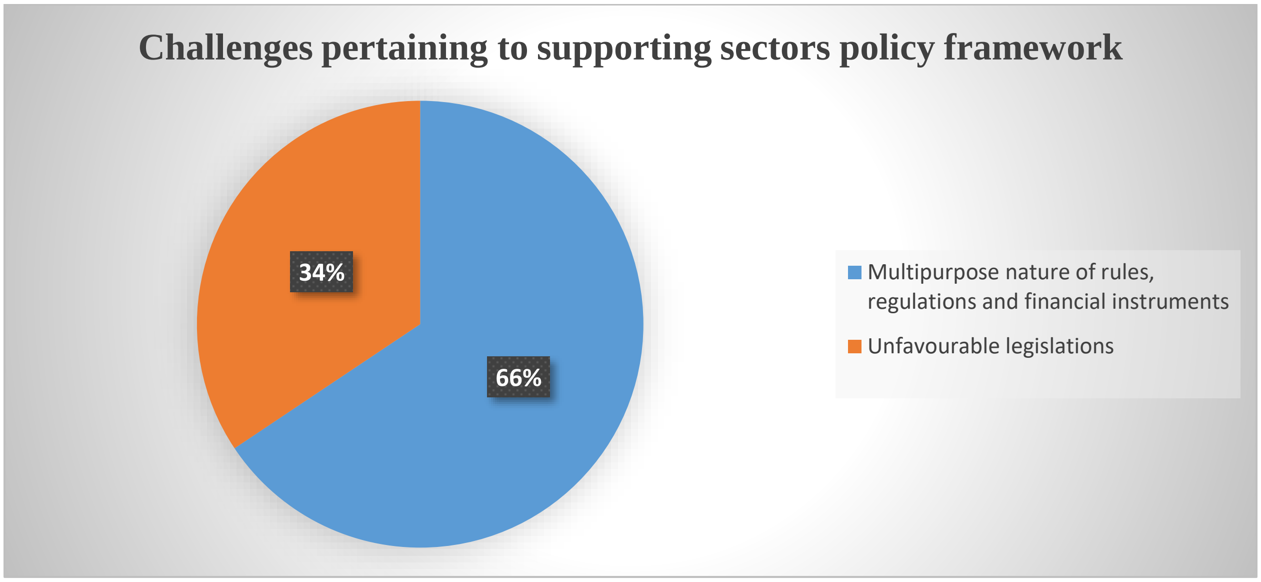
Moreover, stakeholders pointed to the policy structure pertaining to feed-in tariffs as another barrier to timely fruition of policy outcomes with regards to rural electrification in Tanzania. Whereas stakeholders commended the policy for enabling easier registration and cost recovery by investors in off-grids arrangements, the fact that the feed-in tariffs had to be subjected to reviews annually did not give room for long term planning with regards to increased access to rural households. This problem had already been identified by policy makers in Tanzania as articulated in one of their strategy reports that reiterated the problem with feed-in tariffs not only with the aspect of annual reviews by EWURA but also pertaining to the uniformity of tariffs regardless of the renewable technologies used in electricity production and the fact that there was no regulation that accounts for scenarios when the grid reaches areas where such investments were made, which may act as a deterrent for new off-grid investments and thus slow down rural electrification initiatives (United Republic of Tanzania, 2014). Nevertheless, it has been reiterated that policy incentives promoting private investments in the electricity sector would make the sector more attractive if and only if TANESCO were to improve its financial standing and the government to guarantee payment for power produced when TANESCO cannot do so (IRENA, 2017).Failure to observe this makes TANESCO accumulate and struggle to pay arrears which leaves investors short of cash and drives them into debts as they solicit loans to finance their operations (World Bank, 2016). Moreover, the policy design in its prevailing form, only supports greater involvement of the private sector in off-grid investments for SPPs, such measures that allow for flexible tariffs and ease market entrance should be extended to larger electricity grid-based projects, which have not seen enough private investments yet (Sergi et al.,2018). This may give lee way for increased electricity generation and thus have enough electricity to go around the whole country, reliably.

Some policy directions taken by the country and the uncertainty in timelines of policy implementation with regards to some of the plans in the energy sector may lead to the country missing on timely private investments and funding opportunities. One of the policy stances of the country in the electricity sector that was pointed out as a potential bottleneck with regards to securing funding for investments in the sector, is the country's pursuit of an electricity generation mix by 2040 that is heavily dependent on fossil fuels, particularly coal as stipulated in the Tanzanian 2016 Power Master Plan. One of the stakeholders posited that due to climate change concerns, donors are more interested in the supporting of renewable energy projects. Moreover, due to technological advancements and new innovations, renewables such as wind and solar energy generations systems have gradually gotten cheaper and are expected to be much cheaper in the future and thus provide cost effective generation options for the future. Priyavrat and Shweta (2018) had reiterated this concretely in their analysis of the Tanzanian Power Sector Master plan, where they raised caution with regards to financial and environmental costs, reduced interest by international investors and development partners pertaining to coal mining and use of coal for electricity generation. They further stressed that technological unreliability and costs associated with operations of renewable technologies are no longer feasible reasons for the country not pursuing renewable technologies due to technological advancements made in the area. Moreover, the increased global interest in renewables investments provides an opportunity for funding not to be missed.

Similarly, uncertainty in timelines with regards to implementation of projects also derails rural electrification efforts as investments in uncertain conditions are unattractive. Stakeholders pointed to the case of grid extensions over the country, whereby although the national energy policy along with the electrification prospectus clearly stipulate increasing electricity access through enhancement of the grid, timelines on when the grid would reach various parts of the country and priority areas have not been clearly demarcated. This makes investments in off-grid electricity infrastructures unattractive due to the uncertainty of when grid electricity would move-in in certain areas which have been identified by investors as ideal for off grid investments. According to the African Development Bank (2015), such information asymmetries on the power-generation and distribution investment plans, create worries among investors already on the ground and prospective investors about the risks and costs borne by private companies operating in off-grid generation systems once the grid electricity reaches their niche markets.

Furthermore, stakeholders stressed on the uncertainties and hurdles created by the supporting policy framework. This includes policies, rules and regulations and institutional setups in sectors other than the energy sector that support investments and operations in the energy sector or operations in multiple sectors. Most stakeholders, over 60 percent pointed to the multipurpose nature of the rules, regulations and financial instruments as a key barrier as shown in figure 5. It was stressed that as most of such policies, rules and regulations and institutional set ups are multipurpose in nature, some instruments have general and contextual shortcomings with regards to supporting the energy sector. The financial sector lending framework is one of such cases, whereby although the Tanzanian financial sector is well vested in offering loans through various instruments, the consensus has always been that the costs of borrowing are high. Nevertheless, when it comes specifically to energy project investments, the sectors lending instruments do not conform to the context in the energy sector in relations to its operation timelines, costs involved, and services produced. Furthermore, as stipulated in the literature the Tanzanian financial sector lacks expertise in evaluating energy projects and know-how of operations of such projects to come up with informative appraisals. Moreover, this, coupled with the high collateral requirements and the high risk attached to energy projects in Tanzania due to financial constraints of the main power buyer (TANESCO) makes lending to investors in this sector unattractive (IRENA, 2017).

Figure 5: Challenges pertaining to supporting sectors policy framework



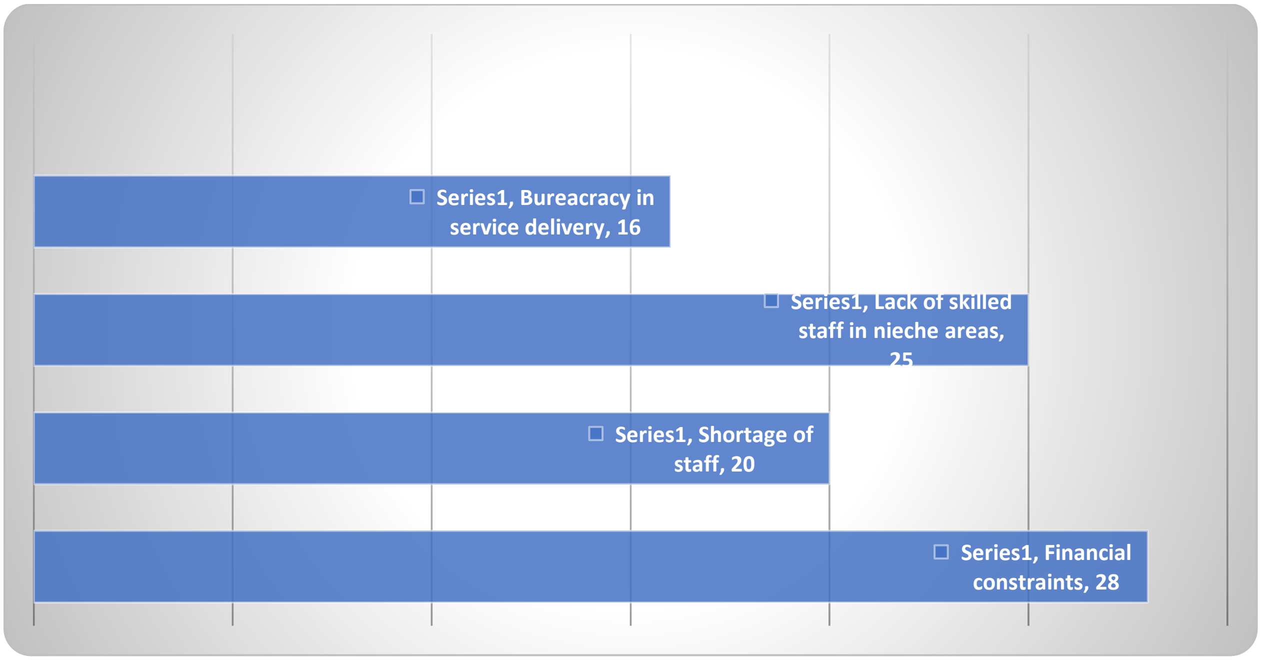
Moreover, 34 percent of stakeholders cited unfavorable legislations within the general policy realm of economy as shown in figure 6. Some of the supporting regulation frameworks that were highlighted to derail access to electricity projects include the local content aspect with regards to procurement in rural electrification projects and the new natural resource law(Natural Resource Act of 2017). Whereas the local content aspect in procurement of inputs and services for electrification projects, is aimed at supporting the industrialization agenda of the country and make sure that local producers become suppliers in the supply chain of various electrification projects, some of the local suppliers that have been given tenders do not have enough capacity to supply the required quantity of inputs on time and thus delay the implementation of various electrification projects, which has an impact on the timelines of the projects and the length at which the contractors have to be on site.

Furthermore, some stakeholders stressed that because producers of most inputs for electrification projects are still few in number and at times having monopolies in the production of some of the inputs, the producers consequently produce inputs at a high price compared to products of the same quality elsewhere. Owing to this,awarding tenders to such suppliers on the basis of local content polices goes contrary to the national and international procurement guidelines. The national and international procurement guidelines generally stipulates awarding tenders on the basis of international competitiveness while offering a percentage margin of preference to local firms, which may lead to missing out on funding opportunities for similar projects in the future due to conflicting guidelines and regulations of supporting frameworks.

Similarly, stakeholders pointed to uncertainties that have been created due to the recently passed Natural Resource Act 2017. The Act was passed as part of the patriotic drive of the country led by the Presidency to help citizens gain appropriately from natural resources (Woodroffe et al., 2019). The Act provides for renegotiation of any contract if it is deemed to have “unconscionable” terms as per criteria laid out in the Act. Unfortunately, these terms have been deemed broad by investors and thus create fear among investors with regards to the safety of their investments. This was one of the issues pinpointed as a barrier to new investments in the rural electrification sector (Woodroffe et al., 2019; Aly et al., 2018).

Nevertheless, institutional specific weaknesses and challenges of institutions governing the energy sector were pointed as barriers to timely implementation of rural electrification projects in Tanzania. Stakeholders pinpointed understaffing, shortage of equipment, financial constraints and bureaucracies associated service delivery as shown in figure 6, as some of the specific institutional weaknesses that derail timely implementation of electrification projects. These institutional challenges have been widely stipulated in literature, financial constraints being the prominent of them all. This is evident in the financial uncertainties that sometime plague REA and TANESCO. Whereas REA derive their funding from government grants through the normal government budget channels, grants from development partners and revenues specific levies on electricity and petroleum, REA does not have complete control of the inflow of such funds, and thus sometimes falls short of its planned budgets due to delayed or non-disbursement of amounts depicted in the national budgets or suspension of some of the grants by development partners due to various technical and regulatory related aspects of the projects. The shortage of funds for REA to implement its projects smoothly leads to delays in completion of rural electrification projects and the sizing down of targeted households in the commissioned projects (World Bank, 2016). On the other hand, TANESCO’s financial constraints are said to emanate from charging non-cost reflective tariffs and electricity lost due to transmission losses which stood at 17 percent in 2015 (Priyavrat and Shweta, 2018). TANESCO’s financial constraints as the sole entity responsible for power distribution and transmission creates uncertainties for investors and would-be investors in generation, and thus deprive the country of immediate investments to increase the amount of power generated.

Figure 7: Institutional specific weaknesses and challenges of institutions governing the energy sector

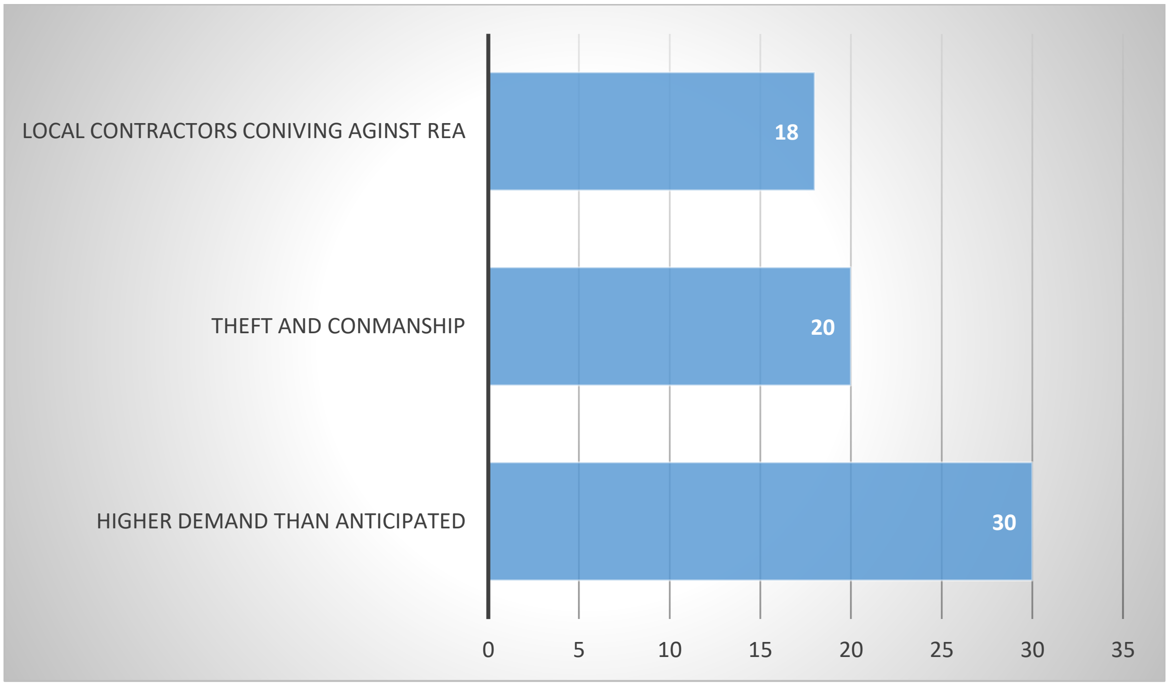


Moreover, shortage of staff has also been widely documented, whereby REA has been the most affected in this regard, especially when it comes to the monitoring and evaluation department of its rural electrification projects. As stipulated by most policy documents in the country, electrification projects aim at alleviate poverty and improve standards of living of households, thus playing a crucial role in social development (United Republic of Tanzania, 2013). The only way to know the impact of such projects is to have a well-staffed monitoring and evaluation departments that come up with detailed evaluations of various interventions with regards to electrification and impacts of such interventions, and thus come up with thorough recommendations for improvement and sustenance of the interventions in question. On the other hand, lack of knowledge and capacity in niche areas such as renewable energies, makes carrying out of feasibility studies, planning and other technical related studies pertaining to renewables and other energy investments projects and hence the country not being able to take advantage of new and cheaper technologies and investments in the renewables electricity sector (Africa Development Bank, 2015).

Nevertheless, shortage of equipment and bureaucracy in service delivery is another institutional challenge plaguing institution governing the energy sector in Tanzania, particularly TANESCO. As pointed out by stakeholders and widely documented, in some electrification projects and interventions, household's connections have been constrained by shortage of materials from TANESCO's end needed for household's connections, such as poles, conductors and earth poles. Furthermore, there is excessive bureaucracy in service delivery resulting in applications for connections taking longer to be processed than anticipated (Miller et al., 2015).

On the other hand, stakeholders also pointed to social inherent barriers to household connections to electricity, which emanate from within the targeted communities. Stakeholders pointed to higher than anticipated demand for electricity connections, theft of connection fees and local contractors conniving against REA's modern technologies as shown in figure 7. In some projects the demand for electricity was higher than anticipated, preventing some of the households from being connected when the contractor was on site, and thus leaving the connected households with a burden of paying higher connection fees, which most of them could not afford. This problem synonymously occurs when household's awareness about rural electrification campaigns in their areas was low or households did not believe in the authenticity of subsidized connection programs, maybe in fear of it being a rogue scheme, and thus only believed after seeing a few households that had benefited from the Program (United Republic of Tanzania, 2018; Miller et al., 2015).

