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Chantale Oweggi. Household energy choices under perceived shocks in Uganda: Are perceived shocks limiting the energy transition process among households in Uganda?. 2023. hal-04199253v1

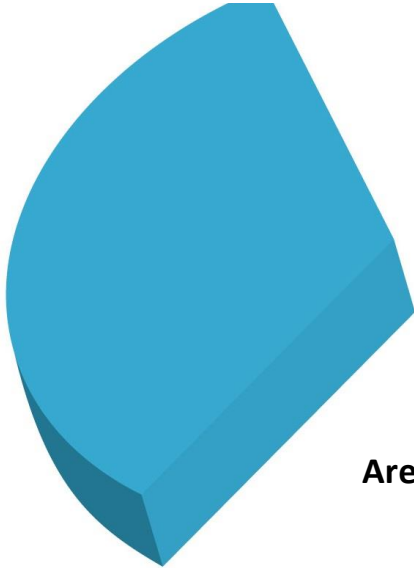
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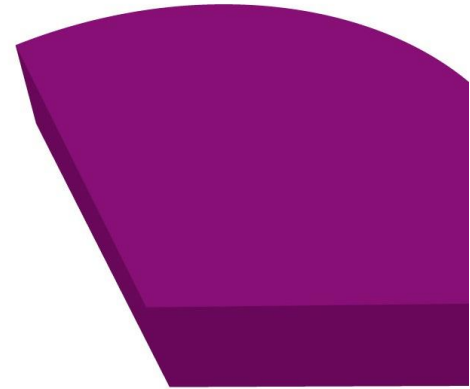
Preprint submitted on 7 Sep 2023 (v1), last revised 7 Feb 2024 (v2)

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**Household energy choices under
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Mise en ligne / Online : 10/07/2023

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JULY 2023

Abstract

Very few studies have focused on the impact of shocks on household fuel choices in Sub-Saharan Africa. This paper seeks to bridge this gap by estimating the effects of shocks on household fuel choices. Using the UNPS 2019/2020 cross-sectional dataset, we apply the logit and mlogit models to study the energy ladder hypothesis and then proceed to analyse the impact of perceived household shocks on household fuel choices. The study finds that wealthier households hold a preference for modern fuels. While this is true for lighting fuels, the transitional fuel charcoal is commonly used for cooking. Finally, shocks limit the energy transition process among cooking fuels. More precisely, Shocks induce a coping strategy where households reduce the likelihood of choosing modern cooking fuels.

Keywords: Energy ladder; Fuel choices; household shocks; Energy poverty; Sub-Saharan

Africa

JEL Classification : O13, Q41, N5, D81

Acknowledgements: This paper has benefitted from critical insight and reading from Pascale Combes Motel and Marcel Voia. I would like to thank all the participants of the seminar at the laboratory of economics of Orleans which took place at the University of Orleans, and my colleagues at the University of Clermont Auvergne for their comments.

1. Introduction

The central role of energy is underscored by its absolute necessity in achieving and promoting human welfare. It is equally crucial for various engines of development both at the micro and macroeconomic levels. This importance has been highlighted through the sustainable development goal (SDG) goal 7, dedicated to improving energy access globally, especially in developing countries. Moreover, access to energy is central to a properly functioning economic sector and enhances the achievement of a majority of other (SDGs) such as poverty alleviation, education, gender equality, health, climate action, labour force, and acts as a catalyst for economic growth. Energy is a tradable good and its consumption generally takes up a percentage of household income. On the other hand, shocks in their element, affect efficiency by inducing a sub-optimal allocation of household resources, which is likely to deteriorate the consumption behaviour of both food and non-food products such as energy. The impact of shocks on household welfare is discernible. Households are faced with rampant widespread covariate shocks such as weather shocks, in addition, they still experience household-specific idiosyncratic shocks. The phenomenon is aggravated when there is minimal existence of formal insurance mechanisms, a situation mostly witnessed in developing countries such as Uganda. Furthermore, shocks have distributive effects as households are differently exposed. Poor households tend to suffer more than their richer counterparts. In view of the reality of climate change, rising levels of inequality and the global efforts for energetic transition, the need to analyse the impact of shocks on household energy choices is inevitable.

Climate change will intensify the vulnerability of human-environment systems (Wheeler & von Braun, 2013). There is abundant literature on the impact of shocks on household consumption patterns in developing countries (Banerjee & Duflo, 2007; Debela et al., 2012; Fafchamps et al., 1998; Morduch, 1990; Quisumbing et al., 2012; Ray, 1998; Townsend, 1995). A limited but growing branch of the literature is seeking to address the impact of climate shocks on energy consumption in developing countries (C.-C. Lee et al., 2021; Paudel, 2023). For instance, a study at a macroeconomic level found that natural disasters negatively impact oil, renewable, and nuclear energy consumption (C.-C. Lee et al., 2021). In Nepal, seismic shocks induce poor households to use traditional fuels and exacerbate the transition towards modern energy (Paudel, 2023). The nexus between shocks and energy is generally understudied in the African continent. Research done in Nigeria show that in peri-urban regions of Kano and its resource hinterlands, the rising prices of kerosene and other petroleum-based domestic fuels, make fuelwood an attractive alternative as a domestic fuel choice (Maconachie et al., 2009). However, in Uganda, the shock literature has majorly focused on aspects such as food consumption and productivity (Debela et al., 2012; Kijima et al., 2006; Mertens et al., 2016; Quisumbing et al., 2012).

The East African country of Uganda is an agricultural economy. Agriculture-based products in primary and processed goods accounted for about 45 per cent of exports and employed about 64 per cent of Ugandans in 2019 (World Bank, 2020a). The sector is thus the lifeblood of the economy and of household welfare. The performance of the largely rainfed agricultural sector and corresponding environmental shocks are closely linked to the living standards of those whose primary income source is agriculture (World Bank, 2020a). From 1900 to 2018, the country encountered 20 floods, 40 epidemics, 9 droughts, and 5 landslides events with cumulative damages amounting to 200,000 deaths and at least \$80 million in economic losses between 1900 to 2018 (World Bank, 2023). Each year, floods impact 50,000 people and over \$62 million in GDP. Droughts affected about 2.4 million people

between 2004 and 2013, and drought conditions in 2010 and 2011 caused an estimated loss and damage value of \$1.2 billion, equivalent to 7.5% of Uganda's 2010 GDP (World Bank, 2023). In addition to these covariate shocks, households in Uganda experience idiosyncratic shocks that may further deteriorate their consumption patterns in the absence of an effective insurance mechanism.

In 2020, 42.1% of the Ugandan population had access to electrification, comprised of both on and off-grid connections (World Bank, 2020b). In 2019, Uganda was among the rare cases in developing countries, where electrification outpaced population growth but nonetheless remains among the world's top electricity-deficit countries (IEA, 2023). 27% of households in Uganda used solar kit for lighting, 19 % used grid electricity and 11 percent used solar home system. Among cooking fuels, wood fuel constituted 94% with firewood taking up 73% and charcoal 21% of cooking fuel needs (UBOS, 2021).

The limited access to clean cooking fuels and the predominant use of biomass fuels, characterised by firewood and charcoal, has negative effects on human welfare. Combustion of biomass results in indoor air pollution which is harmful to health and can cause adverse diseases such as respiratory problems (WHO, 2022). Furthermore, such cooking fuels have been associated with productivity loss as households that lack electricity constrain their activities after dark (Heltberg, 2005). Productivity loss is equally evident when long hours are spent collecting biomass fuels, a common practice in Uganda where in 2020, 66% of households collected firewood from Bush/Forest, 23 % from their own plantations and 9 % bought from the market (UBOS, 2021). This trend limits time for productive work in school and in economic activities with negative implications for gender equality efforts since firewood gathering is mostly tasked to women and girls. In addition, it has negative implications on the environment. Efforts to conserve common property resources such as forests have been challenged with minimal community participation in forest conservation (Gombya-Ssembajjwe & Banana, 1998).

Uganda has formulated various energy policies in its quest to achieve an energy transition to more modern and environmentally friendly energy options. The Uganda energy policy developed in 2002 is aimed at meeting the energy needs of Uganda's population for social and economic development in an environmentally sustainable manner. It is supported by the Energy Development Programme, a vision 2040 initiative of the national planning authority. The policy is aimed at increasing access to and consumption of clean energy through an increase in primary energy consumption, increasing the proportion of population accessing electricity, reducing the share of biomass energy used for cooking, increasing the transmission capacity, and enhancing grid reliability (Uganda, 2020). Moreover, such initiatives are supported by the 2007 renewable energy policy, and the 2008 national oil and gas policy (ERA, 2022). The country's policy efforts are equally backed up by the rural electrification program together with the last mile connectivity program funded by various development partners. Despite these efforts, Uganda's energy trends remain underdeveloped and dwarfed by the predominant use of wood fuels for cooking. The country recognizes the likely fact that biomass is and will remain a dominant source of energy in Uganda in the future (Uganda, 2002). Despite the fact, there still lacks a comprehensive strategy that would incorporate this reality and its consequences on sustainable development. Besides, the presence of income shocks could potentially limit household efforts towards an energy transition. The commitments, policy efforts, stagnant evolution in cooking fuel and the environmental and socio-economic repercussions of the existing paradigm, all make Uganda, a particularly interesting country to study.

Although the determinants of energy choices among households have been studied, the effects of shocks on household energy coping strategies in Uganda have not yet been studied to the best of our knowledge. This study intends to contribute to the existing literature in 3 folds. First, by principally examining the cumulative effect of all perceived shocks on household energy choices. Second, systematically disintegrating specific shocks according to existing literature and studying their impacts on energy choices. It will equally study the determinants of household fuel choices in Uganda, testing the energy ladder hypothesis. It will therefore attempt to respond to the research questions; (1) How do income shocks affect household energy choices? (2) Which shocks are detrimental to household energy choices? (3) What are the determinants of household energy choices?

The proceeding sections of this paper are structured in the following manner. Section 2 is dedicated to providing an overview of conceptual theories of household energy choices and perceived household shocks. Section 3 provides the overview of the data and the variables of study. Section 4 outlines the empirical methodology. Section 5 discloses the econometric findings. Section 6 presents the sensitivity analyses. Section 7 discusses the results and finally, section 8 concludes and draws some policy implications.

2. Household fuel choices and household perceived shocks

This section begins by presenting the conceptual frameworks of household fuel choices and proceeds to discuss the literature on household perceived shocks. It eventually narrows down to address the literature on fuel choices and shocks in Uganda. Finally, it attempts to question the interlinkage between shocks and household energy choices using existing literature.

2.1 Household fuel choices

Literature on household energy choices has focused on two major conceptual frameworks, namely, the energy ladder and the energy stacking hypotheses. The energy ladder hypothesis conceptualizes household energy transition as linearly correlated to income (Leach, 1992). Thus, as income increases, households move up 'the ladder of fuel preferences', from traditional to modern fuels. The fuel ladder proposition has been traditionally represented by three different levels; traditional, transitional, and modern forms of energy. A classical typology classifying different fuels in which modern energy is characterized by higher technology and cleanliness, exemplified by electricity, some petroleum products such as kerosene¹, LPG gas, and now, solar energy has gained considerable popularity. On the other end of the spectrum, traditional energy sources are low in technology as characterized by fuelwood, crop, and animal residue. Transitional energy can then be considered the intermediary between traditional and modern energy. They are characterized by charcoal for cooking and kerosene for lighting, consequently, they offer a climb up the energy ladder to the next level but do not offer the cleanliness of modern fuels. In this view, therefore, income is the key driver, influencing the transition process from traditional to modern energy use.

A critique of the energy ladder hypothesis is the 'energy stacking hypothesis'. The hypothesis challenges the view that there is a complete transition of household fuel from traditional to modern energy, with an increase in income. Instead, proponents of the energy stacking hypothesis propose the view that even as income increases, households do not make a full transition up, but rather, continue the concurrent use of a mixture of traditional, transitional and modern fuels (Heltberg, 2004;

¹ Kerosene is considered modern when used for cooking while transitional when used for lighting (Choumert-Nkolo et al., 2019)

Masera et al., 2000). Indicating that, indeed, an increase in income will lead to an energy transition towards modern energy, but, this transition will not be complete as households will still use traditional and transitional forms of energy. Intrinsically, this introduces an 'energy mix'. A clean break from the use of traditional fuels is unlikely in many developing countries (Choumert-Nkolo et al., 2019).

The stacking hypothesis effectively reduces the energy ladder to a special case. Income, therefore, however central to household fuel choices does not give a complete picture of the behaviour inherent in household fuel decisions. Literature on energy stacking bridges this gap by identifying other determinants, of energy use other than income. For instance, while improved economic status truly leads to a transition towards electricity, various socioeconomic factors, among them, urban location, public infrastructure, and price, additionally influence the energy transition process (Hosier & Dowd, 1987). A study of the determinants of household fuel choices in major cities in Ethiopia find that as household income increases, households increase the number of fuels used, effectively proving the existence of fuel stacking (Mekonnen & Köhlin, 2009). The authors equally find that apart from income, other factors that could explain household fuel preferences include; cooking and consumption habits, dependability of supply, cost, and household preferences and tastes. Furthermore, a panel study of Tanzanian households finds that, apart from household income, key factors such as the household head's age, their level of education, the spouse's level of education, household size, rural or urban location, marital status, women's bargaining power among other factors, are central in forecasting household cooking fuel choice (Choumert-Nkolo et al., 2019). Ergo, the authors propose the view that household fuel choice is not really a climb up the ladder but rather a 'portfolio choice'.

2.2 Household Perceived shocks

The energy consumption theories in practice allude to the classical consumer theory which models the problem of consumer choice as a problem of utility maximization under a budget limit. A claim can be made that shocks, in their very nature, limit consumer choices by inducing a sub-optimal allocation of household resources. With the assumption that shocks are detrimental to income and hence also to consumption, this study will apply the energy ladder hypothesis to analyse the impact of household perceived shocks on their energy consumption choices. Nevertheless, other household characteristics will be used as controls. Extensive literature exists on the nexus between household income shocks and coping strategies in Africa (Fafchamps et al., 1998). These studies have long concentrated on how shocks affected aggregate consumption or specific expenditures such as food (Dercon et al., 2005). This study portrays particular similarities to literature focusing on the impact of shocks on household expenditure and welfare, but equally different as it bases its focus not on aggregate consumption or food consumption, but rather fuel consumption. Despite the fact that energy accounts for a percentage of household expenditure and consumption among traded goods, very few studies concentrates on the effects of shocks on household fuel choices especially in developing countries (Auffhammer & Mansur, 2014; C.-C. Lee et al., 2021; Rakshit, 2021). This study seeks to contribute to this growing literature by focusing on the role of shocks on household energy consumption. The need to focus on energy is underscored by the very fact that energy, like health or food expenditure, also affects well-being. Seconded by that, shocks can alter the energy transition by locking households in continued use of traditional fuels. The dominant use of traditional fuels is associated with indoor air pollution, a phenomenon detrimental to well-being (WHO, 2022).

The shocks literature majorly classifies shocks into two categories, covariate², and idiosyncratic³ shocks. Covariate shocks affect most people in a community at the same time and include: floods, irregular rain, drought among others; while idiosyncratic shocks affect only a few people within a community at the same time and include: death, illness, loss of employment among others (Fafchamps et al., 1998; Townsend, 1995).

Households are assumed to be risk averse (Ray, 1998). To protect their welfare, they will always try to mitigate against the impact of shocks with the mechanisms available to them. The normal reaction of households faced with uncertainties is to smooth consumption through various mechanisms. Some techniques commonly used in developing and agrarian countries include: mutual insurance; self-insurance, use of savings; credit transfer, use of asset stock in the form of sale and purchase of livestock; grain inventory and jewellery among others (Banerjee & Duflo, 2007; Cain, 1981; Paxson & Chaudhuri, 1994; Ray, 1998; Rosenzweig & Wolpin, 1993; Townsend, 1995; Walker et al., 1983). Literature on shocks and coping strategies, illustrate that in anticipation of shocks, asset-poor households cultivate low-risk crop varieties (Morduch, 1990). In Burkina Faso, households were not limited to the sale of livestock for consumption smoothing, indicating that there are possibly more ways to smooth consumption (Fafchamps et al., 1998). In Uganda and Bangladesh, factors such as the involvement in agricultural production, exposure to weather risks, cultural perceptions and social institutions, define the extent to which joint or individually owned assets among women and men are used for consumption smoothing (Quisumbing et al., 2012). In Ethiopia, drought shocks were more severe on consumption of households that were female-headed, households with heads who did not attend school and households in the bottom three quantiles (Dercon et al., 2005). Moreover, the authors find that households that experienced shocks between 1999 and 2001 had significantly lower levels of consumption years later, indicating 'long lasting effect of shocks'.

