Assessing the Determinants of Rural Energy Transition in Cameroon

[1*]Nguiffo J.S. & [2]Etoa E.B
[1]Faculty of Economics and Management, University of Yaoundé II Cameroon
[2]Rector University of Ebolowa, Cameroon
*Corresponding author: salomonjoelnguiffo@yahoo.fr

Received: 8/08/2024 **Revised: 20/09/2024** **Accepted: 31/09/2024**

The demand of energy in rural Cameroon has been mainly met by traditional energy sources despite the availability of health and environmentally friendly clean energy options internationally. This study empirically analyses the determinants of the rural energy transition in Cameroon. The data used in this study come from the National Institute of Statistics (INS), namely ECAM (Enquête Camerounaise auprès des ménages) 3 and 4, and we therefore first resorted to the Markov Transition Matrix in order to estimate the probabilities of transition between the different states of energy well-being, and secondly to an ordered logistic regression in order to highlight the determinants of these different transitions. The results show us firstly that there is a strong transition between the states of energy well-being (the rate of sedentarization for the period 2007-2014 is 32.97%). The positive transition rate is 55.43%, while the negative transition rate is 11.6%. We can therefore conclude that there were more positive transitions than negative transitions. Secondly, it shows that the energy transition of rural households in Cameroon is linked to the characteristics of the household, the quality of service, the status of housing, the initial situation of the household, and finally the level of household income. Based on these results, we recommended Cameroonian Government to bring electricity production and distribution points closer to rural populations through a decentralized approach, and to ensure the good quality of energy services offered by the national operator.
Keywords: Energy Transition, Transition Matrix, Logit Model, Markov Chain

https://dx.doi.org/10.4314/etsj.v15i2.10

Introduction

All phases of human history depend on any known form of energy for survival and prosperity (Smil, 2019). The importance of energy for livelihoods, well-being and prosperity is evident from the continued increase in per capita energy consumption, particularly over the last century; International Energy Agency (IEA, 2021). Along with the industrial and transportation sectors, energy is crucial for cooking, heating and lighting in the residential sector. Therefore, ensuring access to affordable energy is the priority of governments in both developed and developing countries. According to the IEA (2015), the lack of access to clean and affordable energy combined with a low level of income drives households into energy poverty. Rising energy and housing costs for poor households have fuelled the energy policy debate in recent years. The availability of affordable, reliable and sustainable energy services is essential for maintaining well-being, which is also a prerequisite for achieving SDG7 (Sustainable Development Goal number 7) and other specific SDGs. The problem of access to energy has become a crucial issue in public development policies in recent years; in 2013, 1.2 billion people did not have access to electricity (IEA, 2015).

Globally, around 2.4 billion poor people still cook with open fires or inefficient stoves fuelled by biomass and coal, contributing to around 3.2 million deaths a year from inhaling harmful fumes (World Health Organization (WHO), 2022). In addition, studies have warned that the use of traditional solid fuels has particularly created a heavy burden of time and physical effort for women in poor rural areas (Adanguidi *et al.*, 2020). Even though the energy transition, fuel poverty and energy equality are three different issues that require in-depth consideration, they are essentially interdependent, particularly in developing countries. While the energy transition reflects shifts towards (relatively) higher use of clean energy, energy poverty generally refers to lack of access to clean energy and reliance on the tradition of burning solid biomass to meet energy needs. Energy inequality indicates that access to (clean) energy is unfairly distributed among different population groups. As indicated by the UN (2018), the links between energy transition, energy poverty and energy inequality from the perspective of developing countries are of particular concern, as it is often the poorest who end up paying a disproportionate share of their income for energy. Therefore, improving access to clean energy sources for the poor is important because of its potential to increase income for this group. Furthermore, access to energy will do nothing to reduce poverty if it is not affordable for the lowest income households.

Around a quarter of the world's population still relies on traditional solid fuels to meet their energy needs for cooking, lighting and heating (Amegah & Jaakkola, 2016; IEA, 2020). Sub-Saharan Africa (SSA) represents a significant portion of this population. About 66% of households in the region use traditional solid fuels to meet their basic energy needs and are exposed to adverse health and environmental risks (Piabuo & Puatwoe, 2020). In Cameroon, in general, the dynamic of demand comes up against the insufficiency of available supply and results in a lack of access to electricity mainly in rural areas (World Bank, 2021). According to the 4th Cameroonian Household Survey (ECAM 5), the rate of access to electricity in 2021 is 95.9% in urban areas compared to 35.1% in rural areas. Also, the sources of energy in rural areas are mainly traditional (fossil fuels) and the distribution of households according to the source of lighting shows us that 29.5% of households in rural areas use kerosene for lighting. The average household consumption expenditure (in FCFA) on electricity is 55,846 in urban areas compared to 11,855 in rural areas, whereas the average household consumption expenditure on fuel is 31,934 in urban areas compared to 66,299 in rural areas.

The literature on the household energy transition from traditional to modern fuels in developing countries has evolved and provides relevant insights into household fuel selection behaviour. The analysis of household fuel switching behaviour is best understood through the concept of an energy ladder model, (Heltberg, 2005). As described by Van der Kroon *et al.* (2013), the energy ladder model is based on the assumption that households will switch to modern fuels such as electricity and gas when their economic situation improves. The climb up the energy ladder is linear as households move away from previous fuels and technologies that are generally inefficient, impractical and environmentally unfriendly. Most empirical studies supporting energy ladder theory cite income as the primary driver of fuel switching.

