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Determinants of household energy fuel choice in Lesotho

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Abstract

The determinants of household energy fuel choice have not been studied in some developing countries, including Lesotho, despite the potential benefits such a study might have for policy design and implementation. This study uses the data collected by Lesotho's Bureau of Statistics through a national household energy consumption survey of 2017, and a multinomial logistic regression to analyse the determinants of household energy fuel choice in Lesotho. The results indicate that the gender of the household head does not influence the choice of cleaner energy fuels for cooking and water heating. However, the age and education of the household head, household size, level of income, and access to electricity are drivers of energy fuel choice. The older the household head and the larger the household, the less likely it is to adopt cleaner energy fuels. Generally, higher income, access to electricity and a better-educated household head make a household more likely to adopt clean energy fuels. Thus, policies aimed at promoting household income-generating opportunities, effective provision of access to electricity, and investment in education can influence the choice of clean energy use within households. But these policies must be tailored to the unique characteristics of different settlement types, given that the significance of these determinants vary across rural, peri-urban, and urban areas.

Keywords: *energy fuel choice, multinomial logistic regression*

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1. Introduction

Understanding household energy-use pattern is essential for formulating effective clean energy and climate change policies and for implementing relevant energy solutions by independent parties. A large number of people, around 2.7 billion, rely on biomass to meet some of their basic household energy needs (Rahut *et al.*, 2016). With the Paris Agreement in place – an agreement made under the United Nations Framework Convention on Climate Change that is aimed at curbing temperature increase to below 2 °C above pre-industrial levels – closer attention to the household energy fuel choice is required (Alfredsson *et al.*, 2018). The use of unclean energy fuels by households not only degrades the environment but also impacts the health of people within those households (Ezzati and Kammen, 2002; Nasir *et al.,* 2015). Poor households are more susceptible to illness that results from indoor air pollution, as cleaner energy fuels are usually associated with higher costs. It is therefore important to explore factors that influence household energy choice to formulate sustainable development policies.

In Lesotho, households consume around 80% of all the traditional fuels (fuelwood, shrubs, crop waste, animal dung) (Letete *et al.*, 2019). The World Bank states that the poverty rate in Lesotho is around 49.7% and as high as 60.7% in the rural areas, as of 2017 (World Bank, 2019). Moreover, the country has an electrification rate of around 41% (LEWA, 2018), with the rate for rural areas around 5% in 2015 (Mpholo *et al.*, 2018). These statistics show that many households in the country are poor and lack access to electricity. The largely mountainous topography of the country makes the situation worse. Grid extension to cover the whole country is economically prohibitive, while access to other clean energy resources like liquefied petroleum gas (LPG) is also a challenge in the rural areas because of the shortage of access roads. Therefore, biomass provides an affordable and easily accessible source of energy within households.

Energy fuel choice is, however, not restricted to affordability and accessibility. Although these may be the most obvious determinants of choice, factors such as age, social norms, and education can influence a household's choice of energy (Amoah, 2019; Trac, 2011; Uhunamure *et al.*, 2017). For instance, old age leads to limited strength and an older person may prefer less labour-intensive energy sources. On the other hand, an energy fuel choice may be based on the preferred taste of food and how it is cooked. Those with further education are more likely to be aware of the environmental impacts of energy fuels such as biomass and may be inclined towards the use of clean energy fuels. Issues of convenience and opportunity-cost are also critical in energy choices. For example, some energy sources may be chosen based on the proximity of an energy fuel source relative to the household or because the time used for collecting wood can better be used for other activities. These result in a wide pattern of energy uses across different households or settlement types.

A number of studies examine patterns of energy fuel use and determinants of energy fuel choice in developing and emerging market economies such as China, India and Bhutan (Ekholm *et al.*, 2010; Rahut *et al.*, 2014; Sehjpal *et al.*, 2014; Hou *et al.*, 2017; Malakar, 2018; Acharya and Marhold, 2019; Zou and Luo, 2019), and sub-Saharan Africa (Pundo and Fraser, 2006; Hiemstra-van der Horst and Hovorka, 2008; Arthur *et al.,* 2010; Onoja and Idoko, 2012; Bamiro and Ogunjobi, 2015; Nlom and Karimov, 2015; Uhunamure *et al.*, 2017; Guta, 2018). Although there is a consensus that households do not switch to cleaner energy fuels due to an increase in income, there is ambiguity on the effect of other socio-economic factors for the choice of energy to be used within a household.

According to the energy ladder model, an increase in income influences a household to use cleaner, more convenient and more efficient energy fuels such as electricity and LPG (Masera *et al.*, 2000). On the other hand, the energy fuel-stacking model proposes that households do not switch to cleaner energy fuels with an increase in income but, instead, tend to stack energy fuels (Gould and Urpelainen, 2018). Energy fuel choice, therefore, is not only dependent on income but on other factors as well. For instance, Rahut *et al.* (2014) report that, in Bhutan, the gender of the household head is important in the choice of energy for cooking. They report that female-headed households prefer electricity over firewood. Further, they show that age and education are critical and positively influence the choice of cleaner energy fuels relative to biomass. On the contrary, Bamiro and Ogunjobi (2015) report that in Ogun State, Nigeria, gender, age, and education are not important in the choice of energy use within a household. Nlom and Karimov (2015) show that age is critical but negatively influences the choice of clean energy fuel in Northern Cameroon, but this the opposite of what Rahut *et al.* (2014) found in Bhutan. However, both studies agree that education is positive and important in the choice of energy fuel within a household. Thus, the differences in the empirical findings show that patterns of energy use vary with the country or region under consideration.