2.3 Fuel choices and shocks in Uganda

In Uganda, literature proposes that household fuel choice could be driven by household income, age of household head, gender of household head, marital status, household head's level of education, and household's location (Katutsi et al., 2020; Mwaura et al., 2014). The authors also highlight the high dependency on firewood as a cooking energy source among households in Uganda. An earlier study confirmed both the energy ladder and energy stacking hypothesis in Uganda, arguing that, as income increases, solid and transitional fuels use evolves in an inverse U manner, while electricity consumption is directly related to income (L. Y.-T. Lee, 2013). Other authors found that the combined influence of the kitchen type, dwelling, and tenure type determine the choice of cooking fuel of households in Uganda (Elasu et al., 2021).

Uganda's vulnerability to extreme climatic conditions could expose a large proportion of the population whose income depends on agriculture and the environment to climate shocks. The effects of shocks on consumption and production strategies have been studied in Uganda (Quisumbing et al., 2012). A study found that among the asset poor, low skilled and low-wage jobs are used to mitigate idiosyncratic shocks while the asset non-poor responded by expanding the self-employed business (Kijima et al., 2006). In a study of the direct impact of landslides as a localized shock on household income in the mountainous regions of Rwenzori in Uganda, authors discover that landslides reduce household income during the first year, leading affected households to seek wage employment or self-employment to cover for the loss of agricultural income (Mertens et al., 2016). A different study found that poor households have a more diversified portfolio and larger shocks lead to greater use of forest

² Also referred to as collective or aggregate

³ Also known as household specific

resources in the subsequent periods (Debela et al., 2012). These studies indicate to existing coping mechanisms among the Ugandan population but also, a lack of properly installed formal mechanisms and structures that could enable households mitigate against shocks.

2.4 The interlinkage between shocks and household energy choices

A well-developed base of literature on the nexus between shocks and energy consumption majorly focuses on developed countries (Auffhammer & Mansur, 2014; Mansur et al., 2008). Authors have explored both the short and long run impacts of climatic shocks and corresponding adaptation strategies in energy use. For instance, some energy related coping strategies of households experiencing climate shocks in developed nations include purchasing appliances such as air conditioners, using fuel substitutes and changing building characteristics (Auffhammer & Mansur, 2014). In America, a study concluded that there is a likely increase in energy expenditure as a result of climate change (Mansur et al., 2008). The authors also find that global warming will lead to fuel switching as more homes will use electricity for heating. Equally, warmer summers will result in higher electricity and oil consumption while warmer winters result in reduced consumption of natural gas at household level.

There is nascent literature on the impact of shocks on household energy choices in developing countries. A study found that that natural disasters have a significant and strong negative impact on oil, renewables, and nuclear energy consumption especially in low income countries (C.-C. Lee et al., 2021). In India, a study highlights that frequent occurrence of floods and droughts alters energy demand and natural disasters negatively impact per capita energy consumption (Rakshit, 2021). In Africa literature is scant. A study of Nigeria found that a hike in kerosene prices leads to a corresponding increase in use of firewood as an alternative household fuel (Maconachie et al., 2009). In Uganda, no record of existing literature was found. This study seeks to bridge this gap by analysing the coping strategy of households faced with perceived shocks, with respect to their fuel decisions.

3. Overview of the data

This section will begin by presenting the data used during the study. It will proceed to introduce the variables being examined and give a description of energy use in Uganda.

3.1 Presentation of the data

This study uses the cross-sectional dataset referred to as the Uganda National Panel Survey (UNPS) 2019/2020, carried out by the Uganda Bureau of Statistics and sourced from the World Bank Living Standard Measurement Survey (LSMS) database. The dataset is a composed of surveys carried out between 2019-2020 over a twelve-month period. The Uganda Bureau of Statistics reports that the sample was designed to allow for the generation of separate estimates at the national level, for urban and rural areas, and for the 15 sub-regions of Uganda⁴. A two-stage stratified sampling design was used. First, enumeration areas (EAs) were grouped by districts of similar socio-economic characteristics and by rural-urban location and then drawn using Probability Proportional to size. Second, households as the sampling units were drawn using Systematic Random Sampling (UBOS, 2021). The dataset is divided into distinctive sub-data groups, each containing specific household

⁴ The study uses the 15 sub-regions as the administrative level of study

information. However, the number of households in various sub-data groups vary. For instance, in the sub-data groups containing asset information of households, the number of households surveyed was 3078⁵. On the other hand, sub-data containing household basic information and link with agriculture, 3098 households were surveyed⁶. Most critical, the sub-data containing household information on shocks has only 1046 households⁷. We therefore run T-tests comparing the means of various variables of study belonging to the 1046 households who reported having experienced shocks versus the means of other households with no data on shocks. In all cases, we fail to reject the null hypothesis. The means of households with shock data and those without shock data are not significantly different at the 95% confidence intervals. The data set retained is therefore a national representative cross-sectional data comprised of 1046 households who experienced at least one shock.

About 73 % of the Ugandan population live in rural areas (UBOS, 2021). The local Government Act 2000 of Uganda defines an urban area as a town, municipality or city. It first dictates that except for the areas already gazetted, the requirements for declaring urban areas include the population size which must be above twenty-five thousand inhabitants for towns, above one hundred thousand inhabitants for municipalities and five hundred thousand inhabitants for cities. Secondly, it declares that the area must have capacity to meet its cost of delivery of services; have its offices, have a master plan for land use; and have water sources. Third, where a district headquarters is established, the area shall be declared a town (Uganda, 2000). Regardless of the population size, all district headquarters are urban areas by law because they are located in town councils and all town councils are urban areas (Mbabazi & Atukunda, 2020). These attributes are limited in scope especially with regards to energy provision thresholds that are not clearly outlined. Hence raising questions as to if all urban centres have modern energy sources. In the study of household energy choices, this classification may fail to register the relative differences or similarities in the use of various fuels among households that may be located in rural or urban areas and which, may give confounding results. This paper will therefore cautiously apply the rural-urban classification.

3.2 Variables

The following section will present the variables used in this study. It begins by discussing variables of energy use. It then proceeds to present the shock variable which is the variable of interest attempting to analyse the effect of shocks on energy consumption patterns. Fundamentally, testing the energy ladder proposition requires a measure of wealth or income. This study will thus build a wealth index to measure the socio-economic status of households under study. Finally, borrowing from existing literature, other control variables are presented.

3.2.1 Dependent variable: Household energy choice as a discrete/categorical variable

The energy ladder variables estimating the hypothesis that, an increase in income leads to a simultaneous adoption of modern forms of energy, is estimated using variables that represent three classifications: traditional, transitional and modern household fuels. Among cooking fuels, traditional fuels are represented by firewood, dung and crop residue. Transition cooking fuels are represented by charcoal whereas modern cooking fuels include electricity, LPG gas, solar and kerosene. Among lighting fuels, firewood and crop residue represent traditional fuels. Kerosene represents transitional

⁵ Sub-data group Gsec 14 & Gsec 9

⁶ Sub-data group Gsec 19 & Gsec 1

⁷ Sub-data group Gsec 16

lighting fuels and modern lighting fuels include electricity and solar. Borrowing from seminal authors, kerosene is considered a modern fuel for cooking and a transitional fuel for lighting (Choumert-Nkolo et al., 2019). Very few households rely on “modern” fuels for cooking. Hence, it doesn’t make sense to add a category that distinguishes “dirty” fuels like kerosene within this already limited scope.

The energy choice variables are constructed in the following manner. For the principal model, the fuel choice variables are discrete choice variables taking 1 if the household uses a fuel category and 0 otherwise. For instance, a household that uses firewood for cooking will take 1 for traditional cooking fuels and the households that do not will take the value 0. For robustness purposes, the energy choice variables are categorical variables alluding to the energy ladder concept where traditional fuels will be assigned the value 1, transitional fuels 2 and finally, modern fuels will take the value 3.

The UNPS asks households the questions, “Do your household use [Fuel]? A follow up question “Do you use this [Fuel] for cooking? Same question is asked for lighting. Hence for each purpose of use such as cooking, we could have multiple responses.⁸ In what concerns the categorical classification used for robust studies, a question arises on how to classify households that use a mixture of two or more categories of fuel for the same purpose, say cooking. For instance, a household that uses both transitional charcoal and modern LPG gas for cooking. Consequently, in this study, for households who use multiple categories of fuels for the same purpose like cooking, the fuel higher up the ladder is accorded superiority. Therefore, a household that uses gas and charcoal will be recorded as using gas and will take the value 3. An assumption is made that by the very fact that a household reports using modern energy, we could assume that they have ascended up the fuel ladder and use traditional fuels only if the modern energy, is limited. This bias has been justified in a different study in which the authors apply an upward selection where a household that uses both electricity and kerosene, are assumed to use electricity and are not included in the kerosene estimation even if they reported using kerosene (Blimpo et al., 2018). Table 1 decomposes the variables of the energy ladder model using major household fuels, it additionally gives a statistical outlook of household fuels using different classifications.

Table 1: Major household fuels as discrete/categorical choice variables

Fuel	Variable type	Variable description	HH ⁹ Count	HH percentage	Mean	SD
Cooking	Discrete (1) Applied in the principle logit model	1 if traditional (<i>firewood/ Crop residue /dung</i>)	808	77.25	0.77	0.42
		1 if transitional (<i>Charcoal</i>)	283	27.06	0.27	0.44
		1 if modern (<i>kerosene/LPG gas/ solar/electricity</i>)	56	5.35	0.05	0.23
	Categorical ¹⁰ (2) Applied in the mlogit model for robustness	1 if traditional (<i>firewood/ Crop residue /dung</i>)	689	68.97	1.37	0.59
		2 if transitional (<i>Charcoal</i>)	254	25.43		

⁸ This is a fundamental difference between the UNPS and other LSMS surveys such as the Tanzania National Panel Survey which puts emphasis on the fuel most frequently used by households.

⁹ ‘HH’ will henceforth be used in tables and figures as an abbreviation for households

¹⁰ 47 households reported using none of the 3 categories of cooking fuels

		3 if modern (<i>kerosene/LPG/ solar/electricity</i>)	56	5.61		
	Discrete ¹¹ (3)	1 if jointly use traditional (<i>firewood/ Crop residue /dung</i>) & transitional fuels (<i>Charcoal</i>)	101	9.66	0.10	0.30
		1 if Jointly use traditional (<i>firewood/ Crop residue /dung</i>) & modern fuels (<i>kerosene/LPG/ solar/electricity</i>)	22	2.10	0.02	0.14
		1 if Jointly use transitional (<i>Charcoal</i>) & modern fuels (<i>kerosene/LPG/ solar/electricity</i>)	29	2.77	0.03	0.16
	Discrete (4)	1 if strictly traditional (<i>firewood/ Crop residue /dung</i>)	689	65.87	0.66	0.47
		1 if strictly transitional (<i>Charcoal</i>)	157	15.01	0.15	0.36
		1 if strictly modern (<i>kerosene/LPG/ solar/electricity</i>)	9	0.86	0.01	0.09
Lighting	Discrete (1) <i>Applied in the principle logit model</i>	1 if traditional (<i>firewood/ crop residue</i>)	25	2.39	0.02	0.15
		1 if transitional (<i>Kerosene</i>)	192	18.36	0.18	0.39
		1 if modern (<i>solar/ electricity</i>) ¹²	600	57.36	0.57	0.49
	Categorical ¹³ (2) <i>Applied in the mlogit model for robustness</i>	1 if traditional (<i>firewood/ crop residue</i>)	20	2.60	2.76	0.49
		2 if transitional (<i>Kerosene</i>)	148	19.27		
		3 if modern (<i>solar/ electricity</i>)	600	78.13		
	Discrete (3)	1 if jointly use traditional (<i>firewood/ crop residue</i>) & transitional fuels (<i>Kerosene</i>)	2	0.19	0.00	0.04
		1 if Jointly use traditional (<i>firewood/ crop residue</i>) & modern fuels (<i>solar/ electricity</i>)	4	0.38	0.00	0.06
		1 if Jointly use transitional (<i>Kerosene</i>) & modern fuels (<i>solar/ electricity</i>)	44	4.21	0.04	0.20
	Discrete (4)	1 if strictly traditional (<i>firewood/ crop residue</i>)	20	1.91	0.02	0.14
		1 if strictly transitional (<i>Kerosene</i>)	147	14.05	0.14	0.35
		1 if strictly modern (<i>solar/ electricity</i>)	553	52.87	0.53	0.50

¹¹ Only 4 households jointly used the 3 categories for cooking whereas only 1 household jointly used the 3 categories for lighting

¹² No household reported using LPG gas or dung for lighting, they are therefore not included among household lighting fuels

¹³ 278 households reported using none of the 3 categories, this is driven by the use of torches. This study does not use torches as there is no information on how the torches were powered, e.g. battery or solar.

Source: Author's calculation from the UNPS 2019/2020 dataset

The table above decomposes household fuels. For each use (cooking or lighting), the table decomposes the variable type and its statistics. The first classification is used in the principle model. The second classification acts as a robustness check. The last two classifications give more details on household fuel choices among Ugandan households.

The first classification presents the variables as discrete choices taking 1 if household uses a fuel category and 0 otherwise. Second, household fuel choices are presented as categorical variables. Households take the values 1 for traditional forms of energy, 2 for transitional forms and 3 for modern forms respectively. As detailed in the previous paragraph, energy choices higher up in the hierarchy are considered dominant over fuels lower in the energy ladder hierarchy, if a household uses more than one fuel category for the same purpose. This explains why the number of observations in each category varies depending on variable construction as discrete or categorical. Third, the table additionally provides statistics for joint fuel use of different fuel categories, identifying how many households use a combination of different fuels. Finally, it identifies the statistics of households that strictly use one fuel type for each purpose.

3.2.2 Shock (Interest variable)

This section is dedicated to shocks as the interest variable. It first presents household perceived shocks that can be said to be subjective as they are reported by households themselves and may raise the question of endogeneity bias. Consequently, the study presents an objective measure of shocks for robustness known as the Standardized evapotranspiration index (SPEI).

3.2.2.1 Household perceived shocks

The Uganda National Panel Survey (UNPS) defines shocks as “events that happen suddenly and whose effects are felt for a long time”. The dataset includes a list of twenty predetermined shocks that affected households in the last 12 months before the survey period 2019-2020. The survey asked households if they experienced any of the 20 shocks, to which they either answered Yes or No. The shock variable first measures the cumulative incidence(s) of exposure to either one or many shocks in general. Of the 1046 studied sample, all households reported experiencing at least one shock. It is therefore a variable taking the values 1 to 4 with a mean of 1.2 and a standard deviation of 0.5. The maximum shocks reported by either one of the households totalled up to 4, while the minimum reported was 1 shock. Other shocks are however dummy variables taking 1 if household experienced the shock category and 0 otherwise.

As the shocks in this study are perceived by households themselves, the question of endogeneity arises. To overcome this bias, the study borrows from existing literature and classifies shocks into 2 categories; covariate and idiosyncratic shocks (Townsend, 1995). Because of their very nature, often affecting just a small proportion of the population, idiosyncratic shocks are potentially insurable through insurance mechanisms and credit transfers (Ray, 1998). Contrarily, covariate shocks cannot be insured against as they affect a greater proportion of the population. For this reason, for robustness purposes and to overcome the omitted variable bias, the study will proceed to classify and examine the effect of covariate and idiosyncratic shocks separately. The covariate shock variable is a dummy variable taking 1 if household experience either one of the covariate shocks: droughts, irregular rains, floods and erosion. Otherwise, the variable will take the value 0. The idiosyncratic shock variable is also a dummy variable taking 1 if the household experiences either of the following shocks: Illness or accident of income earner, illness or accident of member, death of income earner(s), death of other

household member(s), theft of money/valuables/non-agricultural assets, theft of agricultural assets/output or reduction in the earnings of currently employed. 0 is assigned otherwise.