Figure 8: Community specific challenges



Nevertheless, household's tendencies to have reservations about subsidized household electricity connections stems from the fact that some intervention programs in the past have been plagued by conman ship and theft. Rural electrification projects have also been plagued with theft, as some unfaithful members of the community have impersonated REA or TANESCO officials and collected the connection fees from households, who end up not getting connected during the project due to fraud.

On the other hand, some resident electricians within the communities have also tried to connive against REA and thus downplay some of the innovative technologies REA has come up with to aid quicker household connections to electricity. For example, REA has come up with a board that enables a household to attach a bulb and socket for charging phones along with other utilities, thus save the households in the rural areas the cost of doing wiring for the entire household; these enabled connections to be done in any type of housing regardless of its building materials.

Nevertheless, such technologies have been mislabeled as “dangerous, susceptible to fire” by some members of the society due to a low understanding of how the technology works and resident electricians who hope to benefit from household wiring jobs. This makes the use of such technologies hard for areas where housing materials may not be adequate for the full-scale wiring of the house or in area where wiring costs could be hindrance to household’s connection to electricity (Miller et al., 2015).

THE INTERACTIONS

In a nutshell, the views from the stakeholders confirm the role of political clergy and institutions in the delay of implementation of rural electrification projects in Tanzania. Whereas the political elite may delay projects and interfere in the running of established institutions in the sector due to their power and authority elicited from the people, so will state designated energy entities due to their weaknesses financially and capacity-wise in terms of human and physical resources. This lack in capacities, more importantly human resources in terms of expertise, may result in plans that are not well informed in terms of technologies in use and actual costs pertaining to projects in terms of the costs of inputs and operations within the regulatory framework present in the country, which has been vindicated in plans of incorporating coal and less of renewables in the generation mix of the country in the future, thus end adopting cost inefficient ways from the start and thus make the electrification process as a whole unstainable due to high generations costs (Priyavrat and Shweta, 2018). As stipulated by Ahlborg and Hammar (2011), whereas political priorities drive rural electrification in Tanzania, national energy entities face critical institutional and financial constraints which lead to flawed or no planning at all and subsequently ineffectual implementation of rural electrification projects.

Moreover, a subsequent deduction from our discussion is that, due to financial constraints facing the governmental energy entities in the sector, private investors and donors have had a major role to play in terms of financing the electrification process in terms of investments, loans and grants as discussed earlier. Nevertheless, this has given financers power in dictating the direction the country's energy sector would pursue. This is typically evident in terms of choice of generation projects that donors choose to fund, whereas others only support renewable technologies investments with climate change concerns at the forefront, others are open to supporting investments in fossil fuels generation and associated projects (Aly et al., 2018; Serge et al., 2018). Thus, countries like Tanzania that have-not incorporated a big percentage of renewables in their plans may miss out on funding for electricity projects. Such missing out will impact the aspirationto improve the reliability of electricity supply that is enough to distribute across both urban and rural areas and thus see the full manifestation of electrification impacts in the rural areas. On the other hand, a question of sustainability of using such a model of donor dependency in improving access to electricity as a whole and rural electrification hover over the sector. Most of the donor support, is committed to the expansion of electrification through grid electrification projects, commitments for off-grid projects which could by far be useful to electrify remote rural areas are still very low (Serge et al., 2018). Moreover, this dependency brings about budget uncertainties and thus impacts implementation outcomes (Ahlborg and Hammar, 2011).

Nevertheless, even though the country has done its fair share to attract investors in the electricity supply industry, there are still uncertainties created by the regulations, an example being the uniform tariff setting system for all off-grid renewable power generating projects, which hinders the investors' ability to recover their costs, thus limit further investments by prospective investors and ultimately slowing down rural electrification initiatives. Furthermore, some of the country's laws in other supporting sectors also impact rural electrification efforts by delaying timely investments in the electricity supply industry which is integral in improving access to electricity and rural electrification. These laws raise uncertainties due to either inducing operational procedures contrary to the norms of donor's host countries and investor's origin of capital or concerns with safety of their investments in the country.

On the other hand, our analysis also deduced some areas that have been covered concretely by the policies, strategies, and interventions on the ground, with regards to rural electrification. For example, in accordance with the stakeholder's views, subsidization of connection fees by the Tanzanian government has not solved the affordability problem, moreover, the fact that the subsidy is only effective when the contractor is on site brings about the question of sustainability of such interventions in the long run.

4.6 Conclusion and Policy Implications

The paper looked at the institutional barriers to rural electrification in Tanzania. It specifically substantiated if the political clergy and energy sector governing entities in Tanzania constrain the smooth implementation of rural electrification projects, moreover the study investigated if the current rules, regulations and laws within the electricity supply industry and supporting sectors support the smooth investments in electrification projects in rural areas, and lastly the paper analysed the policies, strategies and interventions within the energy sector with regards to rural electrification. The paper borrowed conceptually from the Institutional and Development Framework by Ostrom (2005) as stipulated in Polski and Ostrom (1999) and applied qualitative methods to analyze the institutional barriers to rural electrification in Tanzania. Data was collected through key informant interviews from various stakeholders in government institutions, donors, international institutions, and research community affiliated to the Tanzanian energy sector and prominently, the electricity supply industry. The paper was further supplemented with literature from peer reviewed articles, institutional and government reports.

The stakeholder interviews revealed barriers pertaining to non-independence of institutions within the energy sector which delays the implementation of projects, results in over commissioning of households to be electrified in rural electrification projects and uncertainties in investment environment due to interference in setting up of cost reflective tariffs. Moreover, stakeholders stressed that some of the deficiencies of the existing policies, strategies and interventions pertaining to rural electrification led to unsatisfactory outcomes with regards to number of connected households. Some of these deficiencies are an unresolved affordability problem beyond the connection fees covered by the subsidies, unsustainability of investments due to tariff regulations that do not provide for full cost recovery and missing out on prospective funding due to the policy direction pursued by the country. On the other hand, supporting sectors framework's *modus operandi* are not accustomed to support specific investments in the electricity supply industry, others lead to delay of implementation of rural electrification projects themselves with regards to procurement procedures. Moreover, the laws governing some of the supporting sectors create uncertainties with regards to investments in electricity supply industry. Nevertheless, institutional specific challenges such as financial constraints and shortage of staff facing the various energy governing institutions like TANESCO and REA respectively have also led to the delay of project implementation and inadequate monitoring of projects. Lastly stakeholders stressed on the community and social inherent challenges such as awareness issues during project implementation, petty theft of project equipment and conmanship as factors depriving a large percentage of households the opportunity to be connected during the project phase.

The results have substantiated how politics and institutions within the energy sector derail the pace at which rural electrification takes place due to interfering with the mandate of the respective institutions and the inherent challenges facing the energy governing institutions within the sector. Moreover, due to financial constraints and need for investment in the sector to push rural electrification and the electrification agenda, the financers have acquired much power and authority of shaping the energy sector in terms of resources to be used and the kind of technologies they would support. Nevertheless, despite the country's efforts to attract private investments, some of the rules and regulations still fall short in some areas to make the investments in the area sustainable in terms of costs. Analogously, the regulations in other supporting sectors still fall short in instilling full confidence with regards to safety of private investments in the country. On the other hand, some of the policies, strategies and interventions have not solved the fundamental issues with regards to household's adoption of electricity in rural areas. The paper puts forward a few recommendations to smoothen the institutional barriers in the electricity supply industry in line with the barriers identified in the paper.

Household energy transitions have been mostly deterred by affordability issues in most sub-Saharan African countries. Although Tanzania has done its fair share through its rural electrification initiative which subsidizes connection fees, the initiative would benefit by taking into account the extra costs that a household faces for the connection to be completed. REA has already come up with innovative technologies to do away with wiring costs, it's imperative to promote these technologies so that they are readily accepted by rural households by raising awareness on the importance and usefulness of such technologies. Moreover, Programs could include a wiring component in terms of subsidies or credit schemes so as to enable the transition to take place. Nevertheless, as reiterated in literature subsidies will only be sustainable in the long run if development partners and the country continue working together. On the other hand, other interventions have been suggested before and implemented in other contexts as a substitute for subsidies, these include the reduction of connection fees and spreading the subsidized amount over a period as part of usage fees (Miller et al., 2015). Some projects implemented in Tanzania, have provided strong evidence of the impact of lowered connection fees on connection rates (Miller et al., 2015). These initiatives would be of much help to households in the long run when combined with the current subsidy interventions applicable when the contractor is on site, so that households that have not been connected during the project phase can still be incentivized to do so. Furthermore, the push by development partners and piloted by REA for use of low-cost network designs and technical standardization should be advocated so as to lower the cost of rural electrification projects and subsequently address affordability (World Bank, 2016).

The country should also iron out a few issues with regards to private investments in the country as raised by stakeholders. As reiterated in the country's electricity prospectus, provision of loans, lower financial risk and establishment of loan guarantee schemes are paramount for private investments in the sector (United Republic of Tanzania, 2013). The country has put in several instruments to support private investments, but as revealed from stakeholder interviews a few regulations issues still must be ironed out. As revealed in the stakeholder's interviews, the issue of feed in tariffs to consider the technology used is something paramount for the sustainability of private investments, in line with recommendations in official government reports and development partners (United Republic of Tanzania, 2013: African Development Bank, 2016).The world Bank through the Tanzania energy development and access expansion project have led way in rectifying these anomalies within the sector with regards to feed in tariff schemes. The bank's support to EWURA has resulted into a much-improved regulatory environment for SPPs that is transparent and revision of SPPs regulation rules which made feed in tariffs be calculated based on generation technologies used (World Bank, 2016). Moreover, the country should also iron out policy uncertainties with regards to when national grid investments would reach, what will happen to the off-grid investments. This has started being addressed by the ministry through EWURA. Nevertheless, with regards to new laws governing the investment sector as a whole that have created uncertainties, the government through the ministry of foreign affairs should make an effort to have dialogue with development partners and investors on the good and patriotic intentions enshrined within the laws and how the country is committed in safe guarding private investments in the country, and come up with clear rules and guidelines of how the laws will effected in line with international regulations safeguarding investments.

On the other hand, the country may find it handy to consider the direction of using more renewables to harness the readily available funds in the global renewables sector, as the world moves away from the use of fossil fuels to combat climate change. As reiterated in literature, the advancement in science and technologies has made the use of renewables much cheaper. Moreover, studies have shown that incorporating renewables could constitute a least cost energy mix rather when combined with other few fossil generation sources (IRENA, 2017). Moreover, the country's potential with regards to renewable energy resources is massive with regards to hydro power and solar (Ahlborg and Hammar, 2011). The country has continued to take advantage of the big capacity that comes with hydro power generation with the commissioning of the Stigler's gorge hydro power project. Nevertheless, because of droughts that have previously engulfed the country whilst its generation mix was heavily dependent on hydro, it isimportant to integrate projects that use other renewables too to complement the hydro generation. The inclusion of more renewables not only provides a platform for access of much needed funds to push rural electrification, but also renders a way to electrify remote areas much cheaply through off grid systems and thus improve energy access for the poor (Priyavrat and Shweta, 2018: IRENA, 2017: African Development Bank, 2013). On the other hand, in instances like Tanzania's, where the country has abundant reserves of coal, the country should seek cooperation with development partners who can invest in advanced technologies that can abate the harmful emissions accompanied with coal power generations (Aly et al., 2018).

Nevertheless, the country should strive to solve problems that have inherently perturbed key energy sector institutions like TANESCO and REA. Firstly, the institutions should be allowed to exercise their mandates without political interference so as to make expert informed decisions that are optimal for the sector and smooth implementation of projects. Moreover, the institutions themselves should eliminate any bureaucratic tendencies in service delivery so as to reduce lags in service delivery. Analogously, reducing uncertainties that emanate from delays of procured materials for electrification projects due to low capacity of local suppliers. The local companies responsible for supplying rural electrification projects should equip themselves to procure materials of high quality in bulk, so that projects can meet their timelines. Furthermore, enhancement in the capacity of their personnel should be at the fore front to aid the electrification agenda, so as to have ample expertise when it comes to planning and analyzing ample energy paths the country should pursue, monitoring of project outcomes and deduction of ample recommendations.

Furthermore, TANESCO and REA should improve their financial viability. Whereas raising of tariffs has always been viewed as an ample way to increase revenues forTANESCO, a reduction in technical losses with regards to transmission and distribution would go a long way in increasing the power supply TANESCO can supply and increase its revenues in line with most of the stakeholder's views in the sector. Moreover, the government should effectively implement the decision to transfer the petroleum levy collections to REA to make the institution more certain with regards to finance. Moreover, a minimal increase in the levy could be an avenue for REA to raise funds to sustainably subsidize some of its projects effectively (World Bank, 2016).

Generally, Improvement of household's access to modern energy services is paramount for facilitating economic growth and improving welfare, as enshrined in goal number seven of the United Nations sustainable development goals. Whereas policies, strategies and interventions try to effect factors pertinent at household level and national level, it is equally important to improve the institutional factors to improve the operations and implementation efficiency of rural energy projects. Rural electrification in Tanzania would benefit from smooth institutional processes in terms of rules and regulations, improved capacity in terms of warranted skills and human resources of the implementing institutions and subsequently well formulated interventions to trigger household energy transitions.

Chapter Five

General Conclusion

5.1 Summary of findings

Access to modern energy services is necessary for any country's economic transformation as enshrined in goal number 7 of the United Nations 'Sustainable Development Goals and prioritized in the Tanzanian 2015 Energy Policy. The Tanzanian energy policy is centered on improving access, reliability, and affordability of modern energy services. Up to the year 2018, Tanzania was among a small group of countries that dominated both the top 20 lists of countries in the world with electricity and modern cooking energy access deficits, respectively. Nevertheless, whereas the country's electrification rate and access to electricity have increase over the years, the country's use of modern cooking technologies is still dwindling. Moreover, country's political stability, wealth in policies, plans and strategies within the energy sector and the strategic position it enjoys with development partners made it an interesting case study to understand the economics of household energy transition.

The thesis examined the economics of household energy transitions in Tanzania. The thesis was premised around three key issues deduced from the country's household energy use scenario. The Tanzanian's energy use scenario first depicts a heavy reliance on wood fuels (charcoal and firewood) for cooking with 90 percent of Tanzanian households using wood fuels for cooking. Secondly, it depicts gradual and modest improvements in household's modern energy use, with regards to electrification and use of modern fuels for cooking particularly in urban areas (LPG and Electricity) which need to be linked to household welfare to warrant evidence-based importance of household energy transitions. Thirdly, the scenario depicts that despite having elaborate policies, plans, strategies, and programs in place, most of the Tanzanian households in the rural areas have not transitioned to the use of modern energy services. Thus, from these key issues the thesis specifically (i) analyzed the role of social capital in the adoption of modern cooking fuels in Tanzania (ii) substantiated the impact of household energy transition on household welfare in Tanzania and (iii) Analyzed the institutional barriers to rural electrification in Tanzania, which formed the three substantive chapters (chapter two, chapter three, and chapter four, respectively).

The second chapter modeled the determinants of household adoption of modern cooking fuels, with an emphasis on the role of social capital in the adoption of modern cooking fuels (LPG and Electricity). As the adoption of fuels such as electricity and LPG entail the use of complex technologies, social capital could affect the adoption of such technologies through knowledge sharing, peer-pressure towards adoption and fundraising.

We utilized membership into key community groups; Savings and Credit Co-Operative Societies (SACCOS) and other self-help groups as a measure of social capital. We make use of three waves of the 2008-2016 Tanzanian panel data set from a nationally representative household panel survey that collects information on a wide range of topics such as agricultural production, non-farm income generating activities, consumption expenditure, and several other social-economic characteristics of the households.

We employed panel data techniques to ascertain the role of social capital on household energy transitions in Tanzania. For robustness purposes, we ran two regression analyses, one incorporating the social capital variable as a dummy variable and the other as a continuous variable to observe the stability of our results. Moreover, beyond the panel data model specifications, we ran alternative model specifications to check the stability of our results. The paper contributed to literature by first going beyond the income, and social demographic determinants of household adoption of modern cooking fuels and bringing in the aspect of social capital. Moreover, by using membership in key community groups as proxy for social capital, it allowed us to study the role of structural social capital, and thus go beyond the common aspects of social capital explored in literature, such as social networks, social learning, and peer effects. Furthermore, the paper's use of nationally representative panel data set enabled us to consider household heterogeneity in our analysis.

The third chapter investigated the impacts of household energy transitions on welfare indicators in Tanzania. We conducted two impact analyses, whereby we analyzed the impact of household's use of modern cooking fuels (LPG and electricity) on household welfare indicators (energy expenditure and health) and the impact of household use of electricity on household welfare indicators (energy expenditure, time use, study hours, acute respiratory health). The paper used two nationally representative data sets, that is the fourth wave of the national panel survey of 2014/15 and the 2015/16 Tanzanian Demographic and Health and Malaria Indicator Survey to analyze the impacts of household energy transitions on non-health and health related outcomes, respectively. We employed propensity score matching techniques to ascertain the impact of household energy transitions. We estimated the propensity scores, chose the appropriate matching algorithm to do the matching assessed the matching quality and performed a sensitivity analysis of the results. The paper contributed to the literature by comprehensively looking at the impact of household energy transition for both cooking and lighting and added to the few quantitative studies on impact of household energy transitions in Tanzania. Moreover, our study provides the first suggestive evidence of the impact of household's use of electricity and modern cooking fuels on fertility and health, respectively in Tanzania.