Several studies have investigated the factors influencing household energy transition in developing countries in Asia, Latin America and Africa. An example is that of Aklin *et al.* (2018) who studied the determinants of solar microgrid usage in rural India and found that household spending and savings are strong predictors of technology adoption. Similarly, Behera *et al.* (2016) explored the pattern and determinants of household fuel transition for cooking and lighting in African countries such as Ethiopia, Malawi and Tanzania. They concluded that female-headed households, household heads with higher education levels, urban and affluent households are more likely to use modern energy sources such as electricity and gas. These studies mostly focus on the characteristics of rural households for population, economy, education, etc. The “fuel stacking” hypothesis admits that household income plays a crucial role in household energy choice. Zou and Luo (2019) and Wang *et al.* (2012) indicated that rural labour migration drives fuelwood substitution. There are also other household characteristics that have been concluded to be drivers of transition to modern energy in rural households, namely: household economic characteristics, such as income, and housing (Arora & Jain, 2016; Ding *et al.*, 2019; Xie *et al.*, 2020). The characteristics of the household population, such as the gender and age of the household head, and the level of education (Baul *et al.*, 2018; Behera *et al.*, 2015). And social characteristics of households, such as cultural traditions and traditional consumption habits of indigenous communities (Jiang *et al.*, 2020a; Ping *et al.*, 2013).

The objective of this study is to highlight the main factors explaining the rural energy transition of households in Cameroon. This concern reinforces the interest of this study which can be understood at three levels: Firstly, to our knowledge, there is limited studies on the rural energy transition in Cameroon, this reflection therefore enriches the empirical literature in this regard. Secondly, this study evaluates the determinants of the energy transition as in previous studies but considers new determinants (quality of energy services and the initial energy situation of the household). And thirdly, methodologically, we use a dynamic approach based on the Markovian model (transition matrix). The transition matrix tells us the probability for a household to switch from traditional energy to modern energy (positive transition), to remain in the same state (sedentary), or to switch from modern energy to traditional energy (negative transition). This matrix is very important in well-being analysis because it precisely shows the evolution of household well-being states (Hodounou *et al.*, 2010). Also Ordered logistic regression will allow analysis of the explanatory factors of the different transition movements.

This article is organized as follows: section 2 provides a theoretical and empirical overview of the literature, section 3 explains the data and the methodology used, section 4 presents and discusses the results, and section 5 provides conclusion.

Literature Review

Energy scale and energy stacking

Although there is no universally accepted definition, energy transition is generally understood as a change leading to increased access and use of clean energy sources, such as gas and electricity, and to a reduction in dependence on traditional energies, such as coal and biofuels (Berkhout *et al.*, 2012). Historically, the world has seen many changes in energy consumption. Typical examples include the shift from traditional energy sources such as biomass to fossil fuels such as coal, and then from fossil fuels to cleaner energy sources such as electricity (Pachauri & Jiang, 2008; Fouquet, 2010). In the literature, there are two main hypotheses relating to the energy transition, namely energy scale and energy stacking. The energy ladder model is based on consumer theory that as income increases or decreases, households not only consume more or less of the same goods, but they also shift toward consuming higher or lower quality goods (Hosier & Dowd, 1987). Traditional fuels such as firewood and straw are considered inferior goods for relatively high-income households, but normal goods for low-income households.

The energy ladder model assumes that households have an ordered preference for different energy sources with respect to cleanliness, convenience, versatility, and efficiency. Based on household income, the energy ladder model describes a three-step linear switching process. The first stage involves a heavy reliance on biomass fuels, while in the second stage households turn to "transitional" fuels involving the use of kerosene, coal and charcoal, and in the third step, they move on to the use of gas, natural gasoline, and electricity, which is a function of increases in household income, and other factors such as deforestation and urbanization (Inayatullah *et al.*, 2011). This model has two major limitations. First, the energy transition is described as unidirectional and linear. In other words, the energy transition is the complete replacement of one energy by another. Second, his assumption that only one specific energy is used for a particular purpose ignores the fact that multiple energies are employed for a given purpose.

However, the simple nature of the energy ladder model emphasizing income wealth and substitution as a determinant of household fuel choice has been criticized by many studies (Heltberg, 2005; Masera *et al.*, 2000; UNDP/ESMAP, 2003) for its hypothesis that as household income increases, the household shifts from traditional fuel consumption to modern clean fuels that it can afford. In response to these limitations of the energy ladder model, the energy stacking model hypothesizes that households use a portfolio of energy sources even if they have different income levels. The difference between energy portfolios is reflected in the variety of energy sources and their corresponding proportions in total energy. Therefore, moving up the energy ladder does not mean completely abandoning an energy (Han *et al.*, 2018), and energy transition does not necessarily involve a gradual movement from one energy to another (Mensah & Adu, 2015). In this regard, the energy transition results in changes in the use of energy sources and their shares in total energy consumption is influenced by various factors representative of the socio-economic situation.