A claim can be made that the cumulative classification of grouping shocks into covariate or idiosyncratic may produce an upward bias to support the hypothesis put forth, depending on which shocks were included or eliminated in each respective group. For this reason, the study will estimate two of the most commonly reported shocks in each group independently, to capture their individual effects. Hence, among covariate shocks, the effect of drought and irregular rains will be estimated and for idiosyncratic shocks, effects of deaths or illnesses will be estimated.

The rest of the shocks have low observation rates and could either fall under covariate or idiosyncratic shocks. For instance, landslides in their nature produce drastic consequences on household welfare. However, they are smaller in scale and have a relatively diffuse character making the assessment of their impacts challenging (Petley, 2012). Studies on landslides have concentrated on specific regions characterized by mountainous terrains, deforested and overgrazed regions, and areas affected by intense rainfall (Mertens et al., 2016; Ngecu et al., 2004). Despite their disruptive nature, they can be thought of as localized with low frequency in a national representative survey. Landslides and other shocks of this character are therefore grouped under ‘miscellaneous shocks’ in this study to conserve the classical typology in covariate and idiosyncratic shocks. The miscellaneous shocks are also dummy variables taking 1 if a household experienced each shock description. They include: unusually high level of crop pests, unusually high level of livestock diseases, unusually high costs of agricultural input, unusually low prices for agricultural output, loss of employment of previously employed, conflict/violence, fire, other non-Specified shocks and landslides.

Table 2 summarizes the shocks together with their incidence of occurrence. Drought appears to be the most common shock affecting 34.4% households followed by irregular rains which affected 16.2 % of the population. The two shocks are classified as covariate shocks as they affect not just individual households but entire areas, distressing approximately 50% of the households. Overall, weather-related shocks and shocks that could be detrimental to agricultural activities affected approximately more than 60% of the population. A possible explanation for the high reportage of incidences of environmental shocks lie on the dependence on natural weather patterns for livelihood. A study highlighting the importance of rainfed agriculture in Uganda found that higher than average rainfall in the first planting and first harvest seasons results in lower incomes and consumption (Asiimwe & Mpuga, 2007). Another study concentrating on temperature shows that on average, an increase of 1% in maximum temperature during the growing seasons reduces the total value of crop production by 4-7% (Maggio et al., 2022). On the other hand, some authors find few significant effects of climate/weather shocks on consumption, pointing to the existence of possible consumption smoothing mechanisms in Uganda (Asfaw et al., 2015).

Table 2: Summary statistics of perceived shocks

HH shocks	HH count taking 1	HH% taking 1	HH count taking 0	HH% taking 0	Mean	SD
Covariate shocks	620	59.27	426	40.73	0.60	0.49
Idiosyncratic shocks	305	29.16	741	70.84	0.29	0.45
Both covariate and idiosyncratic shocks	50	4.78	996	95.22	0.05	0.21
Shocks classified under covariate shocks						
Drought	360	34.42	686	65.58	0.34	0.48

Irregular Rains	169	16.16	877	83.84	0.16	0.37
Floods	117	11.19	929	88.81	0.11	0.32
Erosion	13	1.24	1033	98.76	0.01	0.11
Shocks classified under idiosyncratic shocks						
Illness or Accident of Income Earner	119	11.38	927	88.62	0.11	0.32
Illness or Accident of member	78	7.46	968	92.54	0.07	0.26
Death of Income Earner(s)	19	1.82	1027	98.18	0.02	0.13
Death of Other Household Member(s)	49	4.68	997	95.32	0.05	0.21
Theft of Money/Valuables/Non-Agricultural	43	4.11	1003	95.89	0.04	0.20
Theft of Agricultural Assets/Output	40	3.82	1006	96.18	0.04	0.19
Reduction in the Earnings of Currently employed	15	1.43	1031	98.57	0.01	0.12
Shocks classified under Miscellaneous shocks						
Unusually High Level of Crop Pests	79	7.55	967	92.45	0.08	0.26
Unusually High Level of Livestock Diseases	5	0.48	1041	99.52	0.00	0.07
Unusually High Costs of Agricultural Input	12	1.15	1034	98.85	0.01	0.11
Unusually Low Prices for Agricultural Output	17	1.63	1029	98.37	0.02	0.13
Loss of Employment of Previously Employed	6	0.57	1040	99.43	0.01	0.08
Conflict/Violence	25	2.39	1021	97.61	0.02	0.15
Fire	9	0.86	1037	99.14	0.00	0.09
Other non-Specified shocks	75	7.17	971	92.83	0.07	0.26
Landslides	2	0.19	1044	99.81	0.00	0.04

Source: Author's calculation from the UNPS 2019/2020 dataset

3.2.2.2 Standardized Evapotranspiration Index (SPEI)

While the robust measures proposed above are interesting, they remain subjective measures as households reported the shocks themselves. The study proposes an objective measure of shocks from an external source. Given that drought ranks high on the list of reported shocks, a measure of drought could be used to estimate the impact of shocks on household energy choices. Consequently, this study proposes the Standardized Evapotranspiration Index (SPEI) to capture the effect of shocks on household energy choices.

The SPEI is climatic drought index that is sensitive to climate change. It is based on precipitation and temperature data, and it has the advantage of combining multiscalar character and including the effects of temperature variability on drought assessment (Vicente-Serrano et al., 2010). The time scale

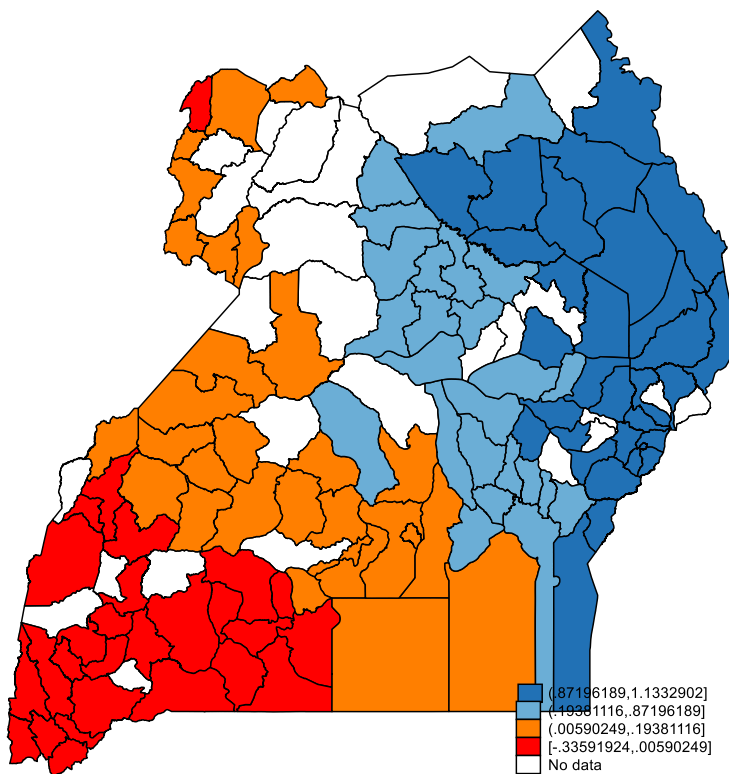
over which precipitation deficits accumulate is extremely important and functionally separates different types of drought (McKee et al., n.d.). Authors therefore classify droughts under the following types: meteorological (1 month timescale), agricultural (3–6 month timescale) and hydrological droughts (12 month timescale) (Vicente-Serrano et al., 2010).

The SPEI is calculated by considering climatic water balance, the accumulation of deficit/surplus at different time scales, and adjustment to a log-logistic probability distribution (Vicente-Serrano et al., 2010). However, for this study, the SPEI is readily calculated and is derived from the Climatic Research Unit Time Series (CRU ts) 4.04 data base. The dataset is composed of 6-month SPEI between march 2019 to February 2020. The SPEI will hence capture ‘agricultural drought’, a suited timescale given that a great percentage of the Ugandan population highly depends on agriculture for livelihood. The period of study corresponds to the period used by the UNPS 2019/2020 shock variables. The monthly mean of SPEI was computed at district level. Some districts that were present in the UNPS 2019/2020 were not represented in the SPEI data. Thus, values of neighbouring districts of the same subregion were assigned to districts with no SPEI values.

Existing literature recommends identifying the magnitude of drought using an existing scale. Extreme drought (≤ -2), severe drought (-2 to -1.5) and (-1.5 to -1) for moderate drought (McKee et al., n.d.; Tirivarombo et al., 2018). Positive values from (0) to (+2) represent precipitation surplus. In this study, we apply the mean SPEI of the 12 months of study and interpret the magnitude per district. With the argument that temperature and precipitation vary widely over 12 months, districts whose average SPEI over 12 months had values less than 0 could be perceived as districts that endured droughts on average. Hence, for robustness, we estimate the fuel behaviour of households in districts with mean SPEI values below 0 (drought) comparing them to districts with SPEI values above 0 (precipitation surplus). Hence, we generate a value taking 1 for drought-stricken districts and 0 otherwise. Figure 1 represents the mean SPEI per district. Districts with the lowest mean SPEI are represented in red.

Moreover, a Pearson correlation between the SPEI index of drought-stricken districts and other covariate shocks suggests a positive and significant relationship at the 5% threshold with a magnitude of 4.4% for drought and 2.7% for floods. However, for irregular rains, the relationship is negative and significant with a magnitude of 2.5%. No correlation was found for erosion.

Figure 1: Mean SPEI per District



Source: Author's calculation from the CRU ts 4.04 dataset

3.2.3 Wealth index: as suggested by the Energy ladder hypothesis

A measure of income is necessary for the estimation of the energy ladder concept. The UNPS 2019/2020 includes datasets on both household consumption and asset ownership. However, in some consumption datasets, household consumption expenditures on food, beverages and tobacco in the last 7 days¹⁴ and household expenditures on non-durable goods and frequently purchased services in the last 30 days¹⁵, portray high percentages of missing values as high as 93% for some variables. As a result, this study does not principally use consumption as a measure of income. In addition, it can also be claimed that self-declared measures of income could be biased. Instead, this study proposes the use of a wealth index to capture the socioeconomic status of households.

A wealth index is constructed by the use of a principal component analysis (PCA). A PCA is a data reduction technique, permitting the reduction of large sets of correlated variables into a smaller number of independent variables, which can help to identify patterns of association that may not be easily discernible in the original set of variables (Martel et al., 2021). The UNPS 2019/2020 provides a detailed dataset of household asset ownership, making it possible to create a PCA indicating household socioeconomic status.

The PCA is created by considering the asset count for each asset variable. This study creates the mean asset count of the variables that could indicate a measure of wealth in Uganda. Borrowing from existing literature, electricity-dependent assets were not included to eliminate two possible biases. First, the endogeneity bias arising from the likely fact that both access to electricity and ownership of

¹⁴ GSEC15B

¹⁵ GSEC15C

electric assets can be a measure of wealth and second, the rural-urban bias, where most rural areas lack electricity and hence ownership of electric assets is concentrated in urban areas (Choumert-Nkolo et al., 2019; Wittenberg & Leibbrandt, 2017). In neighbouring Tanzania, mobile phones were included in the construction of a wealth index because mobile phones are frequently owned even among households without electricity since they can easily be charged at the neighbours' houses or at charging stations in small centres. Radios on the other hand are included on the assumption that most radios, especially in rural areas are battery-powered (Choumert-Nkolo et al., 2019). On that account, only radios and mobile phones were included among the electricity powered assets. The variables used to construct the wealth index are illustrated in table 4, and include the household's: roof type, wall quality, floor type, source of drinking water, ownership of occupied house, ownership of other buildings, mobile phones, motorcycle, motor vehicle, bicycle and radio. The variables are dummies taking 1 if the household met the thresholds outlined for each variable type and 0 otherwise. The criteria in table 4 was used to construct the variables.

The exogeneity of the PCA wealth index can be criticized on the basis that like income, most aspects of wealth are self-declared. However, it also has the advantage that unlike the income declared by a household, most assets are physical and can be seen by the interviewer (Martel et al., 2021). Minimizing to a large extent the bias that could have existed. Table 5 provides summary statistics of variables of the wealth index.

The construction of the PCA wealth index is detailed in Annex 8. The fitted correlation matrix indicates that most variables are positively correlated except for a few. For instance, having a modern roof quality is not positively correlated to the ownership of occupied house. The Kaiser-Meyer-Olkin (KMO) measure (table 11) of sampling adequacy used to compare the correlations and the partial correlations produces a value of 0.63, indicating existing correlations between our variables and substantiates the use of a PCA wealth index in this study. Following a scree plot (table 12), the first 4 principal components were retained as they had eigen values greater than 1. Table 3 presents a table of loadings, useful in understanding how variables contribute to the principal components. For instance, component 1 has a strong positive loading for roof, wall and floor among others. The variables can be said to contribute very strongly to the first component. The first component explains 37.43 % of total variance while the second, third and fourth explained 24.71, 19.28 and 18.57 respectively. In addition, a Pearson correlation between the wealth index and log of real per adult equivalent expenditure¹⁶ suggests a positive and significant relationship at the 1% threshold, with a magnitude of 3.4%.

Table 3: Results of the Principal component loadings

	Comp1	Comp2	Comp3	Comp4
Roof	.3994	-.06765	-.4575	-.2659
Wall	.2963	-.08035	.6625	-.0894
Floor	.5228	-.1863	.0982	-.1158
Drinking water	.3895	-.2082	-.1059	.3391
Owner occupied house	-.0169	.5403	-.1503	.2805
Own other buildings	.2567	.2248	.0018	.3919
Mobile phone	.3032	.148	-.2554	-.4173
Motorcycle	.1969	.1072	.2371	-.2661
Motor vehicle	.3074	-.0198	.05361	.5367

¹⁶ Note withstanding the large numbers of missing values in this variable

Bicycle	.0416	.4928	.3996	-.1461
Radio	.1857	.5401	-.1559	-.0795
Eigen value	2.202	1.4536	1.1343	1.0923
Variance explained	37.43	24.71	19.28	18.57

Source: Author's calculation from the UNPS 2019/2020 dataset

Table 4: Variables used in the creation of the wealth index

Variable	Description
Roof quality	The value 1 was assigned for roofs made of the following materials: Iron sheets, tiles, asbestos, concrete and tin. The value 0 represents thatched roofs and other roof types.
Wall quality	The major construction material of external wall is assigned a dummy variable 1 if the wall is made of: concrete or stones, cement blocks, burnt or stabilized bricks and unburnt bricks with mud. The value 0 is assigned if: wood, mud and pole, tin/ iron or other (specify).
Floor quality	The value 1 is assigned if: concrete, bricks, stone, cement screed, wood and tiles. The value 0 is assigned if: rammed earth or others.
Drinking water	The dummy variable takes 1 if: piped to yards, piped to private dwelling, rain water; assumption of harvesting, vendor, tanker, bottled water. The value 0 is given to: public taps, borehole in yard/plot, public borehole, protected well/spring, unprotected well/spring, river/stream/lake, vendor, tanker truck, gravity flow schemes or other.
Ownership of occupied house	The value 1 is assigned if the household owns the house in which they reside and 0 is assigned otherwise.
Ownership of other buildings	The value 1 is given if household owns other buildings. 0 is assigned otherwise.
Mobile phones	The value 1 is assigned if any household member owns a mobile phone individually and 0 is assigned otherwise. Joint ownership is not considered to avoid counting the same phone several times.
Motorcycle	The value 1 is assigned if the household owns at least 1 motorcycle and 0 is assigned otherwise.
Motor vehicle	The value 1 is assigned if the household owns at least 1 motor vehicle and 0 is assigned otherwise.
Bicycle	The value 1 is assigned if the household owns at least 1 bicycle and 0 is assigned otherwise.
Radio	The value 1 is assigned if the household owns at least 1 radio and 0 is assigned otherwise.