The fourth chapter investigated the institutional barriers to rural electrification in Tanzania. We investigated if the political clergy and energy sector governing entities in Tanzania constrain the smooth implementation of rural electrification projects. Moreover, we investigate if the current rules, laws, and regulations in the electricity supply industry and supporting sectors attract investments in rural electrification projects. Furthermore, we review policies, strategies, and interventions within the energy sector with regards to rural electrification. We used primary data collected from key informants in the sector and augmented this with secondary data from official reports and periodicals from key government and non-government entities in the electricity supply industry sector. The paper adopted the Institutional and Development Framework (IDF) by Ostrom (2005) to systematically substantiate the institutional challenges. We used qualitative data techniques to ascertain the key institutional barriers to rural electrification in Tanzania. The paper added to the existing literature by systematically analyzing the policy paradigm in the energy sector using the IDF, whose use in other fields of expertise other than its famed use in the analysis common pool resources shows how the framework generally facilitates institutional analyses. Moreover, our analysis brings out challenges after the enactment of 2015 Energy Policy and expansion of the rural electrification program in 2016 and thus provides a contemporary view of challenges facing rural electrification initiatives.

The results of chapter two revealed that social capital plays an important role in household energy transitions. Households with membership in self-help groups or Savings and Credit Co-Operative Societies (SACCOS) were more likely to adopt modern cooking fuels (LPG and electricity). Membership in these groups help households 'members to acquire assets associated with the use of modern energy for cooking. Affiliated members can access loans with very low interest rates. This provides credit-seeking households with the financial means to pay for gas cylinders, electrification, and electric/gas stoves they would not have been able to afford under normal circumstances, thus mitigating liquidity constraints. Moreover, these groups help raise awareness, gain technical information about new technologies including modern energy.

Our results suggested that other specific means of communication (i.e., a phone or radio), not based on face-to-face interactions, do not trigger the adoption of modern cooking fuels. The only exchange of information that seems to work in stimulating behavioral change to induce adoption of modern cooking fuels emanates from direct and physical interactions between members of the self-help groups and SACCOS. Our results remained stable in the different specifications of the social capital variable and econometric models. The results also reveal that household income, household's head age, household size and availability of biomass stoves and electricity connection to be important determinants of household's adoption of modern cooking fuels.

The results of chapter three revealed significant impacts of household energy transitions on household welfare indicators. Household use of modern cooking fuels was found to significantly reduce charcoal expenditures, and consequently amount of charcoal used in urban areas. Moreover, the results revealed that use of modern cooking fuels was associated with a reduction of respiratory infection for children under five years of age. On the other hand, household use of electricity was found to improve study hours, years of schooling and consequently schooling outcomes. Moreover, we find suggestive evidence that electrification smoothens information flows and augments social campaigns, thus promoting issues like family planning. The chapter also reveals an elongation of the working day due to electrification.

The results of the fourth chapter show institutional barriers pertaining to non-independence of institutions within the energy sector, deficiencies of the existing policies, strategies and interventions pertaining to rural electrification, the supporting framework's modus operandi not accustomed to serve the electricity supply sector, the uncertainties created by the laws and regulations governing the sector, and the institutional specific challenges such as financial constraints and shortage of staff facing the governing institutions in Tanzania formed some of the key bottlenecks hampering the timely implementation of and achieving of desired outcomes by rural electrification projects in Tanzania as perceived by the stakeholders in the Tanzanian electricity supply industry.

Whereas barriers pertaining to non-independence of institutions within the energy sector which delay the implementation of projects, resulted in over commissioning of households to be electrified in rural electrification projects and uncertainties in investment environment due to interference in setting up of cost reflective tariffs, stakeholders stressed that some of deficiencies of the existing policies, strategies and interventions pertaining to rural electrification lead to unsatisfactory outcomes with regards to number of connected households. This is due to an unresolved affordability problem beyond the connection fees covered by the subsidies, unsustainability of investments due to tariff regulations that do not provide for full cost recovery and missing out on prospective funding due to the policy direction pursued by the country.

On the other hand, supporting sectors framework's modus operandi are not customized to support specific investments in the electricity supply industry, thus leading to delay of implementation of rural electrification projects themselves with regards to procurement procedures. Moreover, the laws governing some of the supporting sectors create uncertainties with regards to investments in electricity supply industry. Nevertheless, institutional specific challenges such as financial constraints and shortage of staff facing the various energy governing institutions like TANESCO and REA, respectively, have also led to the delay of project implementation and inadequate monitoring of projects. Lastly, stakeholders stressed on the community and social inherent challenges such as awareness issues during project implementation, petty theft of project equipment and conman ship as factors depriving a large percent of households the opportunity to be connected during the project phase.

5.2 Policy implications of the findings

The revealed results point to key policy implications. The results from chapter two point to the need to enhance financial inclusion through groups like self-help groups, SACCOS and others of the like in Tanzania as their financial intermediary role helps households in mitigating liquidity constraints. This could be in the form of targeted credit facilities through these groups specifically for the financing of household modern energy infrastructure and the purchase of assets associated with the use of modern fuels for cooking.

Literature has shown that providing credit through groups like the ones explored in this paper goes a long way to ease access to credit for purchase of modern cooking fuels. Specific programs that took this initiative on board such as Switch SA and supported with awareness campaigns on the usefulness of modern cooking technologies, including their health associated benefits along with other incentives for adoption of modern cooking fuels in Haiti have proven successful (ENERGIA, 2014). Moreover, groups like these in the villages could potentially be used in the dissemination of information about modern cooking technologies and thus ease the diffusion of new technologies in the rural areas.

The results in chapter three point to the need for the government to promote the use of modern cooking fuels to cut down the amount of charcoal used, particularly in urban areas. The government should make households more aware of ventures to aid household energy transitions towards the use of such fuels, such as the roll out of natural gas in homes. Policies advocating a reduction in excessive use of charcoal and other traditional cooking by shifting to modern cooking fuels may go a long way in reducing hospital visits by children due to respiratory infections. Moreover, the government should continue it vigorously to improve electricity access, particularly in the rural areas, as electrification may go a long way in improving household welfare through improving schooling outcomes, support small businesses and elongating a working day.

The results of chapter four point to the need for the government to further deal with affordability issues, with regards to cost not covered by the subsidies offered by the government in its rural electrification initiatives. Whereas the current subsidies only cover the connection fees, the government should deliberate to expand and cover additional costs pertaining wiring. This could be achieved either through expanding the already available subsidies or through well targeted credit schemes, as subsidies would only be sustainable in the long run if the government continues to get the financial support from its development partners. Other interventions suggested by the literature include a further reduction of the connection fees and spreading of the extra costs beyond connection fees over a period as usage fees (Miller et al., 2015). Moreover, this should be done during and after the implementation of the projects, so that households that have not been connected during the project phase can still be incentivized to do so. Furthermore, to lower the usage fees and associated costs, TANESCO and its partners should consider using low-cost network designs as well as technical standardization should be advocated in order to lower the cost of rural electrification projects and subsequently address affordability (World Bank, 2016).

The government should also iron out a few issues with regards to regulation and schemes in place to attract more private investment in the energy sector. For instance, the government should continue its efforts to better the feed in tariffs, to consider the technology used is something paramount for the sustainability of private investments, in line with recommendations in official government reports and development partners (United Republic of Tanzania, 2013: African Development Bank, 2016). The World Bank through the Tanzania Energy Development and Access Expansion project have led the way in rectifying these distortions within the sector with regards to feed in tariff schemes. The World Bank's support to EWURA has resulted into a much-improved regulatory environment for SPPs that is transparent and revision of SPPs regulation rules which made feed in tariffs be calculated based on generation technologies used (World Bank, 2016). Moreover, the country should also iron out policy uncertainties with regards to when national grid investments would reach, what will happen to the off-grid investments. This has started being addressed by the Ministry through EWURA. Nevertheless, with regards to new laws governing the investment sector as a whole that have created uncertainties, the government through the Ministry of Foreign Affairs should make an effort to have dialogue with development partners and investors on the good and patriotic intentions enshrined within the laws and how the country is committed to safe guarding private investments in the country. This should be coupled with coming up with clear rules and guidelines of how the laws will be effected in line with international regulations safeguarding investments.

Furthermore, the government should be shrewd enough to align its policies with the global energy and climate change polices to easily solicit funding for its projects. Currently, the country should think about increasing renewables in its energy mix so as to harness the readily available funds in the global renewables sector, as the world moves away from the use of fossil fuels to combat climate change. The country's commissioning of Stigler's gorge hydro power project is one step in the right direction. Nevertheless, since hydro power generation is subject to droughts, other renewables should be advocated and entrenched in the country's grid, mainly solar and wind power. The inclusion of more renewables not only gives a platform for access of much needed funds to push rural electrification, but also provides away to electrify remote areas much cheaply through off grid systems and thus improve energy access for the poor (Priyavrat and Shweta, 2018: IRENA, 2017: African Development Bank, 2013). On the other hand, in instances like Tanzania's, where the country has abundant reserves of coal, the country should seek cooperation with development partners who can invest in advanced technologies that can abate the harmful emissions accompanied with coal power generations, such as carbon sequestration (Aly et al., 2018).

5.3 Areas for further research

Further research with regards to intensity of use of modern energy fuels would give a much broader insight on the impact of household energy transition in Tanzania. Moreover, to differentiate the impacts clearly, an impact evaluation that considers households that use modern energy fuels alone and those that use them in multiple fuels use scenario would be useful.

Moreover, a much more vigorous community perspective analysis into why rural households are not connected to electricity, even when connection fees were subsidized, should be conducted to elicit all policy triggers that have not been covered by the rural electrification program.

References

Abadie, A. & Imbens, G., (2008). On the Failure of the Botstrap for Matching Estimators. *Econometrica,* 76(6), pp. 1537-57.

Abudullahi, D., (2017). Key barriers to the implementation of Solar energy in Nigeria. *IOP Conference Series: Earth and Environmental Science,* p. 83 012015.

Adrianzén, M. A., (2013). Improved cooking stoves and firewood consumption: Quasi-experimental evidence from the Northern Peruvian Andes. *Ecological Economics,* pp. 135-143.

Aevarsdottir, M. A., Barton, N. & Bold, T., (2017). *The impacts of rural electrification on labor supply, Income and and health E-89302-TZA-1,* London: International Growth Centre.

African Development Bank, (2008). *Clean Energy Investment Framework for Africa,* Cote d'Ivore: Operations Policies and Complience Department: AFDB.

African Development Bank, (2015). *Renewable Energy in Africa: Tanzania Country Profile,* Côte d'Ivoire: AFDB.

African Development Bank, (2016). *The Bank's Group Strategy for The New Deal on Energy for Africa ,* Cote d'Ivore: AFDB.

Aguirre, J., (2017). Impact of rural electrification on education: A case study from Peru. *The Lahore Journal of Economics,* p. 91–108.

Ahlborg, H. & Hammar, L., (2011). *Drivers and barriers to rural electrification in Tanzania and Mozambique – grid extension, off-grid and renewable energy sources,* Linköping, Sweden: Linköping University Electronic Press.

Aikaruwa, D. B., Sumari, G. A. & Maleko, G. N., (2014). Social Functionality of Self Help Groups in Tanzania. *Journal of Business Administration and Education,* pp. 99-136.

Akpalu, W., Dasmani, I. & Aglobitse, P. B., (2011). Demand for cooking fuels in a developing country:To what extent do taste and preferences matter?. *Energy Policy,* pp. 6525-6531.

Alem, Y. & Ruhinduka, R. D., (2020). Saving Africa's Tropical Forests through Energy Transition: A Randomized Controlled Trial in Tanzania. *Ruhr Economic papers, No 885.*

Alem, Y., Hassen, S. & Kohlin, G., (2013). The Dynamics of Electric Cookstove adoption: Panel Data evidence from Ethiopia. *RFF Discussion Paper,* pp. EfD 13-03.

Alem, Y., Hasssen, S. & Kohlin, G., (2014). adoption and disadoption of electric stoves in urban Ethiopia: Evidence from panel data. *Resource and Energy economics,* pp. 110-124.

Alem, Y., Ruhinduka, R., Berck, P. & Bluffstone, R., (2015). *Credit, LPG stove adoption and Charcoal consumption:Evidence from randomized control trial; E-89225_TZA-1,* London: International Growth Centre.

Aliston, J. M., Foster, K. A. & Gree, R. D., (1994). Estimating Elasticities with the Linear Approximate Almost Idal demand System: Some Monte carlo results. *The Review of Economics and Statistics,* pp. 351-356.

Aly, A. et al., (2019). Barriers to Large-scale Solar Power in Tanzania. *Energy for Sustainable Development,* pp. 43-58.

Andadari, R. K., Mulder, P. & Rietveld, P., (2014). Energy poverty reduction by fuel switching. Impact evaluation of the LPG conversion program in Indonesia. *Energy Policy, 66* , pp. 436-449. doi:10.1016/j.enpol.2013.11.021.

Arraiz, I. & Calero, C., (2015). From Candles to Light: The Impact of Rural Electrification. *IDB WORKING PAPER SERIES No. IDB-WP-599*, pp. May, 2015.

Atieno, P. O., (2017) . Self Help Groups and Household Asset Acquisition and Income Among Women Group Members in Kisumu East Sub County, Kenya. *Journal of Education and Practice* , pp. 2222-1735 .

Azimoh, C. L., Klintenberg, P., Wallin, F. & Karlsson, B., (2015). Illuminated but not electrified: An assessment of the impact of Solar Home System on rural households in South Africa. *Applied Energy, 155* , pp. 354-364. doi:10.1016/j.apenergy.2015.05.120.

Baker, P., Blundell, R. & Mickelewright, J., 1989. Modelling Husehold energy expenditures using micro-data.. *Economic Journal 99,* pp. 720-738.

Barron, M. & Torero, M., 2015. *Electrification and Time Allocation,* s.l.: MPRA Paper No. 63782.

Barron, M. & Torero, M., 2017. Household electrification and indoor air pollution. *Journal of Environmental Economics and Management,* Volume 86, pp. 81-92.

Bauwens, T. & Defourny, J., 2017. Social capital and Mutual versus Public benefit: The case of renewable energy cooperatives. *Annals of Public and Cooperative Economics,* April.

Bekker, B., Eberhard, A., Gaunt, T. & Marquard, A., 2008. South Africa's rapid electrification Program: Policy, institutional, planning, financing and technical innovations. *Energy Policy,* p. 3125– 3137.

Beltramo, T. & Levine, D. I., 2013. The effect of solar ovens on fuel use, emissions and health: results from a randomised controlled trial. *Journal of Development Effectiveness,* pp. 178-207.

Beltramo, T., Blalock, G., Levine, D. I. & Simons, A. M., 2015. Does peer use influence adoption of efficient cookstoves? Evidence from a randomized controlledtrial in Uganda. *Journal of Health Communication,* pp. 55-66.

Bensch, G., Grimm, M. & Peters, J., 2015 . Why do households forego high returns from technology adoption? Evidence from improved cooking stoves in Burkina Faso. *Journal of Economic Behavior and Organization, 116* , pp. 187-205. doi:10.1016/j.jebo.2015.04.023.

Bensch, G., Kluve, J. & Peters, J., 2011. Impacts of Rural Electrification in Rwanda. *IZA Discussion Paper No. 6195.*

Bernard, T. & Torero, M., 2015. Social Interactions Effects and Connection to Electricity: Experimental Evidence from Rural Ethiopia. *Economic Development and Cultural change.*

Bernard, T. & Torero, M., 2020. Social Interactions Effects and Connection to Electricity: Experimental Evidence from Rural Ethiopia. *Munich Personal RePEc Archive,* pp. MRA paper No 61303, online at http://mpra.ub.uni-muenchen.de/61303/.

Berthélemy, J.-C., 2016. Mini-Grids as an application of Elinor Ostrom's theses on polycentric governance as a way to cope with the tragedy of the commons. *Revue d'économie du développement,* pp. 85 - 106.

Bickton, F. M. et al., 2020. Household air pollution and under-five mortality in sub-Saharan Africa: an analysis of 14 demographic and health surveys. *Environmental Health and Preventive Medicine.*

Bielecki, C. & Wingenbach, G., 2014. Rethinking improved cookstove diffusion programs: A case study of social perceptions and cooking choices in rural Guatemala. *Energy Policy,* pp. 350-358.

Blimpo, M. P. & Cosgrove-Davies, M., 2019. *Electricity Access in Sub-Saharan Africa: Uptake, Reliability, and Complementary Factors for Economic Impact,* Washington, DC: World Bank.: Africa Development Forum series.

Blundell, R., 1988. Consumer Behaviour: theory and emperical evidence- a survey. *Economic Journal 98 (389),* pp. 16-65.

Bollinger, B. & Gillingham, K., 2010. Environmental Preferences and Peer Effects in the Diffusion of Solar Photovoltaic Panels. *Market science working paper.*

Bollinger, B. & Gillingham, K., 2012. Peer Effects in the Diffusion of Solar Photovoltaic Panels. *Market science,* 31(6).

