EFFECTS OF HOUSEHOLD ENERGY CHOICE ON HEALTH OUTCOMES OF WOMEN

MAUREEN NANJALA WANYONYI

X51/85750/2016

A RESEARCH PAPER SUBMITTED TO THE SCHOOL OF ECONOMICS, UNIVERSITY OF NAIROBI IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF DEGREE MASTERS OF ARTS IN ECONOMIC POLICY MANAGEMENT.

SEPTEMBER 2019

DECLARATION

I declare that this is my original work and has not been submitted for the award of a degree in any other university or institution.

MAUREEN NANJALA WANYONYI

X51/85750/2016

SIGNATURE ………………………………. DATE ……………………………………….

This paper is submitted for the award of the Degree of Master of Arts in Economics Policy Management with our approval as university supervisors.

DR. DANIEL MWAI

SIGNATURE ………………………………. DATE ……………………………………….

DEDICATION

I dedicate this work to the almighty, my creator, my source of inspiration, wisdom and understanding and my family members. The inspiration they gave me both in conceptualisation and motivation can never go unmentioned.

ACKNOWLEDGEMENT

I would like to acknowledge most sincerely my supervisor Dr. Daniel Mwai for the fourth write support and knowledge sharing in bringing this proposal to completion.

This research was partially supported by UN Women, Kenya National Bureau of Statistics and the University of Nairobi under the students grants programme. My appreciation also goes to all my lecturers who played a significant role by laying a solid foundation through my course work. I cannot thank Dr. Joy Kiiru enough for her immense support in capacity building for project implementation.

Lastly, I thank all my friends at home and in school for their encouragement and immense support.

TABLE OF CONTENT

DECLARATION ii

DEDICATION iii

ACKNOWLEDGEMENT iv

TABLE OF CONTENT v

LIST OF TABLES vii

ABSTRACT viii

CHAPTER ONE:INTRODUCTION 1

1.1 Background 1

1.2 Statement of the Problem 3

1.3 Research Questions 4

1.4 Research Objectives 4

1.5 Significance of the Study 4

1.6 Organization of the Study 5

CHAPTER TWO:LITERATURE REVIEW 6

2.1 Introduction 6

2.2 Theoretical Literature 6

2.2.1 The Energy Ladder Hypothesis 6

2.2.2 Fuel Stacking Hypothesis 8

2.3 Empirical Literature 8

2.4 Overview of the Literature 12

CHAPTER THREE:RESEARCH METHODOLOGY 14

3.1 Introduction 14

3.2 Theoretical Framework 14

3.3 Empirical Model 17

3.4 Data Source, Measurement and Description of Variables 19

CHAPTER FOUR:RESULTS AND DISCUSSION 22

4.1 Introduction 22

4.2 Summary Statistics 22

4.3 Econometric Results 25

4.3.1 The Determinants of Energy Choice in Kenya 25

4.3.2 The Impact of Energy Choice Mixes on the Health Outcomes of Women 27

CHAPTER FIVE:SUMMARY, CONCLUSIONS AND POLICY RECOMMENDATIONS 31

5.1 Introduction 31

5.2 Summary and Conclusion 31

5.3 Policy Implications 32

5.4 Limitations of the Study 33

REFERENCES 34

APPENDICES 37

Appendix 1: Correlation Matrix 37

Appendix 2: Maximum Likelihood Estimates 38

LIST OF TABLES

Table 3.1: Variables measurements and expected signs of the coefficients for the determinants of household energy choice....................20

Table 3.2: Variables measurements and expected signs of the coefficients for the effects of household energy choice on health outcomes....................21

Table 4.1: Summary statistics....................23

Table 4.2: Summary statistics of fuel expenditure....................24

Table 4.3: Multinomial Logit Marginal Effects of Determinants of Household Energy Choice 27

Table 4.4: Regression results of effects of energy choice on women health outcomes....................28

ABSTRACT

One of the most important areas of economic research is the determination of the factors that influence energy choice and the impact on health outcomes to help in process of formulating and adopting the relevant growth policies to the particular economy. Most empirical work on sources of economic growth for different countries has established that the use of traditional energy types has deleterious effects on health outcomes in any households. Adoption of biomass as a source of energy, has significant health implications, especially in poorly ventilated houses. When these fuels are burned in poorly ventilated rooms incomplete combustion occurs consequently exposing households to respiratory diseases. This paper aimed to examine the relationship between energy choice and health outcomes of women in the households given that in their traditional role as the cooks they are the most prone. The study adopted the multinomial logit and the logit regression models as its econometric approach. The study used the Kenya Integrated Household Budget Survey (KIHBS) dataset for period 2015/2016. The study found that household total expenditure, infrastructure, household size, household head's marital status and location as important determinants of energy choice in Kenya. Concerning the effect of the household energy mix on women's health outcomes in Kenya, the study established that women who use firewood were more probable of experiencing adverse health outcomes. Further, the study established that married women and those with better educational attainments had lower probability of experiencing adverse health outcomes from their choice of the energy mix. The policy implication of study findings is that there should be an intensification of programs that increase the income levels of households especially those in the village so that households' members can easily widen the scope from which they can choose their energy. Further, policies such as building the capacity of women by improving their educational attainments should be geared towards promoting of adoption of modern energy types to reduce the likelihood of women experiencing adverse health outcomes by using traditional energy fuels.

CHAPTER ONE

INTRODUCTION

1.1 Background

Globally, approximately three billion people are exclusively reliant on biomass as the main source of energy with the greatest proportion of the users being rural inhabitants. According to the International Energy Agency (IEA), 2.5 billion people in the developing economies living in the rural areas are reliant on biomass for their cooking energy needs, which is an indication of adverse environmental degradation within these regions which eventually lead to a disastrous effect on their well-being. More strikingly, biomass accounts about 95 percent of the domestic energy in developing economies and little progress is being made in the shifting away from biomass use and, in some cases, the little progress is getting reversed in households of the poor (WHO, 2017). In Sub-Saharan Africa, approximately 730 million people depend on these traditional types of energy for cooking with the numbers expected to reach over 900 million by the year 2020 if the current trend on biomass usage continues (Lambe, et al., 2015).

Within the East African region, at least 0.2 billion people have no access to electricity with 80 percent doing without electricity (African Energy Outlook, 2015). Stark regional differences exist in the household energy mix in Kenya with approximately 90 percent of households in rural localities and 7 percent of those in urban localities being reliant on traditional energy for cooking. Charcoal use stands at 47 percent nationally with 84 percent rural and 34 percent urban usage. Statistics further show that 92 percent of Kenyan households use kerosene. Despite the government's commitment to phase out Kerosene use by 2022, little efforts have been made despite time drawing closer. LPG and electricity use a source of energy consider to a prelude of the rich household's is used by only 7.8 percent of the households in both rural and urban localities (KNBS, 2007). According to KDHS (2014), over 70 percent of Kenyans are reliant on traditional energy types like Biomass, charcoal, Kerosene, among other unclean energy fuel.

Adoption of biomass as a source of energy, has significant health implications, especially in poorly ventilated houses. When these fuels are burned in poorly ventilated rooms incomplete combustion occurs consequently exposing households to respiratory diseases. In developing economies, women who customarily perform a lot of cooking, are highly exposed to air pollution that includes carbon monoxide and other pollutants from burning of biomass (see for example; Bruce, Perez-Padilla, and Albalak, 2000; Amegah and Jaakkola, 2016). Evidence suggests that use of biomass in households is linked to respiratory diseases, adverse pregnancy outcomes, cardiovascular diseases, lung cancer and cataracts (Lambe, et al., 2015) among other diseases. For instance, continued exposure to indoor air pollution leads to lower birth weight, pneumonia among under-5 children (Barnes, et al., 2009) and is considered to be among the leading causes of death among under-5 globally. According to Lewis, et al., (2015) air pollution within the household is one of the 4^{th} health risk globally, representing over 4 million deaths globally. In Sub-Saharan Africa, household air pollution is linked to at least 600, 000 deaths, half of the deaths occurring in under-five children (Lambe, et al., 2015).