This study analyses the determinants of the choice of energy fuel in Lesotho. It specifically aims to assess the determinants of the choice of cooking and water-heating energy fuels in households in rural, peri-urban, and urban settlements. Although

plentiful research has been done on the determinants of the choice of household energy fuel, this kind of study has never been done in Lesotho, to our knowledge. Moreover, studies that have addressed this subject in sub-Saharan Africa have concentrated on specific settlement types within a country, mostly rural, without comparison with other settlement types of the same country. Unlike those previous studies, this study adopts the multinomial logistic regression to investigate the determinants of the choice of household energy fuel by first considering the country as a whole, then disaggregating the sample according to their settlement types. This is important for energy policy design and implementation, since policies can be better targeted toward different settlement types.

The rest of this paper is organised as follows. Section 2 gives the data description and model specification for the study. Section 3 presents the estimation results, while section 4 provides discussion of them. Section 5 concludes the study and gives policy recommendations.

2. Methodology

2.1 Data description

The data used in this study comes from the Household Energy Consumption Survey 2017 conducted by Lesotho's Bureau of Statistics between October and December 2017, covering all ten districts of Lesotho. A two-stage stratified sampling technique was used. The first strata were selected using agro-ecological zones: lowlands, foothills, mountains, and Senqu River Valley (see Figure 1). The second strata were selected based on settlements: urban, peri-urban, and rural. By using the enumeration area of the Population and Housing Census 2016 as primary sample units, 15 households were randomly sampled in each EA. A total of 2 877 households, with a response rate of 93%, were covered.

As shown in Table 1, the average age of the household head was 50 years, while the gender distribution of the household heads was 38% females and 62% males. The most prevalent education level of the household head was primary education with a share of 53%, while those with no education at all accounted for 14%. Respondents with secondary and tertiary education accounted for 24% and 9% respectively. The average household size was recorded as four persons. It was found that 57% of the respondents fell under the low-income class category, M0–M999 per month (1 USD ≈ M17), 34% made the middle-income class (M1 000–M4 999), and the rest (9%) was under the high-income class (M5 000 and above). 30% of the respondents indicated that they received remittances. 37% had access to electricity. Most of the respondents were from rural areas (53%), while those from peri-urban and urban areas accounted for 9% and 37% respectively.

For cooking, predominantly traditional fuels are used (fuelwood, shrubs, crop-waste, and animal dung) with an overall share of 50.3%, as shown in Figure. These types of fuel are mostly used in rural areas, as compared to other settlement types. The penetration of traditional fuels for cooking in rural areas is over 80%, while that of electricity is as low as 1.3%. Consumption of traditional fuels decreases

Figure 1: Map of Lesotho showing agro-ecological zones (Adapted from Mekbib et al., 2011).

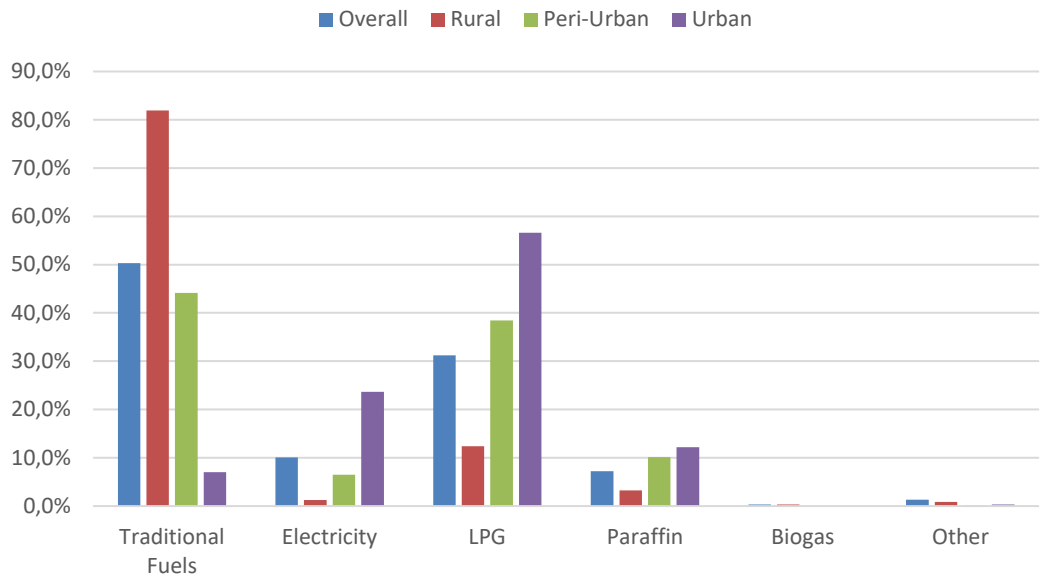

Figure 2: Distribution of cooking fuels in Lesotho.

with increasing urbanisation, as can be observed from Figure 2. The share of traditional fuels is as low as 7% in urban areas. Cleaner energy fuels such as electricity and LPG are mostly preferred in the urban areas, where LPG has a share of 56.6% of the cooking energy fuels used, while electricity has 23.6% penetration. Paraffin accounts for an overall penetration of 7.2% and is preferred more in the urban settlements, where it accounts for 12.2% of cooking energy fuels used. Biogas is hardly used for cooking, accounting for less than 1% of the overall penetration. Other energy fuels (those not covered in the stated energy fuels) are also hardly used, accounting for just about 1% of the overall share.

