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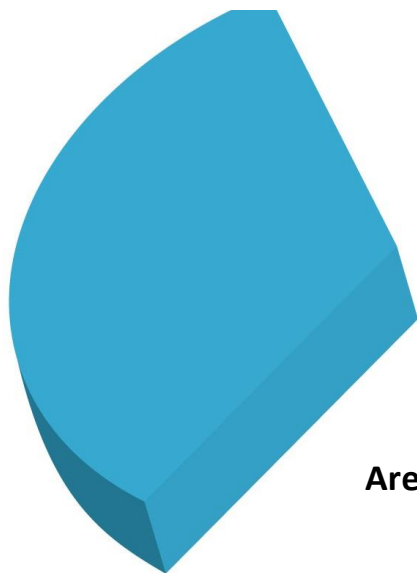
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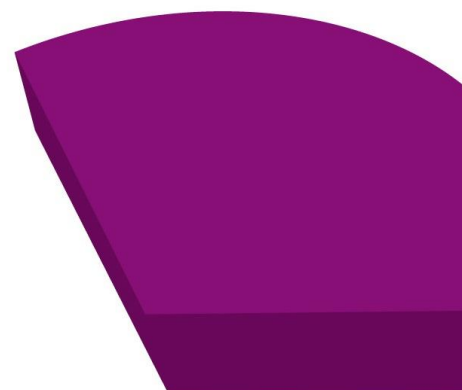
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**Household energy choices under
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Abstract

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 analyze 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

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1. Introduction

Climate change will intensify the vulnerability of human-environment systems (Wheeler & von Braun, 2013). The impact of shocks on household welfare is discernible. Households are faced with rampant widespread covariate shocks such as weather shocks, in addition, they experience household-specific idiosyncratic shocks. The condition is aggravated by the lack of adequate 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. On the other hand, energy is a tradable good and its consumption takes up a percentage of household income. Shocks in their element, affect efficiency by inducing a sub-optimal allocation of household resources, which is likely to deteriorate the consumption behavior of both food and non-food products such as energy. Given the reality of climate change, rising levels of inequality, and the global efforts for energetic transition, the need to analyze the impact of shocks on household energy choices is inevitable.

The central role of energy is underscored by its absolute necessity in achieving and promoting human welfare. Sustainable Development Goal 7 (SDG) precisely outlines the importance of improving global energy access citing the crucial role of energy as a catalyst for economic growth, and the supporting role of energy in the achievement of a majority of other (SDGs) such as poverty alleviation, education, gender equality, health, climate action, and labor force participation.

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 remains among the world's top electricity-deficit countries (IEA, 2023). However, wood fuel constituted 94% of cooking fuels, 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, characterized by firewood and charcoal, have 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 Bushes and forests (UBOS, 2021). This trend limits time for productive

work in school and economic activities with negative implications for gender equality efforts since firewood gathering is mostly tasked to women and girls. In addition, efforts to conserve common property resources such as forests have been challenged with minimal community participation in forest conservation (Gombya-Ssembajjwe & Banana, 1998).

In Uganda, agriculture-based products in primary and processed goods accounted for about 45 percent of exports and employed about 64 percent of Ugandans in 2019 (World Bank, 2020a). The sector is thus the lifeblood of the economy and household welfare. The performance of the largely rainfed agricultural sector and corresponding environmental shocks are vital to the living standards of households depending on 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). 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).

There is abundant literature on the impact of shocks on household consumption patterns in developing countries (Morduch, 1990; Townsend, 1995; Fafchamps et al., 1998; Ray, 1998; Banerjee & Duflo, 2007; Debela et al., 2012; Quisumbing et al., 2012). 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). However, in Sub-Saharan Africa, literature on shocks and energy is scarce (Maconachie et al., 2009). In Uganda, shock literature has majorly focused on aspects such as food consumption and productivity (Kijima et al., 2006; Debela et al., 2012; Quisumbing et al., 2012; Mertens et al., 2016).

To the best of our knowledge, no literature has attempted to address the implications of shocks on household fuel choices in Uganda. The stagnant evolution in cooking fuels, and the environmental and socio-economic repercussions of the existing paradigm, all make Uganda, a particularly interesting country to study. 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 an overview of the data and the variables of the 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 presents the conceptual framework of household fuel choices. It then proceeds to discuss the literature on household perceived shocks and within it, addresses the link between shocks and household energy choices.

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

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

income increases, households do not make a full transition, but rather, continue the concurrent use of a mixture of traditional, transitional, and modern fuels (Masera et al., 2000; Heltberg, 2004). 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 behavior 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 found 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). The authors propose the view that household fuel choice is not a climb up the ladder but rather a 'portfolio choice'.

In Uganda, literature proposes that household fuel choice could be driven by household location, income, and household head's- age, education level, marital status, and gender (Mwaura et al., 2014; Katutsi et al., 2020). The authors also highlight the high dependency on firewood in Uganda. An earlier study confirmed both the energy ladder and energy stacking hypothesis arguing that, as income increases, solid and transitional fuel 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).