Determinants of energy transition

Previous studies on the determinants of rural household energy transition can be divided into two categories. The first category of these studies mainly studies the macro-perspective determinants of the rural residential sector by applying official statistics for specific provinces or countries. For example, based on Chinese province-level panel data for the period 1991–2014, Han *et al.* (2018) concluded that per capita disposable income, number of motorcycles, number of firewood-efficient stoves, price of advanced commercial energy, household size, education level and number of Rural energy management institutions are the underlying drivers of the energy transition of rural households. Based on national statistics, Li *et al.* (2019) found that the economic foundation and accessibility of commercial energy play an important role in the transition process from non-commercial to commercial energy in rural China. Yawale *et al.* (2021) explored the historical characteristics of energy transition and consumption patterns in rural and urban households in India and found that per capita income and urbanization are the most important drivers of energy transition in households. There are also similar studies on the factors of energy transition of rural households in Japan and in China (Han *et al.*, 2022; Zhao *et al.*, 2021) and Sub-Saharan Africa (Nnaemeka *et al.*, 2022). The macro literature is not sufficiently comprehensive, but nevertheless allows us to lay the theoretical foundations for understanding the factors of the energy transition of rural households for large-scale areas of research. However, the data used in these studies represent the overall characteristics of the whole province or country and hide huge disparities in each geographical unit that are widely appreciated for their strong correlation with energy sources and energy expenditure (Ma *et al.*, 2019). In addition, energy behaviour and energy consumption decision for rural areas mainly depend on the cognition of rural residents. Therefore, it is necessary to conduct more empirical studies on the factors that determine the energy transition of rural households for the location or representative rural areas from the perspective of rural households (Zou & Luo, 2019).

To overcome the limitations of macro-level studies, another group of studies explored the drivers of rural household energy transition from the micro perspective by applying survey data for a particular area, such as rural regions to Ghana (Ankrah & Boqiang, 2020), urban and rural areas of Sub-Saharan Africa (Nnaemeka *et al.*, 2022), mangrove areas of Ramsar sites in Benin (Adanguidi *et al.*, 2020) and Chittagong in Bangladesh (Baul *et al.*, 2018). The factors of these micro-studies mainly focused on the characteristics of rural households for population, economy, education, etc. The fuel stacking hypothesis admits that household income plays a crucial role in household energy choice. Johanna & al, (2019), indicated that rural labour migration drives fuelwood substitution. There are also other household characteristics that have been found to be drivers of modern energy use in rural households: household economic characteristics, such as income, (Papada & Kalimpakos, 2018; Recalde *et al.*, 2019; Castaño¬Rosa *et al.*, 2020; Oliveras *et al.*, 2021), housing and cooking (Arora & Jain, 2016; Ther *et al.*, 2022; Yibeltal *et al.*, 2021). Characteristics of the household population, such as the gender and age of the household head (Bollino & Botti, 2017; Bouzarovski & Tirado-Herrero, 2017; Primc *et al.*, 2019; Oliveras *et al.*, 2021), and the level of education (Baul *et al.*, 2018; Behera *et al.*, 2016; Primc *et al.*, 2019; Ogwumike & Ozughalu, 2016; Tabata & Tsai, 2020). Household social characteristics, such as cultural traditions and traditional consumption habits of indigenous communities (Jiang *et al.*, 2020a; Ping *et al.*, 2013). Researchers have continued to study the determinants of energy transitions for lighting and cooking, with a focus on key demographic variables such as income (Mottaleb *et al.*, 2017; Farsi *et al.*, 2007), fuel price (Alem *et al.*, 2016), gender of household head (Bensch *et al.*, 2017) and education (Rahut *et al.*, 2017). The results also confirm the importance of political or institutional variables such as accessibility (Rahut *et al.*, 2017) and property rights (Joshi & Bohara, 2017).

However, it seems that these micro-studies from the point of view of rural households have not taken into account the initial energy situation of the household and the quality of energy service provided on the energy transition of rural households. The research by Li *et al.* (2019) clearly pointed out that rural residents rely heavily on non-commercial energy, as unavailability includes inaccessibility of energy and unaffordability of commercial energy. Many researchers have also confirmed that the convenience of energy access in South Africa for example (Muazu *et al.*, 2020) and energy supply in Ethiopia (Yibeltal *et al.*, 2021) can have a significant impact on residents' energy consumption decisions. In this respect, it is essential to propose an analytical framework to explore the determinants of the energy transition of rural households, taking into account the initial energy situation of the household and the quality of service offered by electricity suppliers.

Research Methodology

Data source

The data used in this study come from the Cameroonian Household Survey (ECAM 3 and 4) carried out by the National Institute of Statistics (INS) in 2007(initial year) and 2014(final year), as Ecam 5 data is not yet available. This survey covered 11,391 and 10,303 households respectively. (with 5,026 and 4,839 households in rural areas). To obtain our data (4000 households in 2007 and 2014) we carried out simple random sampling, which consists of randomly selecting a sample of size *"n"* so that all individuals have the same probability of being selected. We randomly sampled from the ECAM 3 and 4 databases (5,026 and 4,839 households in rural areas for 2007 and 2014) a population of individuals at random, so that all individuals had the same probability of being sampled, and they are independent of each other. To obtain our 4000 households, we randomly used the STATA 17 software by executing the command: "****SIMPLE RANDOM SURVEY, sample 4000, count*". We chose 4,000 households to ensure that the sample was as representative as possible. The data was sent to us by email by the IT department

The Markov chain

A Markov chain is a sequence of random variables, mathematically, a Markov chain on a state space E is a process (X_n) such that: For any state i of E, the event $X_{n+1=}$ i depends only on the state in which the process was at time n. (the future only depends on the present moment). The Markov process is said to be a memoryless process. The probability of moving from state i to state j does not depend on time n. In our study we will consider $E = \{e_i\}$ *, i = 1, 2, …r,* the set of energy well-being states of a household. By construction, the states are ordered and we have:$e_1, e_2, \dots, e_r$ (and reads: e_1 comes before $e_2$etc.), in other words, the state e_2 tracks status e_1, status e_3 tracks status e_2 ; and more generally, the state e_i, follows the state e_{i-1}. Thus, a household which is classified e_i *has* a better energy situation than one classified e_{i-1}. The level of energy well-being achieved by a household is a random phenomenon. When a household moves from one state e_i *to* another state e_{i-1} due to the deterioration of its energetic situation, it is said that it has made a negative change of state (or a negative transition); otherwise, we speak of a positive change of state (or a positive transition).