Source: Author's calculation from the UNPS 2019/2020 dataset

Table 5: Summary statistics of wealth asset variables

Variable	HH count taking 1	HH% taking 1	HH count taking 0	HH% taking 0	Mean	SD
Roof quality	770	73.61	276	26.39	0.74	0.44
Wall quality	724	69.22	322	30.78	0.70	0.46
Floor quality	397	37.95	649	62.05	0.38	0.49
Drinking water	134	12.81	912	87.19	0.13	0.33
Ownership of occupied house	481	45.98	565	54.02	0.46	0.50
Ownership of other buildings	95	9.08	951	90.92	0.09	0.29
Mobile phones	676	64.63	370	35.37	0.65	0.48
Motorcycles	98	9.37	948	90.63	0.09	0.29
Motor vehicles	26	2.49	1026	97.51	0.02	0.16
Bicycle	220	21.03	826	78.97	0.21	0.41
Radio	337	32.22	709	67.78	0.32	0.47

Source: Author's calculation from the UNPS 2019/2020 dataset

3.2.4 Other controls

Based on existing literature, authors have substantially justified the argument that apart from income, household energy choices depend on other socioeconomic factors such as education level, location, fuel prices, gender of household head among others (Choumert-Nkolo et al., 2019; Elasu et al., 2021; Hosier & Dowd, 1987; Katutsi et al., 2020; Mekonnen & Köhlin, 2009; Mwaura et al., 2014). This study will borrow from this school and apply some of these control variables. Table 6 compiles relevant variables used to determine household energy choices.

Table 6: Other control variables

Variable	Variable description	HH count	HH%	Mean	SD	
Household head's education level	Primary	=1 if household head has primary school education and below.	513	52.78	0.53	0.50
	Secondary	=1 if household head has secondary school education.	211	21.71	0.22	0.41
	Tertiary	=1 if household head completed tertiary education.	62	6.38	0.06	0.24
Household head's occupation	Skilled agriculture	=1 if hh head is a skilled worker in agriculture, forestry or fishery.	1363	49.10	0.49	0.50
	Armed forces	=1 if hh head works with armed forces.	7	0.25	0.00	0.05

	Managers	=1 if hh head is a manager.	18	0.65	0.01	0.08
	Professionals	=1 if hh head is a professional e.g. chief.	112	4.03	0.04	0.20
	Technicians and associate professionals	=1 if hh head is a technician or associate professional e.g. credit officer, mechanic, lab assistant etc.	29	1.04	0.01	0.10
	Clerical workers	=1 if hh head is a clerical worker e.g. billing clerk, secretary, accountant etc.	5	0.18	0.00	0.04
	Service and sales workers	=1 if hh head is a service provider e.g. washing cars, bartender, selling charcoal etc.	346	12.46	0.12	0.33
	Craft and related trades workers	=1 if hh head works in crafts or related works e.g. repair of vehicle, building a house etc.	130	4.68	0.05	0.21
	Plant and machine operators and assemblers	=1 if hh head is a machine operator or related jobs e.g. transportation.	95	3.42	0.03	0.18
	Elementary occupation	=1 if hh head is an elementary or casual labourer.	284	10.23	0.10	0.30
Household head's marital status	Married monogamously	=1 if household head is married monogamously.	556	53.21	0.53	0.50
	Married polygamously	=1 if household head is married polygamously.	173	16.56	0.17	0.37
	Widow/er	=1 if household head is a widow/er.	172	16.46	0.16	0.37
	Divorced/Separated	=1 if household head is divorced/separated.	111	10.62	0.11	0.31
Household head's gender	Male household head	=1 if household head is a male.	687	65.74	0.66	0.47
	Female household head	=0 if household head is female.	358	34.26		
Household size		Household size counts the number.	1035	100	4.81	2.62

		of persons that reside and share meals together.					
	Grid electricity	=1 if household has access to grid electricity.	186	17.78	0.18	0.38	
Cooking stove location	Cooking stove located in a separate kitchen	=1 if household has a stove and cooks in a separate kitchen away from the main house.	751	71.80	0.72	0.45	
	Cooking stove located in a room not devoted for cooking	=1 if household cooks in a room not specifically devoted for cooking.	75	7.17	0.07	0.26	
	Cooking stove located in an outdoor space	=1 if household cooks outside.	181	17.30	0.17	0.38	
Household location	Urban	=1 if household is located in an urban area.	251	24.00	0.24	0.43	
	Rural	=0 if household is located in rural area.	795	76.00			
	Subregion dummies	=1 if Kampala		42	4.02	0.04	0.20
		=1 if Buganda South		93	8.89	0.09	0.28
		=1 if Buganda north		98	9.37	0.09	0.29
		=1 if Busoga		113	10.80	0.10	0.31
		=1 if Bukedi		28	2.68	0.03	0.16
		=1 if Elgon		58	5.54	0.06	0.23
		=1 if Teso		57	5.45	0.05	0.23
		=1 if Karamoja		53	5.07	0.05	0.22
		= 1 if Lango		119	11.38	0.11	0.32
		=1 if Acholi		23	2.20	0.02	0.15
		=1 if West Nile		92	8.80	0.09	0.28
		=1 if Bunyoro		41	3.92	0.04	0.19
		=1 if Toro		56	5.35	0.05	0.23
		=1 if Ankole		117	11.19	0.11	0.32
=1 if Kigezi		55	5.26	0.05	0.22		
=1 if 295		1	0.10	0.00	0.03		

Source: Author's calculation from the UNPS 2019/2020 dataset

3.3 Stylized facts on household energy use in Uganda

Ugandan households have a high dependence on traditional fuels and low uptake of modern fuels. The UNPS 2019/2020 affirms this view given that approximately 18% of households reported accessing electricity from the power grid. Among the population without grid electricity, supply-side limitations seem to be the predominant problem with 74.88% citing a lack of electricity in the area. 15.98% cited expensive connection fees, 1.94% could not afford the cost of wiring, 1.74% could not afford monthly

payments, and 3.64% reported being satisfied with present energy sources. The rest cited other reasons.

About 70% of the sampled population reported gathering or collecting household fuel from their own land or from the villages. These were mainly composed of firewood and crop residue. 4.77% of the population purchased fuel from shops, 19.73% purchased from the marketplace, 0.56% purchased from clandestine markets and only 2.95% reported purchasing energy from public utilities. This means that in addition to the market price, fuels have an opportunity cost in terms of time dedicated to fuel collection¹⁷.

The uptake of energy in Uganda is different according to the purpose of consumption. 57.36% of households use either: electricity or solar for lighting while only 5.35 % use electricity, LPG gas, kerosene or solar for cooking. 27.06% of households reported using charcoal for cooking while 18.36% used kerosene for lighting. Cooking accounted for 77.25%, and lighting, only 2.39% of households that used traditional energy sources such as firewood, crop residue and dung. These results depict a particularly high reliance on more traditional forms of fuels in the form of firewood and charcoal for cooking. Using urban-rural classification, table 7 shows that there is no outstanding difference in the use of different types of energy in rural and urban areas of Uganda, possibly arising from the wide definition of rural and urban or the general poor electricity infrastructure.

Table 7: Household Fuels by Rural-Urban classification

Cooking fuels	Traditional fuels		Transitional fuels		Modern fuels	
	HH count	HH %	HH count	HH %	HH count	HH %
Urban	189	23.39	68	24.03	12	21.43
Rural	619	76.61	215	75.97	44	78.57
<i>Total</i>	<i>808</i>	<i>100</i>	<i>283</i>	<i>100</i>	<i>56</i>	<i>100</i>
Lighting fuels	Traditional fuels		Transitional fuels		Modern fuels	
	HH count	HH %	HH count	HH %	HH count	HH %
Urban	7	28.00	43	22.40	143	23.83
Rural	18	72.00	149	77.60	457	76.17
<i>Total</i>	<i>25</i>	<i>100</i>	<i>192</i>	<i>100</i>	<i>600</i>	<i>100</i>

Source: Author's calculation from the UNPS 2019/2020 dataset

Separating the household incomes using the wealth index into three tercile groups, we observe as portrayed in table 8 that indeed, there exists a correlation between wealth and energy transition, giving a hint into a possible energy ladder situation in Uganda. Households with higher incomes (tercile 3) choose modern energy compared to their poorer counterparts (tercile 1). And so, as income increases, households increase their use of modern forms of energy. Nevertheless, the use of traditional and transitional fuels is quite frequent among wealthier households. Despite evidence of a correlation between wealth and energy transition, a great percentage of wealthier households do not make a full transition to modern energy. This occurrence is remarkable among cooking fuels, where

¹⁷ The price effects will be captured by subregion dummies. This is due to the lack of a universal measurement unit for different fuels. Despite the availability of household energy expenditure, the dataset does not clearly indicate a standard measurement unit, especially with regard to firewood, charcoal and kerosene. For instance, firewood is measured in large, small or medium bundles. While charcoal is measured in small, medium and large heaps, and sometimes, in tins of different sizes, plastic basins or sacks. Kerosene is measured in litres and in 'akendo'. In addition, the prices attached to these measurement units such as charcoal with heaps and sacks vary widely even within the same region, limiting the use of the energy price variable.

66.08% of the wealthiest quantile use charcoal for cooking and 22.03% use firewood. It is equally surprising that the percentages are almost similar across income quantiles. Thus, justifying looking further.

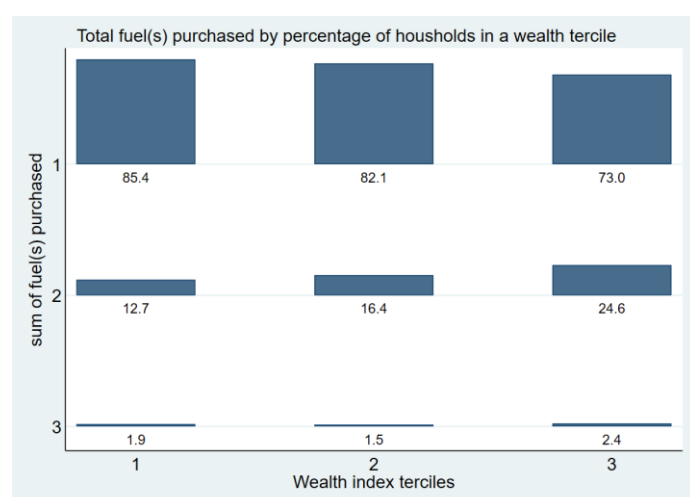
There is a vivid contrast in the use of lighting fuels among the income groups. The poorest households take up 76% of households that use firewood and crop residue for lighting contrasting to only 2% of the rich. To a great extent, a simple correlation between income and energy transition is supported. Moreover, a Pearson correlation between the wealth index and modern cooking and lighting fuels suggests a positive and significant relationship at the 1% threshold, with a magnitude of 44.61% for modern lighting fuels and 22.1% for modern cooking fuels.

Table 8: Household fuel choices by wealth terciles

	Traditional		Transitional		Modern	
Cooking fuels	HH Count	HH %	HH Count	HH %	HH Count	HH %
Tercile 1	350	43.32	28	9.89	3	5.36
Tercile 2	280	34.65	68	24.03	10	17.86
Tercile 3	178	22.03	187	66.08	43	76.79
<i>Total</i>	<i>808</i>	<i>100</i>	<i>283</i>	<i>100</i>	<i>56</i>	<i>100</i>
Lighting fuels	HH Count	HH %	HH Count	HH %	HH Count	HH %
Tercile 1	19	76.00	94	48.96	111	18.50
Tercile 2	4	16.00	70	36.46	204	34.00
Tercile 3	2	8.00	28	14.58	285	47.50
<i>Total</i>	<i>25</i>	<i>100</i>	<i>192</i>	<i>100</i>	<i>600</i>	<i>100</i>

Source: Author's calculation from the UNPS 2019/2020 dataset

Figure 2: Total fuels purchased by percentage of households in a wealth tercile



Source: Author's calculation from the UNPS 2019/2020 dataset

Figure 2 provides a more vivid illustration of an energy mix situation among households in Uganda. It shows that a greater percentage of wealthier households have much larger shares of energy stacking. About 27% of wealthier households typically buy more than 1 types of fuel compared to about 14% of poorer households. This graphical representation also signals a simple correlation between wealth and fuel stacking. Giving room for further analysis of fuel stacking in future.

4. Econometric Model

This section outlines the empirical strategy used to measure the energy ladder concept and to consequently capture the effect of shocks on household energy choices. It principally applies a logit model to test the energy ladder hypothesis. For robustness, it applies the multinomial logit model. A major distinction between the logit model and the multinomial logit model is that the logit model uses a dichotomous set of variables taking 0 or 1 and hence applies the classification (1) outlined in table 1 of section 3.2.1. Whereas, the multinomial logit model will apply the categorical classification of variables taking values 1, 2 or 3, as illustrated by classification (2) of table 1.

4.1 Logit Model for discrete choice household fuel variables

The logit model uses the classification (1) illustrated in 3.2.1 to model the energy ladder hypothesis. To recall, household fuels are classified into cooking and lighting fuels and are categorized into 3 categories. For cooking, traditional fuels comprise of firewood, crop residue and dung while for traditional lighting fuels, only firewood and crop residue are included as no household used dung for lighting. Charcoal is classified under transitional cooking fuel while kerosene is classified under transitional lighting fuel. Modern cooking fuels comprise of electricity, LPG gas, kerosene and solar while for modern lighting, electricity and solar are considered. The variables are modelled as mutually exclusive dichotomous variables and assigned the value 1 if a household used a fuel in a specified category and 0 otherwise. This model will not only capture the energy ladder but estimate the expected change in household fuels when shocks occur.

A linear model is limited when the outcome variable is binary. A logistic model is better suited for such analysing as it allows for the satisfaction of the constraint that the conditional mean must be formulated to be bounded between 0 and 1 and equally allow for the analysis to be bounded on the binomial distribution of the errors (Hosmer Jr et al., 2013). The econometric model estimated for the logit model is as follows.

The logit model for a household fuel choice is specified as follows:

$$y_i = b_0 + \sum_{j=1}^k b_j x_{ij} + e_i = \sum_{j=0}^k b_j x_{ij} + e_i$$

With $x_{i0} = 1$ for any i

By numerical maximisation of the log-likelihood of the model, the parameters b_0, b_1, \dots, b_k are estimated. Average marginal estimates are reported for ease of interpretation.

4.2 Multinomial logit for categorical household fuels

For robustness, a multinomial model is used to test the energy ladder hypothesis. A multinomial logit model is used as it captures the behaviour of households faced with a set of choices of goods with the same consumption objective. The energy ladder is modelled in such a way that cooking and lighting fuels are categorized into three distinct groups as detailed in classification (2) of table 1 in section 3.2.1.

To recall, a cooking fuel takes the value of 1 if the fuel is classified as traditional fuel including firewood, crop residue or dung. The value 2 is assigned to the transitional cooking fuel charcoal whereas, the value 3 is given to modern cooking fuels, including electricity, LPG gas, solar and kerosene. For lighting purposes, the same classification holds. However, traditional lighting fuels assigned the value 1 are represented by either firewood or crop residue. The value 2 is given to kerosene, the transitional lighting fuel while 3 represents modern lighting fuels including electricity and solar.

Thus, for each household i , the choice of cooking or lighting fuel is assigned a value $j = 1,2,3$ where j is the category of the household fuel choice that maximizes the household's utility. The econometric model estimated for the multinomial logit model is of the form;

$$\Pr[Y = j] = \frac{\exp(\beta_j' X_i)}{1 + \sum_{j=0}^j \exp(\beta_j' X_i)}$$

Where; $\Pr[Y = j]$ is the probability associated with choosing a certain fuel category, X_i is a vector of explanatory variables and β_j is a vector of model parameters associated with the outcome j . Average marginal estimates are equally reported for ease of interpretation.

5. Econometric results

The following section is divided into two parts. The first part discusses empirical findings of the energy ladder model under total perceived shocks. It will present tables of empirical results for lighting and cooking fuels and their proceeding explanations. The second part is dedicated to sensitivity analysis and will tackle both robustness and heterogeneity and whose tables are presented in the annexes.

