CONSUMER CHOICE AND WILLINGNESS TO PAY FOR IMPROVED COOKSTOVES IN MALAWI: A CASE OF CHIRADZULU DISTRICT

MSc. (AGRICULTURAL AND APPLIED ECONOMICS) THESIS

JOYCE ANGELA GREVULO

LILINGWE UNIVERSITY OF AGRICULTURE AND NATURAL RESOURCES

BUNDA CAMPUS

JANUARY, 2018

CONSUMER CHOICE AND WILLINGNESS TO PAY FOR IMPROVED COOKSTOVES IN MALAWI: A CASE OF CHIRADZULU DISTRICT

JOYCE ANGELA GREVULO

B.Sc. (Agricultural Economics), Malawi

A THESIS SUBMITTED TO THE FACULTY OF DEVELOPMENT STUDIES IN PARTIAL FULFILMENT OF REQUIREMENTS FOR AWARD OF THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL AND APPLIED ECONOMICS

LILONGWE UNIVERSITY OF AGRICULTURE AND NATURAL RESOURCES

BUNDA CAMPUS

JANUARY, 2018

DECLARATION

I, Joyce Angela Grevulo, declare that this thesis is a result of my own effort and work, and to the best of my knowledge, the thesis has never been submitted to the Lilongwe University of Agriculture and Natural Resources or elsewhere for the award of any academic qualification. Where assistance was sought, it has been accordingly acknowledged.

Joyce Angela Grevulo

Signature: ______________________________

Date: ___________/__________/_________

CERTIFICATE OF APPROVAL

We, the undersigned, certify that this thesis is a result of the student`s own work, and that to the best of our knowledge, it has not been submitted for any other academic qualification within the Lilongwe University of Agriculture and Natural Resources or elsewhere. The thesis is acceptable in form and content, and that satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate through an oral examination held on 30 /11/ 2017.

Major Supervisor: Prof. Charles B.L Jumbe

Signature: ________________________________

Date: ___________/_________/____________

Supervisor: Dr. Beston B. Maonga

Signature: ________________________________

Date: ___________/_________/____________

Supervisor: Dr. Horace Phiri

Signature: ________________________________

Date: ___________/_________/____________

DEDICATION

I dedicate this work to Almighty God, my redeemer and my Lord for making all things work for my good. Any usefulness of this study is to His glory. Lastly, I dedicate the work to my dear husband, Mayamiko Minofu for his moral and spiritual support and companion.

ACKNOWLEDGEMENTS

Firstly, I thank the Almighty God for seeing me through all the stages of this research. May His name forever be praised! Sincere gratitude also go to the African Economic Research Consortium (AERC) for granting me a partial scholarship to pursue the degree of Master of Science in Agricultural and Applied Economics at the Lilongwe University of Agriculture and Natural Resources in collaboration with University of Pretoria, South Africa.

My honest appreciation goes to my major supervisor, Professor Charles B.L. Jumbe for tirelessly reviewing and guiding me throughout my study. This cannot be taken for granted. Sincere appreciation should also go to the other supervisors, Drs., Beston B. Maonga and Horace Phiri for their contributions towards the success of this work.

Many thanks should also go to the District Commissioner for Chiradzulu District for granting me permission to conduct this research in the area. Further thanks should also go to the Traditional Authority Likoswe`s clerk Mr. Sitima for arranging meetings with various people during field work. Lastly, many thanks go to my research team, Ms. Tissie Nadzanja, Ms. Hanna Ganunga, Ms. Memory Chirwa and Mr. Emmanuel Chikoti for helping with data collection.

ABSTRACT

The Government of Malawi is championing the promotion of Improved Cookstoves (ICS) with a target to distribute 2 million stoves by 2020. Although Non-Governmental Organizations (NGOs) have been promoting ICS in Malawi over the past 10 years, the adoption of such technologies has been low and slow. The study was therefore designed to assess the consumer choice and willingness to pay for Improved Cookstoves in Chiradzulu District. The understanding of consumers` choice and their willingness to pay for the ICS is crucial in order to design appropriate strategies to enhance their wider adoption. The ICS technologies considered in this study were Chitetezo Mbaula, Total Landcare Rocket Stove and Portable Rocket Stove. Data used in this research were collected from 404 households in Chiradzulu district (where the distribution of these ICS technologies has not yet started) using a contingent valuation questionnaire. Multinomial Logit model was used to determine factors influencing choice of ICS. Single bounded model was used to elicit willingness to pay (WTP) for ICS. Factors influencing WTP for each Improved Cookstove were analyzed using probit model. The study found that distance to firewood source from home, monthly household expenditure, firewood collection frequency per week, number of adult females, type of firewood source, household head age, knowledge of negative environmental impact of Three-stone Firewood Stove, value of household assets and under-five children ratio were significant factors influencing the choice of ICS. The mean WTP for Chitetezo Mbaula, TLC Rocket Stove and Portable Rocket Stove were estimated as MK1586 ($2.22), MK2838 ($3.98) and MK12032 ($16.87), respectively. WTP for Chitetezo Mbaula was significantly influenced by number of firewood collection helpers in the household, sex of the household head, total time spent collecting firewood and number of adult female members in the households. While firewood source distance from home and age of the primary cooks significantly influenced TLC Rocket Stove`s WTP. Furthermore, WTP for Portable Rocket Stove was significantly influenced by firewood source distance from home and total time spent collecting firewood. These findings have important implications for designing strategies for up-scaling ICS to support government program of reaching two million households by 2020. The study therefore recommends that the dissemination efforts to be extended to Chiradzulu District and that GoM and ICS dissemination partners should consider the socioeconomic differences that affect household`s choice and WTP for ICS.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

CADECOM	Catholic Development Commission in Malawi
CCT	Controlled Cooking Tests
CVM	Contingent Valuation Method
GoM	Government of Malawi
ICS	Improved cook stove
HAP	Household Air Pollution
MBAULA	Movement for Bio-energy Advocacy, Utilization, Learning and Action
MK	Malawi Kwacha
MNP	Multinomial Probit Model
NCSC	National Cookstove Steering Committee
NGOs	Non-Governmental Organizations
NOAA	National Oceanographic and Atmospheric Administration
ProBec	Programme for Basic Energy and Conservation
RUM	Random Utility Model
SSGHM	Stichting St. Gabriel's Hospital Malawi
T.A.	Traditional Authority
TLC	Total Land Care
USD	United States Dollar
WALA	Wellness and Agriculture for Life Advancement
WTP	Willingness to pay
WB	World Bank

CHAPTER ONE

INTRODUCTION

1.1 Background

Globally, biomass fuels are the common sources of fuels for cooking and heating. According to Adkins et al. (2010), between 2 and 2.4 billion people worldwide use wood, dung, charcoal and other biomass fuels for cooking and heating. In Malawi, biomass fuels particularly firewood and charcoal are important sources of energy used by 95 percent of the households (National Statistical Office, 2012). Of all biomass extraction activities, fuel wood accounts for 84 percent of total annual use and 70 percent of Malawian households living in the urban areas have no access to non-biomass fuels (Stanturf et al., 2011). In fact, even households with electricity connection still depend on woodfuels due to high cost of electricity, appliances and unreliable supply of electricity (Jumbe and Angelsen, 2011).

The dependence on biomass as a source of energy is associated with several environmental and health-related problems such as deforestation, carbon emissions and household air pollution (Sagbo, 2014). In Malawi, the recorded deforestation rate of 3.2 percent is among the highest in Africa (Malakini et al., 2014). One of the major causes of deforestation is fuelwood extraction for both household and commercial use (Stanturf et al., 2011). Besides other problems arising from deforestation, the loss of forest cover brings about other environmental problems such as soil erosion, river siltation and floods (Magrath and Sukali, 2009). Floods and washing away of top soil are detrimental to crops and consequently retard economic growth as an agricultural dependent economy. Furthermore, the burning of biomass for cooking and heating on traditional three-stone firewood stove is often associated with greenhouse gas emissions due to incomplete combustion (Wanjohi and Smyser, 2013). Apart from carbon dioxide emissions, soot from burning biomass fuels is considered the second largest contributor to anthropogenic climate change (Sagbo, 2014). In terms of health outcomes, household air pollution (HAP) is considered the second most vital risk factor after childhood underweight in sub-Saharan Africa with 13,000 annual deaths estimated in Malawi alone (Lim et al., 2012). In addition, a study conducted by Wanjohi and Smyser (2013) in Malawi found that particulate matter levels of 226 $\mu g/m^3$ from cooking with biomass energy is above the World Health Organization's (WHOs) acceptable levels of 25 $\mu g/m^3$ (Fullerton et al., (2009).

To reduce the health and environmental effects associated with cooking with biomass fuels, improved cookstoves (ICS) are being promoted in many countries. These ICS are energy efficient cooking technologies that allow a more complete combustion of firewood (Malinski, 2008). The complete combustion minimizes the emission of black carbon particles that are detrimental to human health and environment (Inayatullah, 2011). Increased combustion efficiency through the use of ICS reduces the frequencies of firewood collection and expenditures on firewood purchase by households (Malinski, 2008). The reduction in the frequency of firewood collection releases labour that can be used for other household socio economic activities, such as farming and other income generating activities. In addition, as wood collection is mostly by girls, the reduced frequency of firewood collection gives them the opportunity to concentrate on school work (Malinski, 2008).

1.2 Common Firewood Cooking Technologies in Malawi

There are a number of firewood cooking technologies that are commonly used by households in Malawi. The proceeding section presents a description of some of the firewood stoves found in Malawi.

1.2.1 Three-stone Firewood Stove

As in other developing nations, a `three-stone firewood stove` is the oldest commonly used traditional cooking technology in rural areas of Malawi. As the name suggests, cooking and heating is done with a pot suspended over an open fire by three supports of equal height such as stones, bricks or wood. The fire is tendered by pushing sticks into the centre of the three stones (Malinski, 2008). The advantages of using three-stone firewood stove include easy to light, fast cooking, space heating, easy to move and flexibility to use different pot sizes and wood qualities (shape, type and moisture content). Three-stone firewood stove is easy to construct as no special skills are needed (Wanjohi and Smyser, 2013). Space heating allows socialization in the family as members gather around the stove during night to keep themselves warm. Because of the many advantages of three-stone fire as a very adaptable technology, there is continued use of three-stone firewood stoves in rural areas despite promotion of ICS (Concern Universal, 2012). In most households, an improved cookstove is used as a complementary cooking technology to a traditional three-stone stove or vice versa for some households (see, Malinski, 2008; Concern Universal, 2012).