2.2 Household Perceived Shocks

The shocks literature 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, and drought among others. Idiosyncratic shocks affect only a few people within a community at the same time and include death, illness, and loss of employment among others (Townsend, 1995; Fafchamps et al., 1998).

Households are assumed to be risk-averse (Ray, 1998). To protect their welfare, they mitigate against the impact of shocks with the mechanisms available to them. Some techniques commonly used in developing countries include mutual insurance or self-insurance, use of savings, credit transfer, use of asset stock in the form of sale and purchase of livestock, grain inventory, and jewelry among others (Cain, 1981; Walker et al., 1983; Rosenzweig & Wolpin, 1993; Paxson & Chaudhuri, 1994; Townsend, 1995; Ray, 1998; Banerjee & Duflo, 2007). Literature on shocks and coping strategies illustrates 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 Ethiopia, the effects of drought shocks were more pronounced for female-headed households, 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 long-lasting effect of 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, 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 resources in the subsequent periods (Debela et al., 2012). These studies indicate existing coping mechanisms among the Ugandan population

² Also referred to as collective or aggregate

³ Also known as household specific

but also, lack of properly installed formal mechanisms and structures that could enable households to alleviate the effects of shocks.

Our 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 on fuel consumption.

A well-developed base of literature on the nexus between shocks and energy consumption majorly focuses on developed countries (Mansur et al., 2008; Auffhammer & Mansur, 2014). 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. Even though energy accounts for a percentage of household expenditure and consumption among traded goods, very few studies concentrate on the effects of shocks on household fuel choices especially in developing countries (Auffhammer & Mansur, 2014; C.-C. Lee et al., 2021; Rakshit, 2021). A study in Nigeria found that a hike in kerosene prices leads to a corresponding increase in the use of firewood as an alternative household fuel (Maconachie et al., 2009). In Uganda, no record of existing literature was found to the best of our knowledge. This study seeks to bridge this gap by analyzing the coping strategy of households faced with perceived shocks, concerning their fuel decisions.

Our study seeks to contribute to this growing literature by focusing on the role of shocks on household energy consumption. 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 of both food and non-food items such as fuels. Our study will apply the energy ladder hypothesis to analyze the impact of household perceived shocks on their energy consumption choices. We proceed under the hypothesis that, shocks can alter the energy transition by locking households in continued use of traditional fuels.

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 cross-section rather than a panel due to data limitations across the panel periods. The dataset is composed of surveys carried out between 2019 and 2020 over twelve months. 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 the 15 sub-regions of Uganda⁴. However, the number of households in various sub-data groups varies. Most critical, the sub-data containing household information on shocks has only 1046 households. 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.

3.2 Variables

The following section will present the variables used in this study.

3.2.1 Dependent variable: Household energy choice as a discrete variable

The energy ladder hypothesis is represented using variables in 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 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

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

“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 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. Table 1 decomposes household fuels. 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.

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

Fuel	Variable type	Variable description	HH ⁵ Count	HH percentage	Mean	SD
Cooking	Discrete <i>Applied in the principle logit model</i>	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 <i>Applied in the mlogit model for robustness⁶</i>	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		
		3 if modern (<i>kerosene/LPG/ solar/electricity</i>)	56	5.61		
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
		1 if traditional (<i>firewood/ crop residue</i>)	20	2.60		

⁵ HH refers to household

⁶ 47 hh reported using none of the 3 categories

	Categorical ¹³ (2) <i>Applied in the mlogit model for robustness</i>	2 if transitional (<i>Kerosene</i>)	148	19.27	2.76	0.49
		3 if modern (<i>solar/ electricity</i>)	600	78.13		

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

3.2.2 Household Perceived Shocks (Interest variable)

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 shock variable measures the cumulative incidence(s) of exposure to either one or many shocks in general. Of the 1046 studied samples, all households reported experiencing at least one shock. It is therefore a variable reporting the total sum of shocks experienced by a household with a minimum of 1, a maximum of 4, a mean of 1.2, and a standard deviation of 0.5.

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

Drought appears to be the most common shock affecting 34.4% of 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 population⁷.

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 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, that permits 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 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 (Wittenberg & Leibbrandt, 2017; Choumert-Nkolo et al., 2019). In neighboring 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 neighbors' houses or charging stations in small centers. 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.

⁷ Summary statistics of shocks in the online appendix

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. A Pearson correlation between the wealth index and log of real per adult equivalent expenditure suggests a positive and significant relationship at the 1% threshold, with a magnitude of 3.4%. Table 2 provides summary statistics of variables of the wealth index. The criteria used to construct the variables can be found in the online appendix.

Table 2: 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

Authors have substantially justified the argument that apart from income, household energy choices depend on other socioeconomic factors (Hosier & Dowd, 1987; Mekonnen & Köhlin, 2009; Mwaura et al., 2014; Choumert-Nkolo et al., 2019; Katutsi et al., 2020; Elasu et al., 2021). The control variables used are the household's size, location, stove location, connection to grid electricity, and household head's- level of education, age, gender, marital status, and occupation⁸.