Other than the health-related costs of air pollution within households, it is considered that biomass energy has pronounced effects on the overall economy. According to Limbe et al., (2015) using biomass for cooking presents an opportunity cost of over US$ 36.9 billion in Sub-Saharan Africa translating to a loss of 2.8 percent of the annual GDP, contributes to deforestation as it consumes at least 300 million tonnes of wood yearly. Further, the use of biomass also causes loss of productive time. In Sub-Saharan Africa, customarily women, who gather fuelwood, on average loss over 5 hours a day (Limbe et al., 2015) the effects are compounded by the risks of bites, falls and assault while gathering firewood for cooking?

1.2 Statement of the Problem

The International Energy Agency estimates that 2.5 billion people in the developing economies who live in the rural localities are reliant on biomass in order to sustain their energy requirements including cooking. This is informed by their low-income, the distance of the households from the biomass sources, increased biomass availability and unavailability of cheaper, efficient and better energy types in their locality. Literature supports the lasting effects of exposure on human health and labor productivity (Almond, 2006). As a result of biomass reliance 1.5 million IAP related deaths are reported (Duflo, Greenstone, and Hanna, 2008). The deleterious effects associated with biomass use for cooking and lighting particularly on health outcomes has led to international development agencies initiating interventions aimed at ensuring a switch from traditional to modern energy, for example from firewood to LPG, electricity or even solar.

There exists global evidence pointing to significant adverse impacts of use of solid fuel on health outcomes of women (see for example; Chay and Greenstone, 2003), however there is scanty evidence relating to developing countries, where IAP is the highest, (Ezzati, and Kammen, 2002; Mannucci, and Franchini, 2017). Consequently, lack of empirical evidence on the magnitude of the health loss due to exposure to IAP within the different socio-economic and demographic profiles of the developing countries hinders the ability to develop clear-cut policies to address this problem. This paper, therefore, aimed to fill this gap by examining the link between energy choice and health outcomes of women in the households given that in their traditional role as the cooks they are the most prone.

1.3 Research Questions

This paper sought to answer the following set of questions:

i. What are the main determinants of household energy choice in Kenya?
ii. What is the impact of household energy mix on women's health outcomes in Kenya?

1.4 Research Objectives

This study sought to analyze the effects of household energy choice on health outcomes of women. Specifically, the study sought to:

i. Analyze the main determinants of household energy choice in Kenya.
ii. Examine the impact of household energy mix on women's health outcomes in Kenya.

1.5 Significance of the Study

This study is important in three main ways. First, examining the main drivers of energy use among households in Kenya would offer policymakers robust evidence on how best to tailor policy interventions aimed at generating demand for modern energy products and ensure a switch of energy use from traditional to modern energy important for obtaining energy efficiency in the country. Efficient use of energy is critical because it reduces household expenditures on energy and mitigates the likelihood of household members suffering from respiratory diseases. Secondly, due to the deleterious effect of indoor air pollution that consequently lead not only to increased maternal and child mortality but also reduced household welfare, this study is an effort to bring to fore the urgent and most pressing desire to develop policies that ensure households within the lowest end of the energy ladder gradually transition to upper levels of the ladder. As such, extant discussions on the need of adopting clean energy need renewed focus and it becomes imperative to conduct analytical work on the nexus between energy use and health outcomes are imperative to guide policy discussions.

1.6 Organization of the Study

The rest of the paper is organized as; in Chapter 2, theoretical underpinning of the study and empirical literature that indicates existing gaps on the impact of household energy choices on health outcomes of women is reviewed. Chapter 3 discusses the theoretical framework and empirical model that the study adopted to examine the determinants of demand for household energy type and the effects of household energy choice on health outcomes of women. Chapter 4 presents data analysis, econometric results as well as the discussion of the study findings on the determinants of household energy choice in Kenya as well as the effects of the energy choice on the women health outcomes. Lastly, chapter 5 gives the summary and conclusion of the paper, policy implications and the limitations of the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This section examines the theories that explain the mechanisms in which households choose different energy types for cooking and the literature on the effects of energy choice on respiratory diseases in women.

2.2 Theoretical Literature

2.2.1 The Energy Ladder Hypothesis

The energy ladder hypothesis also called energy transition theory is the first hypothesis advanced in economic literature to explain household energy choices. According to Hossier and Dowd (1987), the energy ladder hypothesis describes the mechanisms on how households move from primitive energy types to much more advanced and sophisticated methods of cooking as their economic status improves. The hypothesis states that under the assumption of rational and utility-maximizing agents, households tend to maximize utility by transitioning from primitive energy to better and cleaner sources of cooking energy as income level increases.

The energy ladder hypothesis asserts that, at the lower level of the ladder, there's tendency for the households to use traditional energy cooking fuels such as biomass and firewood which are inexpensive, inefficient and more polluting (Masera, Saatkamp and Kammen, 2000). However, as household income rises, there's a tendency to transition from primitive energy types to more sophisticated and advanced fuels for cooking which are and less polluting, expensive., clean and efficient (Masera et al., 2010).

Mensah and Adu (2015) further note that in the energy ladder hypothesis, households progression from traditional, inefficient and high polluting fuels too much more sophiticated energy sources is linear and occurs in three main steps. In the first step, households predominantly depend on biomass for cooking. In this stage, households are unable to obtain higher efficient energy technologies due to low their low income levels. However, as the household income level increaeases, households transition to a second stage where they move from biomass to others such as stoves, charcoal and coal. Mensah and Adu (2015) argues that a further increaese in household income level enables the household to climb up to the highest ladder by acquiring the most advanced and modern energy types such as electricity. It is, however, worth to note that, the energy ladder hypothesis implies that households below the ladder who are poor often tend to experience high air pollution within their houses in comparison to those up to the ladder because of the energy type they use for cooking[1]. The energy ladder theory is constructed by comparing the use of energy for cooking by poor and wealthier households (Hossier and Dowd, 1987).

Advancement in research has however found the energy ladder hypothesis to be inefficient in explaining the mechanisms on how households use different energy types for cooking. Masera et al., (2010) argues that households do not switch from primitive to sophisticated energy for cooking in a linear fashion, but by use of a stacking strategy. The fuel stacking hypothesis avers that households rarely abandon even the most traditional mode of cooking when their income levels increases, but instead add more sophisticated cooking technologies to the initial traditional and old technologies (Masera et al., 2010). The theory provides that households change from traditional to

[1] The energy ladder theory is constructed by comparing the use of fuels for cooking by poor and wealthier households (Hossier and Dowd, 1987).

advanced fuels is not entirely discrete and stepwise. A similar assertion is made by Akpalu, Dasmani, and Aglobitse (2011) who notes that even though households are inclined to move towards more advanced energy for cooking, household energy substitution is not always fully complete particularly in developing economies.

2.2.2 Fuel Stacking Hypothesis

The fuel stacking hypothesis provides that household doesn't completely transition from one energy source to the other but instead use multiple fuels for heating and cooking. Masera et al., (2010) argues that the fuel stacking hypothesis is the most ideal theory that explains how households use different energy types for cooking. The theory allows households to enjoy and maximize fuel security as a result of the possession of all cooking technologies as they also use more efficient and advanced energy types.