5.1 Logit regression results

Table 9 reports average marginal estimates of cooking fuel choices after a logit model. They show that the wealth index of a household is significantly correlated with the type of cooking fuel used. Wealthier households are approximately 2.7% more likely to use modern cooking energy and 11.9 % more likely to use charcoal. The high use of charcoal even among wealthy households relative to modern fuels illustrates the dominant use of charcoal and limited adoption of modern energy for cooking. On the other hand, households with higher wealth indices are 9.7 % less likely to use traditional forms of cooking energy. Nonetheless, this provides evidence to support the energy ladder hypothesis that an increase in income results in a simultaneous improvement in energy choices. As demonstrated, wealthier households use cooking fuels higher up in the energy ladder than their poorer counterparts.

Estimates of total shocks indicate that an increase in the total incidences of shocks faced by households reduces the probability of households to choose modern cooking fuels by 2%. This study proposes the hypothesis that shocks limit the energy transition process by decreasing the likelihood of choosing modern energy. The results provide evidence that whenever a household experiences a shock, it will likely choose cooking fuels other than modern fuels. This implies that shocks will inhibit any transitions up the energy ladder towards modern cooking fuels.

Table 9: Average marginal effects of household cooking fuels

	Traditional cooking fuels		Transitional cooking fuels		Modern cooking fuels	
	Firewood, crop residue & Dung		Charcoal		Electricity, gas, kerosene, solar	
VARIABLES	Dy/dx	Std. Err	Dy/dx	Std. Err	Dy/dx	Std. Err
PCA Wealth index	-0.097***	(0.007)	0.119***	(0.009)	0.027***	(0.004)
Total shocks count	0.019	(0.020)	0.002	(0.025)	-0.020**	(0.011)
Household size	-0.001	(0.004)	0.002	(0.003)	-0.003	(0.003)
Head age	0.007***	(0.001)	-0.004***	(0.001)	-0.001***	(0.000)
Head Male	0.005	(0.023)	-0.157***	(0.028)	0.019	(0.020)
Married monogamously	0.138***	(0.040)	0.088***	(0.029)	-0.024	(0.018)
Married polygamously	0.178**	(0.084)	0.052	(0.041)	-0.067***	(0.016)
Divorced or separated	-0.046	(0.067)	0.060	(0.047)	-0.003	(0.006)
secondary	-0.038	(0.027)	0.018	(0.026)	0.013	(0.013)
Tertiary	-0.076	(0.087)	0.076	(0.077)	-0.027	(0.041)
Stove in room not devoted to cooking	-0.048**	(0.015)	0.049	(0.083)	0.008	(0.030)
Stove located in outdoor space	-0.037*	(0.020)	0.049**	(0.023)	-0.007	(0.010)
Grid electricity	-0.064***	(0.018)	0.013	(0.024)	0.013	(0.010)
Urban	-0.024	(0.022)	0.028***	(0.011)	-0.009	(0.020)
Household head occupation dummies	YES		YES		YES	
Subregion dummies	YES		YES		YES	
Observations	941		941		916	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Widow(er) as base for marital status, primary education as base for head's education status, stove located in separate kitchen as base for stove location, Kigezi subregion as base for subregion

The estimates of household head's age illustrate that households with older heads are approximately 0.7% more likely to use traditional energy, 0.4% less likely to use the transitional fuel charcoal, and 0.1% less likely to use modern energy for cooking. This supports results from existing literature which argue that older heads are more hesitant to adopt modern cooking fuels (Elasu et al., 2021). Households headed by older members are more likely to encourage cultural perceptions and may hold a greater preference for traditional styles of cooking. Contrary to existing studies, the household size is insignificant.

The effect of the gender of the household head on household fuel choice has been distinctively different in various studies in Uganda. Existing literature finds both positive and negative results associated with the household head being male. Some studies found that male-headed households have a preference for traditional fuels as compared to transitional and modern fuels (Katutsi et al., 2020). Other studies find that the probability of adopting electricity or gas and kerosene among the male-headed households increased (Elasu et al., 2021). In this study, estimates indicate that male headed households are less likely to use charcoal for cooking and no effects was found on traditional or modern cooking fuels.

With regards to marital status, households whose heads are widows or widowers are used as the base for comparison. Household's whose heads are married monogamously are 13.8% more likely to use traditional cooking fuels and 8.8% equally likely to use the charcoal. It is interesting to observe that household heads that are married polygamously are 17.8% more likely to use traditional fuels and 6.7% less likely to use modern cooking fuels. Approximately 3.7% increase in the probability of using traditional cooking fuels when moving from monogamous to polygamous households. A possible explanation could lie in the fact that polygamous families are likely to share a limited income among more members or households leading them to have few remaining resources that could be channelled towards the use of improved cooking fuels. It is also likely that polygamous families are larger in size and hence have more people who can collect firewood, crop residue or dung at no economic cost. Estimates of divorced or separated household heads are statistically insignificant. Using primary education as the base, household head's education had no significant effects.

On stove location, households with stoves located in a separate kitchen away from the main house were used as a base. The results show that in comparison, stoves located in a room not devoted for cooking, were 4.8% less likely to use firewood. This could be attributed to the fact that most households who use other rooms other than the kitchen for cooking are in most cases less affluent and residing in urban areas with limited housing space. So, despite the low income, such households by virtue of their location in urban areas and housing styles cannot use firewood. On the other hand, households with stoves located in outdoor spaces were 4.9% more likely to use charcoal and 3.7% less likely to use traditional cooking fuels.

The marginal estimates illustrate that households with grid electricity were 6.4% less likely to use traditional cooking fuels. Households located in urban areas were 2.8% more likely to use charcoal. More conspicuous are the modern cooking fuels estimates, which are largely statistically insignificant conditional on access to grid electricity and urban location. Perhaps due to the fact that a very small proportion of the population in both rural and urban areas actually use modern energy for cooking, even when they have access to grid electricity or when located in urban areas.

Table 10: Average marginal effects of household lighting fuels

VARIABLES	Firewood, crop residue & Dung		Kerosene		Electricity, gas, solar	
	Dy/dx	Std. Err	Dy/dx	Std. Err	Dy/dx	Std. Err
PCA Wealth index	-0.023*	(0.013)	-0.051***	(0.009)	0.159***	(0.004)
Total shocks count	0.012	(0.010)	0.032***	(0.005)	-0.028	(0.036)
Household size	0.001	(0.002)	-0.002	(0.002)	-0.003	(0.007)
Head age	0.001	(0.000)	0.002***	(0.001)	-0.000	(0.001)

Head Male	-0.025	(0.016)	-0.019	(0.049)	0.008	(0.050)
Married monogamously	0.005	(0.021)	-0.050	(0.033)	0.112***	(0.027)
Married polygamously	0.009**	(0.004)	-0.014	(0.042)	-0.001	(0.058)
Divorced or separated	-0.037	(0.012)	-0.058***	(0.028)	-0.034	(0.049)
secondary	0.009	(0.016)	-0.002	(0.002)	0.049	(0.059)
Tertiary	-	-	-0.056	(0.108)	0.167**	(0.091)
Grid electricity	-0.008	(0.010)	-0.006	(0.006)	0.012	(0.027)
Urban	0.012	(0.016)	-0.022	(0.026)	-0.027	(0.058)
Household head occupation dummies	YES		YES		YES	
Sub region dummies	YES		YES		YES	
Observations	829		940		943	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Widow(er) as base for marital status, primary education as base for head's education status, Kigezi subregion as base for subregion

Table 10 reports average marginal estimates of lighting fuel choices after a logit model. The marginal estimates for lighting fuels portray significant results in relation to the wealth index. Like in the energy transition hypothesis, wealthier households are 15.9% more likely to use modern fuels for lighting. On the other hand, wealthier households are 5.1% less likely to use kerosene for lighting and 2.3 % less likely to use traditional lighting fuels. The total shocks estimates differ with the observation made on cooking fuels. Among lighting fuels, total shocks have no significant effects on modern lighting fuels such as electricity and solar. Instead, a positive and significant effect of 3.2% is observed in relation to the use of kerosene. This is peculiar and warrants more investigation.

The estimates for the household head's age show that older households are more likely to use kerosene for lighting. Household size and gender largely portray insignificant effects. In what pertains to the marital status of the household head, households with heads that are married monogamously are 11.2% more likely to use electricity or solar compared to households headed by widows or widowers. Fascinatingly, households with heads that are married polygamously were 0.9% more likely to use traditional lighting fuels such as firewood and crop residue. Divorced or separated households were 3.7% less likely to use traditional lighting fuels and 5.8% less likely to use kerosene.

The estimates for household head's education level shows that heads with tertiary education are 16.7 % more likely to use electricity or solar for lighting. No head with tertiary education used traditional lighting fuels and no significant results were found for kerosene. This provides evidence that higher education modifies the fuel decisions of lighting fuels more positively than cooking fuels. Lastly, the household's access to grid electricity and location in urban areas are in most parts not significant in explaining the choice of lighting fuel. This may be due to the high adoption rates of solar panels in Uganda allowing for those without grid connections to still access modern lighting fuels through solar panels.

5.2 Sensitivity analysis

The following section will address the robustness measures and heterogeneity measures used in this study.

5.2.1 Robustness

The robustness section is divided into two parts. The first part is dedicated to the mlogit model as a robustness measure for the logit model. The second part addresses the robustness of the shock variable. Tables of results will be presented in the annexes.

5.2.1.1 *The Multinomial logit model results*

This section is dedicated to ensuring the robustness of the empirical model used in the study. It will present the mlogit results as a robust measure for the logit model used in the principal study. Both models have been applied in existing literature to study household energy (Heltberg, 2004).

The average marginal estimates of cooking fuels are largely consistent with the logit results as expected, however with much larger percentages. Mlogit estimates of the wealth index show that richer households are 13.8% less likely to use traditional fuels, 10.9% more likely to use the transitional fuel charcoal and 2.9% more likely to use modern fuels for cooking. The estimates provide further evidence that shocks reduce the likelihood of choosing modern cooking fuels by 2.3%.

Among lighting fuels, the mlogit marginal estimates echo the results of the logit results to a great degree. Wealthier households are 12.7% more likely to choose modern lighting fuels and 9.4% less likely to choose kerosene for lighting. Traditional lighting fuels which had no significant effect on the logit model, now gain a significant and negative effect in relation to wealth. Wealthier households are 3.3% less likely to use traditional lighting fuels. The estimates on total shocks show that as in the logit model, an additional shock leads to a higher likelihood of use of kerosene by 3.7%. However, unlike the logit results which had no significant effect on modern lighting fuels, mlogit results show that shocks have a significant and negative effect on modern lighting fuels. Shocks reduce the probability of choosing modern lighting fuels by 4.0%. This provides a much clearer perspective, complementing the results of the logit model.

5.2.1.2 *Shock measure*

This section will tackle the robustness of the shock variable in three ways. First, by examining the effects of covariate and idiosyncratic shocks on household energy choices. Second, by disintegrating the shocks to analyse the individual effects of the most reported shocks in each of the two categories. Lastly, moving away from household declared subjective measures used above, the Standardized Evapotranspiration Index (SPEI) as an external measure of climatic shocks will be used for analysis to examine the robustness of the results. Indeed, this study proposed a subjective versus an objective measure of shocks. The former being reported by the households themselves and the later, from external sources.

5.2.1.2.1 *Covariate and idiosyncratic shocks*

This section presents the impact of covariate shocks and idiosyncratic shocks on household energy choices. To recall, as discussed in 3.2.2, the covariate and idiosyncratic shock variables are dummy variables taking 1 if household experience at least one of the shocks defined as either covariate or idiosyncratic respectively, and 0 is accorded otherwise. This is done as a robust measure given that,

shocks were self-declared by households, raising the question of endogeneity bias as those shocks might have been correlated with some unobserved variables. As covariate shocks affect a larger set of population, this study has attempted to overcome the endogeneity issue by using covariate shocks as robustness measures.

The average marginal estimates of idiosyncratic shocks had no significant effect on cooking fuel choices while covariate shocks reduced the likelihood of use of charcoal by 3.5%. However, among lighting fuels, covariate shocks increase the likelihood of use of kerosene by 5.2%. The idiosyncratic shocks reduce the use of both kerosene and modern lighting fuels by 5.0% and 1.3% respectively.

5.2.1.2.2 Individual effects of shocks

As discussed in 3.2.2, a claim can be made that the cumulative classification of grouping shocks into covariate or idiosyncratic may produce a bias. This section addresses this issue by disintegrating the shocks and analysing 4 of the most reported shocks: two covariate shocks; droughts and irregular rains, and 2 idiosyncratic shocks; deaths and illnesses in households.

With regards to cooking fuels, estimates of the drought variables illustrate that drought-stricken households are surprisingly 1.4% more likely to use modern fuel. Estimates of Irregular rains have no significant effects on cooking fuels. These results are not conclusive and justify further investigation.

With regards to deaths of either a head or a member of a household, estimates show that deaths reduce the likelihood of using modern cooking fuels by 4.2%. Estimates of illness indicate that illness of either the head or member of a household have no significant effects on cooking fuels. Nonetheless, the idiosyncratic shock death, seems to drive the negative effect of shocks on the choice of modern cooking fuels.

Among lighting fuels, droughts conform to our earlier hypothesis by reducing the use of modern forms of fuels by 4.5% and increase the use of kerosene by 6.5%. Irregular rains and deaths have no significant effects. Illnesses tend to reduce the likelihood of use of kerosene while having no significant effects on traditional and transitional fuels. These results lead us to conclude that further investigation is required.

5.2.1.2.3 The standardized evapotranspiration Index (SPEI)

The marginal estimates of the SPEI index indicate that households in districts that experienced droughts (mean SPEI indices below 0) were 3.1% less likely to use modern cooking fuels. Indeed, these results support the principle results found using total shocks. The two results provide evidence that shocks limit the energy transition process by discouraging the use of modern cooking fuels.

Among lighting fuels, households in districts that experienced droughts were 6.1% more likely to choose modern lighting fuels. Like the results in the principal model, it seems that droughts have no negative effects on modern lighting fuels and thus no conclusive effects on household energy transition process except in the mlogit model.

5.3 Heterogeneity

To ensure heterogeneity, we compare the main results of the study in two wealth terciles: the poorest versus the richest. Second, the study will analyse the impact of total shocks on the Kampala subregion comparing it to the rest of the 14 other subregions.

5.3.1 The impact shocks in wealth tercile 1 versus tercile 3

In this section, we compare the marginal estimates of the total shocks on the richest tercile to the poorest tercile. Marginal estimates of cooking fuels indicate that shocks increase the likelihoods of households in the poorest tercile to choose traditional forms of cooking fuels by 2.5% and reduce the likelihood of the same households to choose modern fuels by 1.7%. This could mean that risks could feed a kind of poverty trap. Contrarily, among the wealthiest tercile, shocks have no significant effects on household cooking fuel choices. This points to the likelihood that shocks are detrimental to the fuel choices of poor households. Deducing from the energy ladder hypothesis, poorer households are less likely to choose modern cooking fuels. It appears therefore that shocks, further limit poor households in their efforts to transition to more modern fuels.

Among lighting fuels, total shocks increase the use of transitional lighting fuel kerosene in both the poorest and the richest tercile by 4.0% and 3.3 % respectively. The difference is small between the poor and the rich, it appears that shocks do not affect the lighting fuels of the rich and the poor differently.

5.3.2 Kampala versus other regions

The subregion of Kampala is compared to the 14 other subregions for heterogeneity. This is because Kampala, the capital city of Uganda is found in Kampala subregion making it the most urbanized and metropolitan area in Uganda. Marginal estimates of cooking fuels show that total shocks reduce the probability of choosing modern cooking fuels by 2.1% in Kampala Subregion compared to other regions. Estimates of lighting fuels illustrate that total shocks increase the use of kerosene by 3.8%. The results are therefore largely heterogeneous and can be said to represent the country of study.

6 Discussion

This section of the paper will chronologically discuss the empirical findings of the energy ladder model and proceed to analyze the role of shocks on household fuel choices.

6.3 The energy transition process

This paper has studied the energy ladder hypothesis, the role of perceived shocks on energy transition, other determinants of energy use, and the general outlook of energy consumption among households in Uganda. The results suggest that an increase in wealth is associated with an improvement towards more modern fuels. Nevertheless, this change is likely to have a contrasting impact on cooking and lighting fuels. Portraying a higher probability of adopting modern lighting fuels than cooking fuels. Even among wealthy households, a transition to modern fuels is particularly challenging with regards to cooking fuels.