Bonan, J. et al., 2020. Social Interaction and Technology Adoption:Experimental Evidence from Improved Cookstoves in Mali. *DEMS WORKING PAPER SERIES No. 442.*

Bonan, J., Pareglio, S. & Tavoni, M., 2014. Access to Modern energy: A review of impact evaluations. *Fondazione Eni Enrico Mattei.*

Bonan, J., Pareglio, S. & Tavoni, M., 2016. Access to Modern energy: A review of Barriers, Drivers and Impacts. *FEEM working paper series.*

Bonan, J., Pareglio, S. & Tavoni, M., 2017. Access to Modern energy: A review of barriers, drivers and impacts. *Environment and Development Economics,* pp. 491-516.

Bos, K., C. D. & Mamun, A., 2018. Benefits and challenges of expanding grid electricity in Africa: A review of rigorous evidence on household impacts in developing countries. *Energy for Sustainable Development,* Volume 44, p. 64–77.

Bos, K., Chaplin, D. & Mamun, A., 2018. Benefits and xhallneges of expanding grid electricity in Africa: A review of rigorous evidence on household impacts in developing countries. *Energy for Sustainable Development,* Volume 44, pp. 64-77.

Brooks, N. et al., 2016. How much do alternative cookstoves reduce biomass fuel use? Evidence from North India.. *Resource and Energy economics,* pp. 153-171.

Brooks, N. et al., 2016. How much do alternative cookstoves reduce biomass fuel use? Evidence from North India. *Resource and Energy Economics,* p. 153–171.

Brooks, N., 2014. Do Clean Cookstoves Reduce Biomass Fuel Consumption?. *(unpublished Masters thesis),* pp. The Sanford school of public policy, Duke University.

Bruce, N., Pope, D., Rehfuess, E. & Balakrishnan, K., 2015. Strategy implications of new evidence on interventions and exposure risk functions. *Atmospheric Environment,* pp. 451-457.

Burwen, J. & Levine, D. I., 2012 . A rapid assessment randomized-controlled trial of improved cookstoves in rural Ghana. *Energy for Sustainable Development,* p. 328–338.

Bwana, K. M. & Mwakujonga, J., 2013. Issues in SACCOS Development in Kenya and Tanzania: The Historical and Development Perspectives. *Developing Country Studies* , pp. ISSN 2224-607X (Paper) ISSN 2225-0565 (Online) .

Bwenge, S. N., 2011. *The Effects of Adopting Improved Wood Stoves on the Welfare of Rural Women: A case of Kibaha District in Tanzania,* Netherlands: Van Hall Larenstein University of Applied Sciences.

Caliendo, M. & Kopeinig, S., 2008. Some practical guidance for the implemntation of propensity score matching. *Journal of economic surveys,* 22(1), pp. 31-72.

Caliendo, M., Hujer, R. & Thomsen, S. L., 2005. The Employment effects of Job Creation Schemes in Germany: A Microecometric Evaluation. *IZA Discussion Paper No. 1512.*

Chambwera, M. & Folmer, H., 2006. Fuel switching in Harare: An almost ideal demand system. *Energy Policy,* pp. 2538-2548.

Chaplin, D. et al., 2017. *Grid Electricity Expansion in Tanzania by MCC: Findings from a Rigorous Impact Evaluation,* Washngton DC: Millenium Challenge Corporation.

Chen, Q., Yang, H., Liu, T. & Zhang, L., 2016 . Household biomass energy choice and its policy implications on improving rural livelihoods in Sichuan, China. *Energy Policy, 93* , pp. 291-302. doi:10.1016/j.enpol.2016.03.016.

Choumert, J., Motel, P. C. & Le Roux, L., 2019. Stacking up the ladder: A panel data analysis of Tanzanian household energy choices. *World Development,* pp. 222-235.

Christophe, M. & Huijie, Y., 2016. Household Fuel Use in Developing countries; Review of Theory and Evidence. *halshs-01290714.*

Coleman, J., 1988. Social Capital in the Creation of Human Capital. *American Journal of Sociology,* pp. S95-S120.

Crawford, S. & Ostrom, E., 1995. A grammar of Institutions. *American Political Science Review,* 89(3), pp. 582-600.

D'Agostino, A. L., Urpelainen, J. & Xu, A., 2015. Social-economic determinants of charcoal expenditures in Tanzania. *Energy Economics*, pp. 472-481.

Dasso, R. & Fernandez, F., 2015. The effects of electrification on employment in Peru. *IZA Journal of Labour and Development*, 6(4).

Deaton, A. & Muellbauer, J., 1980a. An almost Ideal Deamnd System. *The American economic Review*, pp. 312-326.

Devine-Wright, P., Fleming, P. D. & Chadwick, H., 2001. Role of social capital in advancing regional sustainable development. *Impact Assessment and Project Appraisal,* pp. 161-167.

Dhanda, S., 2015. *Evaluating stakeholder perceptions and approaches for improving the impact of the re-designated Saigachy Reserve, Uzbekistan: Masters thesis,* London: Imperial London College.

DIE, 2016. *German developemnt institte.* [Online] Available at: https://www.die-gdi.de/uploads/media/BP_14.2016.pdf

Dresen, E. et al., 2014. Fuelwood Savings and Carbon Emission Reductions by the Use of Improved Cooking Stoves in an Afromontane Forest, Ethiopia. *Land 3,* pp. 1137-1157; doi:10.3390/land3031137.

Eberhard, A., Gratwick, K. & Kariuki, L., 2018. A review of private investment in Tanzania’s power generation sector. *Journal of Energy in Southern Africa*, pp. 1-11.

Eberhard, A., Gratwick, K., Morella, E. & Antmann, P., 2017. Independent Power Projects in Sub-Saharan Africa: Investment trends and policy lessons. *Energy Policy,* Volume 108, pp. 390-424.

EDWARDS, J. H. Y. & LANGPAP, C., 2012. Fuel choice, indoor air pollution and children's health. *Environment and Development Economics 17,* p. 379–406.

ENERGIA, 2014. *Cooking with Gas: Why women in developing countries want LPG and how they can get it,* s.l.: World LPG Association.

Energy and Water Utilities Regualtoru Authority [Tanzania], 2016. *Downstream Petroleum Sub Sector Performance Review Report,* Dar es Salaam: United Republic of Tanzania.

EngenderHealth, 2016. *Increasing family planning capacity, access, and quality: Results from EngenderHealth's ExpandFP Project in Tanzania. Results Brief.,* New York: s.n.

Ezzati, M. & M, K. D., 2001. Indoor air pollution from biomass combustion and acute respiratory infections in Kenya: an exposure response study. *The Lancet,* Issue 358, pp. 619-624.

FAO, 2020. *Sustainable charcoal production for food security and forest landscape restoration ,* Mpumalanga, South Africa: Food and Agriculture Organization.

Flores-Lagunes, A., Gonzalez, A. & Neumann, T. C., 2007. Estimating the Effects of Length of Exposure to a Training Program: The Case of Job Corps. *Institute for the study of labor (IZA),* pp. Discussion Paper No. 2846, June 2007.

Foel, W., Pachauri, S., Spreng, D. & Zerriffi, H., 2011. Household cooking fuels and technologies in developing economies. *Energy Policy,* p. 7487–7496.

Furukawa, C., 2014. Do Solar Lamps Help Children Study? Contrary Evidence from a Pilot Study in Uganda. *Journal of Development Studies,* 50(2), pp. 319-341.

Gollwitzer, L. et al., 2018. Rethinking the sustainability and institutional governance of electricity access and mini-grids: Electricity as a common pool resource. *Energy Research & Social Science,* p. 152–161.

Graziano, M. & Gillingham, K., 2015. Spatial Patterns of Solar Photovoltaic System Adoption: The Influence of Neighbors and the Built Environment. *Journal of Economic Geography,* pp. Vol.15, pp. 185-839.

Grimm, M., Munyehirwe, A., Peters, J. & Sievert, M., 2016. A First Step Up the Energy Ladder? Low Cost Solar Kits and Household's Welfare in Rural Rwanda-WPS7859. *Policy Research Working Paper 7859.*

Grootaert, C., 1998. SOCIAL CAPITAL: THE MISSING LINK?. *Social Capital Initiative,* p. Working Paper No. 3.

Grootaert, C., Narayan, D., Nyhan, J. V. & Woolcock, M., 2004. Measuring Social Capital: An Integrated Questionnaire. *World Bank* , p. Working Paper No. 18.

Guta, D. D., 2012. Application of an almost ideal demand system (AIDS) to Ethiopian rural residential energy use: Panel data evidence. *Energy Policy,* pp. 528-539.

Hanna, R., Duflo, E. & Greenstone, M., 2016. Up in Smoke: The Influence of Household Behavior on the Long-Run Impact of Improved Cooking Stoves. *American Economic Journal: Economic Policy,* p. 80–114.

Hassen, S., 2015. *On the Adoption and Dis-adoption of Household Energy and Farm Technologies (unpublished PhD Thesis),* Gothenburg: University of Gothenburg.

Hazra, S., Lewis, J., Das, I. & Kumar, S. A., 2014. Adoption and Use of Improved Stoves and Biogas Plants in Rural India. *SANDEE Working Papers No. 86–14,* pp. ISSN 1893-1891.

Heltberg, R., 2004. Fuel switching: evidence from eight developing countries. *Energy Economics,* pp. 869-887.

Hirano, K. & Imbens, G., 2004. The propensity score with continuous treatments. *Applied Bayesian modelling and causal inference from incomplete data perspectives* , pp. 73-84.

Hnyine, Z. T., Lubis, W., Sagala, S. & Yamin, D., 2015. Analysing the economic benefits of rural biogas adoption in Selo Sub-District, Boyolali, Indonesia. *Working paper series No. 8, August 2015.*, p. Resilience development initiative.

Holmes, S. M., 2010. *Potential Effects of Improved Cookstove Use and Barriers to Acceptance: A Case Study Measkron, Tanzania,* Olympia: The Evergreen State College .

IEA, 2010. *World energy outlook 2010,* Paris: International energy Agency.

IEA, 2017. *World Energy Outlook 2017 special report: Energy access outlook,* s.l.: International Energy Agency.

IEA, 2019. *Africa Energy Outlook: A focus on energy prospects in Sub-Saharan Africa,* Paris: International Energy Agency.

IEA, IRENA, UNSD, World Bank, WHO, 2020. *Tracking SDG 7: The Energy Progress Report.*, Washington DC: World Bank.

IEG (Independent Evaluation Group), 2008. *The Welfare Impact of Rural Electrification: A reassessement of costs and benefits,* Washington: World Bank.

Imbens, G., 2000. Teh role of the propensity score in estimating dose-response functions. *Biometrika 87(3),* pp. 706-710.

Imbens, G., 2000. The role of the propensity score in estimating dose-response functions. *Biometrika 87(3),* pp. 706-710.

Imran, M. & Ozcatalbas, O., 2020. Determinants of household cooking fuels and their impact on women's health in rural Pakistan. *Environmental Science and Pollution research International*, pp. 23849-23861.

IRENA, 2017. *Renewables Readiness Assessment: United Republic of Tanzania,* Abu Dhabi: International Renewable Energy Agency .

Ishengoma, R. & Abdallah, J., 2016. *Charcoal market conditions in 2016 in Dar es Salaam and Morogoro, Tanzania,* Dar-es-Salaam: Swiss agency for Development and Cooperation (SDC).

Jain, J. K., 2014. Impact of Adoption of Biogas Plant on Socio-Economic Status of the Biogas Users in Ujjain District of Madhya Pradesh. *(unpublished masters thesis),* pp. Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior College of Agriculture.

Jeuland, M. et al., 2014. Preferences for Improved Cook Stoves: Evidence from North Indian Villages. *DUKE ENVIRONMENTAL AND ENERGY ECONOMICS WORKING PAPER SERIES,* pp. Working Paper EE 14-07, July 2014.

Karimu, A., 2015 . Cooking fuel preferences among Ghanaian Households: An empirical analysis. *Energy for Sustainable Development, 27* , pp. 10-17. doi:10.1016/j.esd.2015.04.003.

Karimu, A., Mensah, J. T. & Adu, G., 2016 . Who Adopts LPG as the Main Cooking Fuel and Why? Empirical Evidence on Ghana Based on National Survey. *World Development, 85* , pp. 43-57. doi:10.1016/j.worlddev.2016.05.004.

Karumba, M. & Muchapondwa, E., 2017. The impact of micro hydroelectricity on household welfare indicators. *ERSA working paper 659.*

Khandker, S. R., Barnes, D. F., Samad, H. & H, M. N., 2008. Welfare Impacts of rural Electrification: Evidence from Vietnam. *World bank.*

Khandker, S. R., Samad, H. A., Ali, R. & Barnes, D. F., 2012. Who Benefits Most from Rural Electrification?: Evidence from India. *World Bank, Policy Research Working Paper 6095.*

Kibrom, A. A., Goytom, K. A. & Guush, B., 2017. Social Networks and Factor Markets: Panel Data Evidence from Ethiopia. *The Journal of Development Studies,* p. DOI:10.1080/00220388.2017.1288224.

Kimemia, D. & Annegarn, H., 2016. Domestic LPG interventions in SouthAfrica: Challenges and lessons. *Energy Policy 93,* pp. 150-156.

Kinyondo, A. & Villanger, E., 2016. Local content Requirements in the Petroleum Sector in Tanzania: A thorny road from inception to Implementation. *CMI Working Paper Number 6.*

Koster Magdalena, A., 2013. *An Institutional Approach to Understanding Energy Transitions,* Arizona: Arizona State University.

Kulindwa, Y. J., Lokina, R. & Ahlgren, E. O., 2018. Driving forces for households' adoption of improved cooking stoves in rural Tanzania. *Energy strategy review*, pp. 102-112.

Kumar, P. & Igdalsky, L., 2019. Sustained uptake of clean cooking practices in poor communities: Role of social networks. *Energy Research & Social Science*, pp. 189-193.

La Ferrara, E., Chong, A. & Duryea, S., 2008. *Soap Operas and Fertility: Evidence from Brazil*, Washington, DC: Inter-American Development Bank.

Lewis, J. J. et al., 2017. Biogas Stoves Reduce Firewood Use, Household Air Pollution, and Hospital Visits in Odisha, India. *Environmental science and technology*, p. 560−569.

Lewis, J. J., 2015. Measuring Impacts of Improved Cookstove Interventions on Technology Adoption and Environmental and Health Outcomes. *(Doctoral Dissertation)*, p. Retrieved from Duke University library database (Publication NO.3739946).

Link, F, C., William, A. G. & Dirgha, G. J., 2012. Household energy consumption: Community context and the fuelwood transition. *Social Science Research*, p. 598–611.

Liu, J. & Florax, R. J., 2014. *The effectiveness of International aid: A Generalized Score analysis.* Minneapolis, July 27-29, 2014.

Lucas, P. L., Dagnachew, A. G. & Hof, A. F., 2017. *Towards universal electricity access in Sub-Saharan Africa: A quantitative analysis of technology and investment requirements* , The Hague: PBL Netherlands Environmental Assessment Agency .

Malla, S. & Govinda, T. R., 2014. Household Cooking Fuel Choice and Adoption of Improved Cookstoves in Developing Countries: A Review. *World Bank Policy Research Working Paper 6903.*

Manski, C., 1993. Identification of endogeneous: The reflection problem. *Review of Economic studies 60 (3).*

Masatsugu, L. & Pattanayak, S. K., 2017. *Household cooking technologies and REDD+:Pilot experiences in Tanzania and across the tropics,* Duke: Duke University.

Masera, O. R., Barbara, S. D. & Daniel, K. M., 2000. "From Linear Fuel Switching to Multiple Cooking Strategies: A Critique and Alternative to the Energy Ladder Model. *World Development,* pp. 2083-103.

Massawe, F. A., Bengesi, K. M. K. & Kweka, A. E., 2015. Patterns of Household Cooking Energy and Associated Factors: Experience from Kilimanjaro Region, Tanzania. *Intersect, Vol 8, No 3* .

Mawhood, R. & Gross, R., 2014. Institutional barrierstoa 'perfect' policy:A case study of the Senegalese Rural Electrification Plan. *Energy Policy,* pp. 480-490.

McEachern, M. & Hanson, S., 2008. "Socio-geographic perception in the diffusion of innovation: Solar energy technology in Sri Lanka,. *Energy Policy,* pp. 2578-2590.

Mensah, J. T. & Adu, G., 2015 . An empirical analysis of household energy choice in Ghana. *Renewable and Sustainable Energy Reviews, 51* , pp. 1402-1411. doi:10.1016/j.rser.2015.07.050.

Mercado, I. R. & Masera, O., 2015. Patterns of stove use in the context of Fule device stacking: Rationale and implications. *Eco Health,* pp. 42-56 DOI: 10, 1007/s10393-015-1009-4.

Miller, C. et al., 2015. *Millennium Challenge Corporation's Electricity Transmission and Distribution Line-Extension Activity in Tanzania: Qualitative Evaluation*, Washington, DC: Mathematica Policy Research.

Miller, G. & Mobarak, A. M., 2014. Learning About New Technologies Through Social Networks: Experimental Evidence on Nontraditional Stoves in Bangladesh. *Marketing Science, Articles in Advance*, p. 1–20.

Miller, G. & Mobarak, A. M., 2015. Learning About New Technologies Through Social Networks: Experimental Evidence on Nontraditional Stoves in Bangladesh. *Marketing Science*, pp. 480-499.

Ministry of finance and Planning and the national Bureau of Statistics, 2019. *Tazania mainland hosuehold budget survey 2017-18, Key Indicators report*, Dodoma, Tanzania: s.n.