The fuel stacking hypothesis provides that households use multiple fuels for cooking rather than a single fuel based on their socio-economic status. The theory provides that households stack different energy types even though their income level and economic status improve because of socio-cultural reasons and the unreliability in the supply of advanced cooking energy types such as LPG and electricity (Mensah and Adu, 2015).

2.3 Empirical Literature

Capuno, et al., (2018) examined the effects of cooking fuel choice on children's respiratory health in the Philippines using survey data. In the study, Capuno, et al., (2018) used the propensity score matching (PSM) methodology to establish the effects of cooking energy choices in respiratory diseases. PSM was used because Capuno, et al., (2018) sought to control for the systematic differences that could arise due to household self-selecting themselves on the use of different energy types for cooking. The study found out that there was a reduction of respiratory diseases in children by 2.4 percent when biogas, LPG, and electricity was used as energy for cooking.

In yet another study, Laxmi et al., (2003) examined the effects of household energy types on the women's health and time allocation. The study finds that the using biomass energy for cooking had adverse effects on increasing the likelihood of individuals suffering from respiratory diseases and eye illness. The results further showed that women spent a lot of time looking for fuel leading to losing productive time thereby negatively impacting on women's welfare.

In a slightly similar study, Burke and Dundas (2015) examined the effects of the using biomass energy for cooking on the labor force participation of females in 114 developing countries. By the use of panel data estimation techniques, Burke and Dundas (2015) find that the use of biomass energy greatly reduces the female's labor force participation. Biomass energy exerts huge opportunity cost in women participating in labor force activities due to the time lost in cooking and looking for solid fuels.

Edwards and Langpap, (2012) examined the impact of using of firewood for cooking on children's health in Guatemala. To measure the health effects of indoor air pollution (AIP) as a result of the use of firewood energy for cooking to children, the study used direct and indirect measures as proxies for health outcomes. Specifically, the study used a binary response variable that captures whether a child in a given household suffered from respiratory disease or not as a direct measure of health outcome. Further, from this, the authors also used weight for age and height for age health outcome measures which are continuous and general in measuring the health impact in children. The results by Edwards and Langpap, (2012) demonstrated that cooking by firewood had significant adverse effects on children's respiratory health.

Pant (2012) also examined the health costs linked with using cheaper energy in Nepal poor and rural households. By the use of probit regression model, the study established that using biomass fuel was associated with greater health costs in rural Nepal. In particular, Pant (2012) reports that the households that used biomass for cooking had higher probability of suffering from eye and asthma diseases. Further, the author noted that the use of biomass for cooking and heating was 61.3 percent much more expensive compared to the use of biogas, a cleaner fuel by the households. The study used household-level data in their analysis.

Khan et al., (2017) also studied the effects of air pollution within households from cooking on different health outcomes in Bangladesh. By use of household survey data, the authors observed that use of solid fuel for cooking increased the likelihood of the risk of acute lower respiratory diseases, pregnancy complications and cesarean delivery among women who used solid fuel and practiced indoor cooking. In yet another study, Rey-Ares et al., (2016) studied the impact of air pollution within households on respiratory illness in under-five children and adverse pregnancy health outcomes in Chile and Argentina. The study established that use traditional cooking technologies had a higher likelihood of increasing the likelihood of adverse pregnancy outcomes and respiratory infections.

Khan and Lohano (2018) studied the effects of household air pollution on the respiratory diseases of children in Pakistan using 2012/13 household survey data. The study used logistic regression model in their analysis. Khan and Lohano (2018) established that children from households that use polluting fuels are more likely to suffer from respiratory diseases compared to those who reside in households that use fewer polluting fuels. Further, the authors observed that educating young girls on the adverse effects of using indoor air pollution could greatly reduce the incidence of acute respiratory diseases in children.

Mishra, Retherford, and Smith (1999) examined the effects of the using biomass energy for cooking on the prevalence of tuberculosis in India. The study found that the use of biomass energy for cooking significantly rises the propensity for individuals to suffer from tuberculosis. Retherford, and Smith (1999) noted that individuals who reside in households that rely on biomass energy for cooking had higher chances of suffering from tuberculosis than those who reside in households that use cleaner energy types for cooking. The study used a logistic regression model because the dependent variable was binary i.e 1 if a household member suffered from tuberculosis, 0 otherwise.

Murray, et al., (2011) examined the effects of household cooking fuel type on the risk of suffering from acute lower respiratory disease in Bangladesh. By the use of bivariate and multivariate logistic analysis, the authors found that children from low-income families and use traditional fuel for cooking and heating were more likely to suffer from acute lower respiratory diseases. Murray, et al., (2011) suggested that if the household adopted the household ventilation mechanism, the prevalence of children suffering from acute respiratory diseases would be greatly reduced.

In South Africa, Wichmann and Voyi (2006) studied the effects of heating and cooking fuel on the respiratory health of pre-school children. By use of the logistic regression model, the study found that school-going children from households that use traditional methods of cooking were more likely to suffer from lower respiratory disease in comparison to those from households that use cleaner type of firewood. In particular, Wichmann and Voyi (2006) observed that 66 percent of the children who live in households that use the traditional type of cooking and fuel were found to suffer from lower respiratory disease. The study used nationally representative survey data that covered nine provinces in South Africa.

In Kenya, Osiolo and Kimuyu, (2017) examined the demand for household air pollution abatement intervention by using the KIHBS data. The paper established that the type of energy used for cooking, household location, income and the nature of the houses significantly affects the demand for indoor air pollution abatement interventions by households. Osiolo and Kimuyu, (2017) used a two-stage Heckman estimation technique in their analysis.

2.4 Overview of the Literature

The reviewed theories of household energy use provide the theoretical mechanisms through which households use different energy types for cooking. The energy ladder theory asserts poor households at the lowest level of the ladder tend to use traditional and primitive energy types for cooking but as the income level rises, the households switch to the higher levels of the ladder and use more sophisticated energy types for cooking. However, according to the fuel stacking theory, households do not completely abandon primitive energy type when their income level increases but tend to stack different energy types. The main argument for the fuel stacking theory is that the unreliability of modern energy types can as well make households to use traditional energy for cooking.

With regards to empirical literature reviewed, the results indicate that generally, the use of traditional means for cooking tend to increase the prevalence of women suffering from respiratory diseases, tuberculosis and even for developing of complications during pregnancy in the case for women. In Kenya, reviewed papers on the effects of household energy mix on health outcomes of women are scarce. Review of literature suggests that the study by Osiolo and Kimuyu, (2017) which examined the demand for household air pollution abatement intervention by households due to the use of traditional and poor energy types for cooking is the only study that comes close to examining the impact of household energy mix on health impacts of women. This is a knowledge gap that this study sought to fill by examining the main determinants of household energy use in Kenya and more importantly the impacts of household energy mix on women 's health outcomes in Kenya.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter gives the theoretical framework that explains the principal determinants of household energy choice and also the link between the household energy choices and the health impacts of women. This chapter also provides an empirical model that explains the effects of energy choices on health impacts of women, variables definition, measurements and data source and lastly model diagnostic tests.

3.2 Theoretical Framework

To achieve the first objective of the main determinants of household energy choice in Kenya, we adopt the McFadden (1984) random utility model (RUM). The random utility model assumes that households are able to rationally choose the alternatives of the energy fuel that yields the maximum possible utility. The model particularly assumes that the utility derived from the choice of energy types are dependent on the characteristics of the alternatives as well as the characteristics of the household.