The first possible explanation for this tendency is the cultural perceptions associated with traditional cooking practices and preferences of taste. Households in Uganda majorly use charcoal for cooking matoke or beans (Elasu et al., 2021). Matoke is the staple food and is culturally cooked using firewood or charcoal by steaming bananas under low heat for long hours. The technique gives it its unique flavour and taste, which is generally preferred (L. Y.-T. Lee, 2013). Such practices are culturally engrained and play a humongous role in determining household fuel choices. Second is the difference

in investment needed prior to the adoption of modern energy for different purposes. Existing studies report this analogy, detailing the high cost of infrastructure associated with changing cooking fuels, stating that the cost of stoves and gas bottles were much more expensive relative to solar lamps and electric lighting (Choumert-Nkolo et al., 2019). The authors argue that lighting fuels are more sensitive to changes in socio-economic status since their decisions have an effect on a more diversified set of activities than cooking fuels.

6.4 Do perceived shocks limit household energy transition process?

While it is not clear why different shocks when individually considered, behave differently in modifying household's behaviour to choose one fuel type over the other, the evidence provided in this study shows that the total shocks a household experiences affects cooking and lighting fuels differently. For cooking fuels, total shocks have a negative impact on modern fuels while for lighting, the same shocks could both reduce the use of modern lighting fuels and increase the use of transitional fuel kerosene. Despite this, the mechanism remains the same, it appears that shocks modify household behaviour nevertheless, with regards to their fuel choices and induces households to choose fuels other than modern fuels.

It seems that shocks would increase the use of kerosene because only about 2% of the population use traditional lighting fuels in the form of firewood and crop residue. Meaning that in Uganda, a large percentage of households have climbed the energy ladder and no longer use traditional fuels for lighting. This could be attributed to both the electrification efforts and home solar systems that are widely used in Uganda. Hence, in the event of a shock, households hold a preference for transitional kerosene which could be viewed as an 'acceptable' substitute. The shock therefore in essence still leads to a 'descent' down the energy ladder, but not a complete 'fall' in lighting fuel choices.

On the other hand, as most households even among the rich minimally use modern cooking fuels. It appears that a shock would effectively further minimize the use of modern cooking fuels among the population. Cooking fuels lower down the energy ladder exemplified by transitional charcoal and traditional firewood are still commonly used even among richer households. It is likely that poor households wishing to ascend the energy ladder are even more disadvantaged in the face of shocks.

The results of this study present an argument that shocks alter the energy choices of households, blocking their energy transition process. Implying that shocks either block the use of modern energy or lead households to choose fuels lower in the energy ladder such as traditional and transitional fuels, hence keeping them in energy poverty. Energy poverty can be defined as a lack of access or inadequate access to modern energy sources, which leads to heavy dependence on traditional energy sources (Pachauri & Spreng, 2011). Existing literature on energy poverty addresses its implications on sustainable development. Authors find that energy poverty has negative effects on socio-economic conditions, health, gender, education among others (Jimenez Mori, 2017; Kanagawa & Nakata, 2007).

While this study provides evidence of the role of shocks in confining households to the use of transitional and traditional energy while limiting the use of modern forms of energy, a possible policy problem could be to question if there indeed exists an energy poverty trap with self-reinforcing mechanisms supported by the occurrence of shocks. This study is a cross-sectional study limited to one study period hence the cyclical nature of a poverty trap cannot be proven. However, given both demand and supply side limitations of electrification and LPG gas use, a great percentage of the

Ugandan population can be considered energy poor, especially with regards to cooking fuels. This study has illustrated that shocks are detrimental to the efforts of households wanting to escape energy poverty. Shocks can be said to be a factor that limits the household energy transition process by inducing a coping strategy towards less expensive fuels, that are equally less 'clean or modern'. In effect, shocks create a conducive environment favorable for the continued existence of energy poverty, a situation that is detrimental to both the human welfare and the environment.

7 Concluding remarks

The results of this study provide evidence that indeed, there may be a transition towards modern energy with an improved economic status but a complete switch to modern energy is not achieved, evidence by the great percentage of wealthier households in continued use of charcoal. Moreover, this study has proven that perceived shocks limit the energy transition process by blocking the use of modern fuels and keeping households in the use of more traditional forms of energy. This has important policy implications as it suggests that in a country like Uganda with a high climate vulnerability index, a shock may limit policy efforts towards energy transition. A policy implication is that better access to modern fuels can be achieved if households can better tackle shocks.

Allied to the above, a policy challenge rests on the basis that in Uganda, there still exists the very high dependence on charcoal and firewood, and electricity is majorly used for lighting and not cooking. A fact recognized by the ministry of energy and mineral development, with the acknowledgement that biomass will still remain in the near future (Uganda, 2002). Nonetheless, there is still limited policy efforts targeted at limiting the negative impacts of such fuels on human welfare.

In addition, limited affordability of modern fuels equally minimizes their use especially with regards to cooking. Some authors discourage the use of subsidies arguing that it strains supply of electricity towards the poor who are likely to need it the most (Heltberg, 2005). Efforts could be directed towards making clean energy, affordable for all subsets of the population, especially those whose income is prone to be affected by shocks. Packaged policies are unlikely to enhance the energy transition in the Ugandan context, policies could cater to those whose incomes can be easily altered by shocks namely, those in the agricultural sector and those in the lower income brackets.

This study is a cross-sectional study, performed by the use of a single-period survey. Future research could incorporate a panel study. With regards to the measurement of shock, the study applies the use of household declared perceived shocks and uses the reported covariate and idiosyncratic shocks together with the SPEI index for robustness. Future research could make use of instrumental variables to overcome endogeneity issues. In addition, the study has provided evidence of existence of the negative role of shocks in enhancing energy poverty. Future research could analyze if shocks could induce energy traps with self-reinforcing mechanisms in the context of multiple equilibria.

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Annex 1: Table results: Multinomial logit model

A1.1 Mlogit cooking fuels

VARIABLES	Traditional cooking fuels		Transitional cooking fuels		Modern cooking fuels	
	Dy/dx	Std. Err	Dy/dx	Std. Err	Dy/dx	Std. Err
	Firewood, crop residue & Dung		Charcoal		Electricity, gas, kerosene, solar	
PCA Wealth index	-0.138***	(0.008)	0.109***	(0.009)	0.029***	(0.005)
Total shocks count	0.022	(0.032)	0.001	(0.020)	-0.023*	(0.013)
Household size	-0.002	(0.004)	0.006	(0.005)	-0.003	(0.003)
Head age	0.006***	(0.001)	-0.005***	(0.001)	-0.001***	(0.000)

Head Male	0.061	(0.044)	-0.101**	(0.049)	0.040**	(0.019)
Married monogamously	0.050	(0.034)	-0.005	(0.018)	-0.055***	(0.020)
Married polygamously	0.091***	(0.032)	-0.004	(0.039)	-0.095***	(0.013)
Divorced or separated	-0.025	(0.047)	0.035	(0.045)	-0.011	(0.008)
secondary	-0.018	(0.027)	0.003	(0.032)	0.014	(0.013)
Tertiary	-0.057	(0.079)	0.087	(0.058)	-0.013	(0.038)
Stove in room not devoted to cooking	-0.075	(0.088)	0.075	(0.078)	-0.001	(0.030)
Stove located in outdoor space	-0.043*	(0.024)	0.053**	(0.021)	-0.011	(0.007)
Grid electricity	-0.020	(0.023)	0.007	(0.032)	0.013	(0.009)
Urban	-0.025**	(0.011)	0.034*	(0.019)	-0.010	(0.018)
Household head occupation dummies	YES		YES		YES	
Subregion dummies	YES		YES		YES	
Observations	901		901		901	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Widow(er) as base for marital status, primary education as base for head's education status, stove located in separate kitchen as base for stove location, Kigezi subregion as base for subregion

A1.2 Mlogit lighting fuels

	Traditional lighting fuels		Transitional lighting fuels		Modern lighting fuels	
	Firewood, crop residue & Dung		Kerosene		Electricity, gas, solar	
VARIABLES	Dy/dx	Std. Err	Dy/dx	Std. Err	Dy/dx	Std. Err
PCA Wealth index	-0.033**	(0.014)	-0.094***	(0.012)	0.127***	(0.005)
Total shocks count	0.003	(0.007)	0.037*	(0.020)	-0.040*	(0.021)
Household size	0.003*	(0.002)	-0.004	(0.004)	0.001	(0.004)
Head age	0.001	(0.000)	0.001***	(0.001)	-0.002***	(0.000)
Head Male	-0.054***	(0.014)	-0.003	(0.051)	0.058	(0.051)
Married monogamously	0.039*	(0.023)	-0.112***	(0.038)	0.074***	(0.028)
Married polygamously	0.031**	(0.016)	-0.034	(0.025)	0.003	(0.015)
Divorced or separated	-0.034***	(0.005)	-0.020	(0.041)	0.053	(0.038)
secondary	0.008	(0.011)	-0.042	(0.032)	0.049	(0.038)
Tertiary	-0.250***	(0.076)	0.052	(0.132)	0.198	(0.127)
Grid electricity	-0.008	(0.008)	0.020	(0.013)	-0.013	(0.020)
Urban	0.012	(0.019)	-0.006	(0.051)	0.006	(0.038)
Household head occupation dummies	YES		YES		YES	
Subregion dummies	YES		YES		YES	
Observations	684		684		684	

Annex 2: Table results: Covariate shocks

A2.1 Covariate shocks results: Cooking fuels

	Traditional cooking fuels	Transitional cooking fuels	Modern cooking fuels

	Firewood, crop residue & Dung		Charcoal		Electricity, gas, kerosene, solar	
VARIABLES	Dy/dx	Std. Err	Dy/dx	Std. Err	Dy/dx	Std. Err
PCA Wealth index	-0.098***	(0.007)	0.118***	(0.009)	0.026***	(0.004)
Covariate dummy	-0.002	(0.011)	-0.035**	(0.016)	0.005	(0.014)
Household size	0.001	(0.004)	0.001	(0.003)	-0.003	(0.003)
Head age	0.007***	(0.001)	-0.004***	(0.001)	-0.001***	(0.000)
Head Male	0.004	(0.023)	-0.155***	(0.028)	0.018	(0.019)
Married monogamously	0.136***	(0.039)	0.088***	(0.028)	-0.024	(0.018)
Married polygamously	0.177**	(0.083)	0.051	(0.040)	-0.067***	(0.017)
Divorced or separated	-0.046	(0.066)	0.060	(0.046)	-0.005	(0.008)
secondary	-0.038	(0.028)	0.020	(0.026)	0.013	(0.013)
Tertiary	-0.071	(0.083)	0.079	(0.079)	-0.029	(0.038)
Stove in room not devoted to cooking	-0.051***	(0.016)	0.044	(0.082)	0.011	(0.029)
Stove located in outdoor space	-0.037*	(0.020)	0.051**	(0.024)	-0.007	(0.008)
Grid electricity	-0.063***	(0.019)	0.014	(0.023)	0.012	(0.009)
Urban	-0.024	(0.022)	0.028***	(0.010)	-0.008	(0.019)
Household head occupation	YES		YES		YES	
Subregion dummies	YES		YES		YES	
Observations	941		941		916	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Widow(er) as base for marital status, primary education as base for head's education status, stove located in separate kitchen as base for stove location, Kigezi subregion as base for subregion

A2.2 Covariate shocks: Lighting fuels

	Traditional lighting fuels		Transitional lighting fuels		Modern lighting fuels	
	Firewood, crop residue & Dung		Kerosene		Electricity, gas, solar	
VARIABLES	Dy/dx	Std. Err	Dy/dx	Std. Err	Dy/dx	Std. Err
PCA Wealth index	-0.023*	(0.013)	-0.050***	(0.009)	0.159***	(0.004)
Covariate dummy	0.004	(0.011)	0.052***	(0.020)	-0.019	(0.033)
Household size	0.001	(0.002)	-0.001	(0.003)	-0.003	(0.007)
Head age	0.001	(0.000)	0.002***	(0.001)	-0.000	(0.001)
Head Male	-0.028	(0.018)	-0.024	(0.048)	0.010	(0.053)
Married monogamously	0.008	(0.023)	-0.049	(0.036)	0.112***	(0.028)
Married polygamously	0.010**	(0.004)	-0.013	(0.044)	-0.002	(0.057)
Divorced or separated	-0.037***	(0.012)	-0.057***	(0.028)	-0.034	(0.050)
secondary	0.008	(0.016)	-0.001	(0.003)	0.048	(0.060)
Tertiary	-		-0.050	(0.107)	0.160*	(0.085)
Grid electricity	-0.007	(0.010)	-0.009*	(0.005)	0.020	(0.027)
Urban	0.012	(0.015)	-0.024	(0.025)	-0.027	(0.058)
Household head occupation dummies	YES		YES		YES	
Subregion dummies	YES		YES		YES	
Observations	829		940		943	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Widow(er) as base for marital status, primary education as base for head's education status, Kigezi subregion as base for subregion

Annex 3: Table results: Idiosyncratic shocks

A3.1 Idiosyncratic shocks: cooking fuels

	Traditional cooking fuels		Transitional cooking fuels		Modern cooking fuels	
	Firewood, crop residue & Dung		Charcoal		Electricity, gas, kerosene, solar	
VARIABLES	Dy/dx	Std. Err	Dy/dx	Std. Err	Dy/dx	Std. Err
PCA Wealth index	-0.097***	(0.007)	0.118***	(0.009)	0.026***	(0.005)
Idiosyncratic dummy	-0.023	(0.015)	0.020	(0.032)	0.003	(0.025)
Household size	0.000	(0.003)	0.002	(0.003)	-0.003	(0.003)
Head age	0.007***	(0.001)	-0.004***	(0.001)	-0.001***	(0.000)
Head Male	-0.005	(0.023)	-0.157***	(0.028)	0.018	(0.020)
Married monogamously	0.137***	(0.040)	0.088***	(0.028)	-0.024	(0.018)
Married polygamously	0.177**	(0.084)	0.052	(0.039)	-0.067***	(0.017)
Divorced or separated	-0.048	(0.065)	0.062	(0.050)	-0.004	(0.009)
secondary	-0.039	(0.027)	0.019	(0.028)	0.013	(0.013)
Tertiary	-0.072	(0.084)	0.077	(0.077)	-0.028	(0.038)
Stove in room not devoted to cooking	-0.051***	(0.016)	0.047	(0.085)	0.009	(0.027)
Stove located in outdoor space	-0.038*	(0.020)	0.049**	(0.022)	-0.007	(0.009)
Grid electricity	-0.064***	(0.019)	0.014	(0.023)	0.012	(0.009)
Urban	-0.024	(0.022)	0.028*	(0.012)	-0.008	(0.019)
Household head occupation dummies	YES		YES		YES	
Subregion dummies	YES		YES		YES	
Observations	941		941		916	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Widow(er) as base for marital status, primary education as base for head's education status, stove located in separate kitchen as base for stove location, Kigezi subregion as base for subregion

A3.2 Idiosyncratic shocks: lighting fuels

	Traditional lighting fuels		Transitional lighting fuels		Modern lighting fuels	
	Firewood, crop residue & Dung		Kerosene		Electricity, gas, solar	
VARIABLES	Dy/dx	Std. Err	Dy/dx	Std. Err	Dy/dx	Std. Err
PCA Wealth index	-0.023*	(0.013)	-0.050***	(0.010)	0.160***	(0.005)
Idiosyncratic dummy	0.006	(0.016)	-0.050**	(0.021)	-0.013*	(0.008)
Household size	0.001	(0.002)	-0.002	(0.003)	-0.003	(0.007)
Head age	0.001	(0.000)	0.002***	(0.001)	-0.000	(0.001)
Head Male	-0.027	(0.018)	-0.020	(0.049)	0.009	(0.050)
Married monogamously	0.008	(0.024)	-0.052	(0.035)	0.111***	(0.026)
Married polygamously	0.010***	(0.003)	-0.015	(0.042)	0.002	(0.057)
Divorced or separated	-0.036**	(0.013)	-0.061*	(0.033)	-0.036	(0.050)

secondary	-0.008	(0.016)	0.005	(0.004)	0.047	(0.058)
Tertiary	-		-0.049	(0.108)	0.159*	(0.084)
Grid electricity	-0.005	(0.010)	-0.009	(0.007)	0.018	(0.028)
Urban	0.012	(0.016)	-0.024	(0.026)	-0.027	(0.058)
Household head occupation dummies	YES		YES		YES	
Sub-region dummies	YES		YES		YES	
Observations	829		940		943	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Widow(er) as base for marital status, primary education as base for head's education status, Kigezi subregion as base for subregion