One limitation of this paper is the inability to use fuel prices as control variables. This is due to the lack of a universal measurement unit for different fuels in the UNPS 2019/2020. Despite the availability of household energy expenditure, the dataset does not indicate a standard measurement unit, especially

⁸ Table compiling relevant variables used to determine household energy choices can be found in the online appendix

concerning firewood, charcoal, and kerosene. For instance, firewood is measured in large, small, or medium bundles. Charcoal is measured in small, medium, and large heaps, and sometimes, in tins of different sizes, plastic basins, or sacks. Kerosene is measured in liters and in a unit known as 'akendo'. Our study could not vividly identify a standard conversion metric. In addition, the prices attached to these measurement units such as charcoal with heaps and sacks vary widely even within the same region, unfortunately limiting the use of the energy price variable. Our study proposes that the price effects will be captured by subregion dummies.

3.3 Stylized facts on household energy use in Uganda

Ugandan households have a high dependence on traditional fuels and a 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 fuels. 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 collection.

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 fuel for cooking.

Separating the household incomes using the wealth index into three tercile groups, we observe as portrayed in Table 3 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 66.08% of the wealthiest quantiles 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 make 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 3: 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 1: Total fuels purchased by the percentage of households in a wealth tercile



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

Figure 1 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 type 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 the future.

4. Econometric Model: Logit Model for Discrete Choice Household Fuel Variables

The logit model uses the variables in Table 1 to model the energy ladder hypothesis. The variables are modeled as mutually exclusive dichotomous variables and assigned the value 1 if a household used 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 analysis 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 allows 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 maximization 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.

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 whose tables are presented in the appendix.

5.1 Logit regression results

Table 4: 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	

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

Table 4 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 on 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 choosing 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 that are different from modern fuels. This implies that shocks will inhibit any transitions up the energy ladder towards modern cooking fuels.

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 argues 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. The household size is statistically insignificant in our study.

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 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 were 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. Households whose heads are married monogamously are 13.8% more likely to use traditional cooking fuels and 8.8% equally likely to use charcoal. It is interesting to observe that household heads who are married polygamously are 17.8% more likely to use traditional fuels and 6.7% less likely to use modern cooking fuels. Approximately a 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 channeled towards the use of improved cooking fuels. It is also likely that polygamous families are larger 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, the 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 to cooking were 4.8% less likely to use firewood. This could be attributed to the fact that most households who use 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 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 because a very small proportion of the population in both rural and urban areas use modern energy for cooking, even when they have access to grid electricity or when located in urban areas.

Table 5: Average marginal effects of household 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)
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	

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

Table 5 reports average marginal estimates of lighting fuel choices after a logit model. The marginal estimates for lighting fuels portray significant results to the wealth index. As 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 shock estimates differ from 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 with 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, polygamous households 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 show 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 household lighting choices more positively than cooking. 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.

The study proceeded to apply some robustness and heterogeneity measures, the results are in the online appendix. To begin with, multinomial logit results as an alternative methodology echo the results from the logit model. Secondly, disintegrating shocks into covariate versus idiosyncratic shock, 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 the 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. Results on individual effects of other shocks can be found in the online appendix.

An alternative measure of drought known as the standardized evapotranspiration index (SPEI) is applied. The SPEI is an objective measure because it gives an alternative to the household-declared shocks and is taken from the Climatic Research Unit Time Series (CRU ts) 4.04 database. The marginal estimates of the

SPEI index indicate that households in districts that experienced droughts 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 conclusive negative effects on modern lighting fuels. Finally, various heterogeneity measures are applied which echo that poorer households are less likely to choose modern cooking fuels and that shocks, further limit poor households in their efforts to transition to more modern fuels.

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.

6.1 The energy transition process

This paper has studied the energy ladder hypothesis and the role of perceived shocks in the energy transition of 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 regard 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 flavor 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 before 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.

6.2. Do perceived shocks limit the household energy transition process?

While it is not clear why different shocks when individually considered, behave differently in modifying a household's fuel choice behavior, the evidence provided in this study shows that the total shocks a household experiences affect cooking and lighting fuels differently. For cooking fuels, total shocks have a negative impact on modern fuels while for lighting, the results are inconclusive. It appears that shocks modify household behavior nevertheless, more precisely with regards to their cooking fuel choices, and induce 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 uses traditional lighting fuels in the form of firewood and crop residue. This means 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 for modern lighting fuels. 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, 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. Poor households wishing to ascend the energy ladder are likely 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, 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 socioeconomic conditions, health, gender, and education among others (Kanagawa & Nakata, 2007; Jimenez Mori, 2017).

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 human welfare and the environment.

7. Conclusion and Policy Implications

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, evidenced 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 toward energy transition. A policy implication is that better access to modern fuels can be achieved if households can better tackle shocks.

This study is a cross-sectional study, performed by the use of a single-period survey due to data limitations. Future research could incorporate a panel study. With regards to the measurement of shock, the study applies the use of total 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 the 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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