Table 1: Summary of statistics for demographic variables.

Variables	*Mean or % share*
Gender of household head	
- Female	38%
- Male	62%
Age of household head	50
Education level of hh head	
- None	14%
- Primary	53%
- Secondary	24%
- Tertiary	9%
Household size	4
Household income class	
- Low	57%
- Middle	34%
- High	9%
Households receiving remittances	30%
Availability of electricity	37%
Settlement type	
Rural	53%
Urban	37%
Peri-urban	9%

Different energy fuel mixes for water heating are observed in different settlement types, as shown in Figure 3. Traditional fuels are the most used for water heating, with an overall share of 49.9%. They are followed by electricity at 22.1%, LPG at 16.8%, paraffin at 10.4% and other fuels (cloths and aloe) at 0.7%. Traditional fuels are most prevalent in rural areas, where they account for 80.6% of the total water-heating energy fuel mix, while electricity predominates in urban areas, with 49.1%.

2.2 Model specification

After a consideration of the models used in the literature, a multinomial logit model was chosen to analyse the determinants of the choice of household energy fuel in Lesotho. Although some authors, like Nlom and Karimov (2015), use both logit and probit models, the two yield similar results, and the choice as to which one to use is arbitrary (Brooks, 2008). The logit model is then expressed as in Equation 1.

$$\mathrm{Ln}\left(\frac{P}{1-P}\right) = E(Y = 1|X_1, \dots, X_n) = \beta_0 + \beta_1 X_1 + \dots + \beta_n X_n \quad (1)$$

where P is the probability that $Y = 1$, meaning when a household chooses a certain energy fuel, and 0 otherwise; β's are the coefficients to be estimated;

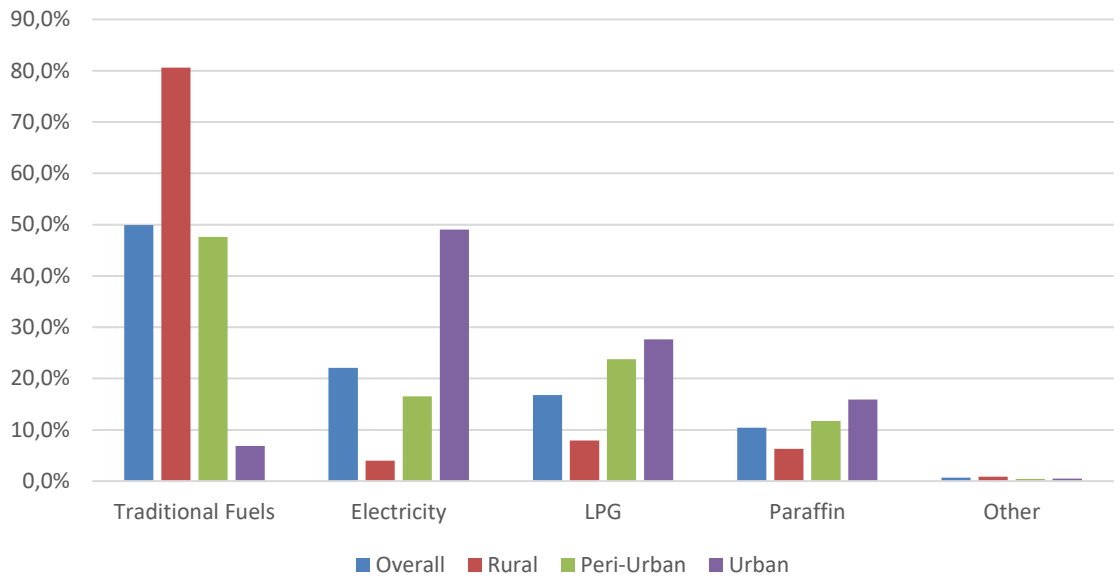

Figure 3: Distribution of water-heating energy fuels in Lesotho.

Table 2: Model adequacy test results

Model	*Settlement type*	*McFadden R^2*	*Chi-square*	*p-value*
Cooking	Whole country	0.41	2521.4	0.000
	Rural	0.20	351.93	0.000
	Peri-urban	0.25	141.06	0.000
	Urban	0.25	549.46	0.000
Water-heating	Whole country	0.43	2845.7	0.000
	Rural	0.24	479.5	0.000
	Peri-urban	0.23	138.69	0.000
	Urban	0.30	734.74	0.000

X's are the independent variables (gender, age and education level of household head, household size, household income, household receiving remittances, availability of electricity, and settlement type); Ln is the natural log. Then *P/(1-P)* gives the *odds* ratio. When the dependent variable has multiple categories, Equation 1 can be re-written as Equation 2.

$$\text{Ln}\left(\frac{\Pr\,(Y=m)}{\Pr\,(Y=n)}\right) = \sum_{r=0}^{R}(\beta_{mr} - \beta_{nr})X_r \qquad (2)$$

The log odds have to change to represent the probability of choosing fuel m over fuel n where there are multiple choices and ensure that the probability of choosing fuel m over fuel n is unaffected by the presence or absence of another fuel k.