Annex 4: Table results: Individual effects of shocks

A4.1 cooking fuel

A4.1.1 Drought

VARIABLES	Traditional cooking fuels		Transitional cooking fuels		Modern cooking fuels	
	Dy/dx	Std. Err	Dy/dx	Std. Err	Dy/dx	Std. Err
	Firewood, crop residue & Dung		Charcoal		Electricity, gas, kerosene, solar	
PCA Wealth index	-0.097***	(0.007)	0.118***	(0.009)	0.027***	(0.004)
Drought	0.035	(0.028)	-0.038	(0.025)	0.014**	(0.006)
Household size	0.001	(0.004)	0.001	(0.003)	-0.003	(0.003)
Head age	0.007***	(0.001)	-0.004***	(0.001)	-0.001***	(0.000)
Head Male	-0.006	(0.023)	-0.156***	(0.028)	0.019	(0.019)
Married monogamously	0.136***	(0.039)	0.090***	(0.027)	-0.025	(0.019)
Married polygamously	0.176**	(0.084)	0.053	(0.039)	-0.068***	(0.017)
Divorced or separated	-0.046	(0.067)	0.060	(0.046)	-0.004	(0.008)
secondary	-0.038	(0.027)	0.018	(0.028)	0.013	(0.013)
Tertiary	-0.073	(0.086)	0.078	(0.078)	-0.028	(0.038)
Stove in room not devoted to cooking	-0.051***	(0.017)	0.048	(0.084)	0.010	(0.031)
Stove located in outdoor space	-0.035*	(0.021)	0.048*	(0.025)	-0.006	(0.008)
Grid electricity	-0.063***	(0.018)	0.014	(0.023)	0.012	(0.009)
Urban	-0.024	(0.023)	0.028***	(0.010)	-0.007	(0.019)
Household head occupation dummies	YES		YES		YES	
Subregion dummies	YES		YES		YES	
Observations	941		941		916	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Widow(er) as base for marital status, primary education as base for head's education status, stove located in separate kitchen as base for stove location, Kigezi subregion as base for subregion

A4.1.2 Irregular rains

	Traditional cooking fuels		Transitional cooking fuels		Modern cooking fuels	
	Firewood, crop residue & Dung		Charcoal		Electricity, gas, kerosene, solar	
VARIABLES	Dy/dx	Std. Err	Dy/dx	Std. Err	Dy/dx	Std. Err
PCA Wealth index	-0.097***	(0.006)	0.119***	(0.008)	0.026***	(0.004)
Irregular rains	-0.031	(0.032)	-0.015	(0.049)	-0.022	(0.035)
Household size	0.001	(0.004)	0.002	(0.003)	-0.003	(0.003)
Head age	0.007***	(0.001)	-0.004***	(0.001)	-0.001***	(0.000)
Head Male	-0.004	(0.023)	-0.157***	(0.028)	0.019	(0.019)
Married monogamously	0.135***	(0.038)	0.087***	(0.026)	-0.024	(0.019)
Married polygamously	0.172**	(0.080)	0.050	(0.035)	-0.070***	(0.015)
Divorced or separated	-0.046	(0.067)	0.060	(0.044)	-0.005	(0.007)
secondary	-0.037	(0.028)	0.019	(0.028)	0.013	(0.013)
Tertiary	-0.068	(0.080)	0.078	(0.076)	-0.026	(0.039)
Stove in room not devoted to cooking	-0.052***	(0.017)	0.048	(0.085)	0.008	(0.029)
Stove located in outdoor space	-0.034	(0.022)	0.051**	(0.021)	-0.004	(0.009)
Grid electricity	-0.062***	(0.020)	0.013	(0.023)	0.012	(0.010)
Urban	-0.024	(0.023)	0.028***	(0.011)	-0.008	(0.019)
Household head occupation dummies	YES		YES		YES	
Subregion dummies	YES		YES		YES	
Observations	941		941		916	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Widow(er) as base for marital status, primary education as base for head's education status, stove located in separate kitchen as base for stove location, Kigezi subregion as base for subregion

A4.1.3 Deaths in household

	Traditional cooking fuels		Transitional cooking fuels		Modern cooking fuels	
	Firewood, crop residue & Dung		Charcoal		Electricity, gas, kerosene, solar	
VARIABLES	Dy/dx	Std. Err	Dy/dx	Std. Err	Dy/dx	Std. Err
PCA Wealth index	-0.098***	(0.008)	0.119***	(0.009)	0.027***	(0.004)
Deaths in household	0.015	(0.041)	-0.022	(0.044)	-0.042**	(0.015)
Household size	0.001	(0.004)	0.002	(0.003)	-0.003	(0.003)
Head age	0.007***	(0.001)	-0.004***	(0.001)	-0.001***	(0.000)
Head Male	-0.004	(0.023)	-0.156***	(0.028)	0.020	(0.019)
Married monogamously	0.137***	(0.038)	0.088***	(0.027)	-0.025	(0.018)
Married polygamously	0.177**	(0.083)	0.051	(0.039)	-0.069***	(0.017)
Divorced or separated	-0.045	(0.064)	0.059	(0.047)	-0.005	(0.007)
secondary	-0.038	(0.027)	0.018	(0.027)	0.013	(0.012)
Tertiary	-0.071	(0.083)	0.076	(0.076)	-0.027	(0.037)
Stove in room not devoted to cooking	-0.051***	(0.015)	0.049	(0.083)	0.009	(0.030)
Stove located in outdoor space	-0.038*	(0.020)	0.049*	(0.025)	-0.006	(0.010)

Grid electricity	-0.062***	(0.019)	0.011	(0.024)	0.010	(0.009)
Urban	-0.024	(0.022)	0.028**	(0.011)	-0.009	(0.020)
Household head occupation dummies	YES		YES		YES	
Subregion dummies	YES		YES		YES	
Observations	941		941		916	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Widow(er) as base for marital status, primary education as base for head's education status, stove located in separate kitchen as base for stove location, Kigezi subregion as base for subregion

A4.1.4 Illnesses in household

	Traditional cooking fuels		Transitional cooking fuels		Modern cooking fuels	
	Firewood, crop residue & Dung		Charcoal		Electricity, gas, kerosene, solar	
VARIABLES	Dy/dx	Std. Err	Dy/dx	Std. Err	Dy/dx	Std. Err
PCA Wealth index	-0.097***	(0.007)	0.118***	(0.009)	0.026***	(0.004)
Illnesses in household	-0.039	(0.037)	0.038	(0.070)	0.010	(0.029)
Household size	0.000	(0.003)	0.002	(0.003)	-0.003	(0.003)
Head age	0.007***	(0.001)	-0.004***	(0.001)	-0.001***	(0.000)
Head Male	-0.004	(0.024)	-0.157***	(0.028)	0.018	(0.019)
Married monogamously	0.137***	(0.040)	0.089***	(0.028)	-0.023	(0.017)
Married polygamously	0.177**	(0.083)	0.052	(0.038)	-0.067***	(0.018)
Divorced or separated	-0.047	(0.067)	0.063	(0.051)	-0.003	(0.011)
secondary	-0.041	(0.029)	0.012	(0.033)	0.013	(0.012)
Tertiary	-0.072	(0.085)	0.078	(0.077)	-0.028	(0.038)
Stove in room not devoted to cooking	-0.054***	(0.016)	0.049	(0.080)	0.010	(0.030)
Stove located in outdoor space	-0.039*	(0.020)	0.049**	(0.022)	-0.006	(0.008)
Grid electricity	-0.063***	(0.019)	0.014	(0.021)	0.012	(0.009)
Urban	-0.026	(0.023)	0.030**	(0.014)	-0.007	(0.020)
Household head occupation dummies	YES		YES		YES	
Subregion dummies	YES		YES		YES	
Observations	963		963		963	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Widow(er) as base for marital status, primary education as base for head's education status, stove located in separate kitchen as base for stove location, Kigezi subregion as base for subregion

A4.2 Lighting fuels

A4.2.1 Drought

	Traditional lighting fuels		Transitional lighting fuels		Modern lighting fuels	
	Firewood, crop residue & Dung		Kerosene		Electricity, gas, solar	
VARIABLES	Dy/dx	Std. Err	Dy/dx	Std. Err	Dy/dx	Std. Err
PCA Wealth index	-0.023*	(0.013)	-0.050***	(0.009)	0.158***	(0.004)

Drought	-0.012	(0.009)	0.065***	(0.012)	-0.045*	(0.027)
Household size	0.001	(0.002)	-0.002	(0.002)	-0.003	(0.007)
Head age	0.001	(0.000)	0.002***	(0.001)	-0.000	(0.001)
Head Male	-0.028	(0.020)	-0.021	(0.048)	0.011	(0.052)
Married monogamously	0.010	(0.024)	-0.055	(0.034)	0.114***	(0.027)
Married polygamously	0.010***	(0.004)	-0.019	(0.044)	0.004	(0.059)
Divorced or separated	-0.037***	(0.013)	-0.060***	(0.029)	-0.032	(0.050)
secondary	-0.008	(0.016)	0.006	(0.005)	0.045	(0.059)
Tertiary	-		-0.052	(0.103)	0.164*	(0.084)
Grid electricity	-0.005	(0.008)	-0.006	(0.006)	0.020	(0.028)
Urban	0.012	(0.016)	-0.021	(0.025)	-0.026	(0.058)
Household head occupation dummies	YES		YES		YES	
Sub-region dummies	YES		YES		YES	
Observations	829		940		943	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Widow(er) as base for marital status, primary education as base for head's education status, Kigezi subregion as base for subregion

A4.2.2 Irregular rains

	Traditional lighting fuels		Transitional lighting fuels		Modern lighting fuels	
	Firewood, crop residue & Dung		Kerosene		Electricity, gas, solar	
VARIABLES	Dy/dx	Std. Err	Dy/dx	Std. Err	Dy/dx	Std. Err
PCA Wealth index	-0.023*	(0.013)	-0.051***	(0.009)	0.159***	(0.004)
Irregular rains	0.010	(0.014)	0.019	(0.016)	0.017	(0.029)
Household size	0.001	(0.002)	-0.002	(0.003)	-0.003	(0.007)
Head age	0.001	(0.000)	0.002***	(0.001)	-0.000	(0.001)
Head Male	-0.027	(0.018)	-0.019	(0.049)	0.009	(0.050)
Married monogamously	0.009	(0.022)	-0.048	(0.037)	0.114***	(0.027)
Married polygamously	0.021***	(0.005)	-0.013	(0.042)	-0.005	(0.058)
Divorced or separated	-0.039***	(0.012)	-0.055*	(0.030)	-0.034	(0.051)
secondary	-0.008	(0.016)	0.003	(0.003)	0.046	(0.059)
Tertiary	-		-0.049	(0.110)	0.158*	(0.085)
Grid electricity	-0.006	(0.010)	-0.004	(0.006)	0.018	(0.028)
Urban	0.012	(0.015)	-0.023	(0.026)	-0.027	(0.058)
Household head occupation dummies	YES		YES		YES	
Sub-region dummies	YES		YES		YES	
Observations	829		940		943	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Widow(er) as base for marital status, primary education as base for head's education status, Kigezi subregion as base for subregion

A4.2.3 Deaths in household

	Traditional lighting fuels	Transitional lighting fuels	Modern lighting fuels
	Firewood, crop residue & Dung	Kerosene	Electricity, gas, solar

VARIABLES	Dy/dx	Std. Err	Dy/dx	Std. Err	Dy/dx	Std. Err
PCA Wealth index	-0.023*	(0.012)	-0.051***	(0.010)	0.159***	(0.004)
Deaths in household	0.022	(0.033)	-0.019	(0.036)	0.005	(0.036)
Household size	0.001	(0.002)	-0.002	(0.003)	-0.003	(0.007)
Head age	0.001	(0.000)	0.002***	(0.001)	-0.000	(0.001)
Head Male	-0.028	(0.020)	-0.019	(0.049)	0.009	(0.050)
Married monogamously	0.011	(0.028)	-0.050	(0.034)	0.112***	(0.027)
Married polygamously	0.011*	(0.006)	-0.016	(0.041)	0.003	(0.058)
Divorced or separated	-0.034***	(0.011)	-0.057*	(0.030)	-0.034	(0.052)
secondary	0.007	(0.015)	-0.004*	(0.002)	0.047	(0.058)
Tertiary	-		-0.048	(0.109)	0.159*	(0.084)
Grid electricity	-0.004	(0.011)	-0.005	(0.008)	0.019	(0.026)
Urban	0.013	(0.015)	-0.019	(0.026)	-0.012	(0.056)
Household head occupation dummies	YES		YES		YES	
Sub-region dummies	YES		YES		YES	
Observations	829		940		943	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Widow(er) as base for marital status, primary education as base for head's education status, Kigezi subregion as base for subregion

A4.2.4 Illnesses in household

	Traditional lighting fuels		Transitional lighting fuels		Modern lighting fuels	
	Firewood, crop residue & Dung		Kerosene		Electricity, gas, solar	
VARIABLES	Dy/dx	Std. Err	Dy/dx	Std. Err	Dy/dx	Std. Err
PCA Wealth index	-0.023*	(0.013)	-0.050***	(0.010)	0.160***	(0.004)
Illnesses in household	0.000	(0.014)	-0.076**	(0.038)	-0.018	(0.021)
Household size	0.001	(0.002)	-0.002	(0.003)	-0.003	(0.007)
Head age	0.001	(0.000)	0.002***	(0.001)	-0.000	(0.001)
Head Male	-0.028	(0.018)	-0.020	(0.048)	0.009	(0.050)
Married monogamously	0.008	(0.023)	-0.054	(0.034)	0.111***	(0.026)
Married polygamously	0.010**	(0.004)	-0.018	(0.042)	0.002	(0.057)
Divorced or separated	-0.037***	(0.013)	-0.062**	(0.031)	-0.036	(0.052)
secondary	-0.007	(0.015)	0.004	(0.006)	0.046	(0.058)
Tertiary	-		-0.051	(0.111)	0.158*	(0.085)
Grid electricity	-0.006	(0.009)	-0.009	(0.006)	0.018	(0.027)
Urban	0.012	(0.015)	-0.026	(0.027)	-0.028	(0.058)
Household head occupation dummies	YES		YES		YES	
Sub-region dummies	YES		YES		YES	
Observations	829		940		943	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Widow(er) as base for marital status, primary education as base for head's education status, Kigezi subregion as base for subregion

Annex 5: Table results: Standardized evapotranspiration Index (SPEI)

A5.1 Cooking fuels

	Traditional cooking fuels		Transitional cooking fuels		Modern cooking fuels	
	Firewood, crop residue & Dung		Charcoal		Electricity, gas, kerosene, solar	
VARIABLES	Dy/dx	Std. Err	Dy/dx	Std. Err	Dy/dx	Std. Err
PCA Wealth index	-0.098***	(0.007)	0.118***	(0.009)	0.026***	(0.004)
SPEI Drought	-0.010	(0.011)	-0.029	(0.021)	-0.031***	(0.009)
Household size	-0.001	(0.004)	0.002	(0.003)	-0.003	(0.003)
Head age	0.007***	(0.001)	-0.004***	(0.001)	-0.001***	(0.000)
Head Male	-0.005	(0.023)	-0.158***	(0.028)	0.018	(0.019)
Married monogamously	0.137***	(0.040)	0.090***	(0.028)	-0.021	(0.017)
Married polygamously	0.178**	(0.084)	0.054	(0.039)	-0.063***	(0.016)
Divorced or separated	-0.047	(0.065)	0.059	(0.048)	-0.005	(0.007)
secondary	-0.039	(0.027)	0.016	(0.026)	0.011	(0.013)
Tertiary	-0.073	(0.082)	0.073	(0.075)	-0.034	(0.037)
Stove in room not devoted to cooking	-0.051**	(0.016)	0.048	(0.082)	0.009	(0.031)
Stove located in outdoor space	-0.037*	(0.021)	0.047**	(0.023)	-0.008	(0.011)
Grid electricity	-0.062***	(0.018)	0.014	(0.024)	0.012	(0.008)
Urban	-0.025	(0.022)	0.027***	(0.010)	-0.010	(0.019)
Household head occupation dummies	YES		YES		YES	
Subregion dummies	YES		YES		YES	
Observations	941		941		916	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Widow(er) as base for marital status, primary education as base for head's education status, stove located in separate kitchen as base for stove location, Kigezi subregion as base for subregion