Let $E = \{ e_i, \}$ *, i = 1, 2, …r,* be the set of energy well-being states of a household; we will therefore have the different ordered states as follows:

Very energy poor households (E1): these are households that use traditional energy sources for lighting such as kerosene lamps, candles, etc.

Energy poor households (E2): these are households using generators, battery-powered lamps, car batteries for lighting. We have classified them in this state given the cost linked to the purchase and maintenance of this equipment, also their limited energy production capacity and the noise pollution for some.

Moderately energy rich households (E3): these are households with a connection to the electricity networks (central network - Electric energy is produced and distributed in the network by renewable or non-renewable sources in rural areas.), with an ENEO meter. Here the voltage is good for lighting and domestic use.

Energy-rich households (E4): these are households using DRE systems from renewable energy sources, such as domestic solar systems, and mini electrical networks whose community has a certain autonomy in the management of the network and benefiting from the support and expertise of the State and the private operator, generally limiting the technical and financial aspects.

In order to classify these different states (E1, E2, E3, and E4), not only did we take into account access to energy but also the quality of energy services.

The transition probabilities are the elements of the matrix $P = (P_{ij})$, *i=1, r and j= 1,… r* ; in general, when the transition probabilities are stationary, Anderson and Goodman (1957, p. 92) and Basawa and Prakasa Rao (1980, p. 54) show that the estimator of P_{ij} by the maximum likelihood is defined by :

$$P_{ij} = \frac{n_{ij}}{n_i}$$

With**:**

n_{ij} **:** the total number of households moving from class *i* at period t_{-1} at class *j* at period *t*. n_i : the total number of households in the class *j* on the *T* transitions, i.e.:

$$n_i = \sum_j n_{ij}$$

This model has been used by Hodounou (2010), on the dynamics of poverty in Benin, also, by Eliana *et al.* (2020) to model sequences and duration as a function of social household vulnerability.

Model specification

The analysis of the determinants of the energy transition will make it possible to know the explanatory factors of household movements between different states of energy well-being. Let the variable Y be defined as follows to materialize the observed transitions:

Y= 0 if the household loses, 1 if the household is sedentary, 2 if the household wins

A household is said to lose if it makes negative transitions, that is to say transitions that are not favourable to it. A household is said to be sedentary if it makes no transitions, and a household is said to be a winner if it makes positive transitions, that is to say transitions that are favourable to it. The variable Y represents access to an energy source, which takes 0 if the household which had access to electricity on the initial date is no longer there on the final date, that is to say uses a traditional energy source like the kerosene lamp for example. It takes the value 1 if it remained in the same state between the two periods, and it takes the value 2 if the household which used a traditional energy source in the initial state finds itself in the final state with a modern energy source (electricity).

The multinomial and ordinal logit model was widely used in empirical modelling (McFadden, 1974), notably to study the choices of transport mode. It was applied a little later to decisions on the choice of the domestic energy source (Cohn, 1980), and the analysis of energy poverty (Tchereni *et al.,* 2013; Ogwumike & Ozughalu 2016). The variable Y thus defined will take naturally ordered values and, in this perspective, the ordered models will adapt well to the analysis of its determinants. Thus, in order to analyse the associations between these different transitions and the socioeconomic characteristics of households, we will use an ordered logit model whose form is estimated as follows: $y^* = x\beta' + \varepsilon$. Where: y* is the exact but unobserved dependent variable, β' is a vector of parameters to be estimated, x a vector of determinants linked to the household, finally ε is an error term distributed according to a logistic law. We further assume that, although we cannot observe y*, we can instead observe the response categories:

$$y = \begin{cases} 0 \text{ si } y^* \leq \mu_0 \\ 1 \text{ si } \mu_0 \leq y^* \leq \mu_1 \\ 2 \text{ si } \mu_1 \leq y^* \end{cases}$$

Where the parameters μ are the externally imposed extremities of the observable categories. Then ordered logistic regression will use the observations on y, which are a form of censored data on y*, to fit the parameter vector β '.

We therefore have the probability of carrying out the event y ϵ {0, 1, 2} of the dependent variable corresponding to the probability of belonging to the interval delimited by estimated points of intersection which corresponds to each of the modalities of the variable dependent (the endpoints μ). We obtain the following after simplification. The probability of y is given by:

Pr (y = 0) = Pr (0< −X β ')

Pr (y = 1) = Pr (U 1< −X β ') – Pr (0< −X β ')

Pr (y = 2) = 1− Pr (U 1< −X β ')

The error term Ui is assumed to be logistically distributed. The coefficients of the linear combination β ' cannot be consistently estimated using ordinary least squares. They are generally estimated using maximum likelihood.