The multinomial logit model specified in Equation 2 is estimated in R software. The regression analysis assesses the determinants of choosing cleaner fuels (electricity, LPG, and paraffin) over traditional fuels for cooking and water heating. For the model adequacy test, the McFadden R^2 is employed. But unlike the conventional R^2, values of McFadden R^2 between 0.2 and 0.4 still represent a very good fit for models applying cross-sectional data (Lee, 2013). In addition, the chi-square statistic is used to evaluate whether there is an association between the dependent and independent variables.

3. Results

3.1 Model adequacy

The study estimates the multinomial logit models for cooking and water heating, with traditional fuels as the base category, under different settlement types. The adequacy test results for these models are shown in Table 2. The models represent a good fit as none of them have McFadden R^2 values below 0.2. Furthermore, the chi-square statistics show that the changes in the independent variables correlate well with shifts in the dependent variable as it is shown by p-values of 0.000 for all models.

3.2 Determinants of energy fuel choice for cooking

The multinomial logit results for the determinants of energy fuel choice for cooking, with traditional fuels as the base category, are shown in Table 3. Gender is statistically insignificant in choosing electricity, LPG, and paraffin over traditional fuels for cooking purposes, for almost all the settlement types. On the other hand, the age of the household head is negative and statistically significant for the choice of LPG over traditional fuels across all settlement types. The same is observed for electricity and paraffin, except in rural areas. This shows that the older household heads are less likely to choose electricity, LPG, and paraffin over traditional fuels than younger ones. The household size variable is negative and statistically significant for the choice of all fuels over traditional fuels across all settlement types, indicating that larger households are less likely to choose other fuels over traditional fuels than smaller households.

Considering income, the middle-income class variable is positive and significant, for the choice of electricity, LPG, and paraffin over traditional fuels across all settlement types. This means that households in the middle-income class are more likely than those in the low-income class to choose cleaner energy fuels over traditional fuels. Further-more, the upper-income class variable is positive and statistically significant for the choice of electricity, LPG, and paraffin over the choice of traditional fuels across the majority of the settlement types; they are thus more likely than those in the lower-income category to adopt these fuels. Also, households that receive remittances are more likely to choose LPG over traditional fuels for cooking relative to households that do not receive any remittances. The same applies in the case of electricity but under the whole country and in urban areas only.

For the education categories (primary, secondary and tertiary), the variables are positive and significant for the choice of LPG in almost all the settlement types; for electricity, under the whole country and mostly in urban areas; and for paraffin, under the whole country and largely in rural areas. This implies that household heads with a certain level of education are more likely to choose clean energy fuels as compared to household heads without any level of education. Lastly, the variable on electricity availability is positive and statistically significant for the choice of electricity, under the whole country and in peri-urban areas, and for LPG, in all settlement types, for cooking, over traditional fuels. This shows that households with access to electricity are more likely to adopt cleaner energy fuels than households without access to electricity. The variable is negative and statistically significant for the choice of paraffin over traditional fuels under the whole country and in urban areas.

3.3 Determinants of energy fuel choice for water heating

The determinants of energy fuel choice for water-heating, with traditional fuels as the base category, are shown in Table 4. Generally, gender is statistically insignificant for the choice of cleaner fuels over traditional fuels here. However, the age of household head is negative and statistically significant for the choice of cleaner energy fuels across all settlement types except under rural settlements in the cases of electricity and paraffin. This indicates that older household heads are less likely to choose cleaner energy fuels over traditional fuels for water-heating than households headed by younger people. In terms of household size, this variable is negative and statistically significant for the choice of LPG over traditional fuels across all settlement types. A similar finding is obtained for the choice of electricity, under the whole country and in urban settlements, and paraffin, under all settlement types except peri-urban areas. As a result, larger households are less likely to choose cleaner energy fuels over traditional fuels for water heating as compared to smaller households.

In terms of income, the middle-income variable is mostly positive and statistically significant, implying that households in the middle-income class are more likely to adopt cleaner energy fuels for water-heating than households in the low-income class. However, this is not the case with households that receive remittances, as the variable is mostly insignificant. Furthermore, the categories for the education variable are largely positive and statistically significant, indicating that household heads with some level of education are more likely to choose cleaner energy fuels over traditional ones for water-heating than household heads without education. Lastly, electricity availability is generally positive and statistically significant for the choice of electricity and LPG relative to traditional fuels. This means that households with access to electricity are more likely to adopt cleaner energy fuels for water-heating.

Table 3: Determinants of energy fuel choice for cooking.