Now since the household has to choose from five energy options i.e firewood, charcoal, stove, LPG and electricity, we can, therefore, assume that the probability the household i chooses some alternative of energy type j i.e P_{ij}, is equal to the probability that utitlity derived by household i from energy type j i.e U_{ij} being the largest of all the utilityu of the alternatives i.e $U_{i1} \ldots \ldots U_{i5}$. Now by denoting the probability of the houehold i to choose the energy alternatives j as $y_i \in \{1, ..5\}$, we can express the household's choice of energy in probability ter ms as;

$P_{ij} = \Pr(y_i = \mathrm{j}) = \; Pr\big(U_{ij} > U_{ik}, \forall k = 1 \ldots .j \; and \; k \neq j\big)$ (1)

Now by assuming that the error term in our model is normally distributed, we can express the above probability as;

$\overline{P_n} = \frac{e^{V_h}}{\sum_{k=1}^{4} e^{V_k}}$, $\mathrm{n} = 1, .., 5$ (2)

Where *n* relates to the different energy type choices.

Now, to achieve the second objective, the theoretical framework of this paper follows the approach by Edwards and Langpap (2012) on the formulation of the effects of energy choice on health outcomes. In this approach, we assume that the household aims to maximize utility from consumption of health good and non-health good. We can write the utility maximization problem of a household in a general form can be written as:

U=$u(h, m)$ ‘(3)

Where U relates to the household utility, *h* is the health good i.e health of women in the household and *m* is the non-health good such as goods purchased from the market.

Concerning the health of the woman and children in the household *h*, household health can be modelled as production function where it depends on the household characteristics as well as the household energy choice that captures firewood, electricity, charcoal, stove and Liquefied Petroleum Gas (LPG). We can write the household's energy production function in a general form as:

H=h (n; z) (4)

Where *n* relates to a household energy mix that captures firewood, electricity, charcoal, stove and Liquefied Petroleum Gas (LPG) and z is other household characteristics that affect women health in the household, for instance, nutrient intake, household consumption expenditure, presence of toilet, clean water among other socioeconomic factors.

But since the household maximizes its utility in equation (1) such that all its resources in terms of income is exhausted in the purchase of consumption commodities, we can write the household's budget constraint as:

M=$p_x X + p_n n$ (4)

Where *M* is the income level of the household, p_x is the price of a market good, p_n is the price of energy types that includes firewood, charcoal, LPG and electricity.

By expressing a langrage objective function to solving the objective function of utility maximization subject to the identified constraints, we obtained the health production function alongside demand functions such as demand for fuel (Edwards and Langpap, 2012). Since health outcome is our variable of interest, we, therefore, write our health production function based on the Grossman (1972) household health model as extended by Edwards and Langpap (2012) in a generalized form as:

H=h (n, x) (5)

Where *H* is the health outcome measured by woman suffering from acute respiratory disease, *n* is the different energy types used in a household, *x* is a set of variables that directly influences the health status of women such as outcome such as mother's education, household size, and residence among others.

3.3 Empirical Model

To empirical estimate the main determinants of household energy choice as indicated in equation 2, we adopt a multinomial logit model specified by the function below

$$R_{ij}^{*} = \beta_x X_{ij} + \beta_z Z_{ij} + \mu_{ij} \qquad (6)$$

Where R_{ij}^{*} is a latent variable that represents household i indirect utility from energy alternative j, X_{ij} is a set of attributes of energy choices. Z_{ij} is a vector of individual attributes (e.g. gender, age, infrastructure, level of education, household size, marital status etc.), β_x is a vector of parameters associated with the attributes of the choices. β_z is a vector of parameters associated with individual attributes. μ_{ij} is an error term.

Turning to objective number 2, we used a logistic regression model for estimations. We choose to use the logistic regression model because our dependent variable is binary in nature that equals 1 if a woman suffered respiratory disease, 0 otherwise.

The binary nature of our dependent variable allows us to define a latent variable Y_i^{*} which is unobserved that generates the observed values of a woman suffering from a respiratory disease or not by linearly linking it to an observed vector of regressors through a structural equation expressed as:

$$Y_i^{*} = X_i\beta + \varepsilon_i \qquad (6a)$$

Where X_i is a vector of regressors explained in detailed in section 3.3 below, β relates to the parameters to be estimated and ε_i error term. Notice that in equation 6a, Y_i^{*} is an unobservable latent variable. What is observable is a binary variable Y_i that captures whether a woman suffers from respiratory disease or not. We therefore connect the latent variable to observed values through the measurement equation expressed as:

$$Y_i = \begin{cases} 1 & if \; Y_i^*>0 \\ 0 & \; Y_i^* \leq 0 \end{cases} \qquad (7)$$

Notice that in the above formulation, if Y_i^* ≤0, then Y_i=0 but when $Y_i^* > 0$, then Y_i =1. We can therefore express the probability of Y_i equals 1 given a vector of regressors if Y_i^* is greater than 0 as:

A generalized expression of the logistic regression can be written as:

$$\Pr(Y_i = 1|X) = \frac{e^{X_i\beta+\varepsilon}}{1+e^{X_i\beta+\varepsilon}} \qquad (8)$$

Where e relates to the exponential parameter.

In equation 8 above, it can be seen that the probability of Y_i equals 1 given a vector of regressors is non-linear in X_i and β. Non-linearity in regressors and parameters implies that ordinary least squares (OLS) method would not be used for estimation.

Now if the probability of a woman suffering from the respiratory disease is given by equation (8) above, the probability of not suffering from the respiratory disease is:

$$1\text{-} \Pr(Y_i = 1|X) = \frac{1}{1+e^{X_i\beta+\varepsilon}} \qquad (9)$$

We can, therefore, combine equation 8 and 9 and obtain:

$$\frac{\Pr(Y_i = 1|X)}{1-\Pr(Y_i = 1|X)} = \frac{1+e^{X_i\beta+\varepsilon}}{1+e^{-X_i\beta+\varepsilon}} = e^{X_i\beta+\varepsilon} \qquad (10)$$

Now by taking the natural logarithm of equation (10), we obtain our estimable equation written as:

$$\text{Log}\left(\frac{Y}{1-Y}\right) = X_i\beta+\varepsilon_i \qquad (11)$$

Y is the dependent variable that equals 1 if a woman suffered respiratory disease, 0 otherwise, X_i is a vector of regressors that explains our dependent variable discussed in 3.3 and ε_i is the error term.

Our specified model for objective 2 can, therefore, be written as:

$$y_i = \alpha + \beta_1 x_{\mathrm{i}1} + \beta_2 x_{\mathrm{i}2} + \beta_3 x_{\mathrm{i}3} + \beta_4 x_{\mathrm{i}4} + \beta_5 x_{\mathrm{i}5} + \beta_6 x_{\mathrm{i}6} + \beta_7 x_{\mathrm{i}7} + \beta_8 x_{\mathrm{i}8} + \beta_9 x_{\mathrm{i}9} + \varepsilon_i \quad (13)$$

Where y_i equals 1 if the woman suffered from respiratory diseases 0 otherwise in household i, x_1=energy choice, x_2=age, x_3= age squared, x_4=household per capita consumption, x_5=woman marital status x_6= head of household gender, x_7= head occupation, x_8= location, x_9= household infrastructure.

3.4 Data Source, Measurement and Description of Variables

We used data from the Kenya Integrated Household Budget Survey (KIHBS) for the period 2015/2016. The KIHBS survey contains data that describes the household's energy type and use, health characteristics, among other modules. KIHBS datasets provide a nationally representative data that covers all the regions in the country. We further focus on women because they more exposed to indoor air pollution since they customarily they do most of the cooking.