A5.2 Lighting fuels

	Traditional lighting fuels		Transitional lighting fuels		Modern lighting fuels	
	Firewood, crop residue & Dung		Kerosene		Electricity, gas, solar	
VARIABLES	Dy/dx	Std. Err	Dy/dx	Std. Err	Dy/dx	Std. Err
PCA Wealth index	-0.023*	(0.012)	-0.051***	(0.010)	0.159***	(0.004)
SPEI Drought	-0.013	(0.018)	0.008	(0.021)	0.061*	(0.032)
Household size	0.001	(0.002)	-0.002	(0.003)	-0.002	(0.007)
Head age	0.001	(0.000)	0.002***	(0.001)	-0.000	(0.001)
Head Male	-0.029	(0.019)	-0.019	(0.049)	0.011	(0.050)
Married monogamously	0.009	(0.023)	-0.050	(0.033)	0.108***	(0.028)
Married polygamously	0.011*	(0.007)	-0.016	(0.041)	0.000	(0.057)
Divorced or separated	-0.035***	(0.013)	-0.056*	(0.031)	-0.030	(0.050)
secondary	0.008	(0.016)	0.004**	(0.002)	0.052	(0.061)
Tertiary	-		-0.047	(0.108)	0.166**	(0.084)
Grid electricity	-0.006	(0.009)	-0.004	(0.006)	0.016	(0.031)

Urban	0.013	(0.015)	-0.022	(0.026)	-0.025	(0.058)
Household head occupation dummies	YES		YES		YES	
Sub-region dummies	YES		YES		YES	
Observations	829		940		943	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Widow(er) as base for marital status, primary education as base for head's education status, Kigezi subregion as base for subregion

Annex 6: Summary statistics of shocks by wealth terciles

A6.1: Household total shocks by wealth terciles

HH total shocks count:	1 shock		2 shock		3 shock		4 shock	
	HH Count	HH %	HH Count	HH %	HH Count	HH %	HH count	HH%
Tercile 1	310	35.43	53	37.86	9	33.33	1	25.00
Tercile 2	273	31.20	42	30.00	11	40.74	3	75.00
Tercile 3	292	33.37	45	32.14	7	25.93	0	0.00
Total	875	100	140	100	27	100	4	100

Source: Author's calculation from the UNPS 2019/2020 dataset

A6.2: Household Covariate shocks by wealth tercile

Household shocks:	Covariate		Drought		Irregular rains		Floods		Erosion	
	HH Count	HH %	HH Count	HH %	HH Count	HH %	HH count	HH%	HH count	HH %
Tercile 1	236	38.06	146	40.56	55	32.54	45	38.46	5	38.46
Tercile 2	191	30.81	107	29.72	50	29.59	42	35.90	7	53.85
Tercile 3	193	31.13	107	29.72	64	37.87	30	25.64	1	7.69
Total	620	100	360	100	169	100	117	100	13	100

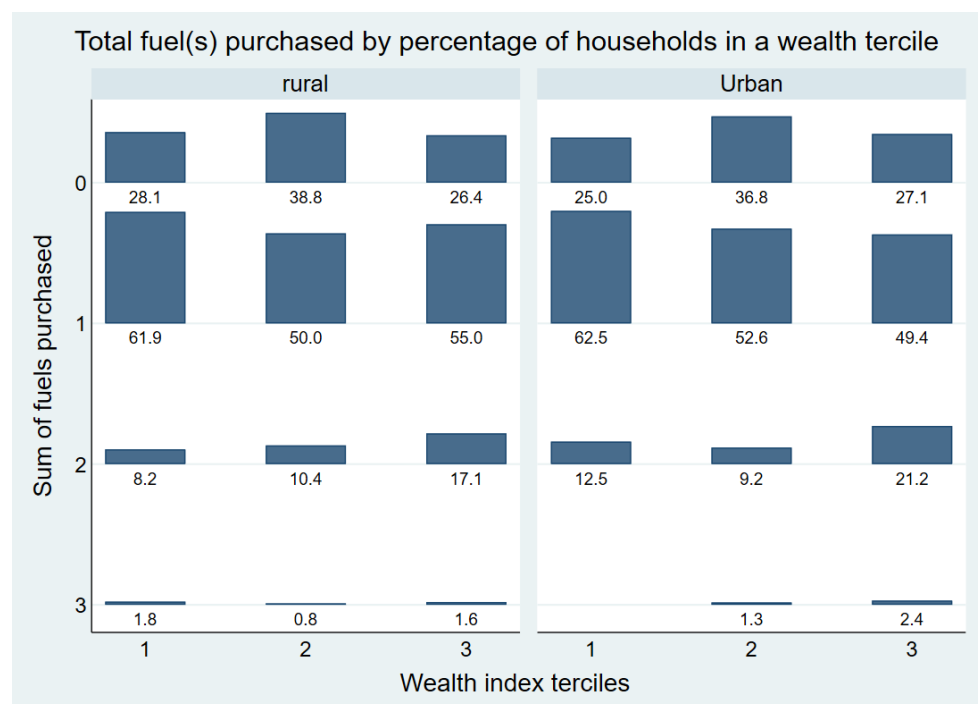
Source: Author's calculation from the UNPS 2019/2020 dataset

A6.3: Household idiosyncratic shocks

Household shocks:	Idiosyncratic shocks		Illnesses		Deaths		Thefts		Reduction in earning	
	HH Count	HH %	HH Count	HH %	HH Count	HH %	HH count	HH%	HH count	HH %
Tercile 1	84	27.54	52	26.94	22	32.35	24	29.63	3	20
Tercile 2	109	38.74	69	35.75	18	26.47	32	39.51	9	60
Tercile 3	112	36.72	72	37.31	28	41.18	25	30.86	3	20
Total	305	100	193	100	68	100	81	100	15	100

Source: Author's calculation from the UNPS 2019/2020 dataset

Annex 7: Rural urban classification of fuels purchased by households in wealth terciles



Source: Author's calculation from the UNPS 2019/2020 dataset

Annex 8: Construction of the PCA Wealth Index

The following section provides tables used during the construction of the PCA wealth index. It provides tables

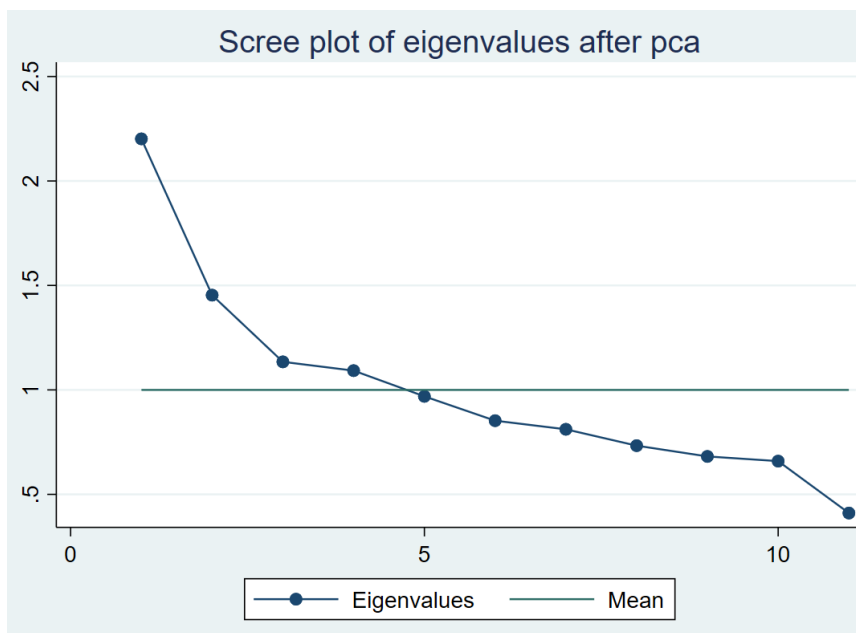
Table 11: The Kaiser-Meyer-Olkin (KMO) measure

Variable	KMO
Roof	0.5955
Wall	0.5103
Floor	0.6118
Drinking water	0.7237
Owner occupied house	0.5820
Owns other buildings	0.7189
Mobile phone	0.7595
motorcycle	0.7427
Motor vehicle	0.7167
Bicycle	0.5529
Radio	0.6075
Overall	0.6304

Source: Author's calculation from the UNPS 2019/2020 dataset

Table 12: Scree plot of eigenvalues after pca

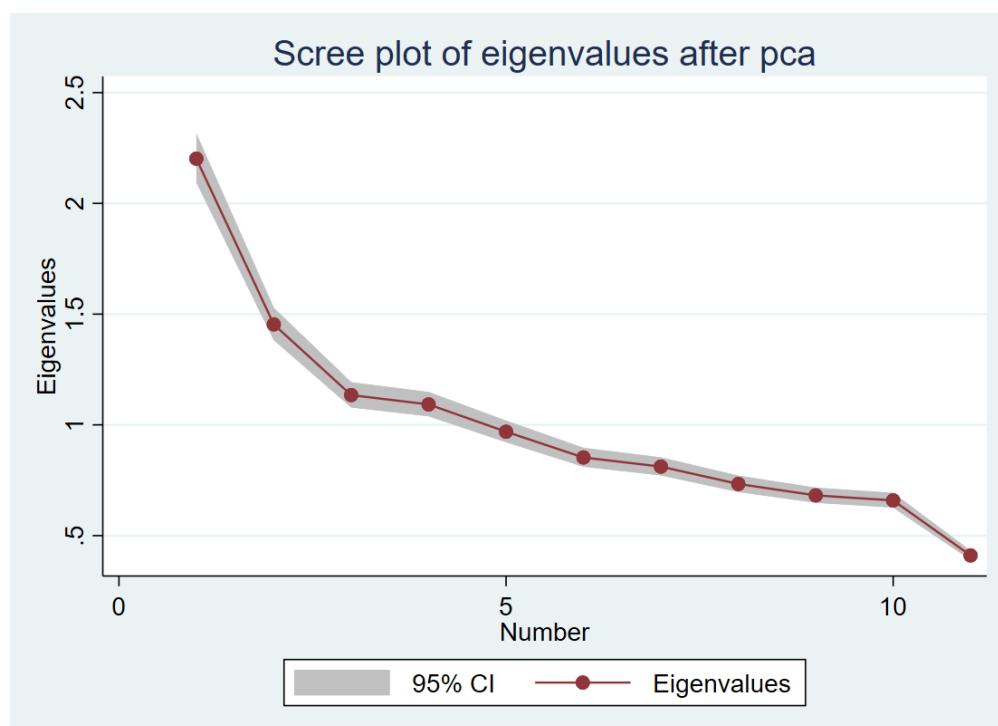
The first four eigenvalues greater than 1 are retained for the study.



Source: Author's calculation from the UNPS 2019/2020 dataset

In a correlation matrix, the mean eigenvalue is 1. The scree plot above helps in visualizing the components with values above 1. In this study, the first four components with eigenvalues higher than 1 are retained. We still retain the 4 components with a 95% confidence interval as portrayed in table 13 below.

Table 13: Scree plot with 95% Confidence interval



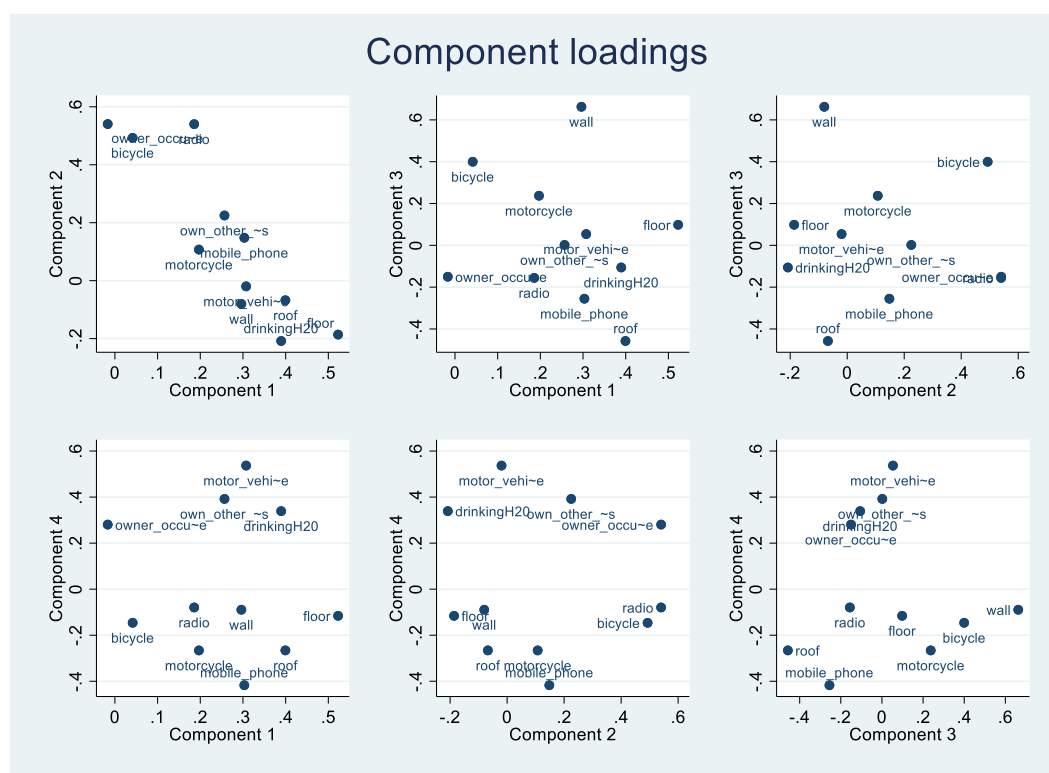
Source: Author's calculation from the UNPS 2019/2020 dataset

Table 14: Correlation matrix of the variables used in the construction of a wealth index

Variable	roof	wall	floor	Drinking water	Owner occupied house	Own other building	Mobile phone	Motorcycle	Motor vehicle	Bicycle	Radio
Roof	0.673										
Wall	-0.049	0.709									
Floor	0.461	0.448	0.678								
Drinking water	0.320	0.166	0.450	0.535							
Owner occupied house	-0.071	-0.214	-0.218	-0.056	0.537						
Own other building	0.089	0.104	0.185	0.297	0.287	0.386					
Mobile phone	0.506	0.029	0.333	0.091	0.021	0.041	0.498				
Motorcycle	0.117	0.320	0.258	0.009	-0.045	0.033	0.207	0.243			
Motor vehicle	0.089	0.191	0.297	0.462	0.128	0.397	-0.059	-0.011	0.527		
Bicycle	-0.177	0.284	-0.023	-0.216	0.273	0.123	0.085	0.245	-0.047	0.561	
Radio	0.214	-0.051	0.060	-0.015	0.420	0.247	0.322	0.146	0.054	0.346	0.535

Source: Author's calculation from the UNPS 2019/2020 dataset

Table 15: Components loading combined



Source: Author's calculation from the UNPS 2019/2020 dataset

Table 16: Principal component loading: sum of squares(column) = eigenvalue

	Comp1	Comp2	Comp3	Comp4
Roof	.5927	-.08156	-.4873	-.2779
wall	.4396	-.09687	.7056	-.0934
floor	.7758	-.2246	.1045	-.121
Drinking water	.578	-.2511	-.1128	.3544
Ownership of occupied house	-.02501	.6515	-.1601	.2932
Ownership of other buildings	.3809	.271	.001894	.4096
Mobile phone	.4498	.1784	-.272	-.4361
Motorcycle	.2921	.1292	.2525	-.2781
Motor vehicle	.4562	-.02381	.0571	.561
Bicycle	.06172	.5942	.4256	-.1526
Radio	.2756	.6512	-.166	-.08309

Source: Author's calculation from the UNPS 2019/2020 dataset