Independent variables	*Electricity*				*LPG*				*Paraffin*			
	Whole country	*Rural*	*Peri-urban*	*Urban*	*Whole country*	*Rural*	*Peri-urban*	*Urban*	*Whole country*	*Rural*	*Peri-urban*	*Urban*
Gender: female	0.07	-1.28	1.47*	0.25	-0.02	-0.09	0.18	0.20	-0.15	-0.53	-0.38	0.30
	(0.22)	(0.85)	(0.80)	(0.36)	(0.15)	(0.20)	(0.37)	(0.32)	(0.20)	(0.37)	(0.58)	(0.35)
Age	-0.04***	-0.01	-0.09***	-0.05***	-0.02***	-0.01**	-0.03**	-0.04***	-0.02***	0.01	-0.06***	-0.03***
	(0.01)	(0.02)	(0.03)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
Household size	-0.37***	-0.49***	-0.31*	-0.48***	-0.20***	-0.15***	-0.17**	-0.32***	0.33***	-0.45***	-0.25*	-0.36***
	(0.05)	(0.17)	(0.18)	(0.08)	(0.03)	(0.04)	(0.07)	(0.07)	(0.05)	(0.09)	(0.13)	(0.08)
Income class: middle	1.72***	2.27***	2.36**	2.00***	1.57***	1.30***	1.59***	2.02***	0.84***	0.99**	1.68***	0.96**
	(0.27)	(0.79)	(0.97)	(0.42)	(0.16)	(0.21)	(0.43)	(0.36)	(0.22)	(0.39)	(0.63)	(0.40)
Income class: upper	1.09***	1.59*	1.44	1.68***	0.95***	0.75***	0.58	1.78***	0.70***	0.92**	0.85	1.31**
	(0.31)	(0.88)	(1.18)	(0.53)	(0.19)	(0.26)	(0.49)	(0.46)	(0.26)	(0.42)	(0.69)	(0.51)
Remittances	0.65***	0.34	1.09	0.84**	0.73***	0.60***	0.92**	0.97***	-0.06	-0.05	0.26	0.08
	(0.25)	(0.62)	(0.97)	(0.42)	(0.15)	(0.19)	(0.38)	(0.36)	(0.22)	(0.35)	(0.60)	(0.42)
Settlement type: peri-urban	0.86**	-	-	-	1.18***	-	-	-	1.69***	-	-	-
	(0.42)				(0.19)				(0.28)			
Settlement type: urban	3.06***	-	-	-	2.89***	-	-	-	3.45***	-	-	-
	(0.32)				(0.17)				(0.23)			
Education: primary	1.72***	0.17	-1.22	2.66***	1.13***	1.00***	1.60*	1.18***	0.84***	1.70**	0.61	0.57
	(0.54)	(0.89)	(1.45)	(0.83)	(0.24)	(0.34)	(0.82)	(0.42)	(0.30)	(0.74)	(0.88)	(0.46)
Education: secondary	2.26***	0.46	-1.56	2.96***	1.81***	1.73***	2.33***	1.55***	0.81**	2.37***	0.13	0.09
	(0.55)	(1.00)	(1.62)	(0.85)	(0.27)	(0.38)	(0.88)	(0.47)	(0.35)	(0.80)	(0.97)	(0.53)
Education: tertiary	3.95***	1.31	1.42	22.14	2.75***	2.23***	3.55***	20.04	1.12**	1.59	1.01	18.18
	(0.63)	(1.28)	(1.83)	(3446.7)	(0.40)	(0.53)	(1.17)	(3446.70)	(0.55)	(1.28)	(1.54)	(3446.70)
Electricity availability	6.24***	21.48	4.18***	21.60	1.24***	1.31***	1.31***	1.06***	-0.59**	0.23	0.50	-1.12***
	(1.01)	(3507)	(1.23)	(2997.70)	(0.16)	(0.22)	(0.36)	(0.31)	(0.24)	(0.50)	(0.56)	(0.36)

Notes: Statistical significance level: *** = 1%, ** = 5%, * = 10%. Values in parenthesis represent standard errors.

Table 4: Determinants of energy fuel choice for water-heating.