Table 3.1: Variables measurements and expected signs of the coefficients for the determinants of household energy choice

Variable	Measurement and Description	*Apriori* Coefficients
Household energy choice	This is the dependent variable and is an energy mix available for consumption by the households.	Dependent variable
Household income	Log of income of a household proxied by the log of household expenditure.	Positive (+)
Household Size	Relates to the number of individuals within the household	Indeterminate (+/-)
Infrastructure	Measured by access to tapped water. 1 if have access to tap water 0 otherwise	Indeterminate (+/-)
Price	Natural logarithm of energy price.	Negative (-)
Age	Age in years of the household head	Indeterminate (+/-)
Head gender	Female = 1; Male = 0 of the household head	Indeterminate (+/-)
Woman Marital status	=1 if a woman is married; 0 otherwise	Indeterminate (+/-)
Education	=Highest schooling level attained by the household head Primary=1, Secondary=2, University=3, Other=4	Indeterminate (+/-)
Residence	=1 if the is in urban; 0 otherwise.	Positive (+)
Household size	Total number of persons in a household	Positive (+)

Table 3.2: Variables measurements and expected signs of the coefficients for the effects of household energy choice on health outcomes

Variable	Measurement	Apriori Coefficients
Dependent variable		
Respiratory disease	This is the dependent variable that equals 1 if a woman suffered from upper and lower respiratory disease; 0 otherwise	
Independent variables		
Energy choice	This is the main independent variable relating to energy choice by the households; 1=Firewood; 2=Charcoal; 3=Kerosene; 4=LPG; 5=Electricity	Indeterminate (+/-)
Age	Age in years. Age is included because it has a larger impact on the risk of contracting respiratory diseases.	Positive (+)
Household wealth index (Income)	Measured by the total household consumption expenditure. This combines both food and non-food household consumption expenditure	Indeterminate (+/-)
Woman marital status	=1 if a woman is married; 0 otherwise	Positive (+)
Household head	=1 if the mother is household head; 0 otherwise	Indeterminate (+/-)
Household location	=1 if the is in urban; 0 otherwise. Households in rural areas are more likely to use traditional energy types and as such suffer from respiratory diseases.	Indeterminate (+/-)
Household head education	Measured by the highest schooling level attained by the household head Primary=1, Secondary=2, University=3, Other=4.	Indeterminate (+/-)
Household infrastructure	This variable would capture the number of rooms in the household, type of floor and roofing material.	Negative (-)

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the empirical results of the main determinants of household energy choice and the link between household energy choices and the health outcomes of women. In the chapter, we also provide the summary statistics as well as the estimates of our model.

4.2 Summary Statistics

The descriptive statistics of the variables used in the study are presented in table 4.1. The table particularly provides the number of observations, the mean, standard deviation, minimum, maximum, skewness and kurtosis of the variables included in this study.

The descriptive statistics show that 60.3 percent of the households used firewood as their principal source of cooking energy, 19 percent used charcoal and 8.01 percent used kerosene indicating that 87.3 percent of Kenyan women use traditional sources of energy. It indicates that 12 percent of women considered in our analysis used LPG with the least proportion of the sample survey using electricity as this accounted for 0.6 percent of the sample surveyed. Table 4.1 reports the mean characteristics of the 18, 625 women surveyed.

The average age of the surveyed women was 40.84 with the maximum and minimum ages being 101 and 10 ages respectively. Concerning the gender of the household head, the statistics indicate that, on average, 42.9 percent of the household heads were women with a standard deviation of 49.5 percent. The statistics also shows that households on average had 4 members, with the minimum and maximum numbers of the household members being 1 and 16 respectively. Further the statistics, on average, 91.1 percent of the women reported being married. Further, 56.3 percent of the surveyed women reside in rural areas. On the infrastructure of the household, summary statistics indicate that 41 percent of the women have piped waters in their households. With regards to the consumption level by the household, the statistics show that the mean logarithm of total household consumption stood at 11.19 with the maximum and minimum expenditures of 7.686 and 0.658 respectively.

Table 4.1: Summary statistics

Variable	Obs	Mean	Std.Dev.	Min	Max	Skewness	Kurtosis
Women Health outcomes	18,625	0.0583	0.234	0	1	3.772	15.23
Energy choice							
Firewood	18,625	0.603	0.489	0	1	-0.4224	1.178
charcoal	18,625	0.190	0.393	0	1	1.577	3.486
Kerosene	18,625	0.0801	0.271	0	1	3.094	10.57
LPG	18,625	0.120	0.325	0	1	2.335	6.451
Electricity	18,625	0.00585	0.0763	0	1	12.96	168.88
Log consumption	18,625	11.19	0.658	7.686	15.71	0.2023	3.207
Household size	18,625	4.022	2.277	1	16	0. 863	3.855
Age	18,625	40.84	14.22	10	101	0.872	3.282
Household head gender	18,625	0.429	0.495	0	1	0.287	1.082
Education							
None	18,625	0.0134	0.115	0	1	8.474	72.81
Primary	18,625	0.573	0.495	0	1	-0.2934	1.086
Secondary	18,625	0.281	0.450	0	1	0.9729	1.946
University	18,625	0.133	0.339	0	1	2.164	5.684
Marital status	18,625	0.911	0.284	0	1	-2.891	9.358
Location	18,625	0.563	0.496	0	1	-0.254	1.065
Presence of piped water	18,625	0.408	0.492	0	1	0.3737	1.140

Source: Author based on KIHBS 2015/2016

Since household energy choice is our variable of interest, Table 4.2 provides the household's mean monthly total budget on fuel types, mean monthly total household expenditure and the ratio of energy expenditure to the total household spending.

Table 4.2 indicates that firewood and charcoal have the highest energy budget shares among surveyed households. The implication of this finding is that modern energy types are unaffordable or unavailable to most of the households and therefore households tend to use modern energy. The statistics further indicate lower energy budget shares for the LPG and electricity energy types. Further, statistics show that most of the households who use firewood and charcoal reside in rural areas. In particular, summary statistics show that firewood and charcoal were used by 79.1 percent and 27.9 percent of the households residing in rural areas.

Table 4.2: Summary statistics of fuel expenditure

Energy choice	Rural	Urban	Mean monthly total energy expenditure	Mean monthly total household expenditure	The proportion of total energy to total household expenditure
Firewood	0.791	0.209	373.0	5474	0.0837
charcoal	0.279	0.721	499.6	8612	0.0713
Kerosene	0.141	0.859	306.9	9435	0.0412
LPG	0.162	0.838	633.2	15412	0.0489
Electricity	0.312	0.688	557.7	10793	0.0578

Prior to our estimation, we performed a correlation analysis between the independent variables used in the study to test for potential multicollinearity. The correlation matrix indicates the absence of multicollinearity problem because all the correlation coefficients are less than 0.9. The correlation matrix is presented in the appendix.

4.3 Econometric Results

4.3.1 The Determinants of Energy Choice in Kenya

In the multinomial logit of energy mix estimation results in table 4, the outcome variable is the energy mix where the type of energy is firewood, charcoal, kerosene, LPG and electricity. The results show the marginal effects which are used for interpretation purposes. The maximum likelihood coefficients of the multinomial logit are presented in the appendix.

The econometric results indicate that the coefficient of the total household expenditure is statistically significant predictor of household energy choices. The results establish that demand for energy rises with income with the exception of charcoal and kerosene. In particular, it is found that a 1 percent increase in consumption increases the probability of the household using charcoal, electricity, and LPG by 2.24 percent, 11.5 percent and 25.2 percent respectively. In this study, household income is proxied by the log of household consumption. We performed a logarithm of the household total expenditure variable to smooth and transform the variable by removing the unequal distribution.