Mokveld, K. & Eije, S., 2018. *Final Energy Report Tanzania*, Dar-es-Salaam: Ministy of Foreign affairs Tanzania.

Mukong, A. K. & Burns, J., 2015. Social networks and Maternal health utilization in Tanzania. *ERSA working paper 540,* p. August 2015.

Mwampamba, T., 2007. Has the wood fule crisis returned? Urban Charcoal consumption in Tanzania and its implications to present and future forest availability. *Energy policy*, pp. 4221-4234.

Nansaior, A., Patanothai, A., Rambo, T. A. & Simaraks, S., 2011. Climbing the energy ladder or diversifying energy sources? The continuing importance of household use of biomass energy in urbanizing communities in Northeast Thailand. *b i o m a s s and b i o energy*, pp. 4180-4188.

National Bureau of Statistics (NBS) [Tanzania], 2017. *National Environment Statistics Report, 2017 (NESR, 2017)*, Dar es Salaam, Tanzania Mainland.: s.n.

National Bureau of Statistics [Tanzania], 2016. *Tanzania Demographic and helath survey and Malaria Inidcator Survey*, Dar-es-Salaam, Tanzania and Rockville Maryland, USA: MoHCDGEC, MoH, NBS, OCGS and ICF.

National Bureau of Statistics [Tanzania], 2016. *Tanzania National Panel Survey Report (NPS)-Wave 4*, Dar-es-Salaam, Tanzania: NBS.

National Bureau of statistics, 2013. *Key findings 2011/12 Household budget survey Tanzania Mainland*, Dar-es-Salaam: National Bureau of Statistics and the Ministry of finance and planning.

National Bureau of Statistics, 2015. *2012 Population and Housing census: Housing condition, household amenities and assets monograph*, Dar-es-Salaam: National Bureau of statistics and Ministry of finance and planning.

National bureau of Statistics, 2015a. *Environmental statistics 2014: Tanzania mainland*, Dar-es-Salaam: Ministry of finance.

National Bureau of Statistics, 2015a. *Environmental statistics 2014: Tanzania mainland*, Dar-es-Salaam: Ministry of finance.

National Bureau of Statistics, 2015b. *2012 Population and Housing Census: Housing condition, househodl amenities and assets mnograph*, Dar-es-Salaam: National Bureau of Statistics and Ministry of Finance.

National Bureau of Statistics, 2015b. *2012 Population and Housing census: Housing condition, household amenities and assets monograph*, Dar-es-Salaam: National Bureau of statistics and Ministry of finance and planning.

Ndumbaro, L. & Kiondo, K., 2007. "Defining the Non-Profit Sector: The Tanzanian Experience" in the Third Sector in Tanzania – Learning More About Civil Society Organisations, Their Capabilities and Challenges.. pp. Aga Khan Development Network, Dar es Salaam.

Ngui, D., Mutua, J., Osiolo, H. & Aligula, E., 2011. Household energy demand in Kenya: An application of the linear approximate almost ideal demand system (LA-AIDS). *Energy policy,* pp. 7084-7094.

Nigussie, Z. et al., 2018. Applying Ostrom's institutional analysis and development framework to soil and water conservation activities in north-western Ethiopia. *Land Use Policy,* pp. 1-10.

Ohunakin, O. S., Adaramola, M. S., Oyewola, O. M. & Fagbenle, R. O., 2014. Solar energy applications and development in Nigeria: Drivers and barriers. *Renewable and Sustainable Energy Reviews,* pp. 294-301.

Ortiz-Correa, J. S., Filho, M. R. & Dinar, A., 2016. Impact of access to water and sanitation services on educational attainment. *Water Resources and Economics 14,* pp. 31-43.

Ostrom, E., 2011. Background on the Institutional Analysis and Development Framework. *Policy Studies Journal,* 39(1), pp. 7-26.

Paudel, U., Khatri, U. & Pant, K. P., 2018. "Understanding the determinants of household cooking fuel choice in Afghanistan: A multinomial logit estimation. *Energy*, pp. 55-62.

pengying, 2018. *xinhuanet.* [Online] Available at: http://www.xinhuanet.com/english/2018-05/02/c_137151657.htm [Accessed 11 09 2019].

Peters, J. & Sieverta, M., 2016. Impacts of rural electrification revisited – the African context. *JOURNAL OF DEVELOPMENT EFFECTIVENESS, VOL. 8, NO. 3*, p. 327–345.

Peters, J. & Vance, C., 2011. Rural electrification and Fertility: Evidence form Cote d'Ivore. *Journal of Development studies*, 12(2), pp. 111-134.

Peters, J., Siever, M. & Toman, M. A., 2019. Rural electrification through mini-grids: Challenges ahead. *Energy Policy,* pp. 27-31.

Polski, M. M. & Ostrom, E., 1999. *An Institutional Framework for Policy Analysis and Design-WP98-27.* Indiana: s.n.

Priyavrat, B. & Shweta, M. K., 2018. *Analysis of Tanzania's Power System Master Plan 2016,* New Delhi: Centre for Science and Environment.

Pueyo, A., Carreras, M. & Ngoo, G., 2020. Exploring linkages between energy, gender and enterprise: Evidence from Tanzania. *World Development,* Issue 128.

Pueyo, A., M. C. & Gisela, N., 2020. Exploring the linkages between energy, gender, and enterprise: Evidence from Tanzania. *World Development,* Volume 128.

Putnam, R., 1993. "The Prosperous Community-Social Capital and Public Life.". *American Prospect,* pp. 35-42.

Putra, R. A. R. S., Liu, Z. & Lund, M., 2017. The impact of biogas technology adoption for farm households – Empirical evidence from mixed crop and livestock farming systems in Indonesia. *Renewable and Sustainable Energy Reviews 74* , p. 1371–1378.

Quansah, R. et al., 2017. Effectiveness of interventions to reduce household air pollution and/or improve health in homes using solid fuel in low-and-middle income countries: A systematic review and meta-analysis. *Environment International,* pp. 73-90.

Rahut, D. B., Ali, A., Mottaleb, K. A. & Arya, J. P., 2020. Wealth, education and cooking-fuel choices among rural households in Pakistan. *Energy Strategy Reviews,* pp. 236-243.

Rahut, D. B., Behera, B. & Ali, A., 2015 . Household energy choice and consumption intensity_ Empirical evidence from Bhutan. *Renewable and Sustainable Energy Reviews, 53* , pp. 993-1009. doi:10.1016/j.rser.2015.09.019.

Rosenbaum, P. & Rubin, D., 1985. Constructing a control group using multivariate matched sampling methods that incoporate the Propensity Score. *The American Statistician,* Volume 39, pp. 33-38.

Rosenbaum, P. R., 2002. *Observational Studies.* Newyork: Springer.

Rosenbum, P. R. & Rubin, D. B., 1983. Teh central role of the propensity score in observational studies for causal effects.. *Biometrika 70(1),* pp. 41-55.

Rosenbum, P. R. & Rubin, D. B., 1983. Teh centrat role of the propensity score in observational studies for causal effects.. *Biometrika 70(1)*, pp. 41-55.

Roy, A., 1951. Some thoughts on distribution of earnings. *Oxford Ecnomic Papers*, Volume 3, pp. 135-145.

Rural Enery Agency, 2020. *Energy access and use situation survey II in Tanzania Mainland 2019/20: Summary of Key findings*, Dar-es-Salaam: National Bureau of Statistics.

Saatkamp, B. D., Masera, O. R. & Kammen, D. M., 2000. Energy and health transitions in development: fule use, stove technology and morbidity in Jaracuaro, Mexico. *Energy for Sustainable Development,* p. Volume IV No.2.

Samad, H. A., Khandker, S. R., Asaduzazaman, M. & Yunus, M., 2013. The Benefits of Solar Home Systems: An Analysis from Bangladesh. *World Bank Policy research working paper 6724,* p. The World bank.

Sana, A. et al., 2020. Household energy choice for domestic cooking: distribution and factors influencing cooking fuel preference in Ouagadougou. *Environmental Science and Pollution Research,* p. 18902–18910.

Seibel, H., 1997. Upgrading, Downgrading, Linking, Innovating: Microfinance Development Strategies-A System Perspective. *Occasional PaperNo 2371,* pp. Department of Agricultural Economics, The Ohio State University, U.S.A .

Semple, S., Apsley, A., Wushishi, A. & Smith, J., 2014. Commentary: Switching to biogas e What effect could it have on indoor air quality and human health?. *biomass and bioenergy,* pp. 125-129.

Sergi, B. et al., 2018. Institutional influence on power sector investments: A case study of on- and off-grid energy in Kenya and Tanzania. *Energy Research & Social Science,* Issue 41, pp. 59-70.

Short S, Bashir H, Marshall P, Miller N, Olmschenk D, Prigge K, Solyntjes L, 2017. *Diagnosis and Treatment of Respiratory Illness in Children and Adults,* s.l.: Institute for Clinical Systems Improvement. .

Sianesi, B., 2004. An Evaluation of the Active Labor Market Programs in Sweden. *The review of Economics and Statistics,* 86(1), pp. 133-155.

Smith, J. & Todd, P., 2005. Does Matching Overcome Lalonde's Critique of Nonexperimental Estimators?. *Journal of Econometrics,* 125(1-2), pp. 305-353.

Smith, K. R. et al., 2011. Effect of reduction in household air pollution on childhood pneumonia in Guatemala (RESPIRE): a randomised controlled trial. *The Lancet 378* , p. 1717–26.

Smith, K. R. et al., 2013. Energy and Human Health. *Annual Review of Public Health,* 16 January, pp. 159-188.

Squires, T., 2015. *THE IMPACT OF ACCESS TO ELECTRICITY ON EDUCATION AND OTHER ESSAYS IN SPATIAL ECONOMICS: PHD THESIS,* Rhode Island: Brown University.

Srinivasan, S. & Carattini, S., 2016. Adding Fuel to Fire? Social Spillovers and Spatial Disparities in the adoption of LPG in India. *Swiss Network for international studies,* pp. Research paper 48, November, 2016.

The National Bureau of Statistics [Tanzania], 2017. *National Environment Statistics Report,* Dar es Salaam, Tanzania Mainland: s.n.

Titcombe, M. E. & Simcik, M., 2011. Personal and indoor exposure to PM2.5 and polycyclic aromatic hydrocarbons in the southern highlands of Tanzania: a pilot-scale study. *Enviro monit assess,* pp. 461-476.

Troncoso, K., Armendáriz, C. & Alatorre, S., 2013. Improved cook stove adoption and impact assessment: A proposed methodology. *Energy Policy,* p. 637–645.

UNEP, 2019. *Review of Woodfuel Biomass Production and Utilization in Africa: A Desk Study,* Nairobi: United Nations Environment Program.

Uninted Republic of Tanzania, 2016. *Power System Master Plan 2016 Update,* Dar-es-Salaam: Ministry of Energy and Minerals.

United Republic of Tanzania, 2012. *Guidelines for finacing rural energy projects,* Dar-es-Salaam: Rural Energy Agency.

United Republic of Tanzania, 2014. *National Electrification Program Prospectus 2013-2022,* Dar-es-Salaam: Rural Energy Agency.

United Republic of Tanzania, 2014b. *Electricity Supply Industry Reform Strategy and Road Map,* Dar-es-Salaam: Ministry of Energy.

United Republic of Tanzania, 2015. *National Energy Policy 2015,* Dar-es-Salaam, Tanzania: Ministry of energy and Minerals.

United Republic of Tanzania, 2015. *Tanzania's SE4ALL action agenda* , Dar-es-Salaam: United republic of Tanzania, ministry of energy and minerals.

United Republic of Tanzania, 2016. *Tanzania country gender profile,* Dar-es-Salaam: Ministry of health, co,mmunity development, gender, elderly and children.

United Republic of Tanzania, 2016. *Tanzania National Panel report (NPS)- Wave 4, 2014-2015,* Dar-es-Salaam: National Bureau of Statistics.

United Republic of Tanzania, 2017. *Energy access situation report, 2016 Tanzania mainland,* Dar-es-Salaam: Rural Energy Agency and National Bureau of Statistics.

United Republic of Tanzania, 2018. *Evaluations of REA Funded Projects Report,* Dar-es-Salaam: Ministry of Energy:REA.

USAID, 2017. *Family Planning and Reproductive Health- Tanzania,* Newyork: USAID.

Vahlne, N. & Ahlgren, E. O., 2014. Policy implications for improved cook stove programs—A casestudy of the importance of village fuel use variations. *Energy Policy,* p. 484–495.

Van de Walle, D., Ravallion, M., Mendiratta, V. & Koolwal, G., 2015. Long-Term Impacts of Household Electrification in Rural India. *World Bank Economic Review,* Volume lhv057.

van der Kroon, B., Roy, B. & van Beukering, P. J., 2014. The impact of the household decision environment on fuel choice behavior. *Energy Economics,* p. 236–47.

van Dijk, K. A. L. & Clancy, J., 2010. Impacts of Electricity Access to Rural Enterprises in Bolivia, Tanzania and Vietnam. *Energy for Sustainable Development 14,* p. 14–21.

Vigolo, V., Sallaku, R. & Testa, F., 2018. Drivers and Barriers to Clean Cooking: A Systematic Literature Review from a Consumer Behavior Perspective. *Sustainability.*

Vulturius, G. & Wanjiru, H., 2017. The role of social relations in the adoption of improved cookstoves. *Stockholm Environment Institute: Working paper No. 2017-01*.

WHO, 2016. *World Health organization.* [Online] Available at: http://www.who.int/mediacentre/factsheets/fs292/en/

Woodroffe, N., Genasci, M. & Scurfield, T., 2017. *resource governance.org.* [Online] Available at: https://resourcegovernance.org/sites/default/files/documents/tanzania-new-natural-legislation-what-will-change.pdf

World Bank, 2016. *Project appraissal document on a proposed credit and scale up of renewable energy program grant to the United Republic of Tanzania for a Rural Electrification Expansion program – Program for resuts,* Washington: World Bank group.

World Bank, 2016b. *Tanzania Rural electrification Expansion Program: Environment and Social Systems Assessment,* Washington DC: World Bank Group.

World Bank, 2018. *Implementation completion and result report on the Unietd Republic of Tanzania energy development and access expansion project,* Washington: World Bank group.

World Bank, 2019. *Tanzania: Country Environmental Analysis – Environmental Trends and Threats, and Pathways to Improved Sustainability*. , Washington, DC: World bank.

Yip, F. et al., 2017. Assessment of traditional and improved stove use on household air pollution and personal exposures in rural western Kenya. *Environment International*, p. 185–191.

Young, H. P., 2009 . Innovation Diffusion in Heterogeneous Populations: Contagion, Social Influence, and Social Learning. *American Economic Review 99:5*, p. 1899–1924.

Yu, F., 2011. Indoor Air Pollution and Children's Health: Net Benefits from Stove and Behavioral Interventions in Rural China. *Environ Resource Econ* , p. 495–514.

APPENDIX A: Appendix for chapter two

Table A.1: Coefficients of the logit random effects model(Dummy)

DepVar: Use of modern cooking fuels VARIABLES	(1) Random effects	(2) Random effects	(3) Random effects	(4) Random effects
Social Capital (Dummy)	0.947*	0.996*	1.021**	1.016**
	(0.498)	(0.509)	(0.464)	(0.468)
Household head is male			-0.257	-0.260
			(0.452)	(0.456)
Age of the head of the household			0.0349**	0.0349*
			(0.0177)	(0.0179)
Real annual household consumption/1000			0.00242***	0.00239***
			(0.000360)	(0.000374)
Household size			-0.389***	-0.387***
			(0.106)	(0.107)
Household owns a biomass stove			-2.087***	-2.109***
			(0.590)	(0.599)
Household owns a telephone			1.237	1.209
			(1.256)	(1.267)
Household owns a radio			0.198	0.213
			(0.414)	(0.425)
Household connected to electricity			2.288***	2.341***
			(0.637)	(0.651)
Household head achieved primary or adult education			0.746	0.702
			(1.244)	(1.254)
Constant	-5.618***	-5.744***	-7.717***	-7.716***
	(0.378)	(0.566)	(2.061)	(2.111)
Observations	1,484	1,484	1,484	1,484
Number of HHID	568	568	567	567
District FE	No	Yes	No	Yes
Time dummies	No	Yes	No	Yes

Table A.2: Coefficient of the logit random effects model(Continuous)

DepVar: Use of modern cooking fuels VARIABLES	(1) Random effects	(2) Random effects	(3) Random effects	(4) Random effects
Social Capital (Continuous)	1.052**	1.132**	1.169***	1.167***
	(0.453)	(0.463)	(0.432)	(0.438)
Household head is male			-0.259	-0.263
			(0.456)	(0.460)
Age of the head of the household			0.0346*	0.0345*
			(0.0179)	(0.0181)
Real annual household consumption/1000			0.00244***	0.00240***
			(0.000362)	(0.000376)
Household size			-0.397***	-0.394***
			(0.107)	(0.108)
Household owns a biomass stove			-2.113***	-2.135***
			(0.595)	(0.604)
Household owns a telephone			1.231	1.195
			(1.260)	(1.273)
Household owns a radio			0.163	0.185
			(0.417)	(0.428)
Household connected to electricity			2.308***	2.363***
			(0.641)	(0.656)
Household head achieved primary or adult education			0.732	0.696
			(1.257)	(1.268)
Constant	-5.616***	-5.791***	-7.687***	-7.716***
	(0.387)	(0.574)	(2.078)	(2.133)
Observations	1,484	1,484	1,484	1,484
Number of HHID	568	568	567	567
District FE	No	Yes	No	Yes
Time dummies	No	Yes	No	Yes

Table A.3: Marginal effects of the logit random effects model with social capital (Dummy)

DepVar: Use of modern cooking fuels VARIABLES	(1) marginal effects	(2) marginal effects	(3) marginal effects	(4) marginal effects
Social Capital (Dummy)	0.0350*	0.0360**	0.0357**	0.0354**
	(0.0182)	(0.0182)	(0.0163)	(0.0163)
Household head is male			-0.00898	-0.00906
			(0.0157)	(0.0158)
Age of the head of the household			0.00122**	0.00122*
			(0.000617)	(0.000621)
Real annual household consumption/1000			8.46e-05***	8.32e-05***
			(1.30e-05)	(1.37e-05)
Household size			-0.0136***	-0.0135***
			(0.00377)	(0.00381)
Household owns a biomass stove			-0.0729***	-0.0734***
			(0.0204)	(0.0206)
Household owns a telephone			0.0432	0.0421
			(0.0439)	(0.0441)
Household owns a radio			0.00692	0.00741
			(0.0145)	(0.0148)
Household connected to electricity			0.0800***	0.0814***
			(0.0229)	(0.0231)
Household head achieved primary or adult education			0.0261	0.0244
			(0.0432)	(0.0434)
Observations	1,484	1,484	1,484	1,484
District FE	No	Yes	No	Yes
Time dummies	No	Yes	No	Yes

Table A.4: Pooled logit model for household modern energy use with the membership variable as a dummy.

DepVar: Use of modern cooking fuels VARIABLES	(1) logit	(2) logit	(3) Logit	(4) logit
HH has a member of a self-help/SACCOS group	1.020***	0.951***	0.848***	0.836***
	(0.250)	(0.258)	(0.294)	(0.297)
Household head is male			-0.00911	-0.00941
			(0.281)	(0.280)
Age of the head of the household			0.0233**	0.0241***
			(0.00930)	(0.00921)
Real annual household consumption/1000			0.00206***	0.00211***
			(0.000318)	(0.000354)
Household size			-0.322***	-0.328***
			(0.0707)	(0.0712)
Household owns a biomass stove			-1.587***	-1.595***
			(0.357)	(0.359)
Household head owns a telephone			1.114	1.165
			(1.050)	(1.052)
Household head owns a radio			0.122	0.0815
			(0.283)	(0.291)
Household connected to electricity			1.941***	1.943***
			(0.499)	(0.492)
Household head achieved primary or adult education			-0.194	-0.182
			(0.606)	(0.624)
Constant	-2.710***	-2.697***	-4.972***	-4.988***
	(0.113)	(0.207)	(1.122)	(1.129)
Observations	1,484	1,484	1,484	1,484
District FE	No	Yes	No	Yes
Time dummies	No	Yes	No	Yes

Table A.5: Marginal effects of the pooled logit model for household modern energy use with the membership variable as a dummy.

DepVar: Use of modern cooking fuels VARIABLES	(1) marginal effects	(2) marginal effects	(3) marginal effects	(4) marginal effects
HH has a member of a self-help/SACCOS group	0.0674***	0.0622***	0.0435***	0.0428***
	(0.0170)	(0.0173)	(0.0153)	(0.0155)
Household head is male			-0.000467	-0.000482
			(0.0144)	(0.0143)
Age of the head of the household			0.00119**	0.00123***
			(0.000483)	(0.000477)
Real annual household consumption/1000			0.000106***	0.000108***
			(1.54e-05)	(1.70e-05)
Household size			-0.0165***	-0.0168***
			(0.00363)	(0.00363)
Household owns a biomass stove			-0.0814***	-0.0817***
			(0.0183)	(0.0184)
Household head owns a telephone			0.0571	0.0597
			(0.0538)	(0.0538)
Household head owns a radio			0.00623	0.00418
			(0.0146)	(0.0150)
Household connected to electricity			0.0995***	0.0995***
			(0.0267)	(0.0263)
Household head has achieved primary or adult education			-0.00994	-0.00930
			(0.0311)	(0.0319)
Observations	1,484	1,484	1,484	1,484
District FE	No	Yes	No	Yes
Time dummies	No	Yes	No	Yes

Table A.6: Pooled logit model for household modern energy use with the number of self-help grou/ SACCOS members in a HH.

DepVar: Use of modern cooking fuels VARIABLES	(1) logit	(2) logit	(3) Logit	(4) Logit
Number members of groups in a HH	0.982***	0.931***	0.841***	0.823***
	(0.222)	(0.237)	(0.278)	(0.283)
Household head is male			-0.00976	-0.0101
			(0.282)	(0.281)
Age of the head of the household			0.0227**	0.0235**
			(0.00936)	(0.00929)
Real annual household consumption/1000			0.00206***	0.00211***
			(0.000317)	(0.000352)
Household size			-0.325***	-0.330***
			(0.0700)	(0.0706)
Household owns a biomass stove			-1.584***	-1.591***
			(0.357)	(0.359)
Household head owns a telephone			1.118	1.164
			(1.050)	(1.053)
Household head owns a radio			0.0992	0.0646
			(0.285)	(0.292)
Household connected to electricity			1.939***	1.938***
			(0.499)	(0.494)
Household head achieved primary or adult education			-0.214	-0.199
			(0.606)	(0.621)
Constant	-2.709***	-2.715***	-4.910***	-4.940***
	(0.112)	(0.210)	(1.117)	(1.122)
Observations	1,484	1,484	1,484	1,484
District FE	No	Yes	No	Yes
Time dummies	No	Yes	No	Yes

Table A.7: Marginal effects of a Pooled logit model for household modern energy use with the number of self-help group/ SACCOS members in a HH.

DepVar: Use of modern cooking fuels VARIABLES	(1) marginal effects	(2) marginal effects	(3) marginal effects	(4) marginal effects
Number members of groups in a HH	0.0647***	0.0608***	0.0430***	0.0420***
	(0.0151)	(0.0159)	(0.0144)	(0.0147)
Household head is male			-0.000499	-0.000517
			(0.0144)	(0.0143)
Age of the head of the household			0.00116**	0.00120**
			(0.000483)	(0.000479)
Real annual household consumption/1000			0.000105***	0.000107***
			(1.54e-05)	(1.69e-05)
Household size			-0.0166***	-0.0169***
			(0.00360)	(0.00360)
Household owns a biomass stove			-0.0810***	-0.0812***
			(0.0183)	(0.0183)
Household head own a telephone			0.0571	0.0594
			(0.0537)	(0.0537)
Household head owns a radio			0.00507	0.00330
			(0.0146)	(0.0149)
Household connected to electricity			0.0991***	0.0989***
			(0.0266)	(0.0263)
Household head achieved primary or adult education			-0.0110	-0.0102
			(0.0309)	(0.0317)
Observations	1,484	1,484	1,484	1,484
District FE	No	Yes	No	Yes
Time dummies	No	Yes	No	Yes

Table A.8: A Linear probability model with the membership variable as a dummy.

DepVar: Use of modern cooking fuels VARIABLES	(1) LPM	(2) LPM	(3) LPM	(4) LPM
HH has a member of a self-help/SACCOS group	0.0934***	0.0882***	0.0499*	0.0490*
	(0.0300)	(0.0303)	(0.0281)	(0.0282)
Household head is male			0.00375	0.00432
			(0.0156)	(0.0159)
Age of the head of the household			0.000752	0.000853
			(0.000526)	(0.000537)
Real annual household consumption/1000			0.000225***	0.000231***
			(3.12e-05)	(3.30e-05)
Household size			-0.0184***	-0.0189***
			(0.00278)	(0.00280)
Household owns a biomass stove			-0.108***	-0.108***
			(0.0298)	(0.0299)
Household head owns a telephone			-0.00280	0.00277
			(0.0114)	(0.0119)
Household head owns a radio			0.00264	-0.00124
			(0.0133)	(0.0137)
Household connected to electricity			0.0322***	0.0314***
			(0.0109)	(0.0110)
Household head achieved primary or adult education			-0.00324	-0.00338
			(0.0153)	(0.0155)
Constant	0.0624***	0.0247**	0.0728*	0.0772*
	(0.00664)	(0.0115)	(0.0371)	(0.0399)
Observations	1,484	1,484	1,484	1,484
R-squared	0.012	0.021	0.185	0.187
District FE	No	Yes	Yes	Yes
Time dummies	No	Yes	Yes	Yes

Table A.9: A linear probability model for household modern energy use with the number of self-help group/ SACCOS members in a HH.

DepVar: Use of modern cooking fuels VARIABLES	(1) LPM	(2) LPM	(3) LPM	(4) LPM
Number members of groups in a HH	0.0967***	0.0926***	0.0556*	0.0542*
	(0.0298)	(0.0304)	(0.0285)	(0.0286)
Household head is male			0.00392	0.00443
			(0.0156)	(0.0159)
Age of the head of the household			0.000736	0.000832
			(0.000525)	(0.000537)
Real annual household consumption/1000			0.000225***	0.000231***
			(3.11e-05)	(3.29e-05)
Household size			-0.0184***	-0.0189***
			(0.00276)	(0.00279)
Household owns a biomass stove			-0.108***	-0.108***
			(0.0298)	(0.0299)
Household head owns a telephone			-0.00278	0.00260
			(0.0114)	(0.0120)
Household head owns a radio			0.00173	-0.00196
			(0.0133)	(0.0136)
Household connected to electricity			0.0320***	0.0313***
			(0.0109)	(0.0110)
Household head achieved primary or adult education			-0.00390	-0.00388
			(0.0152)	(0.0154)
Constant	0.0621***	0.0243**	0.0747**	0.0781**
	(0.00662)	(0.0114)	(0.0369)	(0.0398)
Observations	1,484	1,484	1,484	1,484
R-squared	0.015	0.023	0.187	0.188
District FE	No	Yes	Yes	Yes
Time dummies	No	Yes	Yes	Yes

APPENDIX B: Appendix for chapter three

Table B.1: Definition and measurement of outcomes

Outcome	Definition and Measurement	Measurement
Total energy expenditure	The total amount in Tshs used by a household on Charcoal, electricity, LPG and kerosene in the last month	Tanzania Shillings (Tshs)
Kerosene expenditure	The total amount in Tshs used by household on kerosene in the last month	Tanzanian Shillings (Tshs)
Charcoal expenditure	The total amount in Tshs used by a household on Charcoal in the last month	Tanzanian Shillings (Tshs)
Modern energy budget	The total amount in Tshs used by a household on LPG and Electricity in the last month	Tanzanian Shillings (Tshs)
Traditional energy budget	The total amount in Tshs used by a household on kerosene and charcoal in the last month	Tanzanian Shillings (Tshs)
Modern energy budget share	Ratio of the household's modern energy budget to the total energy budget	Ratio
Traditional energy budget share	Ratio of the household's traditional energy budget to the total energy budget	Ratio
Evening study hours	Number of hours Children between 5 and 20 years of age uses to study at night in a week in a household	Hours
Education years	Years of education for children between 5 and 20 years of age in a household	Years of Education
Standard seven exam result	Whether children who sat for the standard seven exams in household passed/ failed the exam	Dummy (yes/no)
Acute respiratory symptoms	If a household has at least one child under the age of 5 and below with self-reported acute respiratory symptoms (fever, cough and short breaths emanating from the chest and nasal area)	Dummy (yes/no)
Number of children below five years	The number of children below 5 years old in a household	Continuous
Number of births in last five years	The number of births to a woman in a household in the last five years	Continuous
Waiting period between pregnancies	The period between two consecutive births	Years
Contraceptive use	If a woman uses contraceptives as a family planning method	Dummy (yes/no)

Table B.2: The number and percentage of households using modern cooking fuels

Modern energy use	**Full sample**	**Urban sample**	**Rural sample**
Yes	112 (3.35%)	91 (8.3%)	3 (0.17%)
No	3232 (96.65%)	1,005 (91.7%)	1767 (99.83%)
Total	3,344	1,094	1770

Source: Authors own calculations from the Tanzanian National Panel data survey wave 4

Table B.3: The balance of covariates for the full sample before and after matching using NPS Wave 4

Variable	Unmatched Matched	Mean			t-test	
		Treated	Control	%bias	t	p>t
Sex of the household head	U	0.76786	0.71256	12.6	1.27	0.203
	M	***0.76852***	***0.78739***	***-4.3***	***-0.33***	***0.740***
Age of household head	U	42.161	44.505	-15.9	-1.63	0.104
	M	***41.593***	***41.244***	***2.4***	***0.19***	***0.851***
Age of the household head squared	U	1986	2205.7	-15.1	-1.52	0.129
	M	***1918.4***	***1881.7***	***2.5***	***0.21***	***0.836***
Household size squared	U	19.964	32.146	-33.7	-2.79	0.005
	M	***20.102***	***21.633***	***-4.2***	***-0.52***	***0.606***
Household uses a clean stove	U	0.91964	0.05229	348.1	40.20	0.000
	M	***0.91667***	***0.90197***	***5.9***	***0.37***	***0.708***
Education of the household head	U	13.705	6.5699	163.6	16.78	0.000
	M	***13.648***	***13.631***	***0.4***	***0.03***	***0.977***
Household Income	U	15.942	14.936	137.1	14.48	0.000
	M	***15.904***	***15.879***	***3.4***	***0.27***	***0.789***
House ownership status	U	0.30357	0.68657	-82.7	-8.59	0.000
	M	***0.31481***	***0.30802***	***1.5***	***0.11***	***0.915***

Table B.4: The balance of covariates for the urban sample before and after matching using NPS Wave 4

Variable	Unmatched Matched	Mean		%bias	t-test	
		Treated	Control		t	p>t
Sex of the head of household	U	0.74725	0 .67099	16.8	1.49	0.136
	M	***0.74359***	***0.76829***	***-5.4***	***-0.36***	***0.722***
Age of household head	U	40.374	41.074	-5.0	-0.47	0.642
	M	***41.91***	***41.308***	***4.3***	***0.28***	***0.779***
Household size	U	15.22	20.142	-24.8	-1.97	0.049
	M	***16.833***	***17.682***	***-4.3***	***-0.36***	***0.722***
Household has access to electricity	U	.94505	.61316	87.2	6.43	0.000
	M	***.9359***	***.91928***	***4.4***	***0.40***	***0.691***
Household owns a biomass stove	U	1.2198	1.1216	26.2	2.67	0.008
	M	***1.0897***	***1.0829***	***1.8***	***0.15***	***0.880***
Household owns a Clean stove	U	.94505	.09571	322.0	26.80	0.000
	M	***.9359***	***.93599***	***-0.0***	***-0.00***	***0.998***
Education of the household head	U	14.275	8.4018	142.7	12.92	0.000
	M	***13.859***	***13.876***	***-0.4***	***-0.02***	***0.980***
Household Income	U	16.023	15.278	109.2	10.14	0.000
	M	***16.03***	***16.026***	***0.6***	***0.04***	***0.972***
House ownership status	U	.20879	.37288	-36.6	-3.14	0.002
	M	***.23077***	***.24513***	***-3.2***	***-0.21***	***0.834***

Table B.5: The balance of covariates for the full sample before and after matching using THDS 2015/16

Variable	Unmatched (U) Matched (M)	Mean		%bias	t-test	
		Treated	Control		t	p>t
Household has access to electricity	U	.94253	.29543	90.8	6.15	0.000
	M	***.94118***	***.94025***	***0.1***	***0.01***	***0.991***
Education of woman in the household	U	1.977	.97258	161.8	14.72	0.000
	M	***1.9529***	***1.9404***	***2.0***	***0.13***	***0.895***
Household size	U	5.023	6.3985	-51.9	-4.12	0.000
	M	***5.0353***	***5.1006***	***-2.5***	***-0.20***	***0.841***
Household size squared	U	29.598	50.576	-40.8	-2.87	0.004
	M	***29.765***	***30.506***	***-1.4***	***-0.17***	***0.863***
Wealth index	U	4.9655	2.9408	204.6	13.61	0.000
	M	***4.9647***	***4.9088***	***5.6***	***0.98***	***0.327***
Household owns a mobile	U	.96552	.48519	127.6	8.95	0.000
	M	***.96471***	***.95323***	***3.0***	***0.37***	***0.708***
Household's frequency of listening to the radio	U	1.3103	1.1532	19.7	1.82	0.069
	M	***1.3412***	***1.3528***	***-1.5***	***-0.10***	***0.923***
Woman's age	U	30.138	29.987	2.4	0.19	0.849
	M	***30.118***	***30.155***	***-0.6***	***-0.04***	***0.965***
Occupation of the household head	U	4.9195	5.3238	-10.8	-0.92	0.357
	M	***5.0118***	***5.0896***	***-2.1***	***-0.15***	***0.881***
Sex of the household head	U	1.2184	1.1744	11.1	1.07	0.284
	M	***1.2118***	***1.2176***	***-1.5***	***-0.09***	***0.927***
Age of the household head squared	U	1467.9	1757.6	-28.0	-2.28	0.023
	M	***1476.6***	***1455.3***	***2.1***	***0.16***	***0.869***

Table B.6: The balance of covariates for the urban sample before and after matching using the THDS 2015/16

Variable	Unmatched Matched	Mean		%bias	t-test	
		Treated	Control		t	p>t
Household has access to electricity	U	.97333	.62958	47.6	2.95	0.003
	M	***.97183***	***.95426***	***2.4***	***0.17***	***0.867***
Education of the household's wife	U	1.9467	1.2571	110.0	9.10	0.000
	M	***1.8873***	***1.8767***	***1.7***	***0.10***	***0.917***
Household size	U	5	5.915	-36.5	-2.72	0.007
	M	***5.0563***	***5.0952***	***-1.5***	***-0.11***	***0.915***
Household head owns a mobile	U	.96	.74499	63.5	4.25	0.000
	M	***.95775***	***.94538***	***3.7***	***0.34***	***0.734***
Age of the household head	U	36.627	39.618	-27.5	-2.10	0.036
	M	***36.944***	***37.146***	***-1.9***	***-0.12***	***0.905***
Sex of the household head	U	1.2133	1.1852	7.0	0.61	0.542
	M	***1.1972***	***1.2192***	***-5.5***	***-0.32***	***0.748***
Household listens to radio	U	1.3333	1.3642	-4.0	-0.35	0.728
	M	***1.3803***	***1.3543***	***3.4***	***0.20***	***0.843***
Household watches Television	U	1.88	1.1555	106.3	7.37	0.000
	M	***1.8732***	***1.8335***	***5.8***	***0.51***	***0.611***
Age of the household head's wife	U	29.6	29.15	7.4	0.57	0.572
	M	***29.606***	***29.683***	***-1.3***	***-0.08***	***0.935***

Table B.7: Propensity score estimation for impact of expenditure analysis

VARIABLES	(1) Full sample	(2) Urban sample
sex of household head	0.0856	0.00140
	(0.300)	(0.360)
age of household head	-0.0883	-0.00124
	(0.0560)	(0.0139)
Household size squared	-0.0150**	-0.0368***
	(0.00735)	(0.0121)
access to electricity		0.428
		(0.609)
Household owns a biomass stove		1.325***
		(0.491)
Household owns a Clean stove	4.261***	4.404***
	(0.406)	(0.527)
Education of household head	0.0835**	0.0523
	(0.0342)	(0.0439)
Household Income	0.657***	0.807**
	(0.238)	(0.327)
House ownership status	-0.720**	-0.419
	(0.304)	(0.416)
Age of household head squared	0.00100*	
	(0.000561)	
Constant	-13.96***	-19.15***
	(3.488)	(4.807)
Observations	3,344	1,094

*, ** and *** represent 10, 5 and 1 percent level of significance respectively

Table B.8: Propensity score estimation for the health outcomes impact analysis

VARIABLES	(1) full sample	(2) Urban sample
Household has access to electricity	-0.0577	0.283*
	(0.187)	(0.159)
Education of household head's wife	1.168***	1.340***
	(0.206)	(0.210)
Household size	-0.212	-0.192***
	(0.232)	(0.0744)
Household size squared	0.000910	
	(0.0169)	
Wealth Index	3.209***	
	(0.605)	
Owns a mobile telephone	0.960	0.871
	(0.610)	(0.618)
Frequency of listening to a radio	-0.553***	-0.583***
	(0.158)	(0.171)
Household head's wife age	0.0262	0.0491**
	(0.0229)	(0.0248)
Occupation of the household head	-0.0799**	
	(0.0393)	
Sex of household head	-0.212	-0.0748
	(0.316)	(0.332)
Age of household head squared	4.40e-05	
	(0.000174)	
Age of household head		-0.0131
		(0.0164)
Frequency of watching television		1.485***
		(0.334)
Constant	-19.57***	-7.564***
	(3.088)	(1.147)
Observations	5,557	1,522

*, ** and *** represent 10, 5 and 1 percent level of significance respectively

Table B.9: Matching quality Indicators for the impact of household use of modern cooking fuels analysis

	NPS WAVE 4		THDS	
	Full sample	**Urban Sample**	**Full Sample**	**Urban Sample**
Before Matching				
Pseudo R2	0.549	0.558	0.395	0.241
P>chi2	0.000	0.000	0.000	0.000
Mean of standardised bias	101.1	85.6	68.1	45.5
After Matching				
Pseudo R2	0.002	0.004	0.006	0.003
P>chi2	1.000	1.000	1.000	1.000
Mean of standardised bias	3.1	2.7	2.0	3.0

Figure B.1: The common support and Propensity score imbalance before and after matching for the full sample (Impact of household's use of cooking fuels on energy expenditures)

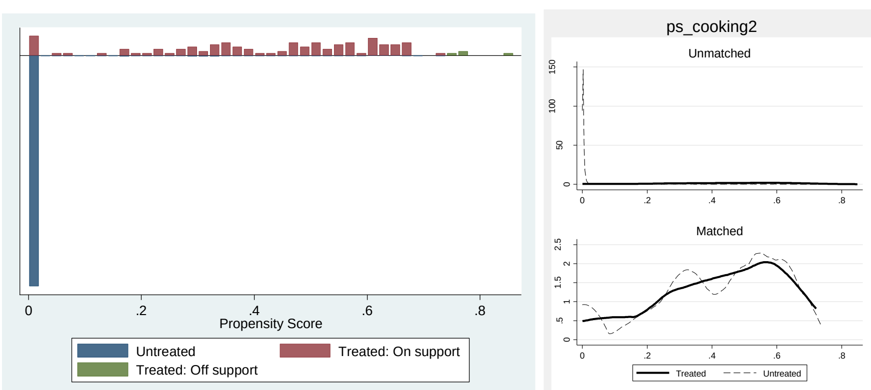


Figure B.2: The common support and Propensity score imbalance before and after matching for the urban sample (Impact of household's use of cooking fuels on energy expenditures)

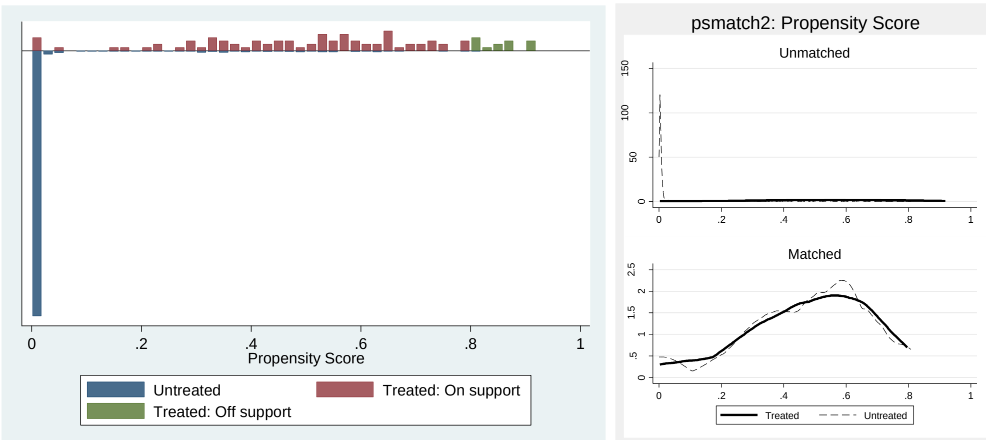


Figure B.3: The common support and Propensity score imbalance before and after matching from the full sample (Impact of household's use of cooking fuels on health)

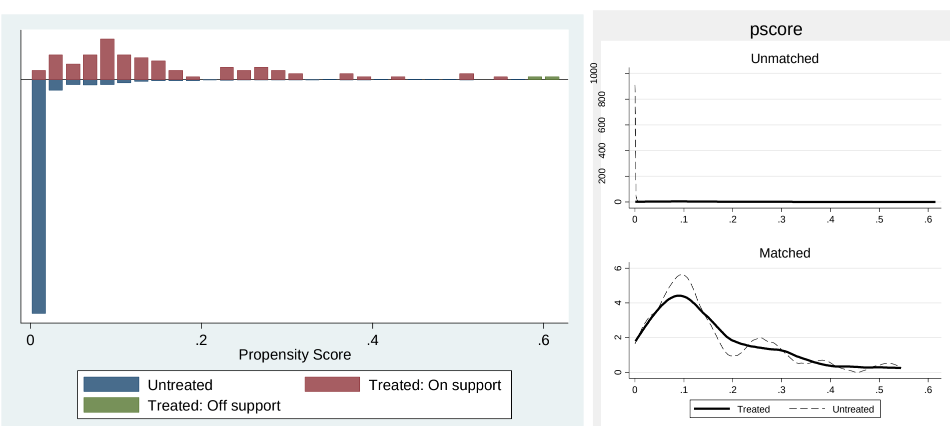
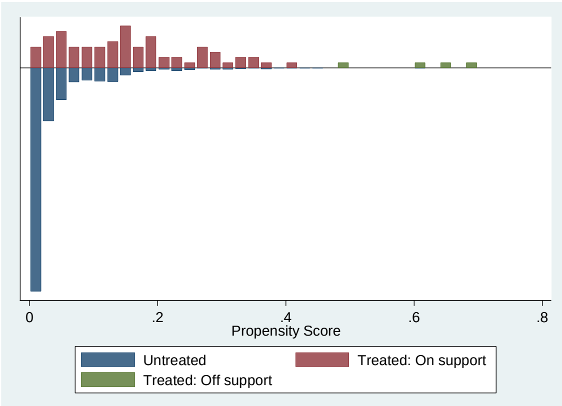


Figure B.4: The common support and Propensity score imbalance before and after matching for the urban sample (Impact of household's use of cooking fuels on health)



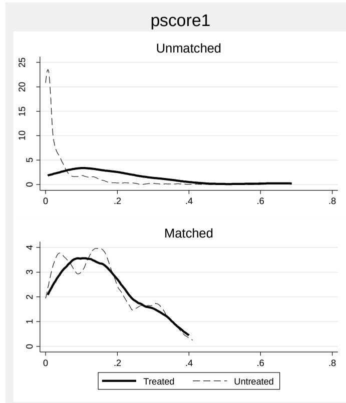


Table B. 10: The number and percentage of electrified households in Tanzania

Electrified	Full sample	Urban sample	Rural sample
Yes	1,284 (38.40%)	704 (64.35 %)	325 (18.36%)
No	2,060 (61.60 %)	390 (35.65%)	1,445 (81.64%)
Total	3,344	1,094	1770

Source: Authors own calculations from the Tanzanian National Panel data survey wave 4

Table B.11: The balance of covariates before and after matching for the full sample using NPS wave 4

Variable	Unmatched Matched	Mean		%bias	t-test	
		Treated	Control		t	p>t
Sex of household head	U	.74533	.69515	11.2	3.13	0.002
	M	***.74207***	***.74367***	***-0.4***	***-0.09***	***0.929***
Age of household head	U	42.439	45.665	-22.0	-6.08	0.000
	M	***42.419***	***42.123***	***2.0***	***0.53***	***0.596***
Household size	U	29.037	33.422	-10.5	-2.72	0.007
	M	***28.79***	***29.139***	***-0.8***	***-0.24***	***0.807***
Education of the household head	U	9.2648	5.2782	94.1	26.83	0.000
	M	***8.7763***	***8.5562***	***5.2***	***1.35***	***0.177***
Income of the Household	U	15.405	14.698	107.2	30.06	0.000
	M	***15.323***	***15.332***	***-1.3***	***-0.35***	***0.728***
House ownership status	U	.50467	.77913	-59.7	-17.17	0.000
	M	***.52003***	***.51827***	***0.4***	***0.09***	***0.931***
Household floor materials	U	.86293	.29806	139.5	38.04	0.000
	M	***.85309***	***.84752***	***1.4***	***0.38***	***0.702***
Household wall materials	U	.62695	.16456	107.3	31.12	0.000
	M	***.60267***	***.5968***	***1.4***	***0.29***	***0.769***
Household's number of dwelling rooms	U	2.8388	2.5927	17.5	5.04	0.000
	M	***2.7604***	***2.725***	***2.5***	***0.59***	***0.558***
Occupation of the head of the household	U	.2391	.67913	-98.4	-27.39	0.000
	M	***.25459***	***.25986***	***-1.2***	***-0.29***	***0.768***

Table B.12: The balance of covariates before and after matching for the rural sample using NPS wave 4

Variable	Unmatched Matched	Mean		%bias	t-test	
		Treated	Control		t	p>t
Sex of the household head	U	.77538	.71142	14.7	2.33	0.020
	M	***.77329***	***.78591***	***-2.9***	***-0.39***	***0.700***
Age of household head	U	44.252	46.122	-12.2	-1.95	0.052
	M	***44.289***	***45.286***	***-6.5***	***-0.87***	***0.383***
Household size	U	39.96	37.269	5.0	0.79	0.432
	M	***40.102***	***42.36***	***-4.2***	***-0.57***	***0.570***
Education of household head	U	7.2369	4.9197	58.2	9.72	0.000
	M	***7.1988***	***6.9522***	***6.2***	***0.78***	***0.436***
Household Income	U	15.134	14.61	79.4	12.85	0.000
	M	***15.125***	***15.13***	***-0.8***	***-0.10***	***0.919***
House ownership status	U	.78769	.86228	-19.7	-3.40	0.001
	M	***.79193***	***.80139***	***-2.5***	***-0.30***	***0.766***
Floor material	U	.56308	.1474	96.3	17.60	0.000
	M	***.55901***	***.55296***	***1.4***	***0.15***	***0.878***
Wall material	U	.14462	.01592	48.7	11.12	0.000
	M	***.13665***	***.13526***	***0.5***	***0.05***	***0.959***
Number of dwelling rooms in the house	U	3.28	2.7163	37.6	6.85	0.000
	M	***3.2764***	***3.2856***	***-0.6***	***-0.07***	***0.943***
Occupation of household head	U	.68308	.85121	-40.5	-7.23	0.000
	M	***.68944***	***.70009***	***-2.6***	***-0.29***	***0.770***

Table B.13: The balance of covariates before and after matching for the urban sample using NPS wave 4

Variable	Unmatched Matched	Mean		%bias	t-test	
		Treated	Control		t	p>t
Sex of household head	U	.70597	.62564	17.1	2.73	0.006
	M	***.69333***	***.6814***	***2.5***	***0.45***	***0.656***
Household size	U	20.051	19.156	4.0	0.62	0.536
	M	***19.16***	***20.044***	***-4.0***	***-0.68***	***0.493***
Education of household head	U	10.125	6.6615	84.7	13.26	0.000
	M	***9.12***	***9.0097***	***2.7***	***0.55***	***0.584***
Household Income	U	15.538	14.983	86.0	13.54	0.000
	M	***15.388***	***15.378***	***1.6***	***0.31***	***0.756***
House ownership status	U	.3054	.45641	-31.4	-5.04	0.000
	M	***.32***	***.32493***	***-1.0***	***-0.18***	***0.855***
Floor material	U	.95597	.66667	79.5	14.04	0.000
	M	***.94833***	***.94726***	***0.3***	***0.08***	***0.933***
Wall material	U	.7571	.50256	54.6	8.84	0.000
	M	***.73167***	***.72118***	***2.2***	***0.41***	***0.684***
Main dwelling room number	U	2.4844	2.1821	21.7	3.37	0.001
	M	***2.2833***	***2.3056***	***-1.6***	***-0.27***	***0.786***
occupation2_head	U	.09233	.21282	-34.0	-5.66	0.000
	M	***.09667***	***.11291***	***-4.6***	***-0.92***	***0.359***

Table B.14: The balance of covariates before and after matching for the full sample using THDS 2015/16

Variable	Unmatched Matched	Mean		%bias	t-test	
		Treated	Control		t	p>t
Age of the head of the household	U	39.771	40.165	-3.2	-1.17	0.244
	M	**39.771**	**39.697**	**0.6**	**0.21**	**0.836**
Education years of the head of the household	U	8.1919	5.9458	57.4	21.14	0.000
	M	**8.1919**	**8.018**	**4.4**	**1.46**	**0.145**
Household size	U	48.869	51.177	-3.5	-1.25	0.213
	M	**48.869**	**48.757**	**0.2**	**0.05**	**0.959**
Households listens to the radio	U	1.3573	1.0202	43.5	15.77	0.000
	M	**1.3573**	**1.3819**	**-3.2**	**-1.10**	**0.270**
Household watches Television	U	1.0067	.36687	85.4	32.39	0.000
	M	**1.0067**	**1.01**	**-0.4**	**-0.13**	**0.897**
Household own a mobile phone	U	.68202	.36536	66.8	24.35	0.000
	M	**.68202**	**.66685**	**3.2**	**1.08**	**0.279**
Occupation of the household head	U	5.6691	5.0798	14.4	5.32	0.000
	M	**5.6691**	**5.7838**	**-2.8**	**-0.66**	**0.510**

Table B.15: The balance of covariates before and after matching for the rural sample using THDS 2015/16

Variable	Unmatched Matched	Mean		%bias	t-test	
		Treated	Control		t	p>t
Age of the household head	U	41.202	40.401	6.3	1.89	0.058
	M	**41.146**	**41.181**	**-0.3**	**-0.07**	**0.942**
Education of the household head	U	7.1994	5.7772	37.4	11.31	0.000
	M	**7.1906**	**7.1611**	**0.8**	**0.20**	**0.845**
Household size	U	55.319	53.336	2.8	0.82	0.413
	M	**54.991**	**53.583**	**2.0**	**0.55**	**0.583**
Household listens to the radio	U	1.2795	1.0014	35.5	10.55	0.000
	M	**1.2784**	**1.2779**	**0.1**	**0.02**	**0.988**
Household watches Television	U	.66541	.33099	48.4	15.47	0.000
	M	**.66339**	**.67029**	**-1.0**	**-0.23**	**0.820**
Household owns a mobile phone	U	.56571	.32853	49.1	14.91	0.000
	M	**.56505**	**.56073**	**0.9**	**0.22**	**0.823**
Occupation of the household head	U	5.2311	4.8974	8.9	2.60	0.009
	M	**5.2277**	**5.3013**	**-2.0**	**-0.38**	**0.701**

Table B.16: The balance of covariates before and after matching for the rural sample using THDS 2015/16

Variable		Mean			t-test	
	Unmatched Matched	Treated	Control	%bias	t	p>t
Age of the household head	U	37.694	38.749	-9.3	-1.70	0.089
	M	**37.319**	**36.828**	**4.3**	**0.97**	**0.333**
Education of the household head	U	9.6327	6.9578	70.2	12.29	0.000
	M	**9.4333**	**9.4612**	**-0.7**	**-0.15**	**0.878**
Household size	U	39.503	38.213	2.8	0.48	0.629
	M	**36.243**	**34.564**	**3.6**	**0.86**	**0.392**
Household watches Television	U	1.5022	.58228	127.5	22.35	0.000
	M	**1.4823**	**1.4871**	**-0.7**	**-0.13**	**0.893**
Household owns a mobile phone	U	.85088	.5865	61.5	11.44	0.000
	M	**.84493**	**.82362**	**5.0**	**1.20**	**0.230**
Occupation of the household head	U	6.3048	6.1751	3.2	0.51	0.608
	M	**6.3489**	**6.5313**	**-4.5**	**-0.93**	**0.354**

Table B.17: Propensity score estimation for impact of electrification on expenditure, education and time use analysis using the NPS wave 4.

VARIABLES	(1) Full sample	(2) Rural sample	(3) Urban sample
sex of household head	-0.133	-0.0152	-0.236
	(0.109)	(0.173)	(0.165)
age of household head	0.00175	-0.00708	
	(0.00388)	(0.00543)	
Household size squared	-0.0027**	-0.00311*	-0.00279
	(0.00137)	(0.00169)	(0.00408)
Household’s head education	0.102***	0.0473**	0.139***
	(0.0132)	(0.0208)	(0.0215)
Household’s Income	1.013***	0.907***	0.932***
	(0.0929)	(0.135)	(0.158)
House ownership status	-0.474***	-0.0658	-0.774***
	(0.124)	(0.213)	(0.213)
Materials used for the floor	1.407***	1.263***	1.620***
	(0.123)	(0.159)	(0.257)
Materials used for the wall	0.450***	1.115***	0.160
	(0.119)	(0.302)	(0.184)
Number of habitable rooms	0.169***	0.129**	0.227***
	(0.0402)	(0.0516)	(0.0787)
occupation of household head	-0.327***	-0.279	0.359
	(0.122)	(0.181)	(0.257)
Constant	-17.37***	-15.40***	-16.36***
	(1.347)	(1.941)	(2.273)
Observations	3,344	1,770	1,094

*, ** and *** represent 10, 5 and 1 percent level of significance respectively

Table B.18: Propensity score estimation for impact of electrification on health and fertility analysis using 2015/16 THDS.

VARIABLES	(1) Full sample	(2) Rural sample	(3) Urban sample
Age of household head	0.00484*	0.00704**	0.00237
	(0.00277)	(0.00303)	(0.00692)
Education of household head	0.0897***	0.0694***	0.133***
	(0.00877)	(0.0101)	(0.0193)
Household size squared	0.00127**	0.00102*	0.00406**
	(0.000511)	(0.000525)	(0.00167)
Frequency of listening to radio	0.156***	0.192***	
	(0.0419)	(0.0476)	
Frequency of watching television	0.789***	0.456***	1.285***
	(0.0434)	(0.0539)	(0.0866)
Owns a mobile telephone	0.789***	0.707***	0.712***
	(0.0643)	(0.0725)	(0.155)
Occupation of household head	0.0173**	0.0116	0.0204
	(0.00730)	(0.00841)	(0.0149)
Constant	-2.487***	-2.367***	-2.688***
	(0.149)	(0.164)	(0.365)
Observations	5,556	4,170	1,386

*, ** and *** represent 10, 5 and 1 percent level of significance respectively

Table B.19: Matching quality indicators for the impact of household use of electricity

	NPS WAVE 4			THDS		
	Full sample	**Rural sample**	**Urban Sample**	**Full Sample**	**Rural sample**	**Urban Sample**
Before Matching						
Pseudo R2	0.350	0.204	0.239	0.166	0.081	0.268
P>chi2	0.000	0.000	0.000	0.000	0.000	0.000
Mean of standardised bias	66.7	41.2	45.9	39.2	26.9	45.7
After Matching						
Pseudo R2	0.001	0.002	0.001	0.001	0.000	0.001
P>chi2	0.941	0.999	0.996	0.542	0.998	0.737
Mean of standardised bias	1.6	2.8	2.3	2.1	1.0	3.1

Figure B.5: The common support and Propensity score imbalance before and after matching for the full sample (The Impact of household electrification on non-health outcomes)

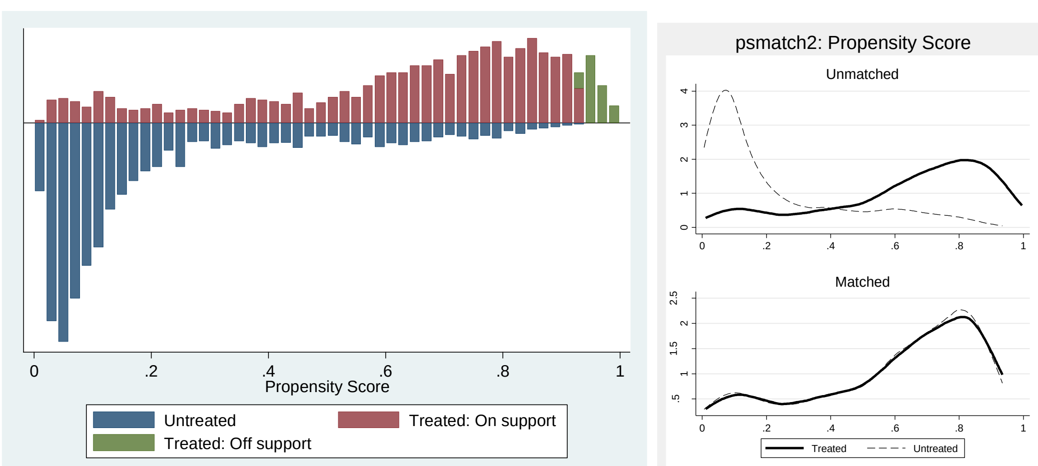


Figure B.6: The common support and Propensity score imbalance before and after matching for the rural sample (The Impact of household electrification on non-health outcomes)

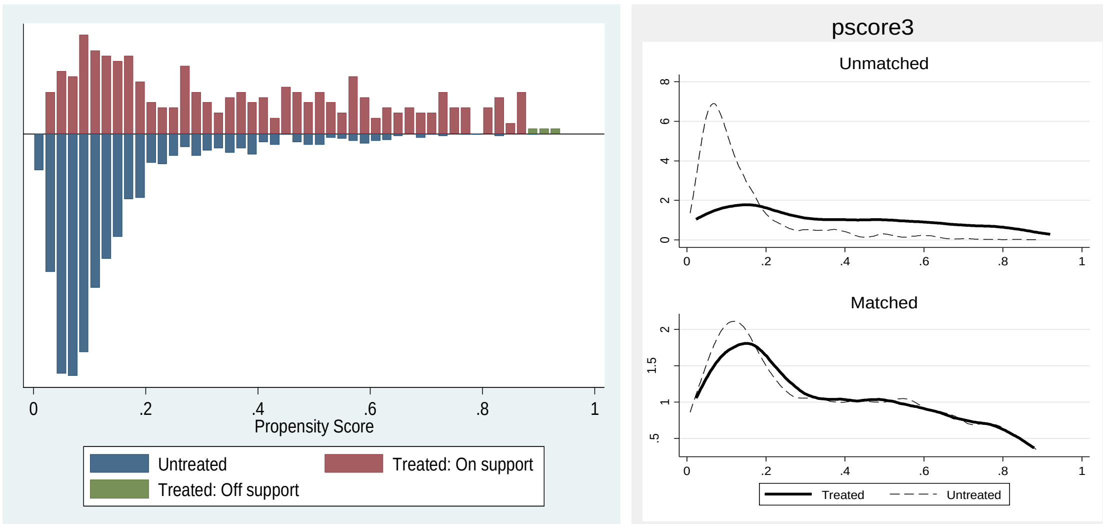


Figure B.7: The common support and Propensity score imbalance before and after matching for the urban sample (The Impact of household electrification on non-health outcomes)

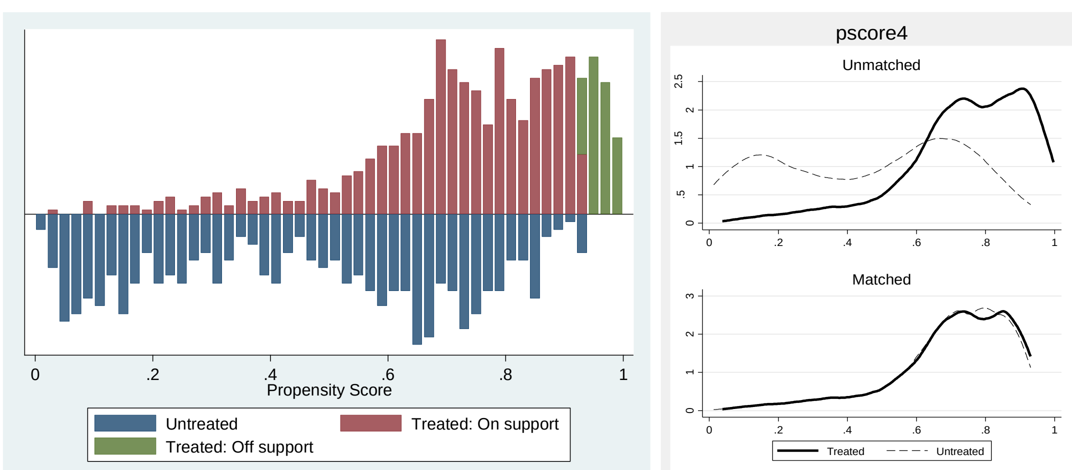
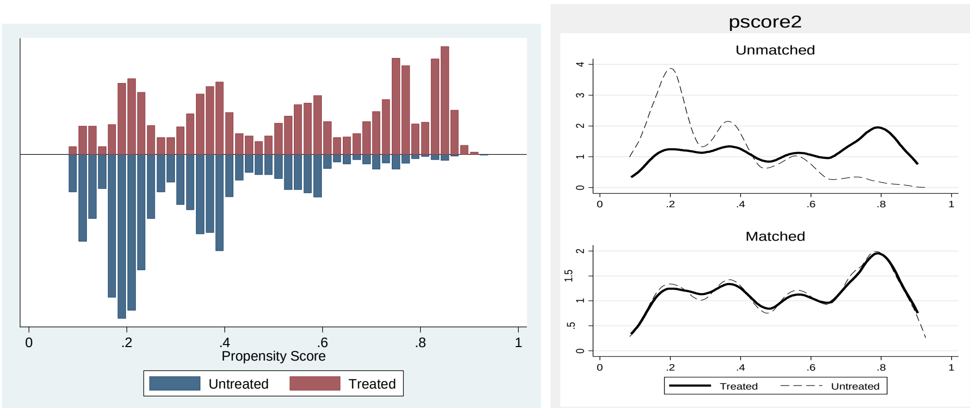


Figure B.8: The common support and Propensity score imbalance before and after matching for the full sample (The Impact of household electrification on health outcomes)



APPENDIX C: Appendix for chapter four

C.1: QUESTIONNAIRE-THE POLITICAL ECONOMY OF HOUSEHOLD ENERGY TRANSITIONS IN TANZANIA: EXPERT INTERVIEW GUIDE 2019

Instructions for using this guide

Use this interview guide to conduct semi-structured interviews for the research project "The political economy of household energy transitions in Tanzania." Before starting the interview. Make sure that you have a signed copy of the consent form from the participant. Ask the participant if he/she has any question about the consent form.

Interviewer Introduction

Read the following to introduce yourself to the interviewee:

My name is Kevin Rugaimukamu, a PhD student, and an affiliate of the Environmental for development network (EfD), I will be interviewing you on the drivers (Incentives and disincentives) of policy outcomes within the Tanzanian energy sector with regards to electricity access in Tanzania. Our Interview will take a maximum of 1 hour.

The Narrative

Tanzania has got prominent energy policies and supporting strategies and plans in place. The current 2015 energy policy has "***outlined improving the security of supply through effective use of energy resources and cross boarder trading; enhancing power reliability and coverage of transmission and distribution networks; accelerating rural electrification; enhancing utilization of renewable energy and increasing private sector participation in the electricity industry"*** as key objectives to improve electricity access in Tanzania**.** Although electricity access has increased over the years, the electrification rates of the country particularly in the rural areas, are still low compared to the global average and far off from the set targets in the development plans and strategy documents of the country. As one of the key stakeholders in the sector I want to get your views on the problem of electricity access and connection in rural Tanzania. How the institutional framework of the sector, the regulatory framework and the private sector/development partners incentivize/disincentives the materialization of policy outcomes in the electricity supply industry in Tanzania.

Interview questions

What is the work of your institution with regards to energy access in Tanzania?

1. How do you characterize the electricity access problem in Tanzania? Does it have to do with the supply/demand side alone/both? Why do you think the policy outcomes of the designed policies and supporting strategies with regards to rural electrification have not materialized? (Probe on: Implementation of the budgets, availability of funds, interactions of stakeholders in the electricity supply industry)

2. The institutional set up managing different operations in the electricity supply industry in Tanzania is key in improving electricity access in Tanzania, with TANESCO (National Power utility company), EWURA (the regulator of the electricity sector), REA (rural electrification agency) and MOE (ministry of energy) being some of the key institutions governing the electricity supply industry.

    - What the pros and cons of the current institution set up of the sector as a whole and the institutional set up of the individual institutions mentioned?

- Are there inefficiencies resulting from the current institutional set up that provide disincentives to the provision of affordable electricity to all in Tanzania? (Probe: On the suggestions in the strategies to unbundle the national power utility institution, what's hindering such transformation of institutions in the country)

3. Tanzania has a vast of legislations and regulations (Energy acts, of 2001, 2005 and 2006; PPP Act N.18; Petroleum Act of 2008) governing the electricity supply industry in terms of electricity generation, transmission, distribution of electricity, Investment in the various part of the electrification process
    - Do you think the rules governing these processes are clear to all the stakeholders involved such as the private sector and other key stakeholders?
    - Do you think they warrant enhanced participation by stakeholders in the electricity supply industry?
    - What do you think are some uncertainties with regards to the rules and regulations that derail the attainment of electrification policy outcomes? (Probe rules and regulations with regards to; Investment in the electricity supply sector, boundaries in authority between institutions, are the ones with authority in terms of rules the ones that determine the outcomes in the sector or interactions between stakeholders override the authority of some institutions?)

4. Tanzania has enjoyed political stability and peace since Independence, with five presidential regimes to date, each regime characterized with its own political agenda. The current regime's agenda is "industrialization of the economy" with the slogan

"HapaKazituu" under the leadership of his Excellency President John Joseph Pombe Magufuli,

- what do you see being the approach pursued by the current regime in achieving policy outcomes in electricity supply industry?
- Have the regimes provided continuity in terms of projects and the direction of the electricity supply industry? How does policy continuity or discontinuity by political regimes affect electricity supply?

5. Development partners and the private sector have played a role in pushing the development agenda of most Sub-Saharan African Countries, Tanzania included.
   - What has been the overall approach of funding of energy projects by development partners (loans/Grants/Partnership) and what determines the approach taken in funding a project? (Does a country have a say in terms of the approach it wants to receive funding? Which approach among the three readily brings funding on the table?)
   - Is there always a coherence in terms of national energy project and funding objectives from development partners? If disparities in objectives exist does this deprive the country of funding for energy projects?
   - What level of influence do development partners have in determining projects to be implemented that are different from the national plans and strategies? (if any, why do these scenarios occur)
   - What challenges are there in terms of increased private sector participation in energy projects in Tanzania?

6. What do you see as the opportunities, areas of improvement in the policy set up, institutional set up and regulatory framework with regards to the supply of affordable electricity and increased access to electricity for households in Tanzania? (Probe improvements regarding investments in the electricity sector, rules governing the sector, and general governance)

C.2: IMPORTANT POLICIES, STRATEGIES AND LEGISLATIONS IN THE TANZANIAN ENERGY SECTOR

Table C.1: Important Policies, Strategies And Legislations in the Tanzanian Energy Sector

Policy framework
National Energy policy of 2015
Electricity Act of 2008
Energy and Water Utilities Act 2001 and 2006
Rural Energy Act of 2005
Public Private Partnership act of 2010
Investment Act of 1997
Contract review Act of 2017
Land Act of 1999
Village Land Act 1999
Public finance act of 2001
Public procurement act of 2011
Water management act of 2009
The environment management act of 2004
Petroleum act of 2008
Government driven strategies and plans
Tanzania's Development Vision (TDV), 2025
National Strategy for Growth and Reduction of Poverty II
Power Systems Master Plan 2012 (2013- 2035)
Electricity Supply Industry (ESI) Reform Strategy and Roadmap 2014-2025
National electrification Program prospectus 2013-2022