Independent variable	*Electricity*				*LPG*				*Paraffin*			
	Whole country	*Rural*	*Peri-urban*	*Urban*	*Whole country*	*Rural*	*Peri-urban*	*Urban*	*Whole country*	*Rural*	*Peri-urban*	*Urban*
Gender: female	-0.24 (0.20)	-0.43 (0.46)	0.07 (0.54)	-0.12 (0.35)	-0.24 (0.16)	-0.27 (0.24)	0.06 (0.40)	-0.06 (0.33)	-0.26 (0.17)	-0.61** (0.27)	-0.10 (0.49)	0.12 (0.34)
Age	-0.01** (0.01)	0.09 (0.01)	-0.04** (0.02)	-0.03** (0.01)	-0.02*** (0.00)	-0.01* (0.00)	-0.02 (0.01)	-0.03*** (0.01)	-0.01** (0.01)	0.04 (0.00)	-0.04*** (0.02)	-0.03*** (0.01)
Household size	-0.23*** (0.04)	-0.04 (0.09)	-0.02 (0.10)	-0.36*** (0.07)	-0.21*** (0.03)	-0.25*** (0.05)	-0.16* (0.08)	-0.25*** (0.07)	-0.20*** (0.04)	-0.2*** (0.05)	-0.11 (0.11)	-0.24*** (0.07)
Income class: middle	1.69*** (0.23)	1.91*** (0.47)	1.34** (0.61)	1.98*** (0.40)	1.44*** (0.17)	1.34*** (0.24)	0.65 (0.44)	1.90*** (0.38)	0.91*** (0.19)	1.10*** (0.27)	0.49 (0.56)	1.12*** (0.40)
Income class: upper	1.11*** (0.27)	0.73 (0.58))	1.31* (0.79)	1.63*** (0.48)	0.31 (0.22)	0.18 (0.34)	-0.18 (0.58)	0.95** (0.46)	0.489** (0.23)	0.64* (0.33)	0.60 (0.59)	0.82* (0.47)
Remittances	0.30 (0.22)	-0.03 (0.42)	0.25 (0.66)	0.59 (0.39)	0.45*** (0.16)	0.43** (0.22)	0.50 (0.41)	0.66* (0.38)	0.20 (0.18)	0.17 (0.24)	0.13 (0.50)	0.44 (0.39)
Settlement type: peri-urban	0.36 (0.31)	-	-	-	1.08*** (0.21)	-	-	-	1.06*** (0.25)	-	-	-
Settlement type: urban	2.77*** (0.25)	-	-	-	2.87*** (0.19)	-	-	-	3.16*** (0.20)	-	-	-
Education: primary	1.88*** (0.39)	1.40* (0.83)	0.76 (1.24)	2.09*** (0.52)	1.29*** (0.28)	1.00** (0.39)	0.97 (0.84)	1.50*** (0.47)	0.70*** (0.25)	1.14*** (0.42)	0.76 (0.85)	0.44 (0.43)
Education: secondary	2.93*** (0.41)	3.0*** (0.90)	1.60 (1.29)	2.90*** (0.58)	2.13*** (0.31)	1.72*** (0.44)	2.07** (0.89)	2.15*** (0.54)	0.99*** (0.29)	1.81*** (0.48)	0.35 (0.94)	0.50 (0.52)
Education: tertiary	3.77*** (0.52)	3.35*** (1.22)	2.52 (1.54)	4.88*** (1.13)	2.31*** (0.44)	1.90*** (0.64)	2.65** (1.14)	3.40*** (1.12)	1.30*** (0.45)	1.14 (0.86)	1.47 (1.27)	2.19* (1.13)
Electricity availability	5.95*** (0.52)	2.58 (2410.00)	4.23*** (0.82)	5.63*** (0.77)	0.99*** (0.18)	1.08*** (0.28)	1.32*** (0.39)	0.53 (0.33)	-0.43** (0.22)	0.03 (0.42)	0.35 (0.52)	-1.01*** (0.34)

Notes: Statistical significance level: *** = 1%, ** = 5%, * = 10%. Values in parenthesis represent standard errors.

4. Discussion

A variety of factors influence a choice of a particular energy fuel for certain household uses, as it has been observed in sections 3.2 and 3.3. The gender of the household head is, in large part, statistically insignificant for the energy fuel choice for cooking and water-heating. A possible explanation could be that, inasmuch as a household may be headed by a male, a woman within that household is likely to be the one that makes or influences the decision of the choice of energy fuel. This is because women are more likely to spend a lot of time in the house relative to men. These findings are in accord with the findings of Nlom and Karimov (2015) and Zou and Luo (2019), who established that gender of the household head has no significant impact on the choice of energy fuel used in a household.

In terms of age of the household head, the finding is that, generally, older household heads are less likely to use cleaner energy fuels than their younger counterparts for cooking and water-heating. This might be because older people are associated with reluctance to change and often adhere to their social norms. Moreover, it could be associated with a perception that is common among older household heads that energy fuel sources such as electricity and LPG are not safe to use and not readily accessible and affordable like traditional fuels (Gould and Urpelainen, 2018; Malakar, 2018).

Large households are less likely to prefer clean energy fuels to traditional fuels. The observed results are in line with the findings of Mensah and Adu (2015). This may be attributed to the fact that large households have enough labour for collecting traditional fuels as opposed to opting for paid energy fuels. These households are likely to have higher household energy demands than smaller households and hence traditional fuels become an attractive option because they are usually available at little or no monetary cost (Özcan et al., 2013a; Uhunamure et al., 2017a). However, when the model is re-estimated for rural settlements only and the peri-urban settlements only for water heating, household size is not significant for the choice of electricity over traditional fuels.

Predominantly, households in higher-income classes are more likely to choose clean energy fuels for cooking and water heating. Sehjpal *et al.* (2014) argue that households maximise their utility subject to constraints such as income and, as such, an increase in income may lead to the use of energy fuels such as electricity and paraffin. A similar view is shared by Arthur *et al.* (2010) and Couture *et al.* (2012), that poor households are most likely to rely on firewood for household energy use, especially in rural areas. These findings are in accord with the energy ladder model associating higher-income households with clean energy fuels.

Education is, on the whole, a key factor for the choice of clean energy fuels within households. An increase in the education level of household head raises awareness of the health and environmental impacts of using traditional fuel and therefore adoption of clean energy fuels (Behera et al., 2015a). However, if the settlements are disaggregated, education is not important for the choice of electricity over traditional fuels for cooking.