Results

Analysis of the Markov chain

Table 1 shows us in the rural area, the different proportions of energy well-being of households. We note that the proportion of very poor energy households increased from 61.38% in 2007 to 30.32% in 2014, thus between these periods, 31.06% of households left the state of very energy poor. On the other hand, between 2007 and 2014 we note an increase in the proportion of 0.81% of households in the E2 state (energy poor), which went from 0.17% to 0.98%. We also note a 5.88% reduction between 2007 and 2014 of households in state E3, which fell from 34.3% to 27.32%. Finally, we note a sharp increase in the proportion of 37.23% of energy-rich households (E4), which rose from 4.15% in 2007 to 41.38% in 2014. This can be explained by the decentralized nature of off-grid generation which provides a proximity opportunity for households in rural areas to be closer to the source of electricity production and distribution and generally has the management largely at the disposal of the community. Also, the quality of service of the national electricity provider may be an explanatory factor of these different transitions towards the E4 state such as load shedding, power cuts, etc.

Table 1: Proportion (in %) of households according to rural energy well-being classes 2007-2014

Years	Energy well-being states (number of households)				Total
	Very poor (E1)	Poor (E2)	Medium (E3)	Rich (E4)	
2007	2455	7	1372	166	4000
2014	1213	39	1093	1655	4000
	States of energy well-being (%)				
2007	61.38	0.17	34.3	4.15	100
2014	30.32	0.98	27.32	41.38	100

Source: From ECAM 3 and 4

According to Table 2, the sedentary rate (remaining in the same state of energy well-being) for the period 2007-2014 is 32.97% (statistics from the model), which is explained by high mobility overall to move from 'one state of energetic well-being to another. We note high mobility of very poor, poor and middle households, and low mobility of rich households between 2007 and 2014, because only 31.65%, 0%, 28.57% and 90.36% remained respectively in the same position.

Between 2007 and 2014, 0.85% of households moved from very energy poor to energy poor, 28.07% and 39.43% moved from very poor to average and energy rich respectively. We also note that all those who were in poor condition moved positively and negatively in proportions of 57.14% (very poor), 28.57% (average rich), and 14.29% (rich condition). Still over this same period, we note respectively that 31.19% and 1.17% of households made negative transitions by leaving the state of moderately rich for the state of very poor and poor, and 39.07% are moved from the state of moderately rich to the state of rich. Finally, regarding the rich state, we note that 2.42%, 1.20% and 6.02% of households made negative transitions respectively for the very poor, poor and moderately rich states. We can therefore conclude that there were more positive transitions (55.43%) than negative transitions (11.6%).

Table 2: Transition matrix (in %) of households between different states of energy well-being over 2007-2014

2007	States of energy well-being 2014				TOTAL
	E1	**E2**	**E3**	**E4**	
E1	**(31.65)**	0.85	28.07	39.43	100
E2	57.14	**(0)**	28.57	14.29	100
E3	31.19	1.17	**(28.57)**	39.07	100
E4	2.42	1.20	6.02	**(90.36)**	100

Source: From ECAM 3 and 4

Descriptive statistics

The table presents the variables retained for this study, we have: socio-economic variables (gender, age of the head of household, income, professional situation and level of education of the head of household). Variables linked to housing status, the initial situation of the household and the quality of energy services.

Table 3: Descriptive statistics of variables

Variable	Obs	Mean	Std. dev .	Min	Max
Household size	4,000	4,588	3.076544	1	41
Sex CM	4,000	1,279	.4485636	1	2
Age CM	4,000	44.148	.1126686	11	99
CM inst level	4,000	2.20975	1.216809	1	5
Housing type	4,000	2.83925	1.373638	2	9
Quality of service	3,028	1.629377	1.341348	1	9
Household income	4,000	277411.4	188824.1	8000	825516

Ordered logistic regression for the analysis of the determinants of the rural energy transition.

Transition movements from one state of energetic well-being to another can be explained by several factors which we will analyse subsequently. Overall, it can be concluded that the model is significant (the p value associated with the chi2 of the model is equal to 0.0000). The Hosmer-Lemeshow test is a statistical test of fit of the logistic regression model, a large value of its Chi2 with a small value of its P value indicates a poor fit of the model, and otherwise it indicates a good fit of the model. We therefore notice that in our case we have a small value of Chi2(4.18) associated with the Hosmer-Lemeshow test and its P-value (0.9721) is greater than 0.05, so our model is well adjusted. Still regarding the adjustment of our model, we can see that our log likelihood is quite high (log likelihood= -4031.3142), so our model is well adjusted. The econometric results being free from any endogeneity bias, they can therefore be interpreted.