However, the econometric results further demonstrate that a 1 percent rise in household consumption reduces the likelihood of women using firewood by 12.2 percent. These results imply that as household income levels increase as proxied by the total household expenditures, households tend to use their preferred energy types as compared to firewood. The implication of this finding is that households in Kenya tend to stack fuel types with the rise in income levels which is therefore in conformity with the energy stacking hypothesis. According to this hypothesis, households use multiple fuels for cooking rather than a single fuel based on their socio-economic status. This theory argues that households stack different energy types even though their income level and economic status improve because of socio-cultural reasons. This result is similar to those found by Mensah and Adu (2015) when they empirically factors determining household energy choice in Ghana. Accoridng to Mensah and Adu (2015), increaese in household income level enables the household to climb up to the highest ladder by acquiring the most advanced and modern energy types.

Regarding the location variable, this study establishes that residence also is critical in influencing household energy demand. In particular, those household in rural areas have a higher likelihood of using firewood and less probability in the use of charcoal and LPG compared to urban households. In particular, marginal results demonstrate that rural households are 24.7 percent more likely to use firewood for cooking in comparison to those in urban localities. Mensah and Adu (2015) also established that rural households are more likely to use the traditional sources of energy in Ghana. The study findings also establish that infrastructure significantly affects the energy use choice by households. In particular, marginal effects shows that households who have access to piped water are 12.5 percent less likely to use firewood compared to those with no access to piped water. Further, the results show that those households with access to piped water are 5.82 percent and 3.04 percent to use charcoal and LPG respectively. This finding is similar to those found by Eakins (2013) in his study of household energy choice in Irish. According to Eakins (2013), a household dwelling characteristic plays a significant role in influencing the choice of energy by the households.

Table 4.3: Multinomial Logit Marginal Effects of Determinants of Household Energy Choice

Variables	Firewood	Charcoal	Kerosene	LPG	Electricity
Log consumption	-0.128***	0.0267***	-0.0162	0.115***	0.00248**
	(0.00486)	(0.00528)	(0)	(0.00382)	(0.00111)
Household Size	0.0195***	0.0139***	-0.0261	-0.00732***	-8.71e-06
	(0.00143)	(0.00165)	(0)	(0.00145)	(0.000344)
Age	0.00543***	-0.00341***	-0.00223	0.000136	7.06e-05*
	(0.000191)	(0.000235)	(0)	(0.000166)	(4.27e-05)
Household head gender	-0.0126**	0.0389***	-0.00554	-0.0185***	-0.00227
	(0.00578)	(0.00655)	(0.00)	(0.00498)	(0.00141)
Education					
Primary	-0.273	-0.426	1.012	-0.304	-0.00985
	(15.69)	(21.68)	(0)	(13.91)	(0.585)
Secondary	-0.329	-0.434	1.004	-0.232	-0.00838
	(15.69)	(21.68)	(0)	(13.91)	(0.585)
University	-0.397	-0.408	0.978	-0.167	-0.00607
	(15.69)	(21.68)	(0)	(13.91)	(0.585)
Marital status	0.110***	-0.0582***	-0.0231	-0.0300***	0.000968
	(0.0110)	(0.0102)	(0)	(0.00585)	(0.00235)
Location	0.248***	-0.114***	-0.0820	-0.0502***	-0.00158
	(0.00359)	(0.00531)	(0)	(0.00439)	(0.00105)
Use of piped water	-0.126***	0.0586***	0.0339	0.0306***	0.00337***
	(0.00466)	(0.00539)	(0)	(0.00405)	(0.00122)
Observations	18,625	18,625	18,625	18,625	18,625

*Notes: (i) Standard errors in parentheses (ii) *** p<0.01, ** p<0.05, * p<0.1*

4.3.2 The Impact of Energy Choice Mixes on the Health Outcomes of Women

The logit results for the effects of the energy choice mix on the health outcomes of women in Kenya are presented in table 4. We present both the maximum likelihood estimates as well as the marginal effects. We focus on the marginal effects for the interpretation purposes. The logit results establish significant variables to be firewood and LPG, household size, age, gender, education of the household head as well as infrastructure of the household.

Table 4.4: Regression results of effects of energy choice on women health outcomes

	Maximum Likelihood Estimates (MLE)	**Marginal Effects (dydx)**
Firewood	1.471**	0.0796**
	(2.05)	(0.0390)
Charcoal	0.943	0.0511
	(1.31)	(0.0390)
Kerosene	1.094	0.0592
	(1.51)	(0.0392)
LPG	1.212*	0.0656*
	(1.68)	(0.0390)
Log consumption	0.0920	0.00498
	(1.42)	(0.00351)
Household size	-0.0761***	-0.00412***
	(-4.05)	(0.00102)
Age	0.00792***	0.000428***
	(3.39)	(0.000127)
Household head Gender	0.241***	0.0131***
	(3.16)	(0.00415)
Education		
Primary	-0.382	-0.0207
	(-1.63)	(0.0127)
Secondary	-0.450*	-0.0244*
	(-1.87)	(0.0130)
University	-0.505**	-0.0273**
	(-1.99)	(0.0138)
Married	-0.588***	-0.0318***
	(-5.62)	(0.00569)
Location	0.0643	0.00348
	(0.81)	(0.00432)
Use of piped Water	0.397***	0.0215***
	(5.64)	(0.00383)
Constant	-4.579***	
	(-4.25)	
Observation	18625	18625

Notes: (i) Women health outcome is the dependent variable (ii) t statistics in brackets (iii) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ (iv) Electricity and no education are reference category for energy choice and education variables respectively.

Concerning energy choice variable, the results establish that households that use firewood have higher chances of suffering from respiratory illness as compared to those that use electricity. In particular, the results indicate that households that use firewood as a source of energy are 8.01 percent more likely to suffer from respiratory illness than those who use electricity. This finding is similar to those found by Edwards and Langpap (2012) where it was demonstrated that use of firewood for cooking had adverse effects on children's respiratory health in Guatemala. Similarly, the study by Pant (2012) in Nepal established that use of biomass and firewood for cooking was linked to health costs in rural and poor households. The study by Duflo et al (2008) in India also established a significant relationship between the symptoms of respiratory diseases and use of traditional stoves. Surprisingly, the results also show that women who use LPG were 6.47 percent more likely to suffer adverse health outcomes than those who use electricity.

Concerning household size, the results show that the addition of one person to the household reduces the probability of women suffering from acute respiratory diseases by 0.4 percent. One possible explanation for this finding is that with bigger household size, each member of the household has less exposure to the adverse effects of the energy mix and therefore being less likely to suffer from acute respiratory diseases. This result is however different from the one obtained by Jagger and Shively (2014) where it was argued that increased number of people in a household increases fuel consumption due to more people to feed thereby increasing likelihood of exposure to adverse effects.

Regarding the age of the household head, the results indicate that older heads are more likely to suffer from acute respiratory diseases. In particular, the results indicate that an additional year of the woman increases the likelihood of experiencing respiratory diseases by 0.1 percent. Possible explanation for this finding is that older women have a greater sense of responsibility in providing for the family and more exposed to the fumes from fuels used in cooking.

The econometric results also indicate that the education variable is a significant predictor of women health outcomes. The result demonstrates that women with better education are less likely to suffer from respiratory diseases. In particular, women with primary, secondary and post-secondary education are 2.15 percent, 2.49 percent and 2.74 respectively less likely to suffer from the respiratory diseases. This result is in agreement of the finding by Khan and Lohano (2018) who found that educating girls on the adverse effects of using indoor air pollution greatly reduced the incidence of acute respiratory diseases in Pakistan. Concerning the marital status of the women, the results establish that married women are 2.75 percent less likely to suffer from respiratory diseases compared to unmarried women.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND POLICY RECOMMENDATIONS

5.1 Introduction

This chapter begins by presenting a brief summary study and then goes ahead to give the conclusions drawn. The summary and conclusion section is then followed by the policy implications of the study. Lastly, we present the limitations of the study.

5.2 Summary and Conclusion

The main objective of this paper was to analyze the effects of household energy choice on health outcomes of women. Specifically, the study sought to examine the main determinants of household energy choice in Kenya and the impact of household energy mix on women's health outcomes in Kenya.

The study used the Kenya Integrated Household Budget Survey 2015/16 where the sample considered comprised of 18, 625 women. The multinomial logit model was adopted to examine the determinants of the household energy choice while logit regressions were used to study the effect of household energy mix on the health outcomes of women.

Concerning the main determinants of the household energy choice mix, the study found that households that are connected with piped water which is a proxy for good infrastructure had a higher likelihood of using modern sources of energy. Concerning household size, the study found that larger households were more probable to use firewood and charcoal and less probable to use LPG. Further, the results established that married women were more likely to use firewood and less likely to use charcoal and LPG. Concerning the location of the household, the study found that household in rural areas is more likely to use traditional sources of energy compared to those in the urban areas.

Concerning the impact of the household energy mix on women's health outcomes in Kenya, the study established that women who use firewood are more likely to have adverse health outcomes compared to those who use electricity. In the study, it was also found that women in larger households had reduced likelihood of suffering adverse health outcomes as compared to those with smaller sizes. Further, the results established that married women were more susceptible to use have adverse health outcomes from the choice of the energy type. Concerning education of the household head, the study found that households heads with higher educational levels were less likely to suffer from acute respiratory diseases.

5.3 Policy Implications

From the study, it is observed that an increase in the household income level increases alternatives for fuel types available to the women. The implication of this finding is that there should be an intensification of programs that increase the income levels of households especially those in the village so that households' members can easily widen the scope from which they can choose their energy.

The study findings also proposed for the promotion of modern energy types. The study found that the use of firewood, which is a traditional source of energy, increases the propensity of households experiencing adverse health outcomes. In Kenya, despite the existence of policies that are geared to connect most households with electricity and expansion of the retail networks of LPG, a lot more can be done to enhance both access and affordability of the modern energy types so as to reduce the likelihood of women experiencing adverse health outcomes by using traditional energy fuels.

The government can as well enhance the adoption of modern energy type by building the capacity of women by improving their educational attainments. Women should be educated on the effects of different energy choices on their health. This is proposition is grounded on the findings of this study where women with better educational attainments had lower chances of suffering adverse health outcomes.

5.4 Limitations of the Study

In examining the main determinants of household energy choice and the impact of household energy mix on women's health outcomes, addressing the endogeneity problem is critical. Presence of endogeneity, which is a situation where an independent variable is linked with the error term in the estimable model, tends to lead to biased estimates. Endogeneity is often caused by issues such as reverse causality, omitted variable, and the measurement errors. In this study, however, the endogeneity problem was not addressed. Endogeneity is often addressed when by either use of instrumental variable approach or use Generalized Methods of Methods estimation techniques for the case of panel data. Based on the aforementioned, future studies on this area can aim to mitigate endogeneity problem in addressing the effects of energy choice on health outcomes.

REFERENCES

Akpalu, W., Dasmani, I., and Aglobitse, P. B. (2011). Demand for cooking fuels in a developing country: To what extent do taste and preferences matter? *Energy Policy*, *39*(10), 6525-6531.

Amegah, A. K., and Jaakkola, J. J. (2016). *Household air pollution and sustainable development goals. Bulletin* of the World Health Organization, 94(3), 215.

Barnes, B., Mathee, A., Thomas, E., and Bruce, N. (2009). *Household energy, indoor air pollution and child respiratory health in South Africa*. Journal of Energy in Southern Africa, 20(1), 4-13.

Jagger, P., & Shively, G. (2014). Land use change, fuel use and respiratory health in Uganda. *Energy policy*, *67*, 713-726.

Eakins, J. (2013). An Analysis of the Determinants of Household Energy Expenditures: Empirical Evidence from the Irish Household Budget Survey. *Degree of Doctor of Philosophy in Economics from the University of Surrey, Surrey Energy Economics Centre (SEEC), School of Economics, University of Surrey*.

Duflo, E., Greenstone, M., & Hanna, R. (2008). Indoor air pollution and respiratory health in rural Orissa. *Economic and Political Weekly*, *43*(32), 71-76.

Behera, B., and Ali, A. (2017). Factors determining household use of clean and renewable energy sources for lighting in Sub-Saharan Africa. *Renewable and Sustainable Energy Reviews*, *72*, 661-672.

Bruce, N., Perez-Padilla, R., and Albalak, R. (2000). Indoor air pollution in developing countries: a major environmental and public health challenge. Bulletin of the World Health Organization, 78(9), 1078-1092.

Burke, P. J., and Dundas, G. (2015). Female labor force participation and household dependence on biomass energy: evidence from national longitudinal data. *World Development*, *67*, 424-437.

Capuno, J. J., Tan Jr, C. A. R., and Javier, X. (2018). Cooking and coughing: Estimating the effects of clean fuel for cooking on the respiratory health of children in the Philippines. *Global public health*, *13*(1), 20-34.

Davis, M. (1998). Rural household energy consumption: the effects of access to electricity-evidence from South Africa. *Energy Policy*, *26*(3), 207-217.

Duflo, E., Greenstone, M., and Hanna, R. (2008). Indoor air pollution, health, and economic well-being. SAPI EN. S. Surveys and Perspectives Integrating Environment and Society, (1.1).

Edwards, J. H., and Langpap, C. (2012). Fuel choice, indoor air pollution, and children's health. *Environment and Development Economics*, *17*(4), 379-406.

Ezzati, M., and Kammen, D. M. (2002). The health impacts of exposure to indoor air pollution from solid fuels in developing countries: knowledge, gaps, and data needs. Environmental Health Perspectives, 110(11), 1057.

Khan, M. N., Islam, M. M., Islam, M. R., and Rahman, M. M. (2017). Household air pollution from cooking and risk of adverse health and birth outcomes in Bangladesh: a nationwide population-based study. *Environmental Health*, *16*(1), 57.

Khan, M. S. B., and Lohano, H. D. (2018). Household air pollution from cooking fuel and respiratory health risks for children in Pakistan. Environmental Science and Pollution Research, 1-9.

Lambe, F., Jürisoo, M., Wanjiru, H., and Senyagwa, J. (2015). Bringing clean, safe, affordable cooking energy to households across Africa: an agenda for action. Prepared by the Stockholm Environment Institute, Stockholm, and Nairobi, for the New Climate Economy. Available at: http://newclimateeconomy. report/misc/working papers.

Laxmi, V., Parikh, J., Karmakar, S., and Dabrase, P. (2003). Household energy, women's hardship and health impacts in rural Rajasthan, India: The need for sustainable energy solutions. *Energy for Sustainable Development*, *7*(1), 50-68.

Leach, G. (1992). The energy transitions. *Energy Policy*, *20*(2), 116-123.

Lewis, J. J., Hollingsworth, J. W., Chartier, R. T., Cooper, E. M., Foster, W. M., Gomes, G. L., ... and Rodes, C. E. (2016). Biogas stoves reduce firewood use, household air pollution, and hospital visits in Odisha, India. Environmental science and technology, 51(1), 560-569.