According to Lewis and Pattanayak (2012), three-stone firewood stove is an inefficient cooking technology which is also a source of HAP. The inefficiency comes during transferring of released energy from firewood into the pot. During cooking on three-stone fire, energy is wasted in heating the surrounding air rather than the pot. That increases the amount of firewood that is used to cook a meal on three-stone firewood stove, especially when firewood is plentiful. Apart from being inefficient, the three-stone firewood stove can create a risk of scalds and burns especially to children who are mostly with their mothers in the kitchen during cooking time (World Bank, 2011). Furthermore, the stove releases a lot of smoke which result in dirty pots. Three-stone firewood stoves also spread ashes which may contaminate food (Concern Universal, 2012). Figure 1.1 shows three-stone firewood stove technology in use.

Figure 1.1 Three-Stone Firewood Stove

1.2.2 Chitetezo Mbaula Stove

Chitetezo Mbaula is one of the most widely distributed ICS in Malawi. By using locally available resources such as pottery clay, the stove is molded, cured and fired to produce the portable ceramic end product as shown in figure 1.2. below. Unlike the three-stone firewood stove, Chitetezo Mbaula has one opening for feeding firewood which reduces the loss of heat through wind. Heat is also retained through the ceramic body of the stove. Furthermore, the stove is portable with two handles so that fire can be moved to wherever one wants even during cooking. Chitetezo Mbaula produces less smoke and soot hence keeps pots, kitchen and surrounding clean (Wanjohi and Smyser, 2013).

Figure 1.2 Chitetezo Mbaula

Disadvantages of Chitetezo Mbaula include selective wood moisture content and size since it cannot accommodate wood sizes larger than the opening. As such, the large firewood sizes need to be split to fit the hole. Thus, labour must be provided to split the wood into smaller pieces that fit the opening.

Other disadvantages of Chitetezo Mbaula are that it provides one cooking place only and difficult to move the stove when in use as handles are usually hot (Concern Universal, 2012). Originally, Chitetezo Mbaula was domestically designed under the Programme for Basic Energy and Conservation (ProBec) which ran from 2004 to 2012 (Malakini et al., 2014). In promoting the stove, the program established production groups and trainers from different organizations across 15 districts of Malawi (MBAULA, 2014). After the ProBec phased out, a number of organizations such as Concern Universal and Christian Aid have been promoting the stove under program called Developing Innovative Solutions with Communities to Overcome Vulnerabilities and Enhance Resilience (DISCOVER). These organizations use marketing campaigns to promote the use of Chitetezo Mbaula in all the districts where the program is implemented (Wanjohi and Smyser, 2013). Chitetezo Mbaula production is done by local entrepreneurs that include women's groups in several districts such as Salima, Balaka, Mulanje and Nsanje (MBAULA, 2014).

1.2.3 Total Land Care Rocket Stove

This stove is being promoted by Total Land Care (TLC) in Salima, Rumphi and Lilongwe districts. Unlike the Chitetezo Mbaula and three-stone firewood stoves, the TLC Rocket Stove is fixed and has metal pot rests and metal firewood stand. These metal features enhance durability and efficiency of the stove. However, the combustion chamber is made of burnt bricks and mud (MBAULA, 2014). Figure 1.3 shows TLC Rocket Stove in use.

Figure 1.3 TLC Rocket Stove

Like the Chitetezo Mbaula, the stove has only one opening therefore, cannot fit pieces of firewood larger than the opening. TLC distributes the stove to users at a cost and monitors the stove usage for carbon accounting (Wanjohi and Smyser, 2013). In 2004, TLC initiated the production and promotion of rocket stove under Wellness and Agriculture for Life Advancement (WALA) project. By 2014, a total of 146, 933 stoves were distributed to households in the country. In 2013, TLC modified the rocket stove so as to qualify it for carbon financing partnerships (MBAULA, 2014).

1.2.4 Potable Rocket Stove

As the name suggests, the Potable Rocket Stove is not fixed; it can be moved from one place to another. It is made of steel, aluminum and insulated bricks hence is the most durable stove compared to the Chitetezo Mbaula and TLC Rocket Stove. The Portable Rocket Stove was first introduced in Malawi through Programme for Basic Energy and Conservation (ProBec) with assistance from Approvecho Research Centre in 2004.

The programme aimed at promoting institutional ICS in Malawi. A total of three producers were trained by the program from the three major regions of Malawi (MBAULA, 2014). The potable rocket stove has an elbow shaped combustion chamber as shown in the figure 1.4.

Figure 1. 4 Portable Rocket Stove

The vertical section works as an internal chimney by drawing air through the stove hence ensuring efficient combustion of the wood and good heat transfer to the cooking pot. However, the height and width of the elbow are designed in particular ratio to maximize heating performance (Roth et al., 2007).

1.2.5 Envirofit Clean Stove

Unlike all the other stoves described above, Envirofit Clean Stove is imported. It was first introduced in Malawi in 2012 by a Dutch non-governmental organization called Stichting St. Gabriel's Hospital Malawi (SSGHM) through Catholic Development Commission in Malawi (CADECOM). The SSGHM mission was to improve healthcare in the Central Region of Malawi through reducing exposure of people (women and children) to harmful smoke during the cooking process (SSGHM, 2013). This was achieved through the distribution of imported envirofit clean stoves to hospitals and health centers for the sterilization of medical instruments and for use in the guardian kitchens. However, some stoves were sold at about USD15 to rural households and USD90 to urban households in the districts of Lilongwe, Mchinji and Dowa (SSGHM, 2013).

Envirofit clean stove is made of steel and metal, the Envirofit clean stove saves firewood by more than 50 percent and reduces production of soot and harmful gasses by about 70 percent relative to the three-stone firewood stove (SSGHM, 2013). It is also relatively cool at the outside which reduces risks of burns during cooking (MBAULA, 2014). Figure 1.5 shows Envirofit Clean Stove in use.

Figure 1. 5 Envirofit Clean Stove

1.3 The National Cookstoves Program

In January 2013, the Government of Malawi (GoM) started the National Cookstoves Program with the aim of promoting the use of ICS. The government plans to distribute two million ICS in households by 2020 (Jagger and Jumbe, 2016). To coordinate this program, the National Cookstove Steering Committee (NCSC) comprising of relevant stakeholders such as GoM, Non-Governmental Organizations (NGOs) and private sector was established. One of the tasks of this committee was to establish stove standards that can be distributed under the program through a quality assurance study on all firewood cookstoves promoted in Malawi. Only stoves that meet minimum efficiency standards would then be included for distribution in the program. The program also promotes any improved stoves for liquid, gaseous fuels and electricity (GoM, 2015).

To complement the government`s efforts, a number of local and international NGOs have been distributing various ICS in Malawi. The NGOs use different approaches in distributing ICS in Malawi. For instance, Concern Universal disseminates Chitetezo Mbaula by selling to households as well as giving out for free to social cash transfer beneficiaries. The common locally made stoves being distributed in this program are Chitetezo Mbaula, TLC Rocket Stoves and Portable Rocket Stove. So that these stoves have been distributed in Balaka, Machinga, Dedza, Salima, Mchinji, Lilongwe, Mulanje, Kasungu, Thyolo and Zomba under this program. According to the Department of Energy Affairs, the government will extend the program to other remaining districts such as Chiradzulu, Likoma and Neno.

1.4 Problem Statement

Although the Government of Malawi and other local and international organizations have been distributing improved cook stoves to Malawian households, research has shown that despite such dissemination and promotion efforts, ICS adoption has been low and slow (see Meyer et al. (2015), Jeuland et al. (2013) and Jueland et al. (2015). This raises the questions as to whether consumer preferences and WTP for ICS are considered when promoting such ICS. The current study therefore assessed consumer choice and WTP for these three ICS in the district of Chiradzulu, one of the districts targeted by the program. The study sought to address the following research questions: (a) what drives households to choose different ICS technologies? (b) how much are consumers willing to pay for ICS? (c) what factors influence household`s WTP for ICS? By addressing these questions, the study has unraveled critical factors that need to be considered by government and other stakeholders involved in the up scaling and out scaling of ICS technologies under the National Cookstove Program and other cookstove initiatives.

1.5 Justification

Researchers and practitioners claim that ICS technologies are not widely adopted because they do not conform to user preferences and local cooking environment (Lewis and Pattanayak, 2012 and Whittington et al., 2012). A thorough understanding of consumer preferences and WTP for ICS is critical for the success of interventions aimed at promoting ICS. The findings of this study are crucial as they inform the design and implementation of appropriate strategies to enhance wider adoption of ICS in Malawi. The analysis of consumer choice and household WTP for ICS provide important insights of how differences in household socioeconomic characteristics affect the ICS choice patterns. Without consideration of consumer preferences, the current efforts by government and other players to promote ICS in Malawi will not lead to wider adoption by users if stoves that are not preferred by users are distributed. In addition, knowledge of WTP for the ICS is important as it helps to design strategies to enhance the sustainability of the program.

1.6 Objectives

1.6.1 Main Objective

The primary objective of this study was to assess consumers` choice and WTP for ICS in Chiradzulu District.

1.6.2 Specific Objectives

Specifically, the study achieved the following two objectives;

i. To determine factors that influence the choice of cookstoves among households in Chiradzulu District.

ii. To determine consumer WTP for ICS and its influencing factors in Chiradzulu District.

1.7 Hypothesis

This research study was conducted with the following hypotheses in mind:

H_0: Choice of ICS technologies in Malawi is not significantly influenced by household`s socio economic characteristics, firewood source characteristics and household cooking behavior, such as, firewood source distance, firewood collection time and age of the household head.

H_0: Household`s socio economic characteristics and firewood source characteristics such as age, household size, firewood collection frequency do not significantly influence WTP for ICS.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews studies on ICS that have been conducted in Malawi. The studies range from ICS efficiency, adoption and marketing. The chapter further reviews studies on consumer choice and WTP that were done elsewhere. The objective of this review is to uncover what has already been done in the energy sector and in the process identify gaps that the present study tried to address.

2.2 ICS Studies Conducted in Malawi

Malakini (2014) conducted a study to compare efficiency among three cooking technologies in Lilongwe District, Malawi. The technologies that were analyzed include three-stone firewood stove, Chitetezo Stove and Rocket Stove. Data used in the study were collected in 2010 through controlled cooking tests (CCT). Cooking efficiency was measured in terms of cooking time, equivalent dry wood consumption and specific fuel consumption. The data were analyzed using CCT Version 2.0 Software. The results showed that three-stone firewood stove had the highest mean cooking time of 50 minutes when compared to both Chitetezo Mbaula (46 minutes) and rocket stove (43 minutes). The study further showed that three-stone firewood stove registered the highest firewood consumption of 1558 grams (to cook a complete typical Malawian dish; nsima, cabbage vegetables and fish) as compared to 902 grams and 689 grams for Chitetezo Mbaula and rocket stove, respectively. The specific firewood consumption was found to increase for cooking technologies in the order of three-stone firewood stove, Chitetezo Mbaula and rocket stove.