Table 4: Ordered logistic regression for the determinants of the rural energy transition

Variables	Coef.
Household size	0.007*
	(0.028)
Sex CM	
Feminine	0.002
	(0.235)
Male	0.214**
	(0.561)
Age CM	-0.002*
	(0.006)
CM instruction level	
Unschooled	-0.144***
	(0.042)
Primary	0.318**
	(0.155)
Secondary	0.133
	(0.301)
Superior	-0.779
	(0.331)
CM activity situation	
Active	2,364***
	(0.098)
Unemployed	-2,881***
	(0.012)
Inactive	0.437
	(0.324)
Housing type	
Modern villa	0.003*
	(1,293)
Apartment building	0.343***
	(1,067)
Family concession	-0.136
	(0.163)
Isolated house	-0.367***
	(0.494)
Service quality	
Too far away	0.930**
	(0.963)
Poor quality of service	0.578**
	(0.705)
Currency of services	1,233***
	(3,074)
Too expensive	0.740***
	(1.012)
Lack of equipment	0.739***
	(0.943)
Initial situation	
Very poor	1,196***
	(0.670)
Poor	0.573**
	(0.468)
Moderately rich	-0.695***
	(0.066)
Rich	1,125
	(0.654)
Household income in FCFA	-5,090***
	(1,621)
Number of observations	4000
Hosmer- Lemeshow Chi2	4.18
Hosmer-Lemeshow P value	0.9721
Prob > chi2	0.0000
Log likelihood	-4031.3142

Note: ***, ** and * represent significance at 1%, 5% and 10% respectively. Numbers in parentheses are standard deviations.

Discussion

Table 4 shows the results of the econometric estimations of the ordered logit model. The results show that the size of the household has a positive effect on the energy well-being of households. This means that a household which is initially large has a greater chance of making positive transitions than a household initially small. In other words, the more household size increases, the more likely it is to make positive transitions. Regarding the gender of the head of household, we note that households headed by a man are more likely to have positive transitions than those headed by a woman. We also note that the age of the head of the household has a negative effect. Therefore, the older the head of the household, the more likely the household will face negative transitions. We can explain this situation by the fact that as age increases, the head of household becomes tired and opportunities narrow for him. This can have a negative impact on the household's income level and can cause negative transitions. These results confirm those of Bollino and Botti (2017) and Oliveras *et al.* (2021). According to the studies, the characteristics of the household (household size, gender of the head of household, etc.) can influence the energy situation of a household.

With regard to the level of education of the head of household, we find that households whose head has secondary or higher education have no influence on the transition of this household from one state to another. Households with a head who has no education are very likely to make negative transitions, and we note that only households whose head has primary education are likely to make positive transitions. This situation can be explained by the fact that, in rural areas, households generally do not go too far with their studies, which means that very few reach secondary or higher education, hence the fact that the *'secondary and higher'* modalities are not significant. We also note that the employment status of the head of household can influence transition movements. Thus, a household whose head is unemployed is more likely to make negative transitions or social demotions, whereas a household whose head is employed is more likely to make positive transitions or social promotions. On the other hand, households with an inactive head have no influence whatsoever on the various transitions. With regard to housing type, we note that the variables linked to households living in modern villas and flat blocks are positive and significant; these households are therefore more likely to make positive transitions. Conversely, those living in detached houses are more likely to make negative transitions, but the family concession variable in our case is not significant. These results confirm previous findings in the literature which have indicated that education, employment and housing status are associated with household energy poverty status (Primc *et al.*, 2019; Ogwumike & Ozughalu, 2016; Tabata & Tsai, 2020).

Regarding the quality of service offered by the national operator, we observe that the problem of distance, poor quality of service, pricing of services, overly expensive services, lack of equipment have a positive and significant effect in our model. In other words, they favour positive household transitions. This situation is explained by the fact that the quality of services offered to moderately rich households in state E3 (confers transition matrix results) have pushed 90.36 % of these households to transit to the upper rich state E4 (in this state electricity is produced in a decentralized way by individual system and by mini networks with a certain autonomy in management by the community). Concerning the initial situation of the household, we note that the households which in 2007 were in the states of very poor and poor are the most willing to make positive transitions, the moderately rich households are those having made more negative transitions, on the other hand the *"rich"* variable is not significant. Finally, the household income level is significant but negative, which means that the income level can lead households to make negative transitions. In other words, the low level of household income in rural areas in Cameroon can push some of them to make negative transitions or to remain in states of energy poverty, thus confirming the studies of (Papada & Kalimpakos, 2018; Recalde *et al.*, 2019; Castaño¬Rosa *et al.*, 2020).

Conclusion

For us in this study, it was a question of carrying out an analysis on the determinants of the rural energy transition in Cameroon. We first analysed the transition matrix of the energy well-being states of households in rural areas. Our results have shown that the sedentary rate for the period 2007-2014 is 32.97% which is explained by high mobility overall to move from one state of energy well-being to another, especially for very poor households, poor and middle. We finally notice a drop in the level of negative transitions for households located in the energy-rich state, we respectively have 1.04% for E1, 1.16% for E2 and 5.34% for E3. Finally, the econometric analysis of the determinants of the energy transition of rural households in Cameroon showed us that, in general, the movements of households between the different states of energy well-being are linked to the characteristics of the household, the sex of the head of the household, the initial situation of the household, the housing status, the level of education, the activity characteristics of the head of the household, the quality of service and the income level of the household.

This article makes a significant contribution in methodological, theoretical and empirical terms. Firstly, it enriches our understanding of the determinants of the rural energy transition by highlighting new determinants, namely the household's initial energy situation and the quality of energy service. This article is also among the first to quantitatively analyse the determinants of the rural energy transition in Cameroon using Markovian and ordered logistic modelling, which is rarely used in the literature to model the determinants of the rural energy transition.

It would therefore be important that the design of rural electrification policies in Cameroon must take into account these different parameters in order to ensure equitable and more sustainable development. To eradicate rural energy poverty in the years to come, it is therefore recommended that public authorities bring electricity production and distribution points closer to rural populations through a decentralized approach, promote access to education, to the job market, and improve income and housing supply policies in rural areas. Also, it is recommended to the Cameroonian Government to ensure that the national operator offers a better quality of energy services (by reducing load shedding, tension and currency problems, etc.), because the results showed that the transitions observed between 2007 and 2014 by rural households between different states of energy well-being are largely due to the quality of service provided by the national operator.

Like all research work, this study has certain limitations, in fact there are several other factors that could explain the rural energy transition in Cameroon which were not taken into account in our study. It would therefore be advantageous to complete this research by integrating into our econometric model, elements such as: the supply of rural electricity (level of access, production and distribution capacities, etc.), capital goods of households (household appliances, TV, computers, etc.), and the spatial dynamics of dispersion of rural energy demand (spatial autocorrelation) to analyze the determinants of the rural energy transition in Cameroon.

References

Alem, Y., Beyene, A., Ohlin, G, & Mekonnen, A. (2016). Modeling household cooking fuel choice: a panel multinomial logit approach. *Energy Econ.*, 59, 129 – 37.

Aklin, M., Chao, Y. & Urpelainen, J, (2018). Social acceptance of new energy technology in developing countries: A framing experiment in rural India. *Energy Policy*, 113, 466-477.

Amegah, K. & Jaakkola, L. (2016). Household air pollution and the sustainable development goals. National Centre for Biotechnology Information, Bull World Health Organ., 94(3), 215-221.

Anderson, T.W. & Goodman, L.A. (1957) Statistical Inference about Markov Chains. *The Annals of Mathematical Statistics*, 28, 89-110. https://doi.org/10.1214/aoms/1177707039.

Ankrah, I. & Boqiang, L. (2020). Renewable energy development in Ghana: beyond potentials and commitment. *Energy*, 198, 117356.

Arora, P. & Jain, S. (2016). A review of chronological development in cookstove assessment methods: Challenges and way forward. *Renewable and Sustainable Energy Reviews*, 55, 203-220.

Baul, T., Datta, D. & Alam, A. (2018). A comparative study on household level energy consumption and related emissions from renewable (biomass) and non-renewable energy sources in Bangladesh. *Energy Policy*, 114, 598-608.

Behera, H., Elise, G. & Hunter, B. (2016). Who's Paying Now? The Explicit and Implicit Costs of the Current Early Care and Education System. Economic Policy Institute.

Bensch, G., Peters, J. & Sievert, M. (2017). The lighting transition in rural Africa — from kerosene to battery-powered LED and the emerging disposal problem. *Energy Sustain Dev.*, 39, 13 – 20.

Berkhout, F., Marcotullio, P. & Hanaoka, T. (2012). Understanding energy transitions. *Sustain. Sci.*, 7, 109–111.

Bollino, C. A. & Botti, F. (2017). Energy Poverty in Europe: A Multidimensional Approach. *PSL Q. Rev.*, 70(283), 473–507.

Bouzarovski, S. & Tirado Herrero, S. (2017). The Energy Divide: Integrating Energy Transitions, Regional Inequalities and Poverty Trends in the European Union. *Urban Regional Stud.*, 24(1), 69–86.

Basawa, IY. & Prakasa Rao B.L.S. (1980). *Statistical Inference for Stochastic Process*. Londres.

Castano-Rosa, R., Solís-Guzman, J., Rubio-Bellido, C. & Marrero, M. (2020). Towards a multiple indicator approach to energy poverty in the European Union: a review. *Energy Build*, 193, 36 – 48.

Farsi, M., Filippini, M. & Pachauri, S. (2007). Fuel choices in urban Indian households. *Environ Dev Econ*, 12, 757 – 74.

Fouquet, R. (2010). The slow search for solutions: lessons from historical energy transitions by sector and service. *Energy policy*, 38(11) ,6586-6595.

Han, H., Wu, S. & Zhang, Z. (2018). Factors underlying rural household energy transition: a case study of China. *Energy Policy*, 114, 234–244.

Han, H., Xin, M., Bo, Z., Yong, W. & Wei, C. (2022). Forecasting short-term renewable energy consumption of China using a novel fractional nonlinear grey

Bernoulli model. *Renewable Energy,* 140, 70-87.

Heltberg, R. (2005). Factors determining household fuel choice in Guatemala. *Environ Dev Econ,* 10, 337–61.

Hodounou, A., Mededji, D., Gninanfon, A. & Astherve, T. (2010). Dynamique de la pauvreté au Benin: une approche de processus Markovien. *Document d travail PEP PMMA.*

Hosier, R. & Dowd, J. (1987). Household fuel choice in Zimbabwe. An empirical test of the energy ladder hypothesis. *Resource Energy,* 9, 337–361.

IEA (2015). *World Energy Outlook*. Paris: OECD/IEA.

IEA (2020). *World Energy Outlook*. Paris: OECD/IEA.

IEA (2021). *World Energy Outlook*. Paris: OECD/IEA.

Inayatullah, J., Khan, H. & Hayat, S. (2011). Determinants of rural household energy choices: an example from Pakistan. *Pol J Environ Stud,* 21(30), 635–41.

Jiang, L., Volker, K., Brian, C., Bas Van, R., Vaibhav, C., Vassilis, D., Jiyong, E., Yu, N., Shonali, P. & Xiaolin, R. (2020). Urban and rural energy use and carbon dioxide emissions in Asia. *Energy Economics,* 34, S272-S283.