Mannucci, P. M., and Franchini, M. (2017). Health effects of ambient air pollution in developing countries. International Journal of Environmental Research and Public Health, 14(9), 1048.

Masera, O. R., Saatkamp, B. D., and Kammen, D. M. (2000). From linear fuel switching to multiple cooking strategies: a critique and alternative to the energy ladder model. *World Development*, *28*(12), 2083-2103.

McFadden, D. (1980). Econometric Models for Probabilistic Choice among Products. Journal of Business, 13-S29.

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

Mishra, V. K., Retherford, R. D., and Smith, K. R. (1999). Biomass cooking fuels and prevalence of tuberculosis in India. *International Journal of infectious diseases*, *3*(3), 119-129.

Mueller, V., Pfaff, A., Peabody, J., Liu, Y., and Smith, K. R. (2011). Demonstrating bias and improved inference for stoves' health benefits. *International journal of* epidemiology, 40(6), 1643-1651.

Murray, E. L., Brondi, L., Kleinbaum, D., McGowan, J. E., Van Mels, C., Brooks, W. A., ... and Bridges, C. B. (2012). Cooking fuel type, household ventilation, and the risk of acute lower respiratory illness in urban Bangladeshi children: a longitudinal study. Indoor air, 22(2), 132-139.

Osiolo, H. H., and Kimuyu, P. (2017). Demand for Indoor Air Pollution Abatement Interventions. *Biophysical Economics and Resource Quality*, *2*(3), 12.

Pant, K. P. (2012). Cheaper fuel and higher health costs among the poor in rural Nepal. Ambio, 41(3), 271-283.

Rey- Ares, L., Irazola, V., Althabe, F., Sobrino, E., Mazzoni, A., Serón, P., ... and Rubinstein, A. (2016). Lower tract respiratory infection in children younger than 5 years of age and adverse pregnancy outcomes related to household air pollution in Bariloche (Argentina) and Temuco (Chile). Indoor air, 26(6), 964-975.

Wichmann, J., and Voyi, K. V. (2006). Impact of cooking and heating fuel use on acute respiratory health of preschool children in South Africa. Southern African Journal of Epidemiology and Infection, 21(2), 48-54.

APPENDICES

Appendix 1: Correlation Matrix

	Log consumption	Household size	Age	Household head gender	No education	Primary education	Secondary education	University education	Marital status	Location	Presence of piped water
Log consumption	1										
Household size	-0.495	1									
Age	-0.0922	-0.0721	1								
Household head gender	0.188	-0.474	0.229	1							
No education	-0.0434	0.0216	0.0510	0.0229	1						
Primary education	-0.393	0.178	0.192	-0.0514	-0.135	1					
Secondary education	0.161	-0.0898	-0.155	0.00670	-0.0728	-0.724	1				
University education	0.374	-0.148	-0.0917	0.0583	-0.0455	-0.453	-0.245	1			
Marital status	-0.255	0.403	0.133	-0.353	0.0248	0.191	-0.0805	-0.180	1		
Location	-0.360	0.192	0.168	-0.0374	-0.0115	0.219	-0.101	-0.182	0.170	1	
Presence of piped water	0.331	-0.205	-0.0901	0.0411	-0.00440	-0.195	0.0998	0.154	-0.145	-0.320	1

Appendix 2: Maximum Likelihood Estimates

Multinomial logistic regression		Number of obs =	18,625
		LR chi2(44) =	14648.82
		Prob > chi2 =	0.0000
Log likelihood = -13307.052		Pseudo R2 =	0.3550

energy	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Firewood	(base outcome)					
Charcoal						
logcons	.8930455	.0505443	17.67	0.000	.7939806	.9921105
lhhsize	-.4044947	.0535706	-7.55	0.000	-.5094911	-.2994983
age	-.0355043	.0112028	-3.17	0.002	-.0574614	-.0135471
age_sq	-.0001408	.000125	-1.13	0.260	-.0003857	.0001042
hh_gender	.1620529	.0577985	2.80	0.005	.0487698	.2753359
primary	-.2521351	.1897441	-1.33	0.184	-.6240266	.1197565
secondary	.0873645	.1927154	0.45	0.650	-.2903507	.4650797
university	.6421683	.2027974	3.17	0.002	.2446927	1.039644
married	-.8555968	.1065686	-8.03	0.000	-1.064467	-.6467261
location	-2.034409	.0493247	-41.25	0.000	-2.131084	-1.937734
p_water	1.030565	.0485666	21.22	0.000	.9353766	1.125754
_cons	-7.448554	.6416887	-11.61	0.000	-8.70624	-6.190867
Kerosene						
logcons	.7424066	.0731572	10.15	0.000	.5990212	.8857921
lhhsize	-1.733788	.0804306	-21.56	0.000	-1.89143	-1.576147
age	.0267388	.0197012	1.36	0.175	-.0118747	.0653524
age_sq	-.0011882	.0002388	-4.98	0.000	-.0016562	-.0007201
hh_gender	-.2627453	.0926269	-2.84	0.005	-.4442907	-.0811999
primary	15.47755	642.8015	0.02	0.981	-1244.39	1275.345
secondary	15.8604	642.8015	0.02	0.980	-1244.007	1275.728
university	16.00245	642.8015	0.02	0.980	-1243.865	1275.87
married	-.8785384	.1277132	-6.88	0.000	-1.128852	-.6282252
location	-2.849488	.0854592	-33.34	0.000	-3.016985	-2.681991
p_water	1.33648	.0715689	18.67	0.000	1.196207	1.476752
_cons	-21.59396	642.8021	-0.03	0.973	-1281.463	1238.275
_LPG						
logcons	2.373129	.0740421	32.05	0.000	2.228009	2.518249
lhhsize	-.993829	.0764316	-13.00	0.000	-1.143632	-.8440258
age	.0179608	.0167108	1.07	0.282	-.0147918	.0507135
age_sq	-.0006652	.0001881	-3.54	0.000	-.0010339	-.0002965
hh_gender	-.2946907	.0877173	-3.36	0.001	-.4666135	-.1227679
primary	-.6925985	.3348445	-2.07	0.039	-1.348882	-.0363153
secondary	.6490087	.3333897	1.95	0.052	-.0044231	1.302441
university	1.944571	.3379331	5.75	0.000	1.282234	2.606908
married	-1.050723	.1260457	-8.34	0.000	-1.297768	-.8036779
location	-2.457517	.078349	-31.37	0.000	-2.611078	-2.303955
p_water	1.305273	.0705256	18.51	0.000	1.167046	1.443501
_cons	-26.06008	.9803792	-26.58	0.000	-27.98159	-24.13857
Electricity						
logcons	1.333676	.2080011	6.41	0.000	.9260013	1.741351
lhhsize	-.5735476	.2224664	-2.58	0.010	-1.009574	-.1375214
age	-.0067129	.0436524	-0.15	0.878	-.0922701	.0788443
age_sq	-.0001542	.00047	-0.33	0.743	-.0010755	.0007671
hh_gender	-.4188238	.2551321	-1.64	0.101	-.9188735	.0812258
primary	.0034765	1.024387	0.00	0.997	-2.004286	2.011239
secondary	.7160271	1.027113	0.70	0.486	-1.297078	2.729132
university	1.591405	1.036005	1.54	0.125	-.4391274	3.621936
married	-.4362973	.4214289	-1.04	0.301	-1.262283	.3896881
location	-1.776561	.2136874	-8.31	0.000	-2.19538	-1.357741
p_water	1.346358	.2132915	6.31	0.000	.9283144	1.764402
_cons	-17.83301	2.764866	-6.45	0.000	-23.25205	-12.41398