Access to electricity is also crucial for the adoption of clean energy fuels within households. These findings are in agreement with the findings of Rahut *et al.* (2014), who assert that an electricity connection is essential for households to adopt electricity. Electricity is associated with convenience and improved standard of living, hence households that are connected to the grid are likely to adopt clean energy fuels over traditional fuels. Adopting electricity within a household means that households can allocate more time to productive activities such as engaging in income-generating activities (Pueyo and Maestre, 2019). But in rural settlements, electricity availability is not enough for the choice of electricity over traditional fuels.

5. Conclusion and policy recommendations

Given the importance of understanding household energy-use patterns when formulating effective clean energy and climate change policies, this study analysed the determinants of the choice of household energy fuel in Lesotho, using the multinomial logistic regression and the data from Lesotho's national household energy consumption survey of 2017. The household energy uses were classified into cooking and water-heating. The study found that the gender of the household head played a limited role in the choice of energy fuel for cooking and water-heating across all settlement types, yielding similar results to those of Nlom and Kamirov (2015). However, the age of the household head negatively influenced the choice of cleaner energy fuels. This corroborates the findings of Gould and Urpelainen (2018) and Malakar (2018) that older people are unlikely to choose cleaner fuels because they are perceived to be unsafe. Furthermore, larger households preferred traditional fuels over clean fuels for cooking and water-heating across all settlement types relative to smaller households. This could be because they have enough manpower for the collection of traditional fuels.

As predicted by the energy ladder model, income and remittances also played an important role in the choice of energy fuel. Households in higher-income classes and the ones receiving remittances are more likely to choose cleaner energy fuels. Education is also observed to be an important determinant of the use of clean fuels. This is in agreement with a couple

of studies (Rahut *et al.*, 2014; Behera *et al.*, 2015; Guta, 2018; Acharya and Marhold, 2019), because the awareness of educated household heads that clean energy fuels are better for the welfare of the household contributes to choosing them. Lastly, electricity availability positively influenced the choice of clean energy. However, electricity is hardly chosen for cooking or water-heating in rural settlements.

The findings of this study have important policy implications. For instance, policies aimed at promoting household income-generating opportunities, effective provision of access to electricity, and investment in education can be pursued as they can influence the choice of clean energy use within households. Nonetheless, these policies must be tailor-made according to the unique characteristics of different settlement types. In the case of energy access policy formulation such as electrification master plans, cheaper alternatives to grid extension such as mini-grids, solar home systems, and improved cookstoves should be explored for the provision of clean energy in households across different settlement types.

In 2019, Lesotho introduced an electricity lifeline tariff for households for the first 30 kWh/month to meet the energy needs of the poorest of the poor (LEWA, 2019). This pro-poor policy was designed to counter the decreasing average household consumption in the country by encouraging the use of electricity for cooking and water-heating. Therefore, as an area of further research, it would be important to assess the determinants of the choice of energy fuel under this policy. The policy may have an influence on the determinants of energy choice especially in the rural settlements where electricity is hardly chosen for cooking and water-heating.

Author contributions

Matsoso Mothala: Writing original draft, formal analysis
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Moeketsi Mpholo: Review and editing

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References

Acharya, B., & Marhold, K. (2019). Determinants of household energy use and fuel switching behavior in Nepal. *Energy*, *169*, 1132–1138.

Alfredsson, E., Bengtsson, M., Brown, H. S., Isenhour, C., Lorek, S., Stevis, D., Vergragt, P. (2018). Why achieving the Paris Agreement requires reduced overall consumption and production. *Sustainability: Science, Practice and Policy, 14(1),* 1-5.

Amoah, S. T. (2019). Determinants of household's choice of cooking energy in a global south city. *Energy and Buildings*, *196*, 103–111.

Arthur, M. de F. S. R., Zahran, S., & Bucini, G. (2010). On the adoption of electricity as a domestic source by Mozambican households. *Energy Policy*, *38*(11), 7235–7249.

Bamiro, O. M., & Ogunjobi, J. O. (2015). Determinants of household energy consumption in Nigeria: Evidence from Ogun State. *Research Journal of Social Science and Management*, *04*(12), 7.

Behera, B., Rahut, D. B., Jeetendra, A., & Ali, A. (2015). Household collection and use of biomass energy sources in South Asia. *Energy*, *85*, 468–480.

BoS. (2019). *Bureau of statistics*. Bureau of Statistics. http://www.bos.gov.ls/.

Brooks, C. (2008). *Introductory econometrics for finance* (Second Edition). Cambridge University Press.

Cameroon Data Portal. (2019). *Census data*. Knoema. Available at: http://cameroon.opendataforafrica.org//rfdefze/census-data (Accessed: 10 June 2020).

Couture, S., Garcia, S., & Reynaud, A. (2012). Household energy choices and fuelwood consumption: An econometric approach using French data. *Energy Economics*, *34*(6), 1972–1981.

Ekholm, T., Krey, V., Pachauri, S., & Riahi, K. (2010). Determinants of household energy consumption in India. *Energy Policy*, *38*(10), 5696–5707.

Gould, C. F., & Urpelainen, J. (2018). LPG as a clean cooking fuel: Adoption, use, and impact in rural India. *Energy Policy*, *122*, 395–408. https://doi.org/10.1016/j.enpol.2018.07.042.

Guta, D. D. (2018). Determinants of household adoption of solar energy technology in rural Ethiopia. *Journal of Cleaner Production*, *204*, 193–204.

Ezzati, M., Kammen, D. M. (2002). Household energy, indoor air pollution and health in developing: Knowledge base for effective interventions. *Annual Review of Energy and the Environment*, 27, 233-270.

Hiemstra-van der Horst, G., & Hovorka, A. J. (2008). Reassessing the "energy ladder": Household energy use in Maun, Botswana. *Energy Policy*, *36*(9), 3333–3344.

Lee, D. (2013). A comparison of choice-based landscape preference models between British and Korean visitors to national parks. *Life Science Journal*, *10*(2), 2028–2036.

Letete, T., Matuszewska, E., Stevens, L., Mahlase, H., & Ntshalintshali, P. (2019). *Lesotho's 4th national GHG inventory: 2011-2017*. Ministry of Energy and Meteorology - Lesotho Meteorological Services.

LEWA. (2018). *Lesotho electricity and water Authority - Annual report 2017/18* (p. 84). Lesotho Electricity and Water Authority (LEWA).

LEWA. (2019). *Lesotho electricity and water authority annual report 2018/2019*. Lesotho Electricity and Water Authority (LEWA).

Malakar, Y. (2018). Studying household decision-making context and cooking fuel transition in rural India. *Energy for Sustainable Development*, *43*, 68–74.

Masera, O. R., Saatkamp, B. D., & Kammen, D. M. (2000). From linear fuel switching to multiple cooking Strategies: A critique and alternative to the energy ladder dodel. *World Development*, *28*(12), 2083–2103.

Mekbib, S. B., Olaleye, O. A., Mokhothu, M. N., Johane, M., Tlali, S. B., Godeto, W. T. (2011). *Assessment on the adaptive capacity of the Machobane Farming System to climate change in Lesotho.* African technology policy studies network. Nairobi. Kenya

Mensah, J. T., & Adu, G. (2015). An empirical analysis of household energy choice in Ghana. *Renewable and Sustainable Energy Reviews*, *51*, 1402–1411.

Mpholo, M., Meyer-Renschhausen, M., Thamae, R. I., Molapo, T., Mokhuts'oane, L., Taele, B. M., & Makhetha, L. (2018). Rural household electrification in Lesotho. In Moeketsi Mpholo, D. Steuerwald, & T. Kukeera (Eds.), *Africa-EU Renewable Energy Research and Innovation Symposium 2018 (RERIS 2018)* (pp. 97–103). Springer international publishing.

Nasir, Z. A., Murtaza, F., Colbeck, I., (2015). Role poverty in fuel choice and exposure to indoor air pollution in Pakistan. *Journal of Integrative Environmental Sciences*, *12(2*), 107-117.

Nlom, J., & Karimov, A. (2015). Modeling fuel choice among households in Northern Cameroon. *Sustainability*, *7*(8), 9989–9999.

Onoja, A. O., & Idoko, O. (2012). Econometric analysis of factors influencing fuel wood demand in rural and peri-urban farm household of Kogi state. *Consilience: Journal of Sustainable Development*, *8*(1), 115–127.

Özcan, K. M., Gülay, E., & Üçdoğruk, Ş. (2013). Economic and demographic determinants of household energy use in Turkey. *Energy Policy*, *60*, 550–557.

Pueyo, A., & Maestre, M. (2019). Linking energy access, gender and poverty: A review of the literature on productive uses of energy. *Energy Research & Social Science*, *53*, 170–181.

Pundo, M., & Fraser, G. (2006). Multinomial logit analysis of household cooking fuel choice in rural Kenya: A case of Kisumu District. *Agricultural Economic Research, Policy and Practice in Southern Africa*, *45*(1), 24–37.

Rahut, D. B., Behera, B., & Ali, A. (2016). Patterns and determinants of household use of fuels for cooking: Empirical evidence from sub-Saharan Africa. *Energy*, *117*, 93–104.

Rahut, D. B., Das, S., De Groote, H., & Behera, B. (2014). Determinants of household energy use in Bhutan. *Energy*, *69*, 661–672.

Sehjpal, R., Ramji, A., Soni, A., & Kumar, A. (2014). Going beyond incomes: Dimensions of cooking energy transitions in rural India. *Energy*, *68*, 470–477.

Trac, C. J. (2011). Climbing without the energy ladder: Limitations of rural energy development for forest conservation. *Rural Society*, *20*(3), 308–320.

Uhunamure, S. E., Nethengwe, N. S., & Musyoki, A. (2017). Driving forces for fuelwood use in households in the Thulamela Municipality, South Africa. *Journal of Energy in Southern Africa*, *28*(1), 25.

World Bank. (2019). Lesotho poverty assessment - progress and challenges in reducing poverty. World Bank Group.

Zou, B., & Luo, B. (2019). Rural household energy consumption characteristics and determinants in China. *Energy*, *182*, 814–823.

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