Malinski (2008) assessed the outcomes and impacts of Chitetezo Mbaula dissemination projects on household economic wellbeing and environment in rural Malawi. Data for 327 households were collected through a survey in districts of Mulanje, Ntcheu and Thyolo. Stove producers were also interviewed to gather ICS business data. Using descriptive analysis, the study found that commercial stove promotion was successful in Mulanje with 3 percent increase in user rate. However, the study found that Chitetezo Mbaula functions the same way as three-stone firewood stove and that it could replace the tradition three-stone firewood stove. The study also estimated that Chitetezo Mbaula saves between 43 percent and 50 percent of the time spent in firewood collection by women and girls. The study further showed that adoption of fuel saving stoves could be considered long term transition in Malawi because people who own ICS continue to use three-stone firewood stove every day.

Concern Universal (2012) commissioned a study to assess the social cultural acceptability of improved cook stoves (ICS) in selected rural Malawian villages. Household data were collected from five villages in Mulanje, Dedza and Balaka districts. Inductive approach was used in the study in order to gather more information on social cultural issues surrounding use of ICS. The study found that many households with ICS continue to use three-stone firewood stove in addition to the ICS. The study also found that there were rituals associated with the three-stone firewood stove (ash and kitchen space) practised by some households. It was found that people in the study area use soot as medicine for several ailments, and smoke as a preservative for seeds and rafters. However, the study found that none of such (ritual) practices had critical impact on stove adoption.

Jagger and Jumbe (2016) conducted a study on willingness to adopt ICS in Malawi. Discrete choice experiment was used whereby 383 rural households were asked to choose between Chitetezo Mbaula and package of sugar and salt. Descriptive statistics showed that 66 percent of the sampled households chose ICS as opposed to salt and sugar. Empirical results from binomial-discrete choice model revealed that households that rely on crop residues as a source of fuel were more likely to adopt the ICS. The odds of choosing ICS were found to be lower among households with many firewood collectors. However, the study found no evidence of influence of demand side factors such as current fuelwood usage rates and household size on ICS adoption. The study further found that 80 percent of households who chose ICS were actively using the stoves which they received in the previous six months. The study concluded that there is potential for ICS adoption in Malawi.

Habermehl (2008) evaluated the economic efficiency of ProBEC program in promoting efficient institutional rocket stoves in Malawi. The evaluation was done on the stoves that were used for 10 years. Cost-benefit and cost-effectiveness analyses were used to estimate economic benefits of firewood savings with 3 percent discount rate. The study found that fuel savings due to the use of institutional rocket stove were significant with saving of between 12 percent and 38 percent of the total catering expenses. On the environmental impact, the study estimated that 689 hectares of natural forest cover was preserved in 2008 by using Institutional Rocket Stoves. The main recommendation from the study was that projects on promotion of energy-efficient institutional cook stove yield promising returns.

2.3 Studies on Consumer Choice and WTP for ICS

While there has been no study on consumer choice and WTP for ICS technologies in Malawi, a number of studies have been conducted elsewhere. For example, Jeuland et al. (2015) assessed preferences for ICS in North Indian villages. The study used a choice experimental design to elicit consumer preferences for ICS on a sample of 2,120 households in India. Both conditional logit and mixed logit were used to determine WTP for ICS attributes. The study found that households had strong preference for traditional stoves relative to ICS. It was also found that households were willing to pay on average, $10 and $5 for reductions in smoke emissions and fuel savings, respectively. However, the preferences for stove attributes was highly variable due to differences in household characteristics and risk preferences. The study concluded that widespread adoption of ICS is unlikely as households still prefer traditional stoves over ICS with similar characteristics.

In Ethiopia, Kooser (2014) used choice experimental design to examine households` valuation of different characteristics of stoves. These include durability of the stove, amount of cooking time reduced, reduction in the amount of fuel wood used, reduction of smoke and cost of the stove. A survey of 504 households was conducted in 2012. Both conditional logit and mixed multinomial logit models were used to determine WTP for each attribute and factors that influence household preferences. The preferred attributes by respondents included durability, fuel reduction, time reduction and smoke reduction. The WTP for durability, fuel reduction, smoke reduction, time reduction were estimated at $20.74, $18.81, $17.46 and $12, respectively. Thus, the results found that stove durability was the most valuable stove attribute. The study further found that socio economic factors such as number of female members and children in the household were key determinant of household WTP for ICS.

In East Africa, Adkins et al. (2010) assessed performance, preferences and usability of ICS among households in Western Uganda and Western Tanzania. In this study, households were asked to compare traditional three-stone firewood stove with improved and manufactured stoves namely, Ugastove, Envirofit, Advent and Stovetec stoves. The stove comparison was done through cooking tests and qualitative surveys. Results from Uganda indicated that relative to the three-stone firewood stove, Ugastove and StoveTec saved fuelwood up to 46 percent and 38 percent, respectively. Statistically significant cooking time increase of 27 percent was observed for Ugastove as compared to three-stone firewood stove. Cooking time difference between three-stone firewood stove and StoveTec was insignificant. In Uganda, StoveTec was ranked first, followed by Ugastove. For Tanzania, StoveTec and Envirofit Stoves showed highest firewood savings of 41 percent while Advent stove showed firewood savings of 25 percent when compared to three-stone firewood stove. Increases in cooking time for Envirofit and StoveTech was not statistically significant (4 percent and 16 percent increases, respectively) compared to three-stone firewood stove. Advent stove showed significant increase (63 percent) in cooking time compared to three-stone firewood stove. Tanzanian households preferred StoveTech, Envirofit, three-stone firewood stove and Advent in the descending order. The study recommends the combined use of quantitative stove tests and qualitative surveys in determining suitability of cookstoves.

Mobarak et al. (2012) applied both stated and revealed preference approaches to analyze the determinants of low demand for nontraditional cookstoves (such as ICS) in rural

Bangladesh. The nationally representative survey data were collected on (i) perceptions about the health risks of indoor smoke, (ii) the relative desirability of different attributes of nontraditional cookstoves, and (iii) the value placed on cleaner cookstoves relative to other basic goods and services. The respondents were asked to make hypothetical choices between ICS and cash in varying amounts of between $0.72 and $7.20. Data collected were used to derive the demand curves for various ICS. The study found that women were less willing to pay for ICS as they reported not to perceive HAP as a high-priority health hazard. Furthermore, the study found that demand for ICS technologies is more price-elastic than demand for other essential goods and services. The study therefore recommends that ICS features that are highly valued should be considered for successful promotion of ICS even when those features are not directly related to the cookstoves' health and environmental impacts.

Sagbo (2014) conducted an economic analysis and WTP for ICS and charcoal briquette in Haiti. The study analyzed the determinants of adoption and dis-adoption of ICS and charcoal briquettes. Data used in the analysis were collected through a survey of 150 respondents in 2014. Choice experimental design was used to elicit WTP for ICS and briquettes with attributes solicited through focus group discussions. Stove price, size, material and fuel consumption were ICS attributes considered in the study while briquettes attributes included price, material, smoke and ash production. From conditional logit and mixed multinomial logit models, the study found that material was the most valued ICS attribute with consumers willing to pay $43.70 for a stove with a steel covered chamber wall as opposed to steel alone. For stoves with low-fuel-consumption or bigger size, consumers were willing to pay on average, $18.86 and $13.75, respectively. However, consumers` WTP for both the ICS and briquettes were found to be influenced by socio-economic factors such as participation in ICS program and household income.

2.4 Approaches to Analyzing WTP for ICS

Haab and McConell (2002) defines WTP as the maximum amount of income an individual will pay in exchange for an improvement in a particular circumstances. WTP could also mean the maximum amount a person will pay to avoid a decline in circumstances. In this study, WTP is defined as maximum amount of income a household will pay in exchange for health and environmental benefits of using ICS as compared to traditional Three-stone Firewood Stove.

WTP is a stated preference technique that can be elicited through contingent valuation method (CVM). Therefore, CVM is a method used to recover information about WTP with the purpose of estimating maximum amount an individual will pay for changes in the quantity or quality of goods or services (Haab and McConell, 2002). It involves asking a hypothetical (contingent) question to the respondent and the response is used to directly calculate WTP (Dlamini et al., 2016). Therefore, depending on how contingent question is posed, there are four approaches to getting information on WTP value. The approaches include open ended contingent valuation, bidding game, payment cards and discrete choice contingent valuation (Haab and McConell, 2002). As the name suggests, the open ended contingent valuation involves asking an individual to give a point estimate of his or her WTP. Bidding game is a contingent method whereby respondents are iteratively asked whether they would be willing to pay a certain amount of money until a point estimate is reached. Discrete choice involves asking the respondents simple yes or no question on whether they are willing to pay certain amount of income. Lastly, payment cards are contingent question format whereby respondents are asked to choose a WTP point estimate from a range of estimates predetermined by the researcher. However, discrete choice approach is reasonable method of eliciting WTP when compared to the other three methods which suffer from incentive compatibility problems (Haab and McConell, 2002). The Incentive compatibility problems may arise when respondents influence potential outcomes of a CVM survey through revealing values other than their true WTP.

2.5 Summary

From the reviewed literature, other than studies on adoption, marketing and efficiency of ICS, there have been no studies on choice and WTP for ICS conducted in Malawi. However, studies conducted elsewhere on WTP used stated and revealed preference approaches to estimate WTP values and their determinants (Kooser, 2014; Adkins et al., 2010 and Sagbo, 2014). The main determinants of choice and WTP for ICS in these studies include socio-economic characteristics, health and local environment factors. From the literature review, it can be deduced that the knowledge of consumer WTP and their determining factors is essential to foster wider ICS adoption. This thesis extends the work done by Kooser (2014), Adkins et al. (2010) and Sagbo (2014) to analyze consumer choices and WTP for three locally made ICS being promoted under the National Cookstove Program in Chiradzulu, a targeted district in the program. The current study considered consumer choice and WTP for three types of ICS namely Chitetezo Mbaula, Rocket Stove and Portable Rocket Stove and how their values vary by household socioeconomic and environmental factors. Since the study was conducted in the district where such ICS technologies have not yet been introduced, information from this research is vital for deciding the types of preferred stoves to be promoted under the program.

CHAPTER THREE

METHODOLOGY

This chapter presents methods that are used in the study. The chapter begins by providing the conceptual and theoretical frameworks of household`s choice and WTP for ICS. Thereafter, empirical strategy and empirical models are specified and estimated. The chapter concludes with a detailed description of the study area, data sources, sampling procedure and study limitations.

3.1 Conceptual Framework

A conceptual framework for analyzing household choice and WTP for ICS is presented in figure 3-1. From the literature review, a number of factors influence household's choice and WTP for energy technologies such as ICS. The commonly highlighted factors include household socio-economic and demographic characteristics, firewood availability, household cooking behavior and ICS characteristics (Lewis and Pattanayak, 2012; Mobarak et al., 2012; Malla and Timinsina, 2014 and Adkins et al., 2010). In this framework, socio-economic and demographic factors that are considered to influence choice and WTP for ICS include: household total monthly income, household head gender, household head age, number of female adults in the household, ratio of under-five children to total household size, location and knowledge of negative impacts caused by using the three-stone firewood stove. These socioeconomic and demographic factors influence the choice and WTP for ICS in different ways, for instance, income positively influences household choice of ICS while age is assumed to have a negative impact on choice and WTP for ICS (Mobarak et al., 2012; Malla and Timinsina, 2014).

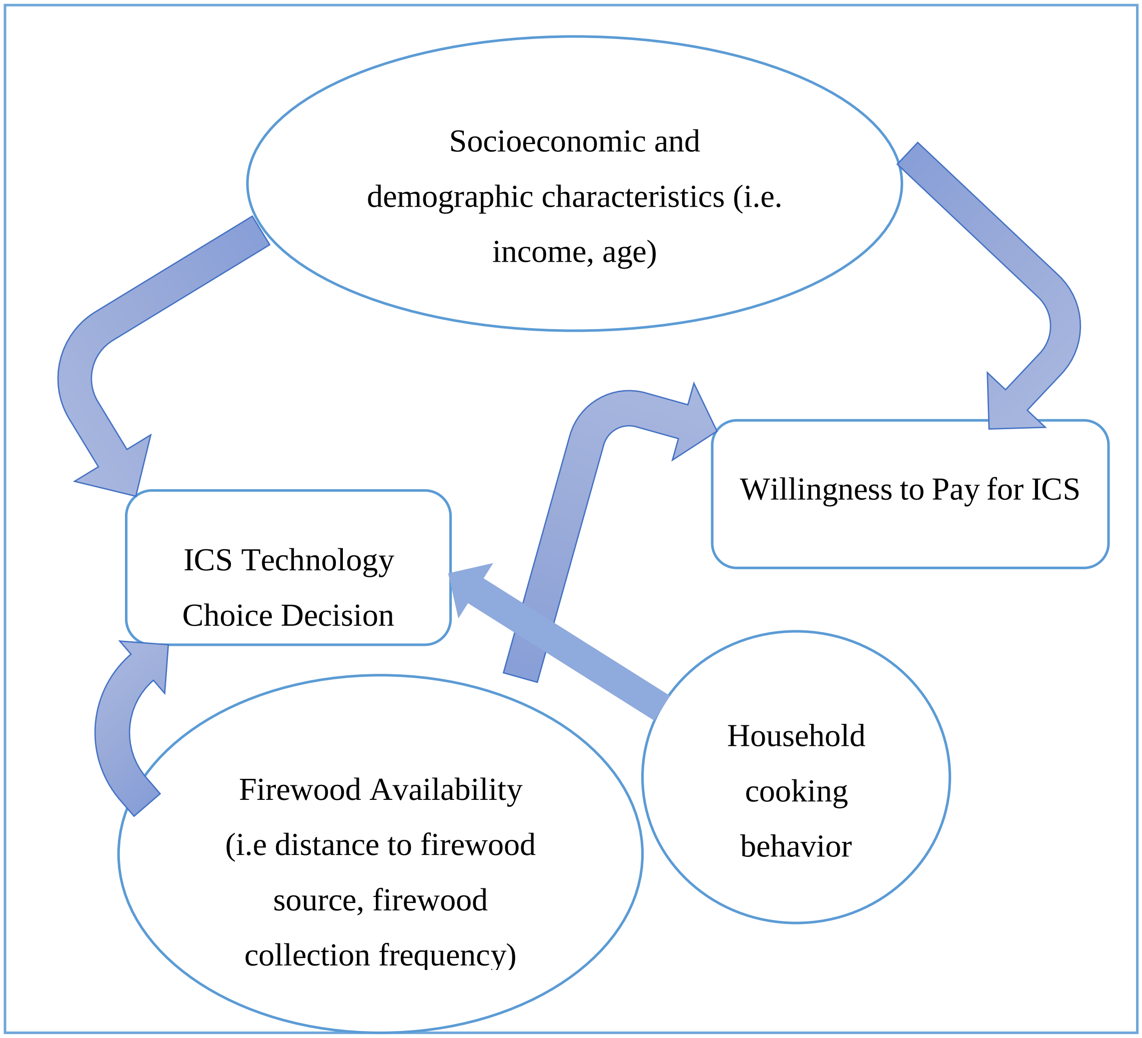

Figure 3.1 Conceptual framework for choice and WTP for ICS

Availability of firewood also impact the choice and WTP for ICS technologies (Lewis and Pattanayak, 2012). The study considers distance to firewood source, frequency of firewood collection per week and total time spent collecting firewood as factors under firewood availability that impact household choice and WTP for ICS. Increase in magnitude of all of these factors are assumed to increase firewood scarcity to the household hence positively influence the choice and WTP for energy saving technologies such as ICS. Furthermore, ICS choice is linked to household (consumer) cooking behavior (Adkins et al., 2010). Consumers are likely to choose a stove with design (size or two cooking places) that mostly fit in their cultural context and sufficient for their specific cooking needs (Nyrud et al., 2008).

The factor considered under consumer cooking behavior is whether the household usually cooks on two cooking places concurrently. This is expected to negatively influence the WTP for ICS that are used in this study because they all have one cooking place. However, the study recognizes that other factors such as stove characteristics (such as amount of smoke emissions, stove time saving, stove efficiency etc.) cannot be easily measured unless in a controlled cooking test. As such, the stove characteristics were used just to provide stove description to the respondents during interviews to ease understanding but none of such characteristics were considered in the choice and WTP functions.

During the interview, the primary cook in the household was asked to choose his/her preferred stove among the three stoves, Chitetezo Mbaula, TLC Rocket Stove and Portable Rocket Stove. The questionnaire was presented with pictures of the three stoves along with the description of their associated features and attributes. The primary cook was then asked to choose from the pictures the stove he/she would prefer based on the description of each stove. After choosing the preferred stove, the respondent was asked to state his/her WTP through a discrete question. Given that bid price reflects the real stove`s market price, respondents were asked to state whether they are willing to pay for the chosen stove or not. In this regard, a respondent with WTP greater than the stated bid amount gives a `yes` response and is considered willing to pay for that particular stove. If WTP is less than the bid, the respondent is considered not willing to pay for the chosen stove.

3.2 Theoretical Framework

The theoretical framework for analyzing the determinants and WTP for ICS is derived from a consumer theory. Consumer theory conventionally states that consumers derive utility from consumption of goods and services (Varian, 1992). ICS consumers are expected to maximize utility from consumption of environmental goods, marketed goods and leisure. In terms of ICS usage, environmental goods are often associated with reduced smoke and HAP that result into positive health outcomes. The marketed good in this study is mainly the consumption of market purchased firewood which a household would want to save by using ICS. However, there could be possible interactions between purchased firewood and other items in the basket of goods since savings from firewood would increase the purchase of other goods. Leisure, however, results from reduced fuelwood collection frequency. The assumption is that ICS consumer chose strictly positive quantities of marketed and environmental goods Q and G with prices P_Q and P_G and leisure (l) by maximizing utility (U) subject to household income (M) and time (T) constraints. Since utility involves consumption of marketed and environmental goods as well as leisure, the production constraint is not considered. In this study, however, consumer preference is assumed to be affected by household demographic and socioeconomic characteristics (Z) and firewood availability (S). Therefore, the utility function can be specified as follows:

$$Max\ U = U(Q, G, l: Z, S) \quad (1)$$

Subject to;

$$M = P_Q Q + P_G G \ \ldots\ldots \text{Income constraint} \quad (2)$$

$$T = l + w + f \text{ ....Time constraint.} \quad (3)$$

For rural households, total time endowment (T) is assumed to consist of time for leisure (*l*), time for firewood collection (w) and time for other more productive activities such as farming and wage labour (f). The use of ICS can save time from collecting firewood hence free up time for leisure and other productive activities. Maximizing the utility problem subject to given constraints is accomplished by using Lagrange`s function as specified in equation (4).

$$L = U(Q, G, l: Z, S) + \lambda\left(M - P_Q Q - P_G G\right) + \rho(T - l - w - f) \quad (4)$$

where λ and ρ are Lagrange multipliers. The first order conditions (FOCs) are therefore derived as shown in equations 5 through 9.

$$\partial L / \partial Q = \frac{\partial U(Q,G,l;\, Z,S)}{\partial Q} - \lambda P_Q = 0 \quad (5)$$

$$\partial L / \partial G = \frac{\partial U(Q,G,l;Z,S)}{\partial G} - \lambda P_G = 0 \quad (6)$$

$$\partial L / \partial l = \frac{\partial U(Q,G,l;\, Z,S)}{\partial l} - \rho = 0 \quad (7)$$

$$\partial L / \partial \lambda = M - P_Q Q - P_G G = 0 \quad (8)$$

$$\partial L / \partial \rho = T - l - f - w = 0 \quad (9)$$

The equation (5) through equation (7) imply that ICS consumer`s marginal utility (derived from marketed good, environmental good and leisure) is positive and increases with increased consumption of marketed and environmental good and leisure. Equation 8 is the income constraint implying that ICS consumers cannot spend more than their income. Lastly, equation (9) is time constraints meaning that time spent on leisure, firewood collection and other economic activities should some up to total time available to the ICS consumer.

The basis for solving utility maximization problem is to get consumer Marshallian demands for both marketed and environmental goods which are function of income and prices (Varian, 1992). The demand for both marketed and environmental good can therefore be specified as;

$$Q^m = d^Q(P_Q, P_G : Z, S) \quad (10)$$

$$G^m = d^G(P_Q, P_G : Z, S) \quad (11)$$

Given the demand functions for both goods, the indirect utility function ($V(P, M)$) can be derived by substituting the demands functions into utility function in equation (1). Since indirect utility is a function of income and prices, leisure is not part of the function.

$$V(P, M) = U\left(d^Q(P_Q, P_G : Z, S), d^G(P_Q, P_G : Z, S)\right) \quad (12)$$

Indirect utility function shows maximum utility that can be attained given the prices of both goods. With such understanding, indirect utility provides a theoretical grounding for welfare estimation (Haab and McConell, 2002). However, indirect utility only provides deterministic component of utility function. For ICS choice, Random Utility Model (RUM) will be used. RUM contains both deterministic component and stochastic component of utility function. Therefore, depending on the assumption made about the stochastic component of RUM, many probabilistic models can be derived as shown in the empirical strategy.

3.3 Empirical Strategy

Consider a household i from a sample of N households who derives utility by choosing a stove from a choice set defined by $j=1,2,3$ alternative stoves, namely, Chitetezo Mbaula, TLC Rocket Stove and Portable Rocket Stove. The assumption is that each household i allocates utility value to each stove alternative depending on household demographic and socioeconomic characteristics Z_i, and personal perception of stove benefits. Therefore, household i will choose stove j only if the utility associated with choosing that particular stove *(j)* is higher than that of other stoves. Let D_{ij} represents a discrete choice variable taking the values of 1 if a household i chooses stove j and zero, otherwise. A rational household chooses first alternative only if the following inequality holds:

$D_{i1} = 1$ If $U_{i1} > U_{ij}, j = 2,3$

$D_{i1} = 0$ Otherwise (13)

Therefore the probability that household i chooses stove alternative 1 can be specified as:

$$P_{i1} = \Pr(U_{i1} > U_{i2} \text{ and } U_{i1} > U_{i3}) \tag{14}$$

The utility that consumers derive from choosing ICS is not observable, however, some household characteristics are observable (Jumbe and Angelsen, 2011). Then utility that a household chooses alternative j can be specified as:

$$U_{ij} = V_{ij}\left(S_{ij}, \beta, Z_i\right) + \varepsilon_{ij} \tag{15}$$

whereby, V_{ij} $(.)$ is the observed component of the utility function and it is the indirect utility function. S_{ij} is the firewood availability, Z_i represents household-specific characteristics and β is the vector of unknown parameters. ε_{ij} is the unobserved or stochastic component of the utility and it captures other unobserved factors that affect utility.

3.4 Model Specifications

3.4.1 Analysis of Stove Choice Decision and its Determinants

From the theoretical framework, assumptions can be made about the random component of utility function in equation (15) to derive probabilistic models (Jeuland et al., 2015). In this study, multinomial logit (MNL) is used with the assumption that the error terms for the stove choices ε_{ij} $(\varepsilon_{i1,}\varepsilon_{i2,}\varepsilon_{i3}$) are independently and identically distributed (iid) with a type one extreme value distribution. Furthermore, most discrete choice studies used multinomial logit (MNL) unlike Multinomial Probit Model (MNP) because of its simplicity in computing probabilities. In estimating MNP, it is a requirement that multivariate normal integrals must be evaluated to estimate the unknown parameters (Hausman & McFadden, 1984). With that requirement, MNP is not commonly applied because it is computationally more intensive than the MNL (Hassan and Nhemachena, 2008).

The iid error assumption in MNL results in the key assumption of the model, namely independence of irrelevant alternatives (IIA). This assumption basically implies that an individual`s evaluation of a particular stove relative to another stove should not vary even if another stove is dropped or added to the stove choices (Hausman & McFadden, 1984). Individual evaluation "scores" for each choice are therefore computed as different continuous latent variables. A stove (Y_j) is therefore chosen if the individual attaches a higher value relative to other stoves. Mathematically the choices can be represented as follows:

$$Y_j = \begin{Bmatrix} 1\ if\ Max\ (U_{i1}, U_{i2}, U_{i3}) = U_{i1} \\ 2\ if\ Max\ (U_{i1}, U_{i2}, U_{i3}) = U_{i2} \\ 3\ if\ Max\ (U_{i1}, U_{i2}, U_{i3}) = U_{i3} \end{Bmatrix} \qquad (16)$$

Furthermore, MNL assumes that the values of independent variables are the same but coefficients (β) differ across choices. Let *h* represents three sets of independent variables (household demographic and socioeconomic characteristics, household cooking behavior and firewood availability) that affect household choice of a particular stove. Therefore, the probability of choosing Y_j alternative by individual *i* is specified as:

$$prob\ (Y_j = j|h) = \frac{\exp(h_i\beta_j)}{\sum_{k=0}^{j} exp(h_i\beta_k)}\ , j = 1,2,3 \qquad (17)$$

However, equation (17) has to be normalized to remove indeterminacy (Long, 1997). To do this, we assume that β_0= 0 and the probabilities are therefore specified as below:

$$prob\left(Y_j = j|h\right) = \frac{\exp(h\beta_j)}{1+\sum_{k=0}^{j} exp(h_i\beta_k)}\ , j = 1,2,3\ \ \beta_0 = 0 \tag{18}$$

The MNL relationship between the nominal categorical dependent variable and vector of independent variables is built by estimating a vector of parameters (β) through a log-likelihood method. Estimating equation (18) gives multinomial log odds ratio. Setting Chitetezo Mbaula as a base category as it is the most widely chosen ICS, the log odds of a household choosing stove j relative to base category (Chitetezo Mbaula) is specified as:

$$ln\left(\frac{P_{ij}}{P_{ik}}\right) = \left(h_i\left[\beta_j - \beta_k\right]\right) = h_i\beta_j, if\ \beta_k = 0. \tag{19}$$

Taking the derivative of equation (19) with respect to *h*, gives unit change effects of *h* on log odds of outcome j versus base category as given below:

$$\partial ln\left(\frac{P_{ij}}{P_{ik}}\right)\Big/_{\partial h} = {\partial h_i\beta_j}\big/_{\partial h} = \beta_j \tag{20}$$

However, these parameter estimates of the MNL model only provide the direction of the effect of the independent variables on the dependent (ICS choice) variable; thus the estimates represent neither the actual magnitude of change nor the probabilities. In order to measure the expected change in probability of a stove choice being made with respect to a unit change in an explanatory variable marginal effects are calculated. The signs of the marginal effects and respective coefficients may be different, as the former depend on the sign and magnitude of all other coefficients (Hassan and Nhemachena, 2008). Therefore, taking derivative of equation (18) with respect to *h* gives marginal effects as shown below:

$$\frac{\partial prob\left(Y_j = j|h\right)}{\partial h_i} = prob\left(Y_j = j|h\right)\left[\beta_j - \sum_{k=0}^{J} \beta_k \; prob\left(Y_k = k|h\right)\right]$$

$$= prob\left(Y_j = j|h\right)\left(\beta_j - \bar{\beta}\right) \tag{21}$$

3.4.2 Estimating Determinants and WTP for ICS

Contingent valuation method (CVM) was used to elicit WTP for ICS as well as the effects of covariates on WTP. CVM is a direct or stated preference technique which involves posing contingent or hypothetical questions to respondents. The responses to the hypothetical questions are used to infer preferences or WTP for welfare changes (Dlamini et al., 2016). However, one can use either WTP or willingness to accept (WTA) to measure economic value depending on the property right to the good, in this case ICS (Haab and McConell, 2002). In situations where an individual wants to acquire a good, WTP is appropriate. WTA is appropriate where an individual is being asked to voluntarily give up a good. Since the targeted population for this study does not own ICS, WTP was used as recommended by National Oceanographic and Atmospheric Administration (NOAA) (Haab and McConell, 2002).

In this study, the hypothetical question asked a respondent about monetary valuation of a service that is appealing to the respondent. In the case of ICS, the respondents comprised households that use three-stone firewood stove hence the use of ICS was considered as an improvement from the status quo. The study employed single-bounded model to estimate mean WTP for environmental and health improvements associated with ICS. Unlike open-ended questions and double-bounded method, single bounded approach is easy in terms of household`s cognitive task in responding to the questions. A decision is made only on the stated price as is the case when buying goods from a supermarket.

When a contingent questionnaire is administered using discrete choice framework, the information that is directly elicited from a respondent is a dichotomous answer to a question about paying determined amount (that is randomly given to individuals). Econometrically, WTP can be estimated assuming that it follows the linear function:

$$WTP_j(Z_i, u_{ij}) = h_i\beta + u_{ij} \qquad (22)$$

β is a vector of parameters, h_i is a vector of household demographic and socioeconomic characteristics and firewood availability and u_{ij} is normally distributed error term, with mean ($\in$) zero ($\in(\varepsilon_i) = 0$). However, true WTP (WTP_j^*) from discrete contingent valuation question is latent and it can only be inferred. WTP_j^* can be assumed to be linearly related to the observed explanatory variables (h_i) as shown in the structural model in equation (22) above. Since WTP_j^* is considered as latent variable the variance of u_{ij} cannot be estimated, we can only assume that it is equal to 1 ($var(u_i/h_i) = 1$). These assumptions qualify use of the probit model in estimation of determinants of WTP for ICS.

In the contingent valuation case, there are two states or scenarios. The first scenario is improved state when the contingent valuation prevails and it is the final state. In this case, it is a state associated with the use of ICS. Using ICS is associated with reduced smoke and HAP which have positive health outcomes. The second scenario is the status quo and it is associated with the use of three-stone firewood stove. If we let t_j denotes the initial bid price, the latent variable WTP_j^* , can be mapped to the observed binary variable (WTP_j) by the following measurement equation:

$$WTP_j = \begin{Bmatrix} 1 \; if \; WTP_i^* > t_j \\ 0 \; if \; WTP_i^* < t_j \end{Bmatrix} \tag{23}$$

However, the probability of observing a positive response by individual *i* given the household characteristics is specified as:

$$\begin{aligned} prob(yes_j|Z_i) &= prob(WTP_j > t_j) \\ &= prob(Z_i\beta + u_{ij} > t_j) \\ &= prob(u_{ij} > t_j - Z_i\beta) \end{aligned} \tag{24}$$

With the normality assumption of the error term u_{ij} made earlier, the probability of observing a positive response becomes:

$$\begin{aligned} prob(yes_j|Z_i) &= prob\left(u_{ij} > \frac{t_j - Z_i\beta}{\sigma}\right) \\ &= 1 - \Phi\left(\frac{t_j - Z_i\beta}{\sigma}\right) \end{aligned}$$

$$= \Phi\left(Z_i \frac{\beta}{\sigma} - t_j \frac{1}{\sigma}\right) \quad (25)$$

where $\Phi(x)$ is standard cumulative normal and u_i is normally distributed with zero mean and variance of 1. However, in estimating the model a simple probit is used with bid price as one of the explanatory variables. From probit results, we obtain coefficients of each of the independent variables ($\hat{\alpha} = \frac{\hat{\beta}}{\hat{\sigma}}$) and coefficient of the bid ($\hat{\delta} = -\frac{1}{\hat{\sigma}}$) . Taking the average of explanatory variables, WTP is calculated using the following formula (Lopez-Feldman, 2012).

$$E(WTP|\hat{z}, \beta) = z^{-1}\left[-\frac{\hat{\alpha}}{\hat{\delta}}\right] \quad (26)$$

where β is the coefficient estimates and z^{-1} is the vector of the average of the explanatory variables.

3.4.3 Description of variables used in the Determinants of Choice of ICS

The dependent variable in choice modeling was a nominal categorical variable comprising three ICS, namely, Chitetezo Mbaula, TLC Rocket Stove and Portable Rocket Stove. The independent variable were classified as socio-economic and demographic variables, firewood availability variables and cooking behavior variables. Below is the description of these variables and their apriori expectations.

3.4.3.1 Socio-economic and Demographic Independent Variables

Household Total Monthly Income

Household total monthly income was considered because poor households are less likely to be willing to pay for ICS (Sagbo, 2014) because of greater concern on meeting basic needs compared to environmental investments. Therefore, household monthly income is expected to increase the probability of choosing more costly and efficient ICS such as Portable Rocket Stove. However, it is difficult to obtain accurate data on monthly income as households tend to under-report their income sources. Similar to other studies, monthly household expenditure was used as a proxy for income and the data was captured through the listing of total expenditures made by the household over the past 30 days from the day of the interview.

Number of Female Adult Household Members

The number of adult female members in the household was assumed to negatively affect the choice of ICS. The higher the number of adult females, the lower is the probability of choosing ICS with higher firewood efficiency (Kooser, 2014). This is because a household with many females has more labour needed in cooking and fuel collection hence may not appreciate time saving benefits of ICS.

Under-Five Children Ratio

This variable was measured as the proportion of children under the age of five to total household size. The assumption is that higher ratios are associated with a higher probability and willingness to pay for more efficient ICS by the household (Kooser, 2014). Children are mostly carried by their mothers during cooking and firewood collection. In this case, a household with an under-five child would have a higher likelihood of adopting ICS to reduce the negative health impacts of smoke during cooking and burden of carrying the child to collect firewood. This data was collected from the household roster that was structured in a questionnaire.

Age of the Household Head

Age of the household head was assumed to be negatively associated with the probability of choosing the more complex ICS types, such as the TLC Rocket Stove. This is the case because older individuals are more cautious and thus less likely to make a switch from traditional cooking methods as compared to younger ones (Nlom and Karimov, 2015).

Household Location

Location in which the household is found was also considered among the factors influencing household choice of ICS. This is because different location likely differ in resource endowment, which affects perception on the benefits of adopting ICS. This study had two household locations, namely Chitera and Likoswe Traditional Authorities.

Knowledge of Negative Environmental Impact of Three-stone Firewood Stove

Knowledge about negative environmental impact of traditional Three-stone Firewood Stove is expected to positively influence choice of ICS (Mobarak, et al., 2012). During interviews, most households admitted that cutting down trees for firewood was the cause of deforestation in their areas. Therefore, such knowledge would make the household choose the firewood efficient ICS.

Knowledge of Negative Healthy Impact of Three-stone Firewood Stove

Cooking on Three-stone Firewood Stove produces a lot of smoke which can be detrimental to human health (Lewis and Pattanayak, 2012). Most households in Chiradzulu admitted that smoke was one of the worst attributes of Three-stone Firewood Stove. The reasons given were that smoke causes eye illness and cough. Therefore, it is assumed that understanding of such impact would positively influence households` choice of ICS. The variable was defined as whether households had prior knowledge of negative health impact of using Three-Stone Firewood Stove.

3.4.3.2 Firewood Availability

Firewood Source

Firewood source was defined based on whether the household sources firewood from private land or other sources (such as commercial forests, forest reserve and market). This is based on the assumption that households with private sources, such as privately owned trees better understand energy saving attributes of the stove.

Firewood Source Distance from Home Stead

Distance to firewood source from home stead proxies firewood availability to the household. The assumption is that in cases where the household members have to take long and strenuous walks to collect firewood, efficient and time saving ICS technologies are preferred (Mobarak et al., 2012). Therefore, a positive association is expected between distance to firewood source from home and choice of ICS.

3.4.3.3 Household Cooking Behavior

ICS choice is directly linked to household`s cooking behavior and perceptions (Nyrud et al., 2008). Households choose stove with design that mostly fit in their cultural context and meet for their specific cooking needs. Therefore it was assumed that households that usually cook on two cooking places at once may find it difficult to choose and adopt a stove with one cooking place. Therefore, it is expected that households which usually cook on two cooking places are less likely to choose ICS (Chitetezo Mbaula, TLC Rocket Stove and Portable Rocket Stove).

3.5 Study Area

The study was conducted in Chiradzulu District, in the southern region of Malawi. The district was chosen because it is one of the districts where ICS technologies have not yet been promoted in Malawi. However, it is one of the districts targeted for ICS promotion under the National Cookstove Program by GoM which aims at distributing 2 million ICS by 2020. Furthermore, the district is densely populated (304 people per km^2) with 90 percent of people living in rural areas (Kamanga et al., 2009). As such the district is not well endowed with forests. Therefore, the distribution of efficient cookstoves will help to reduce forest degradation in the district in addition to health benefits.

3.6 Study Design and Sampling Procedure

The study was a mixed design involving quantitative (household survey questionnaire interviews) and qualitative (key-informant interviews and focus group interviews) methods. Household survey questionnaire interviews were conducted in two traditional authorities in Chiradzulu District. Chiradzulu has six traditional authorities namely:

Kadewere, Nkalo, Likoswe, Mpama, Mtchemo and Chitera. Two of these traditional authorities (Kadewere and Nkalo) were ineligible for this study because they were reported to have just rolled out ICS program initiated by an NGO called Centre for Alternatives for Victimized Women and Children (CAVOC). However, out of remaining four traditional authorities, three (Likoswe, Mpama and Mtchemo) share boundaries hence were assumed to be similar in many ways (homogenous). For that reason, only Likoswe was randomly chosen for the study. Chitera was purposively chosen because it is located at the far end of the district. Therefore, the two traditional authorities of Likoswe and Chitera were sampled for the household survey. However, because the data analysis for this study required a large sample size, a pooled data and not TA specific data was used in the analysis. A total of five group villages were randomly sampled from the two T.A. Furthermore, eleven villages were then randomly sampled from the five group villages. Number of group villages and villages was reached based on the size of a particular T.A and group village. Random sampling procedure was used in selecting households to interview from each village. However, the number of households interviewed from each village was determined by the probability proportional to size (PPS) sampling procedure. Based on PPS procedure, larger villages had a proportionately greater chance of having households selected for the survey than smaller villages. This procedure is important because it is self-weighting and improves the representativeness of the sample (Edriss, 2013).

3.7 Data Sources, Sample Size and Data Collection

The main source of data for this study was the household survey. A semi-structured questionnaire (refer to appendix A) was used in face to face interviews involving household head and/or primary cook. Quantitative data collected using the questionnaire included household head socioeconomic and demographic characteristics, primary cook socioeconomic and demographic characteristics, characteristics of firewood sources, stove choice and WTP for the chosen stove. Key informant interviews were conducted with main ICS stakeholders namely, Department of Energy Affairs, Concern Universal and TLC Green. However, focus group discussions took place at village level with women who were also primary cooks in their families. Qualitative data collected through both key informant interviews and focus group discussions were used to enhance understanding and validate quantitative information collected through the questionnaire.

A total of 404 households which are the units of analysis for this study were sampled from the villages using the simple random sampling procedure. The sample size was calculated using the following formula adapted from Edriss (2003):

$$n = \frac{Z^2(1-P)P}{e^2} \qquad (27)$$

Whereby Z is equal to 1.96 for 95 percent level of confidence, *P* is an estimate of the population proportion (0.5) and *e* is the absolute size of the error in estimating *p* (0.05). The sample size was further increased by 10 percent to carter for the possibility of non-respondents. Using this formula, the sample size was supposed to be 422. However, the actual sample size was reduced to 410 due to missing households, mainly caused by the household visits coinciding with market days as the survey was conducted soon after harvesting period. Although, call backs were conducted, it was still not possible to reach all sampled households. Finally, data from 404 households were used in the final analysis after the cleaning exercise which dropped incomplete questionnaires and outliers in data. The distribution of sampled households is summarized in the table 3.1 below.

Table 3.1 Distribution of Sampled Households

Traditional Authority	Group Village	Village	Sample
Likoswe	Njelemba	Njelemba	45
Likoswe	Njelemba	Kwerani	22
Likoswe	Njelemba	Kazembe	14
Likoswe	Mkonga	Mkonga	62
Likoswe	Likoswe	Natcho	10
Likoswe	Likoswe	Magombo	39
Likoswe	Likoswe	Likoswe	55
Chitera	Mwitha	Mwitha	78
Chitera	Chitera	Mtembo	13
Chitera	Chitera	Sayenda	37
Chitera	Chitera	Ndalama	29
Total			**404**

To ensure data quality, data collection was conducted by well-trained enumerators. A total of four enumerators were recruited and trained to administer the questionnaires. The training covered the content of the questionnaire, method of data collection especially the contingent valuation section and how to approach sample households during the interviews. Before embarking on the actual data collection, the questionnaire was pre-tested in the field to identify critical problems relating to formatting, wording and content of the questionnaire. After data collection, data was entered into a data entry template created using SPSS. After entry, data was validated, cleaned, and analyzed using Stata 12.

During data analysis, econometric diagnosis tests were conducted to ensure that the models were well specified. Data was tested for multicollinearity among explanatory variables using the variance inflation factor (VIF). MNL model was also checked if it meets independent irrelevant alternatives (IIA) assumption using Hausman test.

3.8 Study Limitation

The limitation of this study is that stove attributes were not considered as independent variables in the analysis of stove choice and WTP. However, the attributes were used to describe the stoves during choice experiment. This was the case because most of these variables require lab tests in order to measure them and was not possible given the time frame of this study. Despite this limitation, the study provides useful information for the designing of strategies for up-scaling the distribution of ICS in the country.

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter presents the results of the descriptive statistics for the variables used in the multinomial logit model and single bounded WTP model. Statistical tests such as the t-test and the Chi-square test are used to test the significant difference of the socio-economic variables of households that choose different ICS. The descriptive analysis results are presented in terms of differences between two ICS (*i.e.* Chitetezo Mbaula versus TLC Rocket Stove, TLC Rocket Stove versus Portable Rocket Stove and Portable Rocket Stove versus Chitetezo Mbaula). Also presented in this chapter are the empirical results on determinants of stove choice and WTP for the chosen stoves.

4.1 Descriptive Statistics

Consumer choice of a stove from among the available options (Chitetezo Mbaula, TLC Rocket Stove and Portable Rocket Stove) is assumed to be influenced by a number of socio-economic and demographic factors, firewood availability and household cooking behavior (Lewis and Pattanayak, 2012; Mobarak et al., 2012; Malla and Timinsina, 2014; Adkins et al., 2010). Table 4-1 and Table 4-2 presents descriptive statistics of the continuous and discrete variables, respectively, hypothesized to influence stove choice and WTP.

4.1.1 Age of the household head

The average age of household heads in the study was 43 years (Table 4-1), with no significant difference among households that chose different stoves. In other words, the results imply that there were no differences in the age of the heads of households that chose different ICS designs in Chiradzulu district.

4.1.2 Firewood Source Distance from Home

On average, the distance to the main firewood source from the homestead was 0.723 Kilometers, with no significant difference in the firewood collection distances covered by households that chose different stoves.

4.1.3 Income level of the household

Household monthly expenditure was used as a proxy for household income in this study, because of the tendency for households to under-report their income from different sources. The results show an average monthly household income of MK16, 478 (US$ 23.11)[1]. There was no significant difference in household income between households that chose Chitetezo Mbaula and those that chose the TLC Rocket stove. However, there was significant difference (1 percent significance level) in household income between households that chose Portable Rocket Stove (priced at $37.09) and those that chose the Chitetezo Mbaula (priced at $0.9) and the TLC Rocket Stove (priced at $22.48). Households that chose the most expensive Portable Rocket Stove had monthly household expenditure of MK26, 448 ($37.09) which is much higher than those that chose Chitetezo Mbaula (MK13, 886 or $19.5) and TLC Rocket Stove (MK16029 or $22.48).

[1] Exchange Rate: MK713.02=1$

4.1.4 Firewood collection frequency (trips/week)

The results from the sampled households show that on average, a household collected firewood thrice a week (Table 4-1), with no significant difference in number of firewood collection trips made by households that chose different ICS.

4.1.5 Number of adult female members in the household

The results in Table 4-1 show that a typical household had one adult female and there was no significant difference in the number of adult females across households that chose different stoves.

4.1.6 Value of total household assets

The average value of total asset-holding by a household was estimated at MK42, 000.03. ($5.89). Similar to findings on household income, Table 4-1 results show significant difference in value of total assets between households that chose Chitetezo Mbaula and Portable Rocket Stove, at 5 percent. The results show that households that chose the lowest priced stove Chitetezo Mbaula had assets valued at MK40, 256.61 or $56.46 which was lower than those that chose the most expensive Portable Rocket (MK72, 366.72 or $101.49).

Table 4.1 Descriptive Analysis of Continuous Variables

Variable name	Chitetezo Mbaula vs TLC Rocket Stove (n=337)		TLC Rocket Stove vs Portable (n=163)		Portable Rocket Stove vs Chitetezo Mbuala (n=307)		Pooled Sample (n=404)
	Means	**p-value**	**Means**	**p-value**	**Means**	**p-value**	**Mean**
Age of household head (years)	43.245 (41.750)	0.428	41.750 (41.836)	0.9702	41.836 (43.245)	0.5148	42.656
Firewoood Collection Distance (KM)	0.749 (0.601)	0.172	0.601 (0.813)	0.1685	0.813 (0.749)	0.6329	0.725
Monthly-household expenditure (MK)	13885.54 (16028.86)	0.1771	16028.86 (26448.13)	0***	26448.13 (13885.54)	0***	16478.3
Firewood collection frequency (trips/week)	2.938 (2.604)	0.1680	2.604 (2.900)	0.3458	2.900 (2.938)	0.8810	2.851
Number of Adult Female Members	1.212 (1.104)	0.1027	1.104 (1.179)	0.3627	1.179 (1.212)	0.6681	1.181
Value of total Household Assets (MK)	40256.61 (47066.68)	0.4149	47066.68 (72366.72)	0.2330	72366.72 (40256.61)	0.0294**	42200.03
Under-five children ratio (Total children/Total household size)	0.1357 (0.0967)	0.0370**	0.0967 (0.1485)	0.0180**	0.1485 (0.1357)	0.5700	0.129

* Significant at 1percent level; ** significant at 5percent level; *** significant at 1 percent level. Parentheses indicate the means. vs indicates versus.

4.1.7 Under-Five Children Ratio

The average ratio of under-five children to total household size was estimated at 0.129. Results further show significant difference (at 5 percent level) between households that chose fixed TLC Rocket Stove and households that chose Chitetezo Mbaula and Portable Rocket Stove. The under-five ratio for households that chose TLC Rocket Stove is higher than those that chose other stoves.

4.1.8 Location

The differences in location may influence choice and WTP for a technology. This could be the result of differences in the resource endowment available in the traditional authorities. Results indicate that there is significant difference in the choice between Portable Rocket Stove and Chitetezo Mbaula in the households from Chitera and those from Likoswe Traditional Authorities, significant at 10 percent.

4.1.9 Knowledge of negative environmental Impact of using Three-stone firewood stove

Three-stone firewood stove is inefficient traditional way of cooking. The stove consumes a lot of firewood and increases household air pollution (Lewis and Pattanayak, 2012). It was therefore, hypothesized that if a household knows such negative impacts of using three-stone firewood stove it would be willing to choose and pay a most efficient ICS. Results in Table 4-2 indicates that there is no significant difference in the knowledge of negative environmental impact of using three-stone firewood stove among households that chose Chitetezo Mbaula, TLC Rocket Stove and Portable Rocket Stove.

Table 4.2 Discrete Variables Used in the Analyses

Variable name	Category	Chitetezo Mbaula vs TLC Rocket Stove		TLC Rocket Stove vs Portable Rocket Stove		Portable Rocket Stove vs Chitetezo Mbaula		Pooled n=404
		Percentages	p-value	Percentages	p-value	Percentages	p-value	Percentages
Knowledge of	Yes =1	69 (64)	0.346	64 (69)	0.499	69 (69)	0.972	68
environ. impact	No = 0	31 (36)		36 (31)		31 (31)		32
Firewood	Private land=1	71 (76)	0.309	76 (55)	0.005***	55 (71)		69
Sources	Otherwise = 0	29 (24)		24 (45)		45 (29)	0.018**	31
Location	Chitera TA=1	41 (40)	0.748	40 (30)	0.202	30 (41)	0.084*	
	Likoswe TA=0	59 (60)		60 (70)		70 (59)		39
							0.002***	61
Cooking behavior	Cooking on two places=1	9 (11)	0.438	11(12)	0.061*	12 (9)	0.860	12
	Cooking on one place =0	91 (89)		89 (78)		78 (91)		88
			0.500	63 (60)	0.718	59(59)		
Knowledge of	Yes = 1	59 (63)		37(40)		41(41)		60
health impact	No = 0	41 (37)						40

* Significant at 1percent level; ** significant at 5percent level; *** significant at 1percent significant level. Parentheses indicate the percentages. vs indicates versus.

4.1.10 Firewood Source

The results in table 4.2 show high proportions of households that source firewood from private land. Table 4-2 shows that there is significant difference (at 1 percent level) in the firewood source between households that chose TLC Rocket Stove and those that chose the Portable Rocket Stove. Furthermore, there is significant difference between households that chose Portable Rocket Stove and those that chose the Chitetezo Mbaula in firewood source.

4.1.11 Knowledge of negative Healthy Impact of using Three-stone firewood stove

About 60% of the interviewed households in Chiradzulu admitted that they know the negative health impacts of smoke produced when cooking on Three-stone Firewood Stove. Some of the health impacts that were highlighted include: eye illness and cough. It was therefore, assumed that if a household knows such negative health impacts of using three-stone firewood stove it would be willing to choose and pay a most efficient ICS. Results in Table 4-2 indicates that there is no significant difference in the knowledge of negative healthy impact of using three-stone firewood stove among households that chose Chitetezo Mbaula, TLC Rocket Stove and Portable Rocket Stove.

4.1.12 Cooking Behavior

Households` choice of ICS is directly associated with the design of that particular stove. In that case, the design that mostly fit in households` cultural context and sufficient for specific cooking needs is most prefered. On average, 88 percent of the sampled households cook on one cooking place. Results in Table 4-2 indicate that there is significant difference (at 1 percent significant level) in cooking behavior among households that chose between TLC Rocket Stove and Chitetezo Mbaula. Furthermore, results show significant difference in cooking behaviour among households that chose Portable Rocket Stove and Chitetezo Mbaula.

4.2 Determinants of ICS Choice

The determinants of choice of ICS by households were analyzed using multinomial logit model. Econometric analysis with cross-sectional data is usually associated with problem of multicollinearity among explanatory variables which can lead to imprecise parameter estimates. To explore potential multicollinearity among the explanatory variables in the MNL, correlation matrix was developed which showed weak correlations between independent variables. In addition, Ordinary Least Squares model was fit to test the model for multicollinearity using the variance inflation factor (VIF). Furthermore, all dummy variables with collinearity problem were omitted when estimating MNL model. The VIF of all included variables were less than 10 and mean VIF was 1.22 as shown in Table 4-3 below. The results imply that multicollinearity is not a serious problem to affect the adequacy of the model.

Table 2.3 Variance Inflation Factor Results

Variable	VIF	1/VIF
Total monthly expenditure	1.52	0.6560
Household head age	1.39	0.7203
Household assets value	1.37	0.7320
Under-five children ratio	1.28	0.7831
Knowledge of environmental impact	1.27	0.7878
Knowledge of healthy impact	1.24	0.8078
Firewood source	1.14	0.8802
Firewood source distance	1.11	0.8971
Household Location	1.10	0.9093
Cooking behaviour	1.10	0.9100
Firewood collection Frequency	1.05	0.9490
Household head sex	1.20	0.8333
Mean VIF	**1.22**	

MNL model was further tested to verify whether it meets independent irrelevant alternatives (IIA) assumption. Hausman test results showed no evidence that IIA assumption was violated hence MNL model was correctly specified and there is no problem of heteroskedasticity. Furthermore, the independent variables were tested for their effects in all choice equations. The test results showed that independent variables` coefficients are not zeros across all equations but rather affect the likelihood of choosing different ICS. The MNL model chi-square value of 59.72 indicates that likelihood ratio statistics are highly significant (at 1 % level of significance) suggesting the model has a strong explanatory power. Table 4-4 shows marginal effects, robust standard errors and p-values of multinomial logit model. Chitetezo Mbaula was considered as a base category because it was most preferred stove by the sampled households as compared to TLC Stove and Portable Rocket Stove.

Results in Table 4-4 indicates that estimated probabilities for choosing Chitetezo Mbaula, TLC Rocket stove and Portable Rocket stove are 59 percent, 24 percent and 17 percent, respectively. The results imply that Chitetezo Mbaula was most preferred stove by the sampled households as followed by TLC Rocket Stove and Portable Rocket Stove. Results further indicate that distance to firewood source from home, monthly household income, firewood collection frequency per week, number of adult females, firewood source, household head age, value of household assets, knowledge of negative environmental impacts of using traditional Three-Stone Firewood Stove and under-five children ratio are the significant determinants of ICS choice. Holding other things constant, total monthly household income was found to significantly increase average probability of choosing Portable Rocket Stove by 6.9 percent while decreasing the average probability of choosing

Chitetezo Mbaula by 7.9 percent at 1 percent significant levels. Similarly, value of household assets negatively influences the choice of Chitetezo Mbaula. The results imply that total monthly household income is positively associated with the probability of choosing metallic and durable ICS. In the other words, the probability of choosing clay stoves such as Chitetezo Mbaula is negatively related to total monthly household income and household`s assets value. Furthermore, Chitetezo Mbaula had a lower price bid of 650 (or $0.91) as compared to Portable Rocket Stove (MK12, 000 or $16.83) and TLC Rocket Stove (MK3, 000 or $4.21), therefore the probability of choosing a more expensive stove is positively associated with income. These findings portray that as household income increases, households invest more on environmental conservation technologies such as buying expensive ICS and vice versa (Malla and Timinsina, 2014). The findings are similar with what other researchers found that poor households are mostly prompted to current expenditures such as food and clothing hence not likely to spend more on environmental investments (Sagbo, 2014).

Number of adult female members in the household was found to positively influence the average probability of choosing Chitetezo Mbaula but negatively influence the probability of choosing TLC Rocket Stove by 8.9 and 79.5 percent, respectively. The results show that an increase in the number of adult female members in the household by one increases the average probability of choosing the portable clay Chitetezo Mbaula while decreases the average probability of choosing fixed mud and metal TLC Rocket Stove. The reason could be because adult female household members are usually the primary cooks in rural settings, therefore, increase in their number in the household reduces the burden of cooking and collecting firewood. Jagger and Jumbe (2016) also found the same results that households with a large labour force for fuel collection were less likely to adopt ICS. In that view, households with large number of adult females may not appreciate time saving benefits of using ICS (Kooser, 2014). Since TLC Rocket Stove could save more time for collecting firewood (saves 50 percent) than Chitetezo Mbaula (44 percent), then increase in number of adult female members would decrease the likelihood of choosing TLC Rocket Stove.

Firewood source significantly influences the probability of choosing TLC Rocket Stove and Portable Rocket Stove positively and negatively, respectively. The results show that sourcing firewood from the private land increases the average probability of choosing the fixed TLC Rocket Stove by 9.2 percent but decreases the average probability of choosing the Portable Rocket Stove by 9.1 percent. The results suggest that sourcing firewood from private land is important negative influence in the choice of most fuel efficient Portable Rocket Stove in the study area. The reliance on private land for firewood may signal firewood abundance, so households are not conscious about fuel saving attribute of ICS.

Furthermore, weekly firewood collection frequency significantly increases the average probability of choosing Chitetezo Mbaula, *ceteris paribus*. The results in table 4.4 show that increase in number of firewood collection trips (that a household takes per week) by 1 increases the probability of choosing Chitetezo Mbaula by 2.1 percent. The results imply that as households demand for firewood increases, the probability for choosing ICS increases.

Distance to firewood source from home positively determine the probability of choosing Chitetezo Mbaula, holding other things constant. Increase in distance to firewood collection point from home by 1 kilometre increases the average probability of choosing

Chitetezo Mbaula by 3.2 percent. This implies that households that take long distances to collect firewood are willing to pay for ICS that is portable. The findings agree with what Mobarak et al., (2012) found that in cases where the households have to take long and strenuous walks to collect firewood, ICS is preferred.

Table 4.4 Estimation Results for Choice of ICS from MNL Model

Variable name	Pr(ICS_choice==Chitetezo Mbaula) = 0.5955			Pr(ICS_choice==TLC Rocket Stove) = 0.2384			Pr(ICS_choice==Portable Rocket Stove) =0.1663		
	Marginal Effects	Std. Error	p-value	Marginal Effects	Std. Error	p-value	Marginal Effects	Std. Error	p-value
Household head age (years)	0.0024	0.0019	0.204	-0.0038**	0.0016	0.021	0.0014	0.0014	0.304
Household head gender	0.0265	0.0564	0.638	-0.0650	0.0478	0.174	0.0384	0.0456	0.399
Total monthly-household expenditure (MK)	-.0788***	0.028	0.005	0.0096	0.0236	0.682	0.0690***	0.0270	0.009
Firewood collection frequency (trips/week)	0.0207*	0.0118	0.080	-0.0170	0.0109	0.119	-0.0037	0.0087	0.669
Number of adult female in the household	0.0886*	0.0492	0.072	-0.7950*	0.0458	0.082	-0.0090	0.0343	0.792
Firewood source (1=Private land 0=otherwise)	-0.0007	0.0550	0.990	0.0917*	0.4940	0.063	-0.0910**	0.0385	0.018
Cooking behavior (1=cooking on two places, 0=otherwise)	-0.0731	0.0727	0.314	-0.0053	0.0617	0.931	0.0784	0.0518	0.130
Firewood Source distance (Kilometers)	0.0323**	0.0129	0.013	-0.0179	0.0112	0.109	-0.0143	0.0109	0.187
Under-five children ratio (Total number of under-five children/total household size)	0.3047*	0.1722	0.077	-.4948***	0.1525	0.001	0.1901	0.1263	0.132
Household location (1=Chitera TA, 0=Likoswe TA)	0.0523	0.0507	0.302	-0.0025	0.0444	0.955	-0.0498	0.0403	0.216
Household assets value (MK)	-0.0297*	0.0176	0.092	0.0223	0.0150	0.137	0.0074	0.0136	0.540
Knowledge of health impact of three-stone firewood use (1=know, 0=otherwise)	-0.0443	0.0509	0.384	0.0461	0.0448	0.304	-0.0018	0.0340	0.964
Knowledge of environmental impact of three-stone firewood use (1=know, 0=otherwise)	0.0917*	0.0531	0.084	-0.0863*	0.0476	0.070	-0.0054	0.0423	0.895

* Significant at 10 percent level; ** significant at 5 percent level; *** significant at 1 percent level

Log likelihood = -347.91435
LR ch2 (26) = 59.72
Prob > ch2 = 0.0002
Number of observations = 403

Under-five children ratio influences the probability of choosing Chitetezo Mbaula and TLC Rocket Stove significantly, *ceteris paribus*. The MNL results show that increase in the number of children compared to the total household size increases the probability of choosing Chitetezo Mbaula but decreases the average probability of choosing TLC Rocket Stove at 30 percent and 49 percent respectively. Results for Chitetezo Mbaula are similar with findings by Kooser (2004) who also found a positive relationship between increase in number of under-five children and choice of ICS. The negative relationship between TLC Rocket Stove choice and number of under-five children could be as a result of the fact that children are mostly carried by their mothers during cooking hence the mother may not want to restrict herself to staying in the kitchen (in using fixed TLC Rocket Stove) during cooking.

Knowledge of negative environmental impact of using inefficient Three-stone Firewood Stove positively influences the choice of Chitetezo Mbaula but negatively influences the choice of fixed TLC Rocket Stove, ceteris paribus. During data collection, households admitted that cutting down trees for firewood was one of the leading causes of deforestation. It was also observed that some households planted trees in their homes so as to ease the burden of fetching firewood and also protect their houses from strong winds. Therefore, the choice of Chitetezo Mbaula which saves firewood about 60% could be to control the firewood demand hence reduce the pressure on trees.

The last determinant of ICS choice is household head age. Results in table 4-4 show that increase in age by the household head negatively influences the probability of choosing TLC Rocket Stove, holding other things constant. There is marginal reduction in the probability of choosing fixed stove as household gets older. The results can be attributed to the fact that TLC Rocket Stove is fixed and looks more complicated as it comprises both metal and clay components to improve its efficiency hence not attractive to older people. These results are similar to results by Nlom and Karimov (2015) who found that older individuals are resistant to change and they are less likely to make a switch from less complicated traditional cooking technologies as compared to younger ones.

4.3 Estimation of Mean WTP

A single bounded model was used to estimate the mean WTP for the bid price which was the market price of the stoves. An important aspect when analyzing contingent evaluation data is to check whether the bid amount influences the respondent`s answer to the WTP question. To validate the data, probit model is used with discrete WTP response as dependent variable and bid price as the only independent variable. The results in Table 4-4 show that TLC Rocket Stove coefficient (0.007) and Portable Rocket Stove coefficient (0.004) for bid prices were significant at 1percent and 10 percent, respectively. The results imply that bid prices for TLC Rocket Stove and portable stove were important factors that influence respondents` WTP for the stoves. However, coefficient for bid price for Chitetezo Mbaula was found not significant. This implies that respondents were indifferent to the Chitetezo Mbaula`s bid price that was randomly assigned in the survey. This could be because Chitetezo Mbaula had the lowest bid prices as compared to TLC Rocket Stove and Portable Rocket Stove. Furthermore, respondents regarded Chitetezo Mbaula`s bid prices as affordable because they were similar to the price of a charcoal stove (at the time of the survey). About 33 percent of the interviewed households owned charcoal stove as alternative cooking device.

Table 4.5 Probit Results for WTP and Bid prices

Stove Type	Coefficient	Std. Error	z-value	p-value
Chitetezo Mbaula_ WTP				
Bid price	0.001	0.0018	0.53	0.595
Constant	0.886	1.56	0.76	0.445
TLC Rocket Stove_ WTP				
Bid price	0.0067	0.002	3.19	0.001***
Constant	-19.463	6.311	-3.08	0.002***
Portable rocket stove_ WTP				
Bid price	0.0038	0.0022	1.72	0.085*
Constant	-45.843	26.596	-1.72	0.085*

* Significant at 1percent level; *** significant at 1percent significant level.

Results in Table 4.4 also show significant constant term which implies that there are other factors that significantly influenced household WTP for the chosen stove. Therefore, the mean WTP calculation depends also on the socio-economic factors as shown in equation 23. Table 4-5 shows the estimation results from single bounded model. The mean WTP for Chitetezo Mbaula, TLC Rocket Stove and Portable Rocket Stove are estimated at MK1586 ($2.22), MK2838 ($3.98) and MK12032 ($16.87), respectively. The mean WTP estimates are significant at 10 percent for Chitetezo Mbaula, 1 percent for TLC Rocket Stove and Portable Rocket Stove. Mean WTP value for Chitetezo Mbaula ($2.22) is far above the market price of the stove ($0.9). This implies that respondents are willing to pay for Chitetezo Mbaula even if market price rises by 144 percