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EFFECTS OF POWER OUTAGES ON HOUSEHOLD INCOMES IN SELECTED SUB-SAHARAN AFRICAN COUNTRIES

PETER CLEVER AABEKA

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BY

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A thesis submitted to the Department of Economic Studies of the School of Economics, College of Humanities and Legal Studies, University of Cape Coast, in partial fulfillment of the requirements for the award of a Master of Philosophy degree in Economics.

OCTOBER 2023

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my original research and that no part of it has been presented for another degree at this University or elsewhere.

Candidate's Signature …… Date ……...

Name: Peter Clever Aabeka

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature …… Date ……

Name: Isaac Dasmani (Ph.D.)

Co-Supervisor's Signature ……..…… Date ……..…...

Name: Francis Taale (Ph.D.)

ABSTRACT

Sub-Saharan Africa is home to over 600 million people facing frequent, unplanned as well as unannounced power outages. Though the investigation of the effects of power outages is growing, less attention has been paid to households. This study examined the effects of power outages on household incomes in three selected sub-Saharan African countries namely Nigeria, Ethiopia, and Niger using a weighted least square. The study found that monthly hours of a power outage is negatively associated with the two categories of non-farm income identified in this study namely non-farm industry income and non-farm services income across the three countries. Besides, the study also found a negative association between monthly hours of power outage and total household income. In view of this, it is recommended that the government of Nigeria should explore the integration of renewable energy sources as a potential solution to alleviate electricity shortages in Nigeria. Also, the Ethiopian Electric Power Company should enhance service delivery and expedite infrastructure rehabilitation for a reliable electricity supply in Ethiopia. Finally the government of Niger should promote energy independence and diversification strategies for a reliable electricity supply in Niger.

KEY WORDS

Power outages

Household Income

Non-farm Industry Income

Non-farm Services Income

Total Household Income

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DEDICATION

To Felicitas Aabeka and Thaddeus Aasoglenang

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LIST OF ABBREVIATIONS

AMI	Advanced Metering Infrastructure
CFA	Communaute Financière Africaine
EAPP	Eastern Africa Power Pool
ESS	Ethiopian Socioeconomic Survey
ETB	Ethiopian Birr
GDP	Gross Domestic Product
GERD	Grand Ethiopian Renaissance Dam
GTP	Growth and Transformation Plan
GW	Gigawatts
ICT	Information and Communication Technology
IEA	International Energy Agency
ICW	Income Consumption and Wealth
IPP	Independent Power Producers
IRENA	International Renewable Energy Agency
kWh	Kilowatt-hour
MW	Megawatts
NLSS	Nigeria Living Standards Survey
NIGLELEC	Société Nigérienne d'Electricité
NGN	Nigerian Naira
OECD	Organisation for Economic Co-operation and Development
PASDEP	Plan for Accelerated and Sustained Development to End Poverty
PHCH	Power Holding Company of Nigeria

WAPP	West African Power Pool
WLS	Weighted Least Square

CHAPTER ONE

INTRODUCTION

Globally, it has been recognised and widely documented that access to modern energy services, including electricity, is an important driver of socioeconomic development and livelihood enhancement (Sarkodie & Adams, 2020). Despite this, many people around the world have limited or no access to electricity and other modern energy services. In particular, sub-Saharan Africa faces a "double tragedy" when it comes to electrification. Electricity access rates in the region are minimal, while those who have access also face frequent, unplanned, and sometimes unannounced outages. Like other parts of the region, many households in Nigeria, Ethiopia, and Niger also face chronic and persistent power outages. Frequent power outages have negative effects on the economic well-being of households. They are also said to be responsible for direct damage to household electrical appliances and machinery used for home-based production including refrigerators, television sets, and mobile phones (Meles, 2020).

The causal effect of electricity supply on household income is complex and both direct and indirect. Electricity is an input into the production activities of many households' economic activities particularly, non-farm activities, hence supply disruptions have implications on several household characteristics such as employment, health, safety, leisure as well as income. Previous studies such as (Amoah, Ferrini, & Schaafsma, 2015; Meles, 2020; Nduhuura, Garschagen, & Zerga, 2021) have investigated the impact of power outages on several household characteristics including employment, health, expenditure, and general socio-economic well-being in developing

countries. These studies have however paid less attention to the effect of power outages on household incomes in developing countries. This study contributes to the existing literature by estimating the effect of power outages on household incomes in three sub-Saharan African countries namely Nigeria, Ethiopia, and Niger.

Background to the Study

Recurrent interruption of power supply, otherwise known as a power outage, is the state of complete absence of electricity (power) at the consumer's end (Amadi & Okafor, 2015). This phenomenon comes in different forms: 1) blackout which is a complete loss of power to an area, 2) brownouts typically involve a drop in electrical voltage or the overall power supply, 3) rolling blackouts also known as load shedding are planned power outages usually implemented in areas with unstable grids and 4) permanent faults are sudden loss of power typically caused by a power line fault. Most outages in sub-Saharan Africa are caused by poor infrastructure or a lack of fuel to run power at full capacity to meet a target population due to financial constraints in the power sector (Eberhard, Foster, Briceño-Garmendia, Ouedraogo, Camos, & Shkaratan, 2008).

Power outages in sub-Saharan Africa mainly take the forms of blackouts and rolling blackouts resulting from the inability of many countries to meet the growth in electricity demand and the poor maintenance of equipment (Trace, 2020). Although power outage is a global phenomenon, it is more critical in developing countries. The number of reported power outages is rising globally: in the United States of America (USA) the average number of annual outages doubles every five years (Mukherjee, Nateghi, & Hastak,

2018) and in Europe, countries have experienced multiple energy blackouts since 2000 (de Nooij, Koopmans, & Bijvoet, 2007). High as these global power outages may be, they are better compared to the estimates obtained in developing countries. For instance, over the last three decades, over 620 million people have faced electricity blackouts (International Energy Agency, 2015). This occurred in at least 25 countries including, Nigeria, Ethiopia and Niger, which led to "energy crises" (Amoah, 2015). In addition, a 2016 Afro-barometer report shows that 31% of grid-connected households in Africa experience unreliable power supply.

The unreliability of power supply in households varies across countries, with most countries in sub-Sahara Africa, which traditionally have low electricity access rates recording high-power outages. On average, electricity in sub-Saharan Africa is reported to be unavailable for what amounts to a total of about twenty-three days each year (International Energy Agency, 2015). Energy conditions are particularly critical in Nigeria, Ethiopia, and Niger having some of the lowest electricity reliability rates (experiencing most electricity outages) in the region (Nduhuura et al., 2021). In 2009, Niger recorded on average 22 power outages in a typical month where access to electricity as a percentage of the population is 18.8%. Ethiopia with an access rate of 48.3% recorded 8.2 outages in a typical month (Carlsson, Demeke, Martinsson, & Tesemma, 2020). The situation is much worse in Nigeria where outages occur 32.8 times in a month (Adewuyi & Emmanuel, 2018).

The occurrence of frequent power outages impedes economic activities, particularly of households and those of the informal sector, micro, small, and medium-sized enterprises that have very limited resources to

acquire standby generators or keep sufficient fuel reserves for private electricity generation. Unreliable electricity impacts users by limiting electricity consumption and the benefits that should accrue from having an electricity connection (Nduhuura et al., 2021). Households in particular use electricity to power electrical appliances and equipment including refrigerators, cooling systems, lighting systems, heating and cooking appliances, television, as well as ICT devices. These electrical appliances and equipment offer essential services to support food preparation and preservation, home-based production, academic activities, safety and security, communication, and access to information as well as air conditioning, comfort, and leisure. When power outages occur, all these services are disrupted thereby reducing opportunities, particularly for home-based economic activities, as well as electricity-induced job creation in the form of non-farm enterprises.

Numerous households within the sub-Saharan African region derive approximately 65% of their income from non-farm economic activities conducted at the household level. For instance, according to the data employed in the study, households in Ethiopia, Niger and Nigeria generate approximately 63 %, 47 % and 13% their income from non-farm activities respectively. Nevertheless, when these three countries are combined, they collectively derive 97% of their income from non-farm economic activities. Incomes from these economic activities, commonly known as non-farm income, can be further categorized into two distinct types: non-farm industry income, which encompasses income generated from household economic activities falling within the industrial sector of the economy, and non-farm

services income, which pertains to income derived from household economic activities falling within the service sector of the economy. Given that the majority of household non-farm economic activities rely heavily on a consistent supply of electricity, power outages have a direct effect on the income streams generated from non-farm industry and services activities (Proctor, 2014).

Statement of the Problem

Despite the critical role of electricity in socioeconomic development and livelihood empowerment in Africa, its supply has been persistently unreliable leaving many households in the continent with chronic and persistent outages in the form of blackouts and rolling blackouts. According to a report by the International Energy Agency (2015), nearly 620 million Africans faced power outages in 2015. The severity of this phenomenon is pronounced in sub-Saharan Africa, specifically in Nigeria, Ethiopia, and Niger. Nigeria experiences a monthly average of 32 power outages, while Ethiopia encounters approximately 8.2 power outages per month. Similarly, Niger reports an average of 22 power outages per month with an average duration of 5.8 hours.

Amid these power outages, several questions are raised about the impact of power outages on users of electricity in the region, especially households. Power outages can greatly disrupt the social and economic activities of households that depend on electricity. Several household economic activities such as non-farm economic activities are severely affected by recurrent power disruptions thereby limiting household incomes earned from these activities. The recent studies and interventions about household

electrification in sub-Saharan Africa largely focus on increasing electricity connections with less attention about electricity supply (un)reliability (Nduhuura et al., 2021).

However, there have been few previous studies including Amadi (2015) and Meles (2020) that investigated the impact of electricity outages on the socioeconomic well-being of rural households and the monthly defensive expenditures for urban households in Nigeria and Ethiopia respectively. Nevertheless, the examination of power outages on household incomes especially non-farm industry and services incomes that depend on reliable electricity supply in sub-Saharan African countries is relatively limited and hence little is known about its effect on household incomes in sub-Saharan Africa.

Purpose of the Study

This study aims to fill this knowledge gap by assessing the effects of power outages on household incomes in three selected sub-Saharan African countries namely Nigeria, Ethiopia, and Niger. Hence, the study used a weighted least square to estimate the effects of power outages on household incomes in each of the three countries as well as all of the three countries combined. The weighted least squares technique is employed to help address the potential heteroskedasticity issue associated with cross-sectional data.

Objectives of the Study

The general objective of this study is to assess the effects of power outages on households' incomes in three sub-Saharan African countries (Nigeria, Ethiopia, and Niger). The specific objectives are to:

1. Examine the effects of power outages on household non-farm industry income.
2. Determine the effects of power outages on household non-farm services income.
3. Examine the effects of power outages on total household income.

Hypotheses of the Study

The following hypotheses are formulated and tested:

1. H_0: Power outages have no significant negative effects on household non-farm industry income.

   H_A: Power outages have significant negative effects on household non-farm industry income.

2. H_0: Power outages have no significant negative effects on non-farm services income.

   H_A: Power outages have significant negative effects on non-farm services income.

3. H_0: Power outages have no significant negative effects on total household income.

   H_A: Power outages have significant negative effects on total household income.

Significance of the Study

The outcome of the study will be beneficial to, first, the Ministries of Power/Energy and utility companies in Nigeria, Ethiopia, and Niger, for that matter their governments. The study's recommendation will inform their governments that the provision of households with access to reliable electricity is important to the improvement of household incomes and economic

wellbeing through electricity induced economic activities. Therefore, policies should be formulated and implemented to address the issue of power outages in these countries. To be specific, the Governments and Electricity Companies in Nigeria, Ethiopia, as well as Niger will be motivated to implement the recommendations made by the study.

The Electricity companies in Nigeria, Ethiopia and Niger will be encouraged to invest in advanced metering infrastructure (AMI) to improve revenue collection through the minimization of distributional losses since the financial difficulties through distributional losses is one of the causes of power outages across these countries. Electricity utility companies in Nigeria, Ethiopia, and Niger will be motivated to adopt digital technologies such as sensors and smart meters for accurate data collection and measurement of outages and related information on electricity systems. This will help in the quick detection of minor system failures which are sometimes unnoticed until a customer reports them. Investment in other forms of renewable energy to supplement the low generation of installed capacities in these countries to meet the growing excess electricity demand. Finally, the study will apprise all relevant stakeholders including Governments across the sub-Saharan region, Electricity companies, households, the West African Power Pool (WAPP), and the Eastern Africa Power Pool (EAPP) of the implications of unreliable power systems on household incomes and motivates the need for all stakeholders to work together to expedite their efforts to develop common electricity markets for the regions as envisioned so that countries with low generation capacity can benefit from countries with excess capacity.

Delimitation of the Study

The study is delimited to three countries in sub-Saharan Africa namely Nigeria, Ethiopia, and Niger. Again, the study only used variables from household demographics, education, employment and remittances, non-farm enterprise, and housing living conditions from the living standard surveys of these countries to determine the effects of power outages on household incomes. However, variables representing health conditions, consumption, household shocks, credit, assets, district-level factors as well as other factors that may determine household income were not considered.

Limitations of the Study

The model specified for this study could not include some relevant variables namely, access to credit, water, road, and mobile phone as well as market conditions. These variables were captured as binary variables from the Living Standard Survey data for all three countries. Though these variables are relevant, their inclusion could result in multicollinearity. Also, the study assumes that many household outages occur as a result of the inability of the current generation to meet the current electricity demand. Therefore, most power outages are not randomised but are decided by power utility companies in a form of rolling blackouts (load shedding). The non-random experience of power outages by households raises the issue of selection bias and the method employed is inadequate in dealing with the issue.

That notwithstanding, the objective of the study which was to determine the effects of power outages on household incomes was achieved. Finally, households in the high-income bracket are likely to be targeted with few outages compared to those in the low-income bracket hence, the potential

reverse causation between power outages and household income can lead to endogeneity in the models' estimation. The appropriate technique is instrumental variable estimation. However, the researcher found no appropriate instrument to solve this problem. The availability of an appropriate instrument for power outage at the household level is practically impossible. Night light variability, variability in river flow, variability in oil prices are instruments mostly used to instrument power outages. However, these instruments are not available at the household level. Since the test for endogeneity is not possible in the absence of a valid instrument, the study conducted both correlation and reverse regression to ensure that there is no reverse causation of household income on power outages. This was done to ensure that parameter estimates are not affected by the issue of endogeneity.

Organisation of the Study

This study is organised into five chapters. Chapter One introduces the study. It contains the background of the study, the statement of the problem, the purpose of the study, the objectives of the study, research hypotheses, the significance of the study, the delimitation of the study, the limitation of the study, and, finally, the organisation of the study. Chapter Two reviewed literature related to the study covering an overview of the electricity sectors in all three countries, the definition of household income, composition of household income, classification of household income, sources of non-farm income, classification of non-farm income, a review of the theory of the household, the Beckerian household, household production function, a conceptual framework as well as some previous empirical studies. The methods of the study are discussed in Chapter Three. The discussions included

the research paradigm, research design, data sources, theoretical framework, empirical model, and the definition of variables. Chapter Four presented and discussed the results obtained from the study. Finally, conclusions, a summary of findings, and recommendations are presented in Chapter Five.

CHAPTER TWO

LITERATURE REVIEW

Introduction

This chapter presents a review of the relevant literature related to power outages and household incomes. The first section of the review presents an overview of the electricity sectors in Ethiopia, Niger, and Nigeria. The second section presents the definition of household income, its composition as well as the classification of household incomes. The third section presents non-farm income, the sources, classification, and contribution of non-farm income in sub-Saharan Africa. The fourth section reviews household production theories. The fifth section outlines a conceptual framework detailing the various channels through which power outages affect household income while the final section presents the empirical review focusing on previous studies conducted by earlier researchers. The essence of the review is to bring to the fore what has been done and said about the effect of power outages on households and how it affects household income levels as well as the gaps to be covered in this study.

Overview of the Electricity Sector in Ethiopia

This section explores the electricity generation capacity, investments, growth in electricity demand, and supply shortages in the power sector of Ethiopia. The mandate to generate, transmit, and distribute electricity in Ethiopia lies with Ethiopian Electric Power, a state-owned and operated electricity producer in Ethiopia. Its role in the business of developing, investing in, building, operating, and managing power plants, as well as power generation and transmission, makes it a major player in Ethiopia's energy

sector. Electricity in Ethiopia is generated using a combination of low-cost, clean renewable primary energy sources such as hydropower and wind power. Ethiopia has identified a total of 45 gigawatts (GW) of hydropower and 1,350 gigawatts (GW) of wind power as economically viable. While photovoltaics and geothermal have a total of 5.2 gigawatts (GW) and 7 gigawatts (GW) of economically feasible energy potential respectively (Ethiopian Electric Power, 2014).

The Ethiopian government as part of its development agenda to eradicate poverty saw the implementation of "A Plan for Accelerated and Sustained Development to End Poverty (PASDEP)" from 2005 – 2010. Included in PASDEP were plans to strengthen the energy sector. These plans resulted in the construction of additional hydropower facilities, including the Tekeze, Gilgel Gibe II, and Tana Belese plants, which increased Ethiopia's hydropower generating capacity to 714 megawatts (MW). As part of its overall objective to boost electricity generation in Ethiopia by the end of 2009/10, PASDEP attained a generation capacity of 2,000 megawatts (MW), or 62% of the target of 3,270 megawatts (MW). In addition, 4.6 million energy-saving bulbs were provided to clients during the PASDEP period to conserve electricity (Ministry of Water and Energy, 2012).

According to the Ministry of Finance and Economic Development of the Federal Democratic Republic of Ethiopia (2010), the length of power transmission lines built was to be increased from 8,380 kilometers in 2004/05 to 14,792 kilometers in 2009/l0. In 2009/10, a total of 12,147 kilometers of power transmission lines were built, achieving 82 percent of the PASDEP targets. It was intended to enhance the length of power substation lines from

25,000 kilometers in 2004/05 to 136,320 kilometers in 2009/10. A rural electrification initiative was also implemented to raise the number of towns and rural villages with access to electricity from 648 to 6,000 throughout the plan period. As a result, by 2009/10, 5,163 towns and rural villages have obtained access to electricity, achieving 78 percent of the PASDEP target. The overall number of registered electricity consumers climbed from 952,000 in 2004/05 to 2 million in 2009/10, achieving 77 percent of the target.

The positive results and lessons learned from PASDEP led to the creation of the Growth and Transformation Plan I (GTP I) 2010/11 – 2014/15, which included clear energy sector objectives to support efforts to accelerate rapid and sustainable growth. The country's power generating capacity was expected to increase from 2000 MW in 2009/10 to 8000 MW by the end of the plan period. By 2014/15, total energy generating capacity had reached 4,180 MW, with an average performance of 52 percent across all power installations. GTP I was distinguished by the Grand Ethiopian Renaissance Dam (GERD) (6000 MW), Gilgel Gibe III HEPP (1870 MW), and wind power projects. (Ministry of Water and Energy, 2012).

Despite the energy potential of Ethiopia, poor service delivery, delays in the rehabilitation of aging lines, and protracted institutional reforms in the electricity industry resulted in shortages in electricity supply leaving households and other users of electricity to face frequent power outages. Also, strong GDP expansion over the previous decade, on the other hand, resulted in a steady increase in electricity demand compounding the energy shortages as it tries to serve a population of more than 110 million people and satisfy rising electricity demand, which is expected to increase by almost 30% per year

(Ministry of Finance and Economic Development, 2010). The frequent power outages in Ethiopia are reported to be around 8.2 times in a typical month where the electricity access rate is 48% (Meles, 2020).

Overview of the Electricity Sector in Niger

The overview of the electricity sector in Niger provides a brief description of the energy potential, electricity generation capacity, and supply challenges in the sector. Niger is a country in West Africa that lies south of the Sahara Desert. Niger has a large and diverse energy potential that is currently underutilised. Electricity production, transmission, and distribution are all handled by the Société Nigérienne d'Electricité (NIGELEC). The Autorité de Régulation Multisectorielle is the sector regulator (ARM). Meanwhile, the hydroelectric potential is projected to be around 280.5 megawatts (MW), with 130 MW in Kandadji, 122.5 MW in Gambou on the Niger River, and 26 MW in Dyon dyonga on Mekrou. Furthermore, multiple micro-hydro sites have been located on seasonal rivers namely Sirba, Goroubi, Dargol, Goulbi Maradi, and Tahoua Maggia, as well as tributaries of the Niger River. Wood is used to cook in over 905 Niger households. Modern cooking fuels and modern energy are still in short supply. Niger is heavily reliant on power imports, which account for more than 75% of the country's electricity needs. Five interconnections from Nigeria ensure the country's power supply to its citizens (Bangoura, 2008).

National production facilities include NIGELEC's diesel thermal units, which are situated throughout the country, and SONICHAR's coal thermal power plant, which is located in the north. Two units of a coal thermal plant, 2x18 MW, and diesel generators with capacities ranging from 50 kilovolt-

amps (kVA) to 12 MW make up the total national electrical energy production. All of these facilities are ancient, and several have reached the point of decommissioning, yet they are being used despite their state due to a lack of resources for their renewal, which has an impact on their operating costs. Imported energy from Nigeria is insufficient to meet electricity demand, particularly in recent years, requiring NIGELEC to run its group of outmoded plants to meet demand. One explanation for the comparatively high price per kilowatt-hour (kWh), despite a very low import price from Nigeria, is that these outmoded plants consume a lot of fuel and oil (Salifou, 2015).

Niger is significantly reliant on Nigeria for electricity imports. Nigeria's challenges, along with Niger's expanding energy consumption, have resulted in frequent shortages and blackouts, impeding households' livelihood. The World Bank Enterprise Survey reported that Niger recorded on average 22 power outages in a typical month where access to electricity as a percentage of the population is merely 18.8%. However, efforts are being made to diversify its energy supply, focusing on renewable energy resources in particular (International Renewable Energy Agency [IRENA], 2014).

Overview of the Electricity Sector in Nigeria

The overview of the electricity sector in Nigeria briefly describes the mandate of the Power Holding Company of Nigeria (PHCN), the existing generation capacity as well as the sources of electricity supply shortages. The Power Holding Company of Nigeria (PHCN) is a monopolised entity that generates, transmits, and distributes power using a vertical integration strategy. The first electricity generation in Nigeria was in Lagos in 1896, fifteen years after it was introduced in England. Although electricity has been

in the country for over a century, its generation has progressed at a glacial pace. Before 1999, the power industry in Nigeria experienced virtually little investment in terms of infrastructure development for more than two decades. There was no maintenance performed on the existing plants, and no new ones were constructed. The situation in the sector was so bad that the installed capacity, which had been around 5,600 MW, had dropped to an average of 1,750 MW (Okoro & Chikuni, 2007).

The current generation capacity is over 3,600 MW, with 1,143 MW coming from Independent Power Producers (IPP). Power Holding Company of Nigeria (PHCN) has increased its generation capacity every year since its formation in 2004 to meet the ever-increasing demand for power. In July 2009, the PHCN total installed generation capacity was 9,914.4 MW, with 11,150 MW by IPP from the Okapi, Afam, and Omoku power plants. Due to maintenance work on some gas pipes, this capacity is expected to drop by another 400 megawatts (MW). The largest producing station at Egbin (1,320 MW) is also working below capacity due to a lack of gas supply and the unrest in the Niger Delta, (Ejumudo & Ejumudo, 2014).

The increased need for electricity following the emergence of a new middle class in 2000 and the growth in residential power usage by 51 percent as well as the existing elite class rendered the total installed capacity insufficient to meet electricity demand in Nigeria. The shortfall in electricity supply resulted in periodic outages. The World Bank Enterprise Survey (2014) reported that power outages occur 32.8 times in a typical month, compelling many businesses and households to generate their electricity. According to Nnaji et al. (2013), over 60 million Nigerians are reported to own generators

due to frequent power outages, and they spend a whopping N1.56 trillion ($13.35 million) annually to fuel them. Some business has to relocate to nations with more dependable power supplies due to unreliable power.

Definition of Household Income

Household income is recognised as an essential element in the measurement of economic well-being. Household income enables consumption and the accumulation of wealth. In particular, household income enables households to acquire goods and services to satisfy their needs and wants. It also provides information about the distribution of income across members of society. The Income Consumption and Wealth (ICW) framework defines household income as consisting of all receipts, whether monetary or in-kind (goods and services) received by the household or by members of the household at more frequent intervals, excluding windfalls and other irregular and typically one-time receipts (Organisation for Economic Co-operation and Development [OECD], 2014).

The household income is a lump sum of all monetary and non-monetary receipts from various sources which add to the wealth and support consumption. Household incomes are earned from several sources and can be classified into various categories. The following section presents the various components of household income.

Composition of household income

Household income covers all flows from 1) income from employment (both paid and self-employment e.g. farm and non-farm enterprises); 2) property income; 3) income from the production of household services for own consumption; and 4) transfers (OECD, 2014).

Income from employment is the dominant source of household income across the world. In developed countries, it is contributing 90 percent to total household income mostly from paid employment income. In developing countries, though, employment income contributes a greater proportion to total household income, this contribution is predominantly from self-employment income from farm and non-farm enterprises (OECD, 2014). Income from employment is earned by participating in economic activities in an employment-related capacity. They are payments, in cash or kind, earned by individuals themselves or in respect of their family members as a result of their current or former involvement in paid jobs or self-employment. Such payments are referred to as employee income if they include wages and salaries, commission, tips and gratuities, fees, shares offered as part of remuneration, profit-sharing bonuses, and other forms of profit-related pay. It further includes remuneration from an employer for time not worked such as holidays, annual leave, or other paid leave, free or subsidised goods and services from an employer, severance, and termination pay, as well as employers' social insurance contributions.

According to OECD (2014) income from self-employment is earned by individuals over a given reference period as a result of their involvement in self-employment in the form of profit or loss from self-owned or partnered enterprises, the estimated value of goods produced for own consumption, and for barter less expenses. Additionally, household income includes property income which is a flow of receipts from the ownership of assets. Such income consists of returns from financial assets, flows from investment in unincorporated enterprises in which the household or individual members do

not actively engage in the activities of the enterprise, regular payments from insurance and pension funds that are excluded from social insurance, rents and other receipts from lands, houses, plant, equipment, and copyright material.

Household production of services for own consumption rather than for the market namely services from owner-occupied dwellings and from consumer durables less the expenses that go into their production are all contributions to household income. Besides, current transfers are received in the form of cash or kind namely social security pensions, insurance benefits and allowances from government-sponsored social insurance schemes, benefits from employer-sponsored social insurance schemes, family support from other households, and cash social assistance from the government. Finally, the aggregate of all the income from employment, property, service production for own consumption, and current transfers received by a household or by individual members of the household is the total income of the household (OECD, 2014).

Household income from self-employment is the predominant source of income for households in sub-Saharan Africa. As stated above, income from self-employment such as farm and non-farm activities contributes more than 55 percent to the household income of which non-farm income is the greatest contributor (OECD, 2014). The various components of household income are earned from several activities which can be classified. The following section presents the classification of household income.

Classification of household income

Household incomes are typically classified into several types based on their source. However, this section presents the classification of household

incomes beyond their source to a three-way classification system. The three-way classification system classifies household incomes by sector, function, and space. Typically, household incomes are classified according to their source which often involves seemingly synonymous terms such as "farm income", "agricultural income", "off-farm income", "non-farm income", "nonagricultural income", "nontraditional income", and many more. This routinely synonymous and confusing way of classifying household income is perhaps a result of the disparity in terms of the source of household income across different agro-ecologies, cultures as well as seasons (Barrett & Reardon, 2005).

In order to maintain a logical correspondence between the micro and macro structure of the economy, it is appropriate to use the three-way classification system based on the standard national accounting classification. Since the macro economy is an aggregation of the microeconomy, it follows that we can classify household income according to the conventional national accounting system. The three-way classification of incomes by sector, function, and space is discussed below.

Sectorial classification

The classification of household incomes based on sector follows the national accounting system where activities are classified into primary, secondary, and tertiary. The primary sector involves agricultural, mining, and other extractive activities, whiles manufacturing and services activities are classified as secondary and tertiary sectors respectively. Since the primary sector activities at the household level are usually agricultural, incomes earned from the production or gathering of unprocessed crops, livestock, forest as

well as fish product are classified as agricultural income. Incomes from secondary and tertiary activities such as manufacturing, trade, repair, tailoring, barbering, retail, and other industry and service-related activities as well as income from other non-agricultural activities are classified as non-agricultural or non-farm income (Barrett & Reardon, 2005).

At the macro level, the sectoral activities are classified into agric, industry, and services. The classification at the household level should mimic the macro level. That is, standard accounting practice already exists for sectoral assignment of various activities, but this needs to penetrate household work. To date, such micro-macro correspondence has been too rare. The basic assignment rules for categorising activities: (a) primary sector activities involve producing raw agrifood products using natural resources like land, water, and air. This can involve growing crops, raising livestock, or gathering resources like hunting, fishing, or forestry. (b) secondary sector activities involve taking raw physical materials like maize, milk, iron, or wood, and turning them into manufactured goods like flour, cheese, pails, or furniture. (c) tertiary sector activities involve producing services like transportation, commerce, and banking using physical capital and labor (Barrett & Reardon, 2005).

Functional classification

Household incomes can also be classified on a functional basis. A functional distinction can be made between incomes from wage employment and self-employment. The assignment of particular household income generating activities to functional categories is often difficult in practice. Reardon (1998) stresses the importance of using the right survey tool to

accurately record information about each activity and its related income. Additionally, there are other important considerations to keep in mind when using functional classification, which should also be emphasised.

First, many small household-run businesses involve one household member as the manager and another as an "employee." This raises the question of how to classify the employee. From a household income perspective, it's considered self-employment. However, from an individual income perspective, it's technically wage employment. In practice, the wage may not be in cash and could include things like shared consumption goods or services, access to loans, etc. These factors can be difficult to quantify. Therefore, it's often simpler to classify both individuals as self-employed and allocate shares of the net income of the business.

According to Barrett and Reardon (2005) determining the returns to labour, management, and assets is the easiest measure to obtain. However, estimating profits that are separate from labour or a production function can be more challenging. Nevertheless, it is not essential to distinguish between labour income and profits in order to calculate the total income of an activity. The classification of an activity as either self-employment or wage-employment in the household economy of developing countries is not always clear. There exists a range of activities that can be classified as either wage-employment or self-employment, with some activities falling in a gray area.

Activities that are considered wage employment typically involve an employment contract where the employer has the authority to give orders to the employee. An example of this would be an employee at a small rural firm, like a butcher at a rural market. Self-employment, on the other hand, is

characterized by an individual owning a firm that produces goods or services, with the buyer not being able to give orders to the firm and taking the products "as sold". Examples of self-employment include a charcoal producer who collects and processes wood to sell bags of charcoal by the roadside, or a retail merchant running a small shop or roadside stand. The demand for self-employment labour is derived from the demand for the product or service.

There are often ambiguous activities in the African non-farm economy due to the small scale of enterprises and the nature of agency contracts. For example, small service providers like hairdressers or home granary repair businesses usually take instructions from clients and perform the service at the client's home, using little physical capital. Similarly, small manufacturing firms like furniture makers often take specific orders and instructions from clients and modify the product to suit their needs. These situations involve "agency contracts" where the buyer of services gives detailed instructions to the agent without becoming the manager of the production process. In the rural African economy, where firms operate with low capital and labour ratios, there can be ambiguity in distinguishing between an employment contract and an agency contract (Barrett & Reardon, 2005).

Spatial classification

Household incomes are classified based on the sector in which an activity is undertaken, the function of the activity, and the space or location in which the activity is performed. After the sectoral and functional categorisation of activities, the final categorisation is spatial. There are two main categories with important subcategories. The first category is "local," which has two subcategories: (a) at-home, also known as "on-farm," and (b)

local away-from-home, with subcategories including (i) countryside or strictly rural, (ii) nearby rural town, and (iii) intermediate city. The second category is "distant away-from-home," also known as "migratory," with subcategories including (a) in-country rural (such as in inter-zone migration), (b) in-country urban (such as traveling to a distant metropolitan area), and (c) foreign (Barrett & Reardon, 2005).

The distinction between local, in-country, and foreign activities has several benefits. Firstly, it allows researchers to assess the household's dependence on the local economy and the impact of local economic changes. Secondly, it enables the study of intersectoral linkages between the agricultural sector (farm) and non-agricultural sectors (non-farm). Thirdly, it facilitates the study of rural-urban connections within the country. Finally, this categorisation can help to connect micro-level observations with macro-level observations of workers' remittances and other unrequited transfers in the balance of payments. There are practical challenges when categorising an activity into one of the above categories. Firstly, a household located in a rural area may engage in both rural and urban activities, which can create ambiguity in the use of terms such as "rural nonfarm income". This term can refer to nonfarm income earned by rural households anywhere or nonfarm income earned only in rural areas by rural households. Additionally, it can become more complicated when urban households earn rural income, which is a common phenomenon in Latin America. National surveys often do not differentiate between the location of the earner and the location of the activity, which further adds to the complexity of categorising activities (Barrett & Reardon, 2005).

To assign an activity to the category of "local," researchers use various definitions that can be arbitrary and specific to the case at hand. The most popular definition involves using some administrative unit such as a district or province, which is easily understood by local leaders but may lack economic meaning. Another common definition is based on the area where the household spends most of its consumption expenditures or the distance easily reachable by local transport means, which may be referred to as "daily commuting distance" and is dependent on the quality of the roads and mode of transportation. To assign an activity as a local nonfarm activity or a migratory nonfarm activity, there is ambiguity and variability in the definition of "rural."

The criteria used to classify a location as rural vary across research studies and official classifications. While some researchers define rural based on demographic and spatial terms, others consider economic and social criteria as well. This difference in classification often leads to discrepancies between official and research practices. Some researchers define rural areas to include rural towns and even intermediate cities, as there are close production-linkages and expenditure linkages between rural and urban activities, particularly between agriculture and "rural-urban" nonfarm activity. Commuting is also common between rural households and rural towns, and urban households to agricultural jobs (Barrett & Reardon, 2005).

In contrast, governments often use demographic criteria to define rural areas, such as setting population limits of 5,000 or fewer, without any economic justification. However, these cutoff points may be too low for researchers, resulting in areas classified as urban appearing as rural. In Asia, rural areas are generally classified as being "outside major metropolitan

areas." Furthermore, the definition of rural can vary between countries due to factors such as government preferences, population density, and the size of rural towns.

In Africa, migration is often seasonal and circular, with permanent migration within and between rural and urban areas. These types of migration are generally straightforward to classify, but there are methodological issues to consider. For instance, some activities involve a mix of local and migratory components, such as livestock commerce where the merchant travels outside of the local area to purchase animals and then returns to sell them. Additionally, it can be unclear whether income from migrants is current earned income or transfer income from a family member who permanently migrated. Defining household membership is thus important, often based on the minimum amount of time a person spends in the household. Using national survey data can also be frustrating because it may not be clear whether reported migration remittances are earned or unearned income (Barrett & Reardon, 2005).

Household Non-farm income

Non-farm income refers to any income earned by households or their members that is not derived from agricultural activities or farming. Non-farm income can come from a wide range of sources, such as wages earned through non-agricultural employment, rental income from non-agricultural properties, business profits, investments, and other sources. Non-farm income is often an important source of livelihood for rural households that do not rely solely on agriculture for their income. In many cases, non-farm income can provide a more stable and diversified source of income for rural communities, reducing

their dependence on unpredictable agricultural yields and prices. Non-farm income can also contribute to the overall economic development of rural areas by creating jobs and boosting local economies (International Fund for Agricultural Development (IFAD), 2017).

Non-farm income is generated from several sources and can be classified into various categories. The following section below presents the various sources of household non-farm income, their classification based on activities as well as their contribution in sub-Saharan Africa.

Sources of household non-farm income

The major source of non-farm income is self-employment. Self-employment is recognised in different parts of the world for its role in improving economic well-being through income generation from farm and non-farm activities. This form of employment is dominated by households throughout the world who are in search of ways to survive or accumulate wealth. Generally, self-employment by households takes the form of farm and non-farm enterprises. In developed nations, the majority of the households are in non-farm enterprises, unlike developing countries where a majority of households are engaged in both farm and non-farm enterprises. Recently in sub-Saharan Africa, there has been a growing transition from farm to non-farm economic activities by households (Nagler & Naudé, 2017).

According to the literature on household income diversification, all income-generating activities excluding those on the farm are referred to as non-farm economic activities (enterprise). The term non-farm enterprise is used interchangeably with off-farm and non-agricultural activities. One such usage is by Nagler and Naudé (2014) who used the term 'rural non-farm

enterprises' to refer to small, informal household enterprises including trade and retail, agribusiness, manufacturing, construction, mining, and tourism excluding traditional farming activities. Reardon (1997) showed a body of evidence that pointed out the common non-farm enterprises in most developing countries to be mainly in services, commerce, and manufacturing. Similarly, Haggblade et al. (2010) classified all activities such as mining, construction, utilities, financial services, commerce, and agro-processing as non-farm activities. According to a report by World Bank in 2008, 80–90 percent of these enterprises rely exclusively on family labour.

The fundamental motivation driving households into non-farm enterprises as a major source of household income and economic wellbeing in developing countries tends to be varied. Lanjouw and Lanjouw (2001) made the argument that some households in their struggle to survive may be pushed into non-farm activities, while others may be motivated or pulled into such activities by their desire to accumulate wealth. The authors found that poor households are pushed into non-farm activities, unlike non-poor households who are pulled by their quest to accumulate wealth by engaging in non-farm activities. Ellis (1998) contributed to the argument with findings that suggest the need to improve livelihood, and economic conditions and overcome poor living conditions by households are associated with participation in non-farm activities.

As indicated, self-employment enables households to generate income from a variety of activities which can broadly be classified into two main activities namely agricultural activities (farm enterprises), and non-agricultural activities (non-farm enterprises). However, the non-agricultural activities can

further be broken down into two main sub-activities such as activities from the industry (non-farm industry activities) and activities from services (non-farm services enterprise).

Classification of household non-farm income

The sectoral system of classifying household incomes provides that, household incomes can be classified based on activities or sources from which such incomes are earned. The basic assignment rules for classifying household incomes follow the standard national accounting system where income generating activities can be broadly classified into primary (agriculture), secondary (manufacturing), and tertiary (services) sectors. Household non-farm or non-agricultural income is sourced from the secondary (manufacturing) and tertiary (services) sectors of the economy. At the macro level, these sectors are represented as the agric, industry, and services sectors.

Based on these basic assignment rules, household non-farm incomes according to the sectoral classification can be categorised into non-farm industry income from the secondary (industry) sector, and non-farm services income from the tertiary (services) sector.

Contribution of non-farm income in sub-Saharan Africa

Sub-Saharan Africa is home to some of the world's poorest and most rural populations, with the majority of the region's population living in rural areas and relying on agriculture for their livelihoods. However, in recent years, non-farm income has become an increasingly important source of livelihood for rural households in sub-Saharan Africa, contributing to poverty reduction and economic growth in the region (OECD-FAO, 2016).

Non-farm income has become an important source of livelihood for households in sub-Saharan Africa. According to the World Bank, non-farm income accounts for 23% of household income in sub-Saharan Africa, with the percentage varying by country. In some countries, such as Kenya and Uganda, non-farm income accounts for more than 50% of household income, while in others, such as Niger and Chad, it accounts for less than 10% (Nkurunziza, 2006). This indicates that the contribution of non-farm income to livelihoods varies significantly across the region.

One of the main sources of non-farm income in sub-Saharan Africa is non-farm employment. As rural economies diversify, more people are finding work in non-farm sectors, such as manufacturing, construction, and services. According to the International Labour Organization (ILO), non-farm employment in sub-Saharan Africa grew by 1.8% per year between 2000 and 2013, outpacing the growth of the agricultural sector (International Labour Office, 2016). This trend has been particularly strong in East Africa, where the share of non-farm wage employment in rural areas increased from 24% in 2000 to 40% in 2010 (Christiaensen & Maertens, 2022).

Another important source of non-farm income in sub-Saharan Africa is remittances. According to the World Bank, remittances to sub-Saharan Africa reached $46 billion in 2018, accounting for 2.6% of the region's GDP. Remittances are often sent by migrant workers who have left rural areas to work in urban areas or abroad, providing a vital source of income for their families back home. Non-farm income has important implications for poverty reduction in sub-Saharan Africa. According to the World Bank, households that earn income from both farming and non-farm activities are less likely to

be poor than those that rely solely on agriculture (Zhu, 2008). This suggests that diversification of income sources can help to reduce poverty and vulnerability in households. Furthermore, non-farm income can contribute to economic growth and development by creating jobs and boosting local economies (International Fund for Agricultural Development (IFAD), 2017)

Despite the importance of non-farm income in sub-Saharan Africa, there are still challenges to its growth and sustainability. One of the main challenges is the lack of infrastructure manifesting in a form of poor quality. For example, unreliable electricity supply and as well as inaccessible markets can limit the potential for off-farm employment and non-farm enterprise development. In addition, many households lack the skills and resources to engage in non-farm activities, such as access to finance, education, and training. Finally, climate change and environmental degradation pose a threat to the sustainability of non-farm activities, particularly in rural areas that are vulnerable to climate shocks and natural disasters (IFAD, 2017). In conclusion, non-farm income has become an increasingly important source of livelihood for households in sub-Saharan Africa, contributing to poverty reduction and economic growth in the region. Hence, poor infrastructure such as unreliable electricity supply in the form of power outages limits the ability to earn additional income from non-farm activities.

Theoretical Review

The theoretical review presents economic theories of the household and attempts to explain the intricate structures of households and their behaviour. To understand household incomes, information on households' decision-making process, resource allocation, income earning mechanisms as

well as information on demographic characteristics of households is a requirement. This review explores relevant assumptions and theories that help explain the household at the micro level. The review covers Becker's new household economic theory about households beyond the consumer theory to models that explain the household as a production unit.

Becker's household economic theory

Becker's household economic theory, also known as the New Home Economics theory, is a framework developed by Gary S. Becker, a prominent economist, to analyse household behavior and decision-making within an economic context. Becker's theory extends the traditional economic analysis, which primarily focused on market transactions, to incorporate the household as an economic unit. Becker's household economic theory is applicable to this study as it provides a complete understanding of how households engage in economic activities to earn income (Mattila & Wiro, 2016).

The conventional theory of consumer behavior, in addition to its flaws, provides an incomplete understanding of how households behave. However, some alternative neoclassical models have incorporated some of the missing elements. The "Becker-Lancaster Theory," which was independently developed by Gary Becker and Kevin Lancaster, is the most frequently cited and analysed alternative view on consumer demand theory. Becker focuses on the time element, while Lancaster concentrates on the production of commodity characteristics. Both scholars criticise the traditional theory for oversimplifying the functional relationship between market goods and utility and recommend a more detailed analysis of this relationship (Hawrylyshyn, 1977).

Gary Becker regards the household as the most essential social institution in society. His theory, known as the "new household economic theory," was initially developed to explain how households in the United States, Japan, and Israel allocate resources, make decisions, and maximise their utility. Later on, the theory was also applied to developing countries, with a particular focus on analysing agricultural households. Becker's approach provides significant new insights into the traditional consumer theory, such as viewing the household as both a consumer and a producer. While some of Becker's ideas on household economic behavior have been discussed earlier, his presentation is more formalised than previous ones.

Becker takes an economic perspective to examine issues that go beyond the typical scope of economists. He argues that human behavior is influenced by a broader range of values and preferences than just self-interest, although this is not evident in the theory itself. Becker's approach is based on three interrelated assumptions: maximising behavior, market equilibrium, and stable preferences. He also discusses the rational choice approach, which combines maximising behaviour with the analysis of various topics such as marriage and divorce markets, division of labour, and investment in children. To explain fertility decisions, Becker cites the high value of time, which increases the cost of having children and therefore reduces the demand for large families and fertility. Becker does not differentiate between significant and minor decisions or consider variations in income, education, or family background. Despite these limitations, Becker claims that the rational choice approach is a comprehensive method that can be applied to all types of human behavior (Becker, 1993).

The approach significantly reduces the significance of human behavior. It is crucial to differentiate between major and minor decisions as diverse values and aspirations impact various types of decisions and have distinct effects on human existence. Becker's analysis is unable to account for differences in wealth or culture, and their consequences, as it cannot differentiate between income levels and other background variables.

Beckerian household

Chiappori (1992) notes that in a Beckarian household, there are only two members, each of whom is characterised by his preferences. Becker recognises that conflicts exist between household members but because of the tools he applies to material behaviour, is incapable of including this aspect in the analysis. For Becker, 'caring' (including the rotten kid theorem and altruism) solves the problem of distribution within a household.

Becker presents a specific rule for decision-making or bargaining in which the household maximises the utility function of only one individual, who is also the altruistic member. However, this assumption raises two significant issues. First, how are individual preferences combined and how is the collective decision described? Second, how is it determined who receives what? Becker sidesteps these questions by assuming that there is only one consumption good produced by the household and consumed by both members as a whole (Chiappori, 1992).

Time as a scarce resource

Becker's theory makes an important contribution by considering a consumer's time as a limited resource in the decision-making process. While the availability of goods and services can increase, time remains fixed, leading

to unsatisfied demands. As goods become more abundant, time becomes more valuable. Becker classifies time into two categories: labour time and consumption time, which highlights that a consumer can be either a worker outside the household or a consumer within it. However, his model does not distinguish between various uses of time within a household, leading to an inadequate understanding of individual household tasks and the division of labour, undervaluing household work. Therefore, Becker's model is more suited for studying market labour and goods (Becker, 1993).

The household production function

Becker's theory of the household production function is influenced by the theory of a firm, specifically in the areas of comparative advantage, specialisation, and human capital. According to (Becker, 1965), economists began to view households as small factories in the early 1960s. In this view, households combine capital goods, raw materials, and labor to produce useful commodities such as cleaning, feeding, and procreation. Becker's household production function explains how time, market goods, and services are combined to produce basic commodities, or nonmarket goods (Bergstrom, 1995). Examples of basic commodities according to Becker are children, health, pleasure, sleeping, or seeing a play.

The household maximises its utility function by choosing the optimal combination of these commodities. The household production function as presented demonstrates how production is done at the household level purposely for household consumption. This can be extended to instances where household produces, and output is sold on the market for additional income. The household production function is the theory that underpins this

study, hence more details about the household production function are presented under the theoretical framework.

Conceptual Framework

The conceptual framework provides channels through which power outages affect households and their income levels. This framework only seeks to outline how the incidence of power outage propagates itself through household equipment, appliances, machinery as well as other intermediary pathways to affect household income. Hence, it is not the framework for the study as the theoretical framework is already provided in Chapter three (3).

The conceptual framework applied in this study is based on a framework by Khandker et al. (2013). Khandker used a framework based on an intuitive and anecdotal explanation that electricity adoption and consumption improve health, education, and labour productivity outcomes, as suggested by (Birol, 2007). Based on this, I adapted the framework to include power outages to investigate the effect of power outages on income via the health, education, and productivity pathways, with the inverse intuitive and anecdotal explanation that power outages negatively affect income via productivity, education, and health. This intuition is supported by (Adenikinju et al., 2005) who stated that any type of infrastructure is an intermediate input to production, and thus the reduction in the quality of the infrastructure, such as power outages, affects the profitability of production and, invariably, the levels of income, output, and other welfare outcomes that rely on such infrastructure.

Figure 1 shows a conceptual framework for evaluating the effects of power outages on household income in Ethiopia, Niger, and Nigeria. The

Figure depicts the likely channels of the effect of power outages on education, productivity, and health. The challenge of determining the direction of causality is naturally difficult, given the numerous interactions among a wide range of appliances, outputs, and intermediate consequences.

The effect of a power outage begins when a power outage occurs, as electronic and electrical devices such as bulbs, electric lamps, radio/TV/Internet, refrigerator, fan/AC appliances, electric cooking appliances, and electric machinery are unable to execute their functions due to a lack of electricity (power). The inability of these electronic/electrical devices to perform their functions results in the unavailability of light for study/reading at the night, income generation activities, lack of access to current knowledge and information, food spoilage, discomfort, inefficient cooking, as well as the inability to use electric machines (World Bank, 2020).

The above transmission, in turn, can lead to intermediate outcomes such as limited study time, shorter hours of operating home businesses, lack of exposure to business knowledge and information, poor health, and more inefficient business operations. Over time, these intermediate outcomes can further negatively affect development outcomes. As Figure 1 illustrates, power outages can negatively affect an outcome through multiple pathways. For example, operating a business for shorter hours means fewer sales and thus low profits. In addition, grid-powered tools and machinery, which are unable to function will be inefficient, less productive, and redundant in the long run, contributing to lower earnings.

Furthermore, a lack of business knowledge and information will deny household members up-to-date business knowledge and relevant technology,

which, in turn, disallows them to run their operations more efficiently and economically. In the case of education, decreased study time due to unavailable electric lighting is likely to result in poor school performance, which, in the long run, leads to lower earning potential. Also, lower productivity can lead to a substantial loss in household income. However, it is a challenge to sort out the individual transmission mechanisms of power outage's effect on income, given the many interrelated and overlapping pathways leading to this outcome. In this study, rather than analyse the individual pathways, we examine power outages' ultimate effect on income by controlling for a variety of factors.

The channels through which power outages affect household income identified in the framework are numerous and interconnected making it difficult to identify a single theory to explain the causality between power outages and household income, hence the use of the conceptual framework as provided in Figure 1 below is the only means to properly identify the propagation mechanism through which power outages affect household incomes.

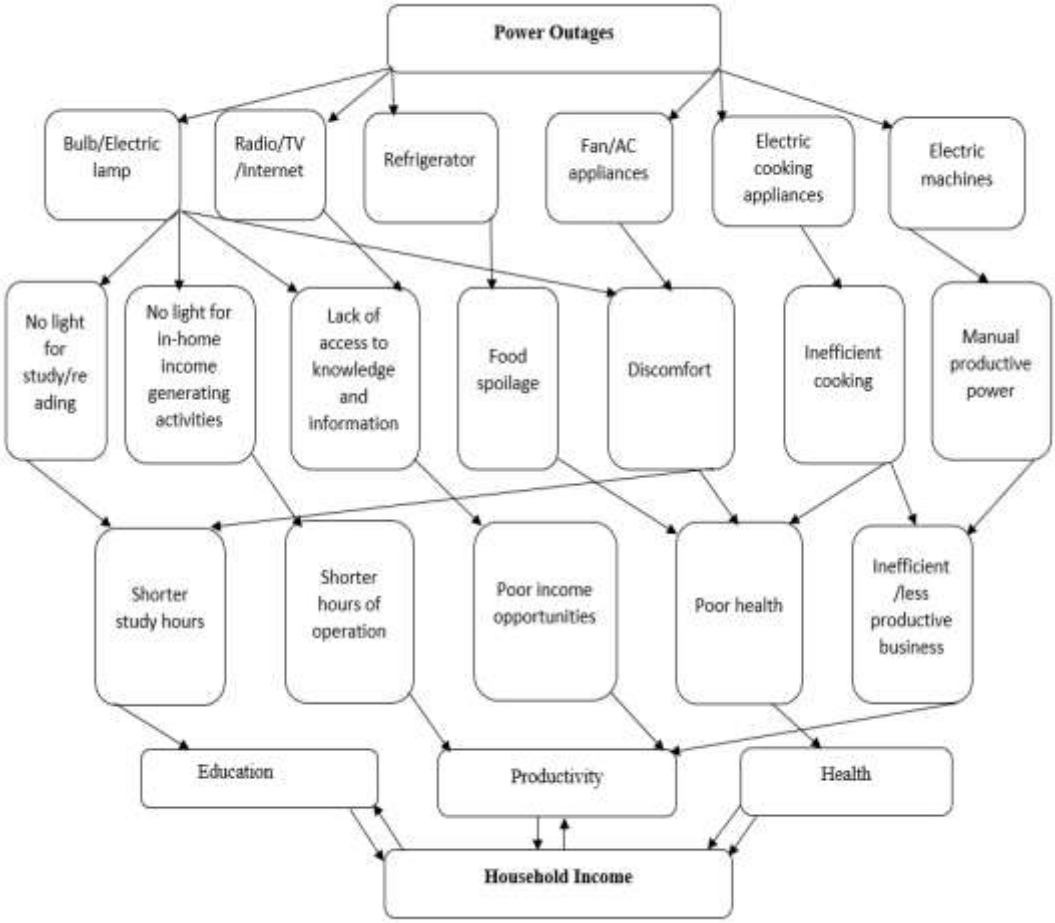

Figure 1: Conceptual Framework
Source: Adapted from Khandher (2013)

Empirical Review

The empirical review covers previous studies related to the effect of power outages on household incomes. The review begins with studies from developing countries across the world, followed by evidence specifically from sub-Saharan Africa.

The studies on the effects of power outages on households in developing countries are still evolving. There is a growing urgency to investigate the dividends of electrification and the issue of reliability following the daily frequent power outages experienced by households and other users of electricity. A study by Rao (2013) estimated the impact of reliable electricity

supply on non-farm incomes in India. Using an instrumental estimation and propensity score matching, the author found robust evidence that suggests that households with poor power supply amounting to less than 16 hours a day suffer a reduction in earnings whereas households with few power outages amounting to 16 hours of reliable power supply benefit higher non-farm incomes.

Chakravorty et al. (2014) employed two rounds of a representative panel of more than 10,000 households to estimate the returns to household income due to improved access to electricity in rural India. The study found that a grid connection with outages enhances only 9 percent of non-agricultural incomes of rural households compared to a 29 percent increase in non-agricultural incomes of grid-connected households without outages. This implies that power outages account for a 20 percent loss in non-agricultural incomes. This emphasises the significance of ensuring a reliable power supply, as the benefits of electricity are not fully achieved by just connecting households to the grid. This study corroborates the findings by Rao (2013) who found reliable electricity of up to 16 hours of supply a day to be associated with higher income.

Also, Samad and Zhang (2016) estimated the welfare impact of rural electrification in India using nationally representative household panel survey data for 2005 and 2012. Based on a propensity-score-weighted fixed effects model, the study found that an additional hour of outage per day is associated with a 0.5 percent loss in average household income. The data also demonstrate that getting a grid connection paired with a regular electricity supply leads to a 17 percent boost in household income, but only 11 percent

when access is accompanied by frequent power outages. This implies that households with power outages earn 6 percent less income than those without power outages.

Ali (2006) examined the effect of outages on employment and earnings using data set with a district-level measure of outages, electricity generation prices, and labour market outcomes of small and medium enterprises owned by households in Pakistan. The findings show that an increase of 10 percent in night lights variability or approximately 26 additional hours of outages per month, reduced total earnings by 18 percent and the probability of employment in the past month by 2.1 percent, days worked by 8 percent, as well as labour productivity by 11 percent.

In sub-Saharan Africa where over 600 million people face unreliable electricity supply, the urgency to investigate the issue of power outages is growing daily. For instance, Adofo (2020) examined the effects of unreliable electricity supply on labour market outcomes in Ghana and found that a 10 percent increase in outages reduces monthly earnings by 3.4 percent and employment by 0.52 percentage points. Nduhuura et al. (2021) provided a broad investigation of the impact of electricity outages on urban households in Accra using correlations and logistic regression and found that power outages were found to reduce household earnings by 29.3 percent as well as damage household lighting appliances by 34.9 percent.

Amadi (2015) investigated the consequences of power outages on the economic lives of rural households in the Niger Delta region of Nigeria using descriptive analysis and the Pearson chi-square test and found that; power outages constitute a major challenge to the economic growth of rural

households in the Niger Delta as it shortens the business hours of those living in rural communities in the Niger Delta and therefore reduces their income and means of livelihood.

Other determinants of household income

Various factors contribute to household income, as evidenced by several studies. De Magalhães and Santaeulàlia-Llopis (2018) conducted research in Malawi, Tanzania, and Uganda, revealing that household location significantly affects income disparity between rural and urban households in sub-Saharan Africa, with the gap increasing by a ratio of 2.23. Demissie (2013) examined income diversification among rural households in the Fedis District of Eastern Hararghe Zone, Ethiopia. The study found that female-headed households face challenges in generating higher income due to religious, cultural, and financial constraints. Additionally, it established a positive correlation between the education level of a household head and off-farm employment income. Furthermore, the presence of economically active members in a household was shown to have a positive impact on household income. Medhikarimi et al. (2015) analyzed data from the United States Census Bureau's American Community Survey in 2013 and discovered a positive association between an individual's personal income and the number of hours worked per week.

Rashidin et al. (2020) investigated the effects of nonfarm income on agricultural productivity in rural Pakistan using the Pakistan Social and Living Standards Measurement Survey (PSLM) 2017-2018. Employing Heckman's two-step procedure, the study found a positive relationship between the age of the household head and per capita income in Pakistan. Moreover, household

size was found to exert a negative influence on per capita income. Similarly, Espenshade et al. (1983) examined the impact of family size variations on various aspects such as family spending, earnings, employment, public assistance, and housing quality. Their findings indicated a modest increase in overall income with larger household size.

Chapter Summary

The chapter presented an overview of the electricity sectors in Ethiopia, Niger, and Nigeria, the composition of household income, sources of non-farm income, a review of the household production theory, a conceptual framework for the study, as well as the empirical studies. Some of the major findings that have been revealed include that poor power supply amounting to less than 16 hours of power supply is associated with lower income. Also, power outages were found to reduce household earnings by 29.3 percent and damage household lighting appliances by 34.9 percent.

Besides, an additional hour of outages per day, for example, is associated with a 0.5 percent loss in average household income. Another study also found power outages reduced the probability of employment and earnings by 2.1 percent and 18 percent respectively. The few empirical findings in the literature indicate that the attention paid to the effect of power outages on household incomes in sub-Saharan Africa is limited and therefore this study seeks to contribute to the existing empirical evidence by investigating the effect of power outages on households' incomes in three Sub Saharan African countries namely Nigeria, Ethiopia, and Niger.

Furthermore, the studies examining additional factors affecting household income have demonstrated that various variables play a significant

role. These include household location, female-headed households, the education level of the household head, hours worked, the age of the household head, household size, and the presence of economically active members in the household. All these factors have been found to have a significant influence on household income.

CHAPTER THREE

RESEARCH METHODS

Introduction

The study examined the effect of power outages on household incomes in three selected sub-Saharan African countries namely Nigeria, Ethiopia, and Niger. This chapter presents a comprehensive and systematic process adopted to achieve the objectives of the study. The main discussions in this chapter include the research paradigm, research design, data sources, theoretical framework, empirical models, and the definition of variables.

Research Paradigm

A research paradigm involves the assumptions that researchers hold about how they perceive reality and how it should be studied. Among the numerous paradigms or philosophies, the study adopts the positivist philosophy. The positivists argued that knowledge creation should be restricted to what can be observed and measured. This philosophy is appropriate for this study because the study relies on observable and measurable data on relevant variables such as monthly hours of power outages, non-farm industry income, non-farm services income, total household income as well as other quantitative variables to achieve the objectives of the study.

Research Design

A research design is a plan comprehensively developed to attain the research purpose. It aims to ensure that the research obtains answers to the research problem and involves systematizing the research activity. Based on the objectives, the study adopts a quantitative approach and an explanatory

research design for the study. This approach and research design are appropriate for this study because the purpose of the study is to provide a quantitative estimate of the effect of power outages on household incomes.

Data Source and Description

This study utilises cross-sectional data of 1,751 households from the 2015/16 Ethiopian Socioeconomic Survey (ESS), 992 households from Niger - National Survey on Household Living Conditions and Agriculture 2011, and 9,558 households from the 2018/19 Nigeria - Living Standards Survey (NLSS). These datasets are all based on surveys of household living conditions that are nationally representative. All these households are connected to their national grid with some experienced power outages.

The 2015/16 Ethiopian Socioeconomic Survey (ESS) collected data on the households' education, time use and labour, health, savings, food aggregate, non-food expenditure, food security, shocks, housing, assets, non-food, non-farm enterprise, expenditure, other income, assistance, and credit. The 2011 Niger–National Survey on Household Living Conditions collected data at the individual and household levels ranging from education, health, employment, housing, durable goods, transfers, shocks, non-food expenditures, food consumption, and non-farm enterprise. The 2018/19 NLSS collected a comprehensive and diverse set of socio-economic and demographic data on education, health, labour, expenditures on food and non-food goods, non-farm enterprises, household assets, and durables, access to safety nets, housing conditions, economic shocks, exposure to crime and farm production indicators.

The 2015/16 Ethiopian Socioeconomic Survey (ESS), the 2011 Niger – National Survey on Household Living Conditions and Agriculture, and the 2018/19 Nigeria - Living Standards Survey from which the data for the study was obtained are the only surveys with relevant data on electricity access and interruptions in terms of the frequency and duration of power outages experienced by households. These surveys have been conducted by various national statistical agencies in collaboration with the World Bank.

For the 2015/16 Ethiopian Socioeconomic Survey (ESS); section eleven (11) contains data on non-farm enterprise activities and earnings. Section nine (9) for housing information provides data on the number of times and hours a household faces electric power failure. Section four (4) for time use and labour information contains data on main, secondary, and temporary/casual jobs and their earnings. Total household income sums the earnings from non-farm enterprise activities, employment (main, secondary, and temporary/casual jobs), and other income sources under section twelve (12).

The 2018/19 Nigeria Living Standards Survey has data on wage/salaried employment under section four (4). Data on the non-farm enterprise is under the same section and total household income sums all the earnings from wage/salaried employment, non-farm enterprise, and other income sources under section thirteen (13).

The 2011 Niger National Survey on Household Living Conditions and Agriculture contains data on employment under section four (4) and electricity connection, outage frequency, and duration under section six (6). Section 5 contains data on non-agricultural/farm enterprises and earnings. The total

household income sums up all the earnings from employment, non-agricultural/farm enterprise, and income from non-employment revenue under section eight (8).

Variable Description

The study uses several relevant variables to achieve its objectives. These variables include; household location, household size, average age, average education, sex of household head, education of household head, number of children, working-age members, number of rooms, hours worked, monthly hours of a power outage, non-farm industry income, non-farm services income, and total household income. The descriptions of these variables are presented below with their expected signs on Table 1 as well.

Household location (HLOC)

This variable captures the location of a household in terms of rural and urban settlement. It is a binary variable capturing households either in a rural or an urban area. The variable captures households in rural areas as one and zero if the household is located in an urban area. Thus, households located in rural areas are set as the base category. This variable is expected to show both positive or negative relationship with non-farm industry income, non-farm services income and total household income for objective one, two and three respectively.

If a positive relationship between household location and non-farm industry and services incomes as well as total household income is realized, it implies that rural households are earning more than urban households. This might be as a result of the already saturated market and competition in the urban areas compared to rural areas where the markets are still developing

with limited competition (De Magalhães & Santaeulàlia-Llopis, 2018). On the other hand, a negative relationship between household location and non-farm industry and services incomes as well as total household income if realized will imply that rural households are earning less than urban households. This will be as a result of the large market access by urban households compared to rural households.

Household size (HSIZ)

This is a discrete variable that captures the number of individuals living in a household. The expected relationship between household size and non-farm industry and services income as well as total household income for the three objectives respectively is either positive or negative. If a positive relationship exists between household size and any of the outcome variables in the three objectives, it will indicate that the addition of a household member leads to an increase in the respective outcome variable. The positive relationship results as larger household size offer a greater pool of labour and resources within the household. This can result in increased productivity and economic output, leading to higher levels of non-farm industry and services incomes as well as the total household income for the three objectives (Espenshade et al., 1983).

If a negative relationship exists between household size and any of the outcome variables in the three objectives, it will indicate that the addition of a household member leads to a decrease in the respective outcome variable. The negative relationship arises due to various factors that are associated with larger household sizes. One possible reason for this negative relationship is the

diminishing returns to scale. As the household size increases, the available resources and labour may be spread thinner among the household members. This can result in reduced productivity and economic output, leading to lower levels of non-farm industry and services incomes, as well as the total household income for the three objectives respectively.

Number of children (CHLD)

The number of children is a discrete variable that captures household members who are under the age of eighteen (18). A child according to United Nations Child's Act (UNCRA) is any person under the age of eighteen (18). The number of children in a household can exhibit both a positive and a negative relationship with household incomes specified in the three objectives. A positive relationship can be observed when the presence of children in a household lead to an increase in household income. Having children often motivates parents to work harder and seek other self-employment opportunities at the household in order to provide for their children's needs. This increased motivation can result in higher levels of income generation.

On the other hand, a negative relationship can also exist between the number of children and household income. This negative relationship arises when the financial burden of raising and supporting children outweighs the income generated by the household. Expenses related to education, healthcare, and basic needs can significantly impact the available resources and limit the household's capacity to generate higher income. In such cases, the presence of more children may strain the household's financial resources and lead to a decrease in overall household income (Espenshade et al., 1983).

Average age (HAGE)

This captures the average age of the household members. The average age of household members can exhibit both a positive and a negative relationship with household income specified in the three objectives. A positive relationship can be observed when the average age of household members is higher, indicating a more experienced and potentially higher-earning workforce. As household members age, they may gain valuable skills, expertise, and experience in their respective fields, which can lead to make better business decisions for the household (Rashidin et al., 2020).

Conversely, a negative relationship can exist between the average age of household members and household income. This negative relationship may occur when older household members are transitioning into retirement or facing reduced work opportunities due to age-related factors. In such cases, the household's income may decline as older members may experience a decrease in earning potential or exit the workforce altogether.

Average education (EDUC)

This variable represents the average years of schooling in a household. Average years of schooling in a household can exhibit both a positive and a negative relationship with household income in the three objectives specified. A positive relationship can be observed when the average years of schooling in a household are higher. Individuals with higher levels of education often possess valuable knowledge, skills, and qualifications that can lead to meaningful economics opportunities and higher income levels. Increased education can enhance individuals' productivity, making them more competitive in their economic activities and increasing their earning potential.

Therefore, households with a higher average level of education tend to have higher incomes.

Conversely, a negative relationship can exist between the average years of schooling in a household and household income. This negative relationship may occur when individuals have attained a higher level of education that enables to seek for paid employment in governmental and non-governmental organisations as well as private corporations leaving them with limited time at home participate fully in household based economic activities (Demissie, 2013).

Sex of household head (HEDU)

The gender captures whether a household head is a male or a female. The gender of the household head can exhibit both a positive and a negative relationship with household income. A positive relationship can be observed when the household head is male. In many societies, males traditionally have greater access to education, employment opportunities, and positions of power. As a result, male household heads may have higher earning potential and more economic opportunities, leading to higher household incomes. Conversely, a negative relationship can exist when the household head is female. Gender inequalities and systemic barriers can limit women's access to education, employment, and economic resources. This can result in lower earning potential and fewer economic opportunities for female household heads, leading to potentially lower household incomes (Demissie, 2013).

Working age members (WAM)

This is a discrete variable that captures household members who are in the age bracket of 15 to 64 years. This represents the working-age members of the household. Working-age members can exhibit both a positive and a negative relationship with household income specified in the three objectives. A positive relationship can be observed when there is a higher number of working-age members in the household. As working-age individuals, they have the potential to actively participate in the labour market, engage in self employment, and contribute to household income. With more working-age members, there is a greater likelihood of multiple income sources, which can lead to higher overall household income.

Conversely, a negative relationship can exist between the number of working-age members and household income. This negative relationship may occur when there is a lack of self employment opportunities or high unemployment rates within the region or country. In such cases, having more working-age members in the household does not necessarily translate into increased income if suitable non-farm self-employment opportunities as well as other economic opportunities at the household level are limited.

Hours worked (HMHW)

This variable captures the total monthly hours of work engaged by the household members who are self-employed in non-farm activities. Total monthly hours of work engaged by self-employed household members in non-farm activities can exhibit both a positive and a negative relationship with household income in the three objectives. A positive relationship can be

observed when there is a higher number of total monthly hours of work engaged by self-employed household members. Increased work hours indicate higher levels of productivity and dedication to their non-farm activities. This can lead to improved business performance, increased client base, and ultimately higher income for the household. By investing more time and effort into their entrepreneurial endeavours, self-employed household members can potentially reap greater financial rewards (Medhikarimi et al., 2015).

Conversely, a negative relationship can exist between the total monthly hours of work and household income. This negative relationship may occur when there is an imbalance between work hours and the income generated. If the self-employed household members are working long hours but their non-farm activities are not generating sufficient income, it can result in low profitability and limited financial gains. Factors such as market saturation, competition, or economic downturns can contribute to the disconnect between work hours and income.

Number of rooms (HCAP)

This variable captures the number of rooms owned by a household. It is a proxy for household physical capital. Number of rooms owned by a household can exhibit both a positive and a negative relationship with household incomes specified in the three objectives. A positive relationship can be observed when there is a higher number of rooms owned by the household. Owning a greater number of rooms indicates a larger physical space, which can be utilised for various income-generating activities. For instance, households with more rooms may have the potential to rent out extra space, such as through long-term leases, generating additional income.

Moreover, having more rooms can provide opportunities for home-based businesses, such as operating a daycare or offering lodging services, which can contribute to higher household income.

Conversely, a negative relationship can exist between the number of rooms owned and household income. This negative relationship may occur when the household incurs high costs associated with maintaining or acquiring additional rooms. Expenses such as mortgage payments, property taxes, utility bills, and maintenance costs can strain the household budget and limit the amount of disposable income available. In such cases, the ownership of a larger number of rooms may not necessarily translate into higher income if the associated expenses outweigh the potential financial benefits.

Hours of power outages (HOUT)

This variable captures the number of hours a power outage last in a household with electricity access in a typical month. Number of hours a power outage can exhibit both a positive and a negative relationship with household income (non-farm industry income, non-farm services income, and total household income). A positive relationship can be observed when power outages compel households to be more productive during the times the power is stable without outages. A negative relationship on the other hand can exist between the number of hours of power outages and household income. Frequent and prolonged power outages can hinder economic activities, particularly those reliant on electricity. Household economic activities may suffer from interrupted operations, reduced productivity, and potential financial losses. Additionally, households may incur additional costs to mitigate the effects of power outages, such as purchasing backup power

sources or relying on alternative energy solutions, which can strain their financial resources and impact overall income levels.

Non-farm industry income (NFIND)

This is a continuous variable that captures all earnings from members of a household who are self-employed in mining and quarrying, manufacturing, electricity, construction, and other industry-related activities.

Non-farm services income (NFSERV)

This is a continuous variable that captures all earnings from members of a household who are self-employed in wholesale and retail trade, repair of motor vehicles and motorcycles, transportation, and storage, accommodation and food service activities, information and communication, financial and insurances activities, real estate activities, education, health and social work, arts, entertainment, and recreation.

Total household income (TINC)

This is a continuous variable that captures all the earnings by a household from non-farm enterprises, wages, and salaries, as well as income from other sources such as remittances, government transfers, pensions, investments, and rents.

Table 1: Variable Description and Expected Signs

Variables	Definition and measurement of variables	Expected sign
HLOC	=1 if household is located rural area, 0 otherwise	+/-
HSIZ (log)	Number of household members	+/-
CHLD (log)	Number of household members under 18 years	+/-
HAGE (log)	Average age of household members	+/-
EDUC	Average years of schooling in a household	+/-
HGEN	=1 if household head is female, 0 otherwise	+/-
WAM (log)	Household members within the age bracket of 15 to 64 years	+/-
HMWH (log)	Total monthly hours of work by household members who are self-employed in non-farm activities	+/-
HCAP (log)	Number of rooms in a household (Proxy for capital)	+/-
HOUT (log)	Total monthly hours of power outages	+/-
NFIND (log)	Non-farm industry income	
NFSERV (log)	Non-farm services income	
TINC (log)	Total household income	

Non-farm industry income, non-farm services income and total household income are dependent variables. All other variables are independent variables.

Non-farm industry income, non-farm services income, total household income, total monthly hours of power outages are all logged.

Source: Author (2022)

Theoretical Framework

The theoretical framework presents the theory that underpins this study. The study draws from the theory of household production by Becker (1965). The theory of household production is relevant to this study because it shows how households act as production units by combining unpaid labour

time and market goods used as inputs to produce goods and services either for their consumption or for sale on the market.

Household is recognised as a micro-unit in the economy with the role of a consumption unit. However, Sadoulet et al. (1998) argued that the household can be recognised with the dual role as a consumption and a production unit. They described the household as a semi-commercialised entity that makes decisions relating to consumption, reproduction, and production over time. Household production, therefore, involves the production of goods and services by the members of a household, for their consumption, using their capital and other resources as well as unpaid labour time. Goods and services produced by households for their use include accommodation, meals, clean clothes, and child care (Ironmonger, 2000).

Becker (1965) is best known for modeling household decisions and resource allocation in a model where a household is both a producing and consuming unit. According to Becker, the output that is produced by the household is consumed directly and not sold in the market. Becker claimed the productive household model was a major advance in understanding household behavior relative to models that treated households as purely consuming units.

The unique feature of adding the household production function to the theory of household decision making is that it becomes possible to bring the theory of the firm to bear on household decisions (Becker, 1965). Becker's model of household production postulated that a household produces only commodities that it consumes, and the production of each commodity requires an input of human time of one or more household members and market goods purchased to be used as inputs (Michael & Becker, 1973). These market goods

and services purchased depend on what is to be produced by the household. Generally, market goods and services such as refrigerators, furniture, utensils, automobiles, pipe water, and electricity could be combined to produce desired commodities.

It can be extended from this model that, the commodities produced by households for their consumption can also be sold on the market for profit. The argument that goods and services produced by households are not sold on the market is made to limit the theory of production to firms and consumer behaviour to households so that the behaviour of these two economic agents can be distinctively analysed without collapsing. However, it should be noted that goods and services produced by households can be sold on the market to generate income, just as firms can equally consume goods and services produced by them. Because the production of these commodities by households begins with a household consuming market goods and services, the model begins with the traditional household utility function.

$$U = U(x_1, x_2, \dots, x_n) \quad (1)$$

Subject to the constraint

$$\sum p_i x_i = I = W + V \quad (2)$$

Where x_i are goods purchased on the market, p_i are their prices, I is money income, W is earnings and V is other income. Now considering the production decision of households, it is assumed that households will combine time and market goods and services such as refrigerators, furniture, utensils, automobiles, pipe water, and electricity to produce basic commodities that are consumed or sold on the market. Based on this statement, it can be argued that the amount and quality of these market goods and services determine the

output level that can be produced by a household. Therefore, unreliable electricity in the form of power outages used as an input into household production can influence the output(income) level of households.

The output that is produced can either be consumed by the household or sold on the market to generate income. The output that is consumed is equally considered as household income as explained in the literature review. These commodities (household output) will be denoted Y_i and functionally specified as;

$$Y_i = f_i(Z_i\ L_i) \tag{3}$$

Where Z_i is a vector of market goods and services and L_i a vector of time inputs by household members used in producing ith commodity. In the above formulations, households combine time inputs by household members and market goods and services via the production function f_i to produce Y_i and these market goods and services are chosen in a way by maximising the utility function. In an imperfect market arrangement, production and consumption decisions become non-separable (LaFave & Thomas, 2016). This implies that households maximise both utility and profit, given their resources, available technology, prices as well as their specific characteristics as a household. Considering the dual role of the household, it is fundamentally faced with the problem of both profit and utility maximization as it simultaneously deals with decisions related to consumption and production.

Becker (1965) viewed the commodities produced by a household as an output meant for their consumption and therefore, they enter back into the household utility function.

$$U = U(y_1, y_2, \dots, y_n) \tag{4}$$

Subject to the constraint

$$g(y_1, y_2, \ldots, y_n) = Y \quad (5)$$

Where g is an expenditure function of y_i and Y is the bound-on resource. The combination of production and consumption in the household model is inconsistent with the general modelling of households and firms where households are modelled as consumption units and firms as production units. However, there has been a growing recognition that a household is truly a "small factory". It pools capital goods, raw materials, and labour input to feed, clean, procreate and produce useful commodities for their consumption and sale on the market.

In summary, the theoretical model or framework showed that the household as a consumption unit equally acts as a production unit by combining unpaid labour time, market goods and services as inputs, and specific characteristics of the household to produce goods and services for their consumption or sale on the market. These market goods and services as inputs include household equipment, appliances, refrigerators, as well as a utility such as electricity and water. All these market goods and services together with household characteristics such as household size, household location, average education, average age, number of working age members, and many more are combined to produce an output that is considered a portion if not the entire household income. Therefore, the amount and quality of these market goods such as electricity manifested in terms of its reliability (few or more power outages) affect the output (income) level of households.

Empirical Models

The study employed the weighted least square to estimate the three objectives set for the study. The weighted least square was used to examine the effects of power outages on non-farm industry income, non-farm services income, and total household income. The weighted least squares technique was employed for the estimations because of the issue of heteroskedasticity that is eminent in cross-sectional data. That is, the set of explanatory variables used in the model exhibited considerable variability with the variance of the unobserved error term.

Based on the household production model expressed below:

$$Y_i = f_i(M_i\, L_i; H_c) \quad (6)$$

Where M_i is a vector of market goods and services serving as inputs into household production. The L_i a vector of time inputs by household members used in producing ith output and H_c is a vector of household characteristics. The main empirical model is expressed as:

$$Y_i = \beta' X_i + \mu \quad (7)$$

Where Y_i is the dependent variable, X_i is the set of explanatory variables comprising all the explanatory variables captured in the theoretical model: market goods and services serving as inputs into household production as captured by X_i, time inputs by household members used in producing ith output as captured by L_i and household characteristics as captured by H_c.

Testing the first hypothesis

To examine whether there is a significant negative relationship between power outages and household non-farm industry income, a weighted least square is employed. The dependent variable: non-farm industry income is a

continuous variable that captures the total monthly earnings of all members in a household who are self-employed in the industrial economic activities at the household level. Self-employment in the industry includes construction, electricity, manufacturing, mining, and quarrying, as well as other industry-related activities. The set of explanatory variables includes household characteristics such as household size, household location, average education of household, education of household head, sex of household head, hours worked, working age members, number of children, number of rooms (a proxy for household capital), and hours of power outages as the main independent variable.

Household income comes from several activities, this hypothesis sought to test the effect of power outages on only non-farm industry income. That is income from industry activities by households. Based on the relationship between the non-farm industry income as the dependent variable and the set of explanatory variables, the following equation is specified to find the effect of power outages on non-farm industry income from the main econometric model specified in equation 7:

$$(NFIND_i) = \beta_0 + \beta_1 HLOC_i + \beta_2 HSIZ_i + \beta_3 HAGE_i + \beta_4 HGEN_i + \beta_5 EDUC_i + \beta_6 CHLD_i + \beta_7 WAM_i + \beta_8 HCAP_i + \beta_9 HMHW_i + \beta_{10} HOUT_i + \nu_i \quad (8)$$

Because of the potential heteroskedasticity associated with cross-sectional data, the weighted least square is applied to transform the model equation into a form that lends the estimates to be efficient compared to using the OLS estimates. The presence of heteroskedasticity requires the variance of the

unobserved error term in equation (8) to be non-constant because it varies with the set of explanatory variables in the model. This is written as;

$$Var\ (v|x) = \sigma_i = \ \sigma^2 f(x) \qquad (9)$$

$$f(x) > 0$$

Where $f(x)$ represents some function of the set of explanatory variables that causes the heteroskedasticity in the model. The heteroskedasticity implies the variance of the unobserved error term varies across the observations given the set of explanatory variables. This is written as;

$$\sigma_i^2 = Var(v_i|x_i) = \sigma^2 f(x_i) = \ \sigma^2 f_i \qquad (10)$$

The changes in the variance of the unobserved error term are captured by i in $\sigma_i^2$and the changes in the set of explanatory variables causing the heteroskedasticity are captured by f_i.

Therefore, the heteroskedastic variance of the unobserved error term in the model is written as;

$$Var(v_i|HLOC_i, \quad HSIZ_i, \quad HAGE_i, HGEN_i, EDUC_i, CHLD_i, WAM_i, HCAP_i, HMHW_i, HOUT_i)$$
$$= \sigma^2 HLOC_i, HSIZ_i\, HAGE_i, HGEN_i, EDUC_i, CHLD_i, WAM_i, HCAP_i, HMHW_i, HOUT_i$$

This implies that the variance of the unobserved error term is proportional to the set of explanatory variables. So as the explanatory variables change, the variance in the unobserved error term also changes.

To transform the heteroskedastic error term v_i, its standard deviation conditional on the explanatory variables is written as;

$$\sigma\sqrt{HLOC_i, HSIZ_i\, HAGE_i, HGEN_i, EDUC_i, CHLD_i, WAM_i, HCAP_i, HMHW_i, HOUT_i}$$

Now transforming the heteroskedastic error term so that $Var(v_i|x_i) = \sigma^2$

Since f_i is a function of the explanatory variables, $v_i/\sqrt{f_i}$ has a zero expected value conditional on the explanatory variables. Besides, $Var(v_i|x_i)$ =

$E(v_i^2|x_i) = \sigma^2 f_i$, the variance of $v_i/\sqrt{f_i}$ conditional on the explanatory variables is σ^2 as shown below; $E\left[(v_i/\sqrt{f_i})^2\right] = E(v_i^2)/f_i = \sigma^2 f_i/f_i = \sigma^2$. By obtaining the variance of the residual to be $Var(v_i|x_i) = E\left[(v_i/\sqrt{f_i})^2\right] = E(v_i^2)/f_i = \sigma^2 f_i/f_i = \sigma^2$ shows that it is homoscedastic.

The standard deviation of the residual which is the source of the heteroskedasticity is applied to the model to transform it into a homoscedastic model. This is done by multiplying the weight of ($\sqrt{1/f_i}$) through the model equation making the variance of the residual to be homoscedastic. By applying the division to the model equation, I suppressed the explanatory variables by using only $\sqrt{f_i}$ for simplicity. The division is done as shown below and the transformed equation is obtained with a homoscedastic error term in the equation.

$$(NFIND_i)/\sqrt{f_i} = \beta_0/\sqrt{f_i} + \beta_1 HLOC_i/\sqrt{f_i} + \beta_2 HSIZ_i/\sqrt{f_i} + \beta_3 HAGE_i/\sqrt{f_i} + \beta_4 HGEN_i/\sqrt{f_i} + \beta_5 EDUC_i/\sqrt{f_i} + \beta_6 CHLD_i/\sqrt{f_i} + \beta_7 WAM_i/\sqrt{f_i} + \beta_8 HCAP_i/\sqrt{f_i} + \beta_9 NFEHW_i/\sqrt{f_i} + \beta_{10} HOUT_i/\sqrt{f_i} + v_i/\sqrt{f_i} \quad (11)$$

Where $Var(v_i|x_i) = \sigma^2$

The empirical model for objective one is now transformed and rewritten as;

$$Log(NFIND_i)^* = \beta_0{}^* + \beta_1 HLOC_i{}^* + Log\beta_2 HSIZ_i{}^* + Log\beta_3 HAGE_i{}^* + \beta_4 HGEN_i{}^* + \beta_5 EDUC_i{}^* + Log\beta_6 CHLD_i{}^* + Log\beta_7 WAM_i{}^* + Log\beta_8 HCAP_i{}^* + Log\beta_9 NFEHW_i{}^* + Log\beta_{10} HOUT_i{}^* + v_i{}^* \quad (12)$$

Testing the second hypothesis

The second hypothesis examines whether there is a significant negative relationship between power outages and household non-farm services income.

The dependent variable is the household non-farm services income which captures the total monthly earnings by all members of a household who are self-employed in the service sector of the economy. Self-employment in the service sector includes wholesale and retail trade, repair of motor vehicles and motorcycles, transportation, and storage, accommodation and food service activities, information and communication, financial and insurances activities, real estate activities, education, health and social work, arts, entertainment, and recreation, as well as other service-related activities. The set of explanatory variables includes household characteristics such as household size, household location, average age, average education of household, education of household head, sex of household head, working age members, number of children, number of rooms (a proxy for capital), and hours of power outages as the main independent variable.

This hypothesis sought to test the effect of power outages on only income earned from services activities. Based on the relationship between the non-farm services income as the dependent variable and the set of explanatory variables, the following equation is specified to find the effect of power outages on non-farm services income from the main econometric model specified in equation 7:

$$(NFSERV_i) = \beta_0 + \beta_1 HLOC_i + \beta_2 HSIZ_i + \beta_3 HAGE_i + \beta_4 HGEN_i + \beta_5 EDUC_i + \beta_6 CHLD_i + \beta_7 WAM_i + \beta_8 HCAP_i + \beta_9 NFEHW_i + \beta_{10} HOUT_i + \varepsilon_i \quad (13)$$

The model transformation operation is replicated for the second objective as specified below:

$$(NFSERV_i)/\sqrt{f_i} = \beta_0/\sqrt{f_i} + \beta_1 HLOC_i/\sqrt{f_i} + \beta_2 HSIZ_i/\sqrt{f_i} + \beta_3 HAGE_i/\sqrt{f_i} + \beta_4 HGEN_i/\sqrt{f_i} + \beta_5 EDUC_i/\sqrt{f_i} + \beta_6 CHLD_i/\sqrt{f_i} + \beta_7 WAM_i/\sqrt{f_i} + \beta_8 HCAP_i/\sqrt{f_i} + \beta_9 NFEHW_i/\sqrt{f_i} + \beta_{10} HOUT_i/\sqrt{f_i} + \varepsilon_i/\sqrt{f_i} \quad (14)$$

Therefore, the transformed empirical model for objective two is rewritten as;

$$Log(NFSERV_i)^* = \beta_0^* + \beta_1 HLOC_i^* + Log\beta_2 HSIZ_i^* + Log\beta_3 HAGE_i^* + \beta_4 HGEN_i^* + \beta_5 EDUC_i^* + Log\beta_6 CHLD_i^* + Log\beta_7 WAM_i^* + Log\beta_8 HCAP_i^* + Log\beta_9 NFEHW_i^* + Log\beta_{10} HOUT_i^* + \varepsilon_i^* \quad (15)$$

Where $Var(\varepsilon_i|x_i) = \sigma^2$

Testing the third hypothesis

To determine whether there is a significant negative relationship between power outages and total household income, the weighted least square is also employed. The dependent variable is the total household income which captures the total monthly wages and salaries, earnings from non-farm enterprises, and income from other sources such as pensions, remittances, investments, transfers, as well as rents earned by all members of a household. The set of explanatory variables includes household characteristics such as household size, household location, average age, average education of household, education of household head, sex of household head, working age members, number of children, number of rooms (a proxy for capital), and hours of power outages as the main independent variable.

This hypothesis sought to test the effect of power outages on the overall household income consisting of all incomes available to the household.

To find the effect of power outages on total household income, the following model is specified from the main econometric model in equation 7:

$$(TINC_i) = \beta_0 + \beta_1 HLOC_i + \beta_2 HSIZ_i + \beta_3 HAGE_i + \beta_4 HGEN_i + \beta_5 EDUC_i + \beta_6 CHLD_i + \beta_7 WAM_i + \beta_8 HCAP_i + \beta_9 TOHW_i + \beta_{10} HOUT_i + \mu_i \quad (16)$$

The model transformation operation is replicated for the third objective as specified below:

$$(TINC_i)/\sqrt{f_i} = \beta_0/\sqrt{f_i} + \beta_1 HLOC_i/\sqrt{f_i} + \beta_2 HSIZ_i/\sqrt{f_i} + \beta_3 HAGE_i/\sqrt{f_i} + \beta_4 HGEN_i/\sqrt{f_i} + \beta_5 EDUC_i/\sqrt{f_i} + \beta_6 CHLD_i/\sqrt{f_i} + \beta_7 WAM_i/\sqrt{f_i} + \beta_8 HCAP_i/\sqrt{f_i} + \beta_9 TOHW_i/\sqrt{f_i} + \beta_{10} HOUT_i/\sqrt{f_i} + \mu_i/\sqrt{f_i} \quad (17)$$

Therefore, the transformed empirical model for objective three is rewritten as;

$$Log(TINC_i)^* = \beta_0{}^* + \beta_1 HLOC_i{}^* + Log\beta_2 HSIZ_i{}^* + Log\beta_3 HAGE_i{}^* + \beta_4 HGEN_i{}^* + \beta_5 EDUC_i{}^* + Log\beta_6 CHLD_i{}^* + Log\beta_7 WAM_i{}^* + Log\beta_8 HCAP_i{}^* + Log\beta_9 TOHW_i{}^* + Log\beta_{10} HOUT_i{}^* + \mu_i{}^* \quad (18)$$

Where $Var(\mu_i|x_i) = \sigma^2$

Post-estimation Diagnostics Test

In order for the model estimates to be efficient and consistent, it is necessary for the error term to follow a normal distribution. To assess the assumptions of homoscedasticity and normality, two tests were performed and presented: White's Test for Homoscedasticity and the Skewness and Kurtosis Test for Normality of the error term. The null hypothesis for the normality test states that the residuals are normally distributed, while the null hypothesis for the homoscedasticity test states that the residuals exhibit equal variance. If the probability value for the significance test is greater than 0.5, the researcher rejects the null hypotheses. Conversely, if the probability value is less than or equal to 0.5, the researcher fails to reject the null hypotheses. Nevertheless, the utilisation of weighted least squares in the models estimation effectively

addresses the issues posed by heteroskedasticity and fulfils the assumptions of normality.

Chapter Summary

The chapter presented the research paradigm and design that guided the entire research process. The theoretical framework and the empirical models adopted for the study were discussed as well as variable descriptions and data sources. The specified empirical model namely the standard log-linear multivariate regression model used by the study was discussed in detail. The standard log-log linear multivariate regression model was used to derive general linear estimates of the effects of power outages on household incomes and determine the direction of the effects as well. The inefficiency of the estimates resulting from the heteroskedastic variance of the unobserved error term made the use of the weighted least squares method the appropriate estimation technique for the study and it was also discussed in this chapter.

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

The study examined the effects of power outages on household incomes in three selected sub-Saharan African countries namely Nigeria, Ethiopia, and Niger. The study employed an explanatory research design using quantitative data from the World Bank Living Standard Measurement Surveys for Nigeria 2018/19, Ethiopia 2015/16, and Niger 2011. The study set three objectives and they were estimated using the weighted least squares technique. The results from the estimations are presented as follows; the first section presents descriptive statistics of the variables used for the study. The next sections present and discusses results obtained from testing the three main hypotheses of the study.

Descriptive Statistics

Table 2 shows the summary statistics of the variables employed for the analysis. From Table 2, 45 percent of the households in Nigeria are located in an urban area and 55 percent in a rural area. In Ethiopia, 22 percent and 78 percent are located in urban and rural areas respectively. The distribution of households' location in Niger shows that 6 percent of the households are located in an urban area and 93 percent in a rural area. The distribution in all three countries combined shows that 39 percent of the households are located in an urban area and 61 percent are in a rural locality. Table 2 also presents the distribution of the sex of household heads. In Nigeria, 79 percent of the households are headed by males, and 21 percent are headed by females. The

number of female-headed households is higher in Ethiopia at 38 percent. Niger records the lowest number of female-headed households at 15 percent.

In Table 2, the average household size is 5 members in Nigeria, 4 members in Ethiopia, 6 members in Niger, and 5 members for all three countries combined. The average age of the household head is 49 years in Nigeria, 44 years in Ethiopia, 46 years in Niger, and 48 for all three countries combined. The average years of schooling is 11 years in Nigeria, 7 years in Ethiopia, 2 years in Niger, and 10 years for all three countries combined. The average number of children in a household ranges between 2 and 3 across the three countries. Nigeria has an average of 2 children in a household, Ethiopia has an average of 2 children in a household, Niger has an average of 3 children in a household and the average number of children for all three countries combined is 2 children.

The average total monthly hours worked by households is 112 hours in Nigeria, 93 hours in Ethiopia, 16 hours in Niger, and 102 hours for all three countries combined. During the study period, the number of outages experienced by households in a month on average is 39 outages in Nigeria, 12 outages in Ethiopia, 67 outages in Niger, and 38 outages for all three countries combined. The duration of power outages measured by hours of outages shows that a typical outage on average lasted 39 hours in Nigeria, 74 hours in Ethiopia, 39 hours in Niger, and 44 hours for all three countries combined. Finally, the average household income in Nigeria, Ethiopia, Niger, as well as all three countries combined are NGN 700,236.65 (Nigerian naira), ETB 13,876.72 (Ethiopian Birr), CFA 48,766,568 (West Africa CFA franc) and US $ 4,478,790 respectively.

Table 2: Descriptive Statistics

Country	Nigeria		Ethiopia		Niger		All	
Binary variable	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent
Rural	5238	54.80	1363	77.84	932	93.95	7533	61.24
Urban	4320	45.20	388	22.16	60	6.05	4768	38.76
Male household head	7529	78.77	1093	62.42	839	84.58	9461	76.91
Female household head	2029	21.23	658	37.58	153	15.42	2840	23.09
Continuous variable	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Household size	4.93	3.12	4.20	2.29	6.04	3.32	4.92	3.06
Age	48.93	15.50	44.21	15.21	45.51	12.72	47.99	15.36
Years of schooling	11.38	6.38	6.93	6.33	2.08	2.10	10.00	6.75
Number of children	2.33	2.30	1.77	1.64	3.16	2.51	2.32	2.26
Working age members	2.93	1.83	2.82	1.54	3.61	2.14	2.97	1.83
Number of rooms	2.61	1.58	2.28	1.81	3.16	1.72	2.61	1.64
Total hours worked	112.47	121.48	93.49	151.36	16.94	13.00	102.06	124.17
Number of outages	39.32	27.32	11.98	4.46	67.80	34.69	37.73	29.14
Hours of outages	38.80	62.26	74.66	78.26	39.09	34.59	43.93	64.32
Non-farm industry income	47366.921	126033.8	7511.176	28604.754	948512.87	2748319.7	398717.66	2652362.2
Non-farm services income	40436.158	97764.844	13786.72	603894.18	22023045	3.124e+08	3925597.7	1.974e+08
Total household income	700236.65	20222949	33901.782	332241.03	48766568	8.208e+08	4478790	2.340e+08
Number of observations	9,558		1,751		992		12,301	

Source: Author's computation (2022)

Relationship between Power outages and Non-farm industry income

The results presented in Table 3 under this section addressed the first hypothesis of the study, which is to determine whether there is a statistically significant negative relationship between power outages and household non-farm industry income. The results for this hypothesis were obtained by estimating a standard log-log linear multivariate model to determine whether non-farm industry income as the outcome variable has a significant negative relationship with hours of power outages as the main independent variable.

Table 3: Effects of Power outages on Non-farm industry income

Variables	Nigeria	Ethiopia	Niger	All
Dependent variable: non-farm industry income (log)				
Hours of power outage (log)	-0.117***	-0.572***	-0.868***	-0.215***
	(0.0241)	(0.0985)	(0.114)	(0.0409)
Urban	-0.618***	0.347	2.182***	-0.457***
	(0.0657)	(0.313)	(0.214)	(0.0777)
Household size (log)	-0.783***	-5.984***	3.071***	1.549***
	(0.233)	(0.743)	(0.622)	(0.367)
Age (log)	1.570***	1.258***	0.087***	2.341***
	(0.102)	(0.335)	(0.00797)	(0.118)
Female household head	-0.713***	-0.018	1.018***	-2.116***
	(0.0662)	(0.179)	(0.226)	(0.100)
Education	0.147***	0.094***	-0.079*	0.228***
	(0.00552)	(0.0222)	(0.0435)	(0.0349)
Number of children (log)	0.080	3.908***	-0.471	0.862***
	(0.118)	(0.430)	(0.498)	(0.194)
Working-age members (log)	0.174*	2.788***	-1.319***	-0.890***
	(0.105)	(0.516)	(0.427)	(0.272)
Number of rooms (log)	0.509	0.390	-1.086	-2.033***
	(0.559)	(0.706)	(0.960)	(0.459)
Hours worked (log)	0.480***	0.763***	0.451**	-0.191**
	(0.132)	(0.131)	(0.216)	(0.0932)
_cons	1.672**	2.620*	6.940***	2.377***
	(0.783)	(1.395)	(0.636)	(0.681)
N	1096	307	280	1683
R^2	0.878	0.991	0.986	0.777
adj. R^2	0.877	0.991	0.986	0.775

Standard errors in parentheses
Note: ***, ** and * signify statistically significant at 1%, 5% and 10%
Source: Author's computation (2022)

The estimated results in Table 3 above contain individual country estimates for Nigeria, Ethiopia, Niger, and an estimate for all three countries combined. The results show that most of the explanatory variables in the model are statistically significant across the three countries including the results obtained for the three countries combined. The expected signs of some of the explanatory variables vary across the countries including the combined results.

Hours of a power outage have a negative significant relationship with non-farm industry income at a one percent significance level in Nigeria, Ethiopia, Niger, and all three countries combined. This implies that in Nigeria, a one percent increase in the hours of a power outage is associated with a 0.17 percent reduction in non-farm industry income. The same impact of power outages in Ethiopia decreases non-farm industry income by 0.57 percent. The impact of a one percent increase in the hours of a power outage is quite greater in Niger with a 0.87 percent reduction in non-farm industry income and even greater than the 0.22 percent reduction felt when all three countries are combined. Generally, when a power outage occurs, household activities in the industrial sector of the economy such as manufacturing, mining, construction, and quarrying that depend on electricity are disrupted thereby reducing productivity and potential earnings. The negative relationship between power outages and non-farm industry income is consistent with the literature. For instance, Nduhuura et al. (2021) and Samad and Zhang (2016) found a negative relationship between power outages and household income in Ghana and India respectively. Nonetheless, according to the findings of Samad and Zhang (2016), power interruptions in India result in a 6 percent reduction in income derived from non-farm activities. This indicates that the consequences

of power outages are comparatively less severe in comparison to the circumstances observed in India.

In addition, some of the variables included in the model are observed to have a significant relationship with non-farm industry income. Urban households have a negative significant relationship with non-farm industry income at a one percent significance level in Nigeria and all three countries combined but show no significant relationship in Ethiopia. On the contrary, it exhibits a positive significant relationship with non-farm industry income in Niger. The negative influence of urban location on non-farm industry income in Nigeria and all three countries combined implies that urban households earn 61.8 percent and 45.7 percent less non-farm industry income than rural households respectively. The plausible explanation supporting the findings in Nigeria and all three countries combined is that households in urban areas have most of their members engaged in formal employment which leaves them with very limited time and commitment to home-based self-employment in the form of non-farm activities.

However, on the contrary, urban households in Niger earn 218 percent more non-farm industry income than rural households. In countries all over the world, economic opportunities are less in rural areas compared to urban areas. It was found that in sub-Saharan Africa, income generating activities in rural areas are much worse thereby expanding the income gap between rural and urban households (De Magalhães & Santaeulàlia-Llopis, 2018).

Household size is negatively related to non-farm industry income in Nigeria and Ethiopia and it is statistically significant at a one percent significance level. In Niger and all three countries combined it shows a

positive relationship with non-farm industry income at a one percent significance level. The negative influence of household size on non-farm industry income in Nigeria and Ethiopia is an indication that a one percent increase in household membership decreases non-farm industry income by 0.78 percent and 5.99 percent respectively. The growing unemployment in sub-Saharan Africa compounds as the size of households increases. The associated cost of living in large households limits their savings ability and access to excess resources to engage in non-farm industry activities. According to Rashidin et al. (2020), household size has a negative influence on per capita income in Pakistan. On the contrary, the results in Niger and all three countries combined show that a one percent increase in household membership increases non-farm industry income by 3.07 and 1.55 percent respectively. This is consistent with (Espenshade et al., 1983) who found that overall income rises somewhat with household size.

The age of the household head is positively associated with non-farm industry income across all three countries including all three countries combined at one percent significance levels. The contribution associated with a one percent increase in the age of a household head is found to cause a 1.57 percent, 1.26 percent, 0.09 percent, and 2.34 percent increase in non-farm industry income in Nigeria, Ethiopia, Niger as well as all the three countries combined respectively. The plausible explanation is that as household heads grow older, they become very experienced in such non-farm economic activities with a large customer base and therefore able to manage such activities into profitable entities.

The results further show that households with female heads earn less non-farm industry income than those with male heads in Nigeria and all the countries combined and it is statistically insignificant in Ethiopia. Unlike Niger, where households with female heads earn more non-farm industry income than those with male heads at a one percent significance level. The negative relationship between female household heads and non-farm industry income in Nigeria and all three countries combined implies that households with female heads earn 71.3 percent and 211.6 percent less non-farm enterprise income than households with male heads. It is assumed that females do not have the same access as males to economic opportunities due to religious, cultural, and financial constraints hence their ability to participate in non-farm industry enterprises and earn higher incomes for their households is limited (Demissie, 2013). On the contrary, female-headed households in Niger earn 101.8 percent more non-farm enterprise income than male-headed households.

The education of a household head shows a positive association with non-farm industry income and is statistically significant at one percent in Nigeria, Ethiopia as well as all three countries combined. The relationship between the education of a household head and non-farm industry income is however negative and statistically significant at 10 percent in Niger. The implication of the positive influence of the education of the household head on non-farm industry income is that an additional year of schooling by a household head increases non-farm industry income by 14.7 percent, 9.39 percent, and 22.8 percent in Nigeria, Ethiopia, and all the three countries combined respectively.

The positive influence of the education of a household head on non-farm industry income is rooted in the assumption that household heads with formal education are better skilled and informed to engage themselves or motivate household members into profitable economic activities and make decisions that generate more income for the household. This is supported by Demissie (2013) who found a positive relationship between the education level of a household head and non-farm employment income. On the contrary, an additional year of schooling by a household head in Niger is associated with a 7.87 percent reduction in non-farm industry income. The plausible explanation is that, as one gets more education their chances of getting into formal employment increase. The arrangement in formal employment leaves an individual with fewer unpaid labour hours (leisure time) at one's disposal which is not adequate to fully concentrate on other income-generating sources for the household.

Also, hours worked have a positive significant relationship with non-farm industry income in Nigeria, Ethiopia, and Niger at a one percent significance level in Nigeria and Ethiopia and a 5 percent significance level in Niger. However, the relationship between hours worked and non-farm industry income is negative and statistically significant at a 5 percent significance level in all three countries combined. The positive influence of hours worked on non-farm industry income implies that a one percent increase in hours worked by households in non-farm industry enterprises increases their income by 0.48 percent in Nigeria, 0.76 percent in Ethiopia, and 0.45 percent in Niger. In labour economics, it is established that hours worked have a positive influence on family income.

As mentioned already, most households' income in sub-Saharan Africa is earned from non-farm enterprises which are self-employment and their profitability largely varies with the amount of time allocated to such activities. The finding in the study is consistent with (Medhikarimi et al., 2015) who demonstrated that personal income is positively associated with hours worked. On the contrary, a one percent increase in hours worked by a household in the non-farm industry enterprise decreases their earnings by 0.19 percent when all three countries are combined.

Relationship between Power outages and Non-farm services income

The results presented in Table 4 under this section addressed the second hypothesis of the study, which is to examine whether there is a statistically significant negative relationship between household non-farm services income and hours of power outages. The results for this hypothesis were generated by estimating a standard log-log linear multivariate model to examine whether hours of a power outage have a statistically significant negative relationship with non-farm services income as the outcome variable. Table 4 contains individual country results for Nigeria, Ethiopia, and Niger as well as a result for the three countries combined. As expected, some of the explanatory variables have their expected signs varying across the countries including the combined results.

Table 4: Effects of Power outages on Non-farm services income

Variables	Nigeria	Ethiopia	Niger	All
Dependent variable: Non-farm services income (log)				
Hours of power outage (log)	-0.510***	-0.538***	-0.579***	-0.650***
	(0.0132)	(0.134)	(0.189)	(0.138)
Urban	-1.111***	-1.097***	0.730	-1.016***
	(0.0489)	(0.289)	(1.577)	(0.0414)
Household size (log)	0.319	0.654	1.738	-3.214***
	(0.199)	(0.637)	(1.149)	(0.198)
Age	-0.040***	-0.050***	0.041***	-0.045***
	(0.00152)	(0.00890)	(0.0115)	(0.00164)
Female household head	-0.527***	-0.540**	-0.119	-0.191***
	(0.0673)	(0.213)	(0.534)	(0.0483)
Education	-0.019**	-0.493**	0.235**	-0.101***
	(0.00752)	(0.201)	(0.0962)	(0.0360)
Number of children (log)	-1.313***	0.486	-1.271*	0.829***
	(0.118)	(0.383)	(0.723)	(0.122)
Working-age members (log)	1.488***	0.342	-0.949	4.292***
	(0.140)	(0.444)	(0.846)	(0.124)
Number of rooms (log)	-1.378***	-0.981***	-1.452***	0.776***
	(0.0438)	(0.213)	(0.476)	(0.0663)
Hours worked (log)	0.253***	0.879***	0.307	-0.380***
	(0.0589)	(0.175)	(0.407)	(0.139)
_cons	13.92***	8.780***	11.76***	14.13***
	(0.190)	(0.710)	(1.215)	(0.182)
N	5027	523	471	6021
R^2	0.629	0.753	0.942	0.801
adj. R^2	0.629	0.748	0.941	0.801

Standard errors in parentheses
Note: ***, ** and * signify statistically significant at 1%, 5% and 10%
Source: Author's computation (2022)

The estimated results in Table 4 above show that hours of a power outage have a negative significant relationship with non-farm services income at a one percent significance level in Nigeria, Ethiopia, Niger as well as all three countries combined. This implies that a one percent increase in the hours of power outage in Nigeria is associated with a 0.51 percent reduction in non-farm services income. In Ethiopia, an additional percentage in the hours of power outage decreases non-farm services income percent by 0.54 percent which is within the range in Niger as a 0.58 percent reduction in non-farm services income is felt by households in Niger for an additional percentage of a power outage. The effect of an additional percentage increase in the hours of a power outage is 0.65 in all the countries combined. Power outages constrain households' consumption of electricity thereby negatively affecting service enterprises that depend on electricity. For instance, Khandker et al. (2013) found a reduction in benefits from rural electrification in India as a result of unreliable electricity supply. However, as stated by Samad and Zhang (2016), power disruptions in India lead to a decline of 6 percent in non-agricultural earnings. This implies that the impact of power outages is relatively milder compared to the situation in India.

Additionally, other control variables that have a significant relationship with non-farm services income include household location. Urban households earn less non-farm services income than rural households and it is statistically significant at a one percent significance level in Nigeria, Ethiopia as well as all three countries combined. This implies that urban households earn 111 percent, 101 percent, and 102 percent less non-farm services income than rural households in Nigeria, Ethiopia, and all three countries respectively.

Generally, the availability of market opportunities and facilities in urban areas enables the participation of households in non-farm enterprises and boosts their profitability in urban areas more than in rural areas. Non-farm enterprises in Ethiopia are more prominent in small and large towns than in rural areas. Small and large towns account for almost 90 percent compared to 18 percent in rural areas (OECD, 2020). Therefore, low participation in non-farm service enterprises in rural areas increases the market share of households that can set up non-farm service enterprises in rural areas. The increase in market share coupled with minimal competition enable rural households to earn more than urban households where markets are highly competitive with each household having no or minimal control over the market.

The results further revealed that household size is found to be negatively related to non-farm services income and statistically significant only in all three countries combined at a one percent significance level. This implies that one more household member decreases non-farm services income by 3.21 percent in all three countries combined. As the size of a household increases, the cost of living borne by a household increases as well. Amid growing unemployment and limited opportunities for income generation, an extra household member rather adds to the cost of living in the household than the income envelope. A study by Rashidin et al. (2020) found the household size to have a negative influence on per capita income in Pakistan.

The age of the household head is also found to be negatively associated with non-farm services income in Nigeria, Ethiopia, and all three countries combined all at a one percent significance level. This indicates that the marginal effect associated with an additional year in the age of a household

head decreases non-farm services income by 3.96 percent, 4.99 percent, and 4.49 percent in Nigeria, Ethiopia, and all three countries combined respectively. Most non-farm services enterprises require the physical involvement of household heads who often are the owners or caretakers of such activities and as they grow older, their productivity falls resulting in reduced earnings. Unlike in Niger as household heads get older by an additional year, non-farm services income increases by 4.07 percent. This finding though inconsistent with findings in Nigeria, Ethiopia, and Niger is similar to (Rashidin et al., 2020) who found the age of household head to be positively associated with per capita income in Pakistan.

The results also display that households with female heads earn less non-farm services income than those with male heads in Nigeria, and Ethiopia, as well as all three countries combined, and are statistically significant at a one percent significance level in Nigeria and all three countries combined and at 5 percent significance level in Ethiopia. This implies that in Nigeria, Ethiopia, and all the countries combined, households with female heads earn 52.7 percent, 54 percent, and 19.1 percent less non-farm services income than households with male heads respectively. This corroborates the finding by Demissie (2013) who found that due to religious, cultural, and financial constraints, female-headed households were less capable of generating more income.

The education of household heads shows a negative association with non-farm services income and is statistically significant at 5 percent in Nigeria, and Ethiopia, as well as at a one percent significance level in all three countries combined. The implication is that an additional year of schooling by

a household head decreases non-farm services income by 1.9 percent in Nigeria, 49 percent in Ethiopia, and 10 percent in the three countries combined. The plausible explanation is that, as one gets more education their chances of getting into formal employment increase. The arrangement in formal employment leaves an individual with fewer unpaid labour hours (leisure time) at one's disposal which is not adequate to fully concentrate on other income-generating sources for the household. On the contrary, the association between the education of household head and non-farm services income is positive in Niger. This implies that an additional year of schooling by a household head increases non-farm services income by 23.5 percent in Niger. The positive contribution of the education of the household head is based on the assumption that household heads with formal education are better equipped to make economic decisions that generate more income for the household. As posited by Demissie (2013) the education level of a household head has a positive impact on off-farm employment income.

Besides, hours worked have a positive significant relationship with non-farm services income in Nigeria and Ethiopia and are both statistically significant at a one percent significance level. On the contrary, the relationship between hours of work and non-farm services income is negative in all three countries combined and is also statistically significant at one percent. This positive influence of hours worked on non-farm services income in Nigeria and Ethiopia implies that an additional hour worked by a household increases non-farm services income by 0.25 percent in Nigeria, and 0.88 percent in Ethiopia.

In labour economics, it is established that hours worked have a positive influence on family income. As mentioned already, most households' income in sub-Saharan Africa is earned from non-farm enterprises which are self-employment and their profitability largely varies with the amount of time allocated to such activities. The finding in the study is consistent with (Medhikarimi et al., 2015) who demonstrated that personal income is positively associated with hours worked. On the contrary, the effect of an additional hour worked in all three countries combined is a 0.38 percent decrease in non-farm services income.

Relationship between Power outages and Total household income

The third objective of the study sought to determine the existence of a statistically significant negative relationship between power outages and total household income. The results presented in Table 5 under this section addressed this hypothesis. The results for this objective were obtained by estimating the effect of power outages on total household income using a standard log-log linear multivariate model.

Table 5: Effects of Power outages on Total household income

Variables	Nigeria	Ethiopia	Niger	All
Dependent variable: Total household income (log)				
Hours of power outage (log)	-0.0334***	-0.115*	-0.142**	-0.201***
	(0.00878)	(0.0685)	(0.0556)	(0.0164)
Urban	-0.322***	-0.975***	-0.325*	0.208***
	(0.0120)	(0.155)	(0.193)	(0.0553)
Household size (log)	-2.581***	0.498***	0.260	0.895***
	(0.388)	(0.129)	(0.296)	(0.226)
Age	-0.010***	-0.0605***	-0.016***	0.028***
	(0.000807)	(0.00454)	(0.00417)	(0.00197)

Table 5 Cont'd

Female household head	-0.957***	-0.792***	-0.205	-0.657***
	(0.0367)	(0.150)	(0.137)	(0.0603)
Education	0.009***	-0.160***	0.163***	0.084***
	(0.00246)	(0.0107)	(0.0265)	(0.00452)
Number of children (log)	0.563***	0.127	0.023	-0.398***
	(0.184)	(0.123)	(0.176)	(0.121)
Working-age members	0.827**	-0.070	1.103***	-1.014***
	(0.364)	(0.225)	(0.244)	(0.187)
Number of rooms (log)	0.865***	-0.739***	0.471**	0.870***
	(0.165)	(0.179)	(0.189)	(0.0963)
Hours worked (log)	0.869***	1.568***	0.0771	0.704***
	(0.0316)	(0.0720)	(0.0713)	(0.0171)
_cons	10.29***	3.195***	12.23***	5.808***
	(0.164)	(0.444)	(0.336)	(0.161)
N	9558	1751	992	12301
R^2	0.415	0.589	0.190	0.343
adj. R^2	0.414	0.587	0.181	0.343

Standard errors in parentheses
Note: ***, ** and * signify statistically significant at 1%, 5% and 10%
Source: Author's computation (2022)

The results obtained in Table 5 show that hours of a power outage have a negative significant relationship with a total household income at a one percent significance level in Nigeria as well as all three countries combined and a 5 percent and 10 percent significance levels in Niger and Ethiopia respectively. This indicates that a one percent increase in the hours of outage in Nigeria, Ethiopia, Niger, and all three countries combined is associated with a 0.03 percent, 0.12 percent, 0.14 percent, and 0.20 percent reduction in total household income respectively. The incidence of power outages disrupts

household economic activities that depend on electricity resulting in low productivity. Low productivity of household economic activities limits the potential income of households. The negative relationship between power outages and income is consistent with studies by Nduhuura et al. (2021) and Samad and Zhang (2016) who found a negative relationship between power outages and household income in Ghana and India respectively. Nonetheless, as indicated by Samad and Zhang (2016), power outages in India result in a 6 percent reduction in non-farm income. This suggests that the effect of power outages is comparatively less severe than in India.

The estimated results also reveal that urban households earn less total income than rural households at a one percent significance level in Nigeria, Ethiopia as well as all three countries combined and a 10 percent significance level in Niger. This implies that urban households in Nigeria earn 32 percent less total income than those in rural areas. In Ethiopia, urban households earn 97 percent less total income than rural households. In Niger, urban households earn 33 percent less total income than rural households. The effect of power outages on urban households compared to rural households in all the countries combined is 20 percent more total income than those located in a rural area.

The economic opportunities available to rural households across the world are far less than those in urban areas. Like countries all over the world, sub-Saharan African countries have less income generating activities in rural areas. This argument is supported by De Magalhães and Santaeulàlia-Llopis (2018) who found that the income gap between rural and urban households increases by a ratio of 2.23 in sub-Saharan Africa. The limited economic opportunities in rural areas allow the few households with non-farm

enterprises to enjoy a greater market share than those in the urban area. The increase in market share coupled with minimal competition enable rural households to earn more than urban households where markets are highly competitive with each household having no or minimal control over the market.

Besides, the age of a household head reveals a negative relationship with total household income in Nigeria, Ethiopia, and Niger all at a one percent significance level. On the contrary, the age of a household head is positively related to total household income in all three countries combined at a one percent significance level. This implies that in Nigeria, Ethiopia, and Niger as household head age increases by one more year, total household income decreases by 1.02 percent, 6.05 percent, and 1.62 percent respectively. As household heads grow older they become less economically active and probably spend less time in non-farm activities resulting in low earnings (OECD, 2020). However, in all three countries combined, as household heads grow old by an additional year, total household income increases by 2.78 percent. An additional year in the age of a household head comes with experiences that can be utilised in making profitable income generating activities for households.

It is further observed that households with female heads earn less total income than those with male heads in Nigeria, Ethiopia, Niger as well as all the countries combined all at a one percent significance level. This implies that in Nigeria, Ethiopia, Niger, as well as all three countries combined, households with female heads earn 96 percent, 79 percent, 21 percent, and 66 percent less total income than households with male heads respectively. This

is consistent with (Demissie, 2013) who found that due to religious, cultural, and financial constraints, female-headed households were less capable of generating more income.

The education of a household head is positively related to total household income and is statistically significant in Nigeria, Niger, and all three countries combined all at a one percent significance level. On the contrary, the education of a household head in Ethiopia was found to be negatively associated with total household income and also statistically significant at one percent. These estimated results imply that an additional year of schooling of a household head increases total household income by 0.91 percent, 16.3 percent, and 8.41 percent in Nigeria, Niger, and all three countries combined respectively. The ability of the education of a household head to positively influence total household income is hinged on the assumption that household heads with formal education are better equipped to make economic decisions that generate more income for the household.

This is similar to the estimated positive relationship between the education level of a household head and off-farm employment income (Demissie, 2013). In Ethiopia, an additional year of schooling of the household head is rather found to be responsible for a 16 percent decrease in total household income. The average years of schooling of household heads in Ethiopia during the study is 6 years equivalent to primary level education. This depicts that most of the households during the study period were headed by less educated household heads and therefore lack the necessary abilities to make profitable economic decisions in the household resulting in a reduction in total incomes. Demissie (2013) found similar estimates when he further

extended the effect of education on both non-farm employment and wage employment income in Ethiopia.

The number of working-age members is observed to have a positive relationship with total household income and is statistically significant at a 5 percent significance level in Nigeria, and at a one percent significance level in Niger. It however shows a negative relationship in all three countries combined at a one percent significance level. This indicates that an additional working-age member increases total household income by 0.83 percent in Nigeria, and 1.03 percent in Niger. The positive influence of an additional working-age member on total household income in Nigeria and Niger implies that additional incomes are generated through their participation in economic activities. Demissie (2013) found similar estimates establishing a positive relationship between economically active members and household income in Ethiopia.

The number of rooms – a proxy for physical capital has a positive influence on total income in Nigeria, Niger as well as all three countries combined at a one percent significance level in Nigeria and three countries combined and a 5 percent significance level in Niger. On the contrary, the number of rooms in a household contributes negatively to total household income and it is statistically significant at one percent in Ethiopia. This signifies that an additional room to the stock of rooms of a household contributes 0.87 percent, 0.47 percent, and 0.87 percent increase in total household income in Nigeria, Niger, and all three countries respectively. Unlike in Ethiopia an increase in the stock of rooms of a household by one more unit decreases total household income by 0.74 percent.

Also, hours worked have a positive significant relationship with total household income in Nigeria, Ethiopia, and all three countries combined all at a one percent significance level. This implies that an additional hour worked by a household increases total household income by 0.87 percent in Nigeria, and 1.57 percent in Ethiopia. The effect of an additional hour worked in all three countries combined is a 0.70 percent increase in total household income. In labour economics, it is established that hours worked have a positive influence on family income. As mentioned already, most households' income in sub-Saharan Africa is earned from non-farm enterprises which are self-employment, and their profitability largely varies with the amount of time allocated to such activities. The finding in the study is consistent with (Medhikarimi et al., 2015) who demonstrated that personal income is positively associated with hours worked.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

This chapter captures the summary of findings that were made from the study. It goes on to provide conclusions made from the study and thereafter gives recommendations to various stakeholders in society based on the findings. The chapter ends by giving suggestions for further research.

Summary of Findings

The study generally sought to examine the effect of power outages on household incomes in three selected sub-Saharan African countries namely Nigeria, Ethiopia, and Niger. The study specifically then looked at whether there is a negative significant relationship between power outages and non-farm industry income, non-farm services income, and total household income in the three selected sub-Saharan African countries and the effect with all three countries combined.

The findings from objective one were obtained using a standard log-log linear multivariate regression model to determine whether there is a significant negative relationship between monthly hours of power outages and non-farm industry income. The outcome variable of the model is the non-farm industry income. Included in the model are the monthly hours of power outages as the main independent variable and other control variables namely, household location, household size, age of household head, sex of household head, and, years of schooling of household head, number of children, hours worked, number of working age members and number of rooms (a proxy for physical capital),

The findings show that an hour of power outages is associated with 0.12 percent, 0.57 percent, and 0.87 percent reductions in non-farm industry income in Nigeria, Ethiopia, and Niger respectively. The effect of power outages on all three countries combined is a 0.22 percent reduction in non-farm industry income. Also, the location of households is significant in Nigeria, Niger, and all three countries combined with urban households in Nigeria earning 62 percent less income than rural households, and 46 percent less income in all three countries combined. Contrary to the findings in Nigeria, Nigerien urban households earn 218 percent more income than their rural counterparts. The sex of the household head is found to be significant in Nigeria, Niger, and all the countries combined. Households with female heads earn 71 percent and 212 percent less income in Nigeria and all three countries combined respectively. On the contrary households with female heads earn 102 percent more income in Niger.

The findings further show that household size is associated with a 0.78 percent and 5.98 percent reduction in non-farm industry income in Nigeria and Ethiopia respectively. On the contrary, household size contributes 3.07 percent and 1.55 percent increase in non-farm industry income in Niger and all three countries combined respectively. Besides, the age of the household head is positively associated with non-farm industry income in Nigeria with a 1.57 percent increase in income for an additional year in the age of the household head. An additional year in the age of a household head in Ethiopia is observed to be responsible for a 1.26 percent increase in non-farm industry income. In Niger and all three countries combined, one more year in the age of a household head is associated with a 0.09 percent and 2.34 percent increase in

non-farm industry income respectively. Hours worked is estimated to be positively associated with non-farm industry income in Nigeria, Ethiopia, and Niger translating into 0.48 percent, 0.76 percent, and 0.45 percent increase in non-farm enterprise income. When all three countries are combined, the relationship is found to be negative with a 0.19 percent reduction in non-farm industry income. Education of a household head is also found to be positively associated with non-farm industry income in Nigeria, Niger as well as all three countries combined contrary to the negative relationship in Niger.

The findings from objective two are equally obtained using a standard log-log linear multivariate regression model. The model is used to determine whether there is a significant negative relationship between monthly hours of power outages and non-farm services income. The model is specified with non-farm services income as the dependent variable and monthly hours of power outages as the main independent variable. Other control variables are also included in the model. Monthly hours of a power outage is found to be negatively associated with non-farm services income in Nigeria, Ethiopia, Niger as well as all three countries combined. Additionally, hours worked is observed to have a positive relationship with non-farm services income in Nigeria, Ethiopia, all three countries combined, and is insignificant in Niger. Urban households earn less non-farm services income than rural households in Nigeria, Ethiopia, and all three countries combined.

A standard log-log linear multivariate regression model is also used to obtain the findings for objective three which sought to determine whether there is a significant negative relationship between monthly hours of power outages and total household income. The model is specified with total

household income as the dependent variable and monthly hours of power outages as the main independent variable as well as other control variables also included in the model. Monthly hours of a power outage is negatively associated with total household income in Nigeria, Ethiopia, Niger as well as all three countries combined.

Nevertheless, when considering the effects of power outages on total household income, it is important to note that the impact is relatively low compared to the income derived from non-farm industry and services. Total household income encompasses various income sources, including financial investments, remittances, rent, pension payments, and government transfers, which are not directly dependent on electricity. Consequently, the overall effect of power outages on total household income is expected to be minimal. Furthermore, the low R-squared values observed in objective 3 can be attributed to the multidimensional nature of total household income. Total household income comprises multiple income sources that are influenced by various factors. However, due to the need to avoid overspecification of the model, it may not be feasible to include all the factors that affect total household income. Consequently, the model's goodness of fit is diminished, leading to lower R-squared values.

Household size is positively related to total household income in Ethiopia and all three countries combined and shows a negative relationship with total household income in Nigeria. Finally, hours worked is observed to have a positive relationship with total household income in Nigeria, Ethiopia, and all three countries combined. Urban households earn less total household

income than rural households in Nigeria, Ethiopia, and Niger, as well as all three countries combined.

Conclusions

The study sought to primarily determine the effect of power outages on household incomes. It is found that an hour of a power outage is associated with the reduction of non-farm industry income, non-farm services income, and total household income in the three selected countries namely Nigeria, Ethiopia, and Niger including all three countries combined. The estimated effect of power outages on the various types of household incomes in Nigeria, Ethiopia, and Niger including all three countries combined is unanimous. This implies that power outages have a negative impact on household incomes in the sub-Saharan Africa region.

Comparing the two forms of household non-farm enterprise income considered in the study namely non-farm industry income and non-farm services income, the effect of a power outage is higher on non-farm services income than non-farm industry income. Though household non-farm industry enterprises are largely centered around manufacturing, and construction activities that require electric machines and equipment, very few households are engaged in those activities. On the other hand, service enterprises in the form of repairs, dressmaking, trade, and retail activities are the dominant activities engaged by households who work into the night making regular power supply an essential input into their activities. But overall, the effect on total household income is the lowest compared to both non-farm industry and services enterprises' income. These findings varied across countries in terms of

magnitude and on a sectoral level, the effect echoes the negative effect of power outages on household incomes.

It can therefore be concluded that the gains aimed at connecting households to the grid decrease with the frequent incidence of power outages in sub-Saharan Africa. Even economic activities that do not depend on electricity are indirectly affected by unreliable electricity supply. The interrelationship among households in their economic activities presents the possibility that the incomes of households that do not depend on electricity fall as a result of a lack of demand for their output by households who are affected by power outages.

Recommendations

The following recommendations are made based on the findings of the study: To begin with, the governments through the relevant Ministries in Nigeria, Ethiopia, and Niger should formulate and implement policies to help address the issue of power outages since the study has been able to establish the existence of a negative relationship between power outages and household incomes which is an important element of household economic wellbeing.

1. The Nigerian power sector is facing significant challenges in meeting the growing electricity demand due to the emergence of a new middle class. To address the issue of power outages in Nigeria, the Nigerian government should explore the integration of renewable energy sources as a potential solution to alleviate electricity shortages in Nigeria.
2. The Ethiopian power sector is facing challenges related to poor service delivery, delays in infrastructure rehabilitation, and protracted

institutional reforms, leading to electricity shortages and frequent power outages. To address the issue of frequent power outages in Ethiopia, the Ethiopian Electric Power Company should enhance service delivery and expedite infrastructure rehabilitation for a reliable electricity supply in Ethiopia.

3. Niger's heavy reliance on electricity imports from Nigeria, coupled with the challenges faced by Nigeria's power sector and Niger's expanding energy consumption, has led to frequent shortages and blackouts in Niger. To address the issue of frequent electricity shortages and blackouts, the government of Niger should promote energy independence and diversification strategies for a reliable electricity supply in Niger.
4. Nigeria, Ethiopia, and Niger have implemented tariff regimes that do not reflect the true cost of electricity generation, resulting in financial challenges and frequent power outages in their respective power sectors. To address these financial issues and mitigate power outages, it is crucial for the governments of Nigeria, Ethiopia, and Niger to undertake tariff reforms within their electricity sectors. The current low revenue generated from tariffs, which are set below the cost recovery rate, is a significant factor contributing to the inability of electricity companies in these countries to address the persistent issue of power outages.
5. Besides, electricity utility companies in Nigeria, Ethiopia, and Niger should adopt digital technologies such as sensors and smart meters for accurate data collection and measurement of outages and related

information on electricity systems. This will help in the quick detection of minor system failures which are sometimes unnoticed until a customer reports them. An example is in Ghana where a team from the University of California, Berkeley, has developed and deployed remote sensing devices to measure power outages, voltage, and frequency fluctuations across households and businesses in Accra.

6. Finally, the West African Power Pool (WAPP) and Eastern Africa Power Pool (EAPP) should intensify their efforts to develop common electricity markets for the regions as envisioned so that countries with low generation capacity can benefit from countries with excess capacity.

Suggestions for Further Research

Though, the study ensured that the parameter estimates are not affected by endogeneity as indicated in chapter one, future studies on the effect of power outages on household incomes should consider and control for endogeneity. One of the major limitations of this study is the unavailability of an appropriate and valid instrument to capture power outages which is likely to create the issue of endogeneity because of its potential to be an endogenous variable. Future studies should also look for appropriate ways to capture other relevant variables such as access to credit, market, and road in a continuous format other than the binary form that existed at the time of my study. Finally, studies can also do a panel study of the effect of power outages on household incomes since it is most informative than the cross-sectional study.

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