Johanna, C., Pascale, M. & Leonard, R. (2019). Stacking up the ladder: A panel data analysis of Tanzanian household energy choices. *World Development,* 115, 222-235.

Joshi, J. & Bohara, A. (2017). Household preferences for cooking fuels and inter-fuel substitutions: unlocking the modern fuels in the Nepalese household. *Energy Policy,* 107, 507 – 23.

Ther, A., Pamela, J., Kay, T., Khin, K. & Wakako, K. (2022). City living but still energy poor: Household energy transitions under rapid urbanization in Myanmar. *Energy Research & Social Science,* 85, 102432.

Li, Q., Xiaojun, M., Changxin, W., Biying, D., Guocui, G., Ruimin, C., Yifan, L., Hongfei, Z. & Wenfeng, Z. (2019). Carbon emissions from energy consumption in China: its measurement and driving factors. *Science of the total environment,* 648, 1411-1420.

Ma, W., Lihan, L., Muhammad, H. & Sidra, S. (2019). Do economic policy uncertainty and financial development influence the renewable energy consumption levels in China? *Environmental Science and Pollution Research,* 1-10, 2021.

Masera, O., Saatkamp, B. & Kammen, D. (2000). From linear fuel switching to multiple cooking strategies: a critique and alternative to the energy ladder model. *World Dev.,* 28(12), 2083–103.

Mensah, J.T. & Adu, G. (2015). An empirical analysis of household energy choice in Ghana. *Renew. Sustain. Energy Rev.,* 51, 1402–1411.

Muazu, B., Ogujiuba, K. & Tukur, H. (2020). Biomass Energy Dependence in South Africa: Are the Western Cape Province households descending the energy ladder after improvement in electricity access? *Energy Reports,* 6, 207-213.

Mottaleb, K., Rahut, D. & Ali, A. (2017). An exploration into the household energy choice and expenditure in Bangladesh. *Energy,* 135, 767 – 76.

Nnaemeka, V., Emodi, E., Umoru, H., Nizam, A., Aldana, M., Michael, O. & Magnus, C. (2022). Urban and rural household energy transition in Sub-Saharan Africa: Does spatial heterogeneity reveal the direction of the transition? *Energy Policy*, 168, 113-118.

Ogwumike, F. & Ozughalu, U. (2016). Analysis of energy poverty and its implications for sustainable development in Nigeria. E*nviron Dev Econ.,* 21, 273 – 90.

Oliveras, L., Peralta, A., Palència, L., Gotsens, M., López, M. J. & Artazcoz, L. (2021). Energy Poverty and Health: Trends in the European Union before and during the Economic Crisis. *Health and Place*, 67, 102294.

Pachuari, S. & Jiang, L. (2008). The household energy transition in India and China. *Energy policy,* 36(11), 4022-4035.

Papada, L. & Kaliampakos, D. (2018). A Stochastic Model for Energy Poverty Analysis. *Energy Policy,* 116, 153–164.

Ping, W., Rahman, K., Akikur, R.S. & Khan, R. (2013). Comparative study of stand-alone and hybrid solar energy systems suitable for off-grid rural electrification: A review. *Renewable and sustainable energy reviews,* 27, 738-752.

Pubuo, S. & Puatwoe, T. (2020). Public health effect of firewood in Africa: bioenergy from forest products as a sustainable remedy. Public health in developing countries - challenges and opportunities.

Primc, K., Slabe-Erker, R. & Majcen, B. (2019). Building profiles of energy poverty for an effective energy policy. *Energy policy,* 128, 727-734

Rahut, D., Mottaleb, K., Ali, A. & Aryal, J. (2017). Energy consumption transition through the use of electricity for lighting and cooking: evidence from Bhutan. *Renew Energy Focus,* 18, 11 – 21.

Recalde, M., Peralta, A., Oliveras, L., Tirado-Herrero, S., Borrella, C. & Palència, L. (2019). Structural Energy Poverty Vulnerability and Excess Winter Mortality in the European Union: Exploring the Association between Structural Determinants and Health. *Energy Policy,* 133, 86-110.

Tabata, T. & Tsai, P. (2020). Fuel poverty in Summer: an empirical analysis using microdata for Japan. *Sci Total Environ,* 703, 135038.

UNDP/ESMAP (2003). *Access of the poor to clean household fuels in India*. Washington, D.C.: World Bank

Van Der Kroon, B., Roy, B. & Pieter, J. (2013). The energy ladder: Theoretical myth or empirical truth? Results from a meta-analysis. *Renewable and Sustainable energy reviews,* 20, 504-513.

World Bank (2011). *One goal, two paths: achieving universal access to modern energy in East Asia and Africa*. Washington DC: World Bank 2011. http://documents.worldbank.org/curated/en/281841468245390286/pdf/646690PUB0one000Box361543B00PUBLIC0.pdf.

Yawale, K., Hanaoka, T. & Kasha, M. (2021). Development of energy balance table for rural and urban households and evaluation of energy consumption in Indian States. *Renewable and Sustainable Energy Reviews,* 136, 110392.

Yibeltal, T.W., Meley, M.R., Muyiwa, S. & Adaramola, (2021). Determinants of household energy choices in rural sub-Saharan Africa: An example from southern Ethiopia. *Energy,* 221, 119785.

Zhao, P., Peter, J. & Andrew, K. (2021). Gouverner le secteur énergétique chinois pour atteindre la neutralité carbone. *Speed Green*, 56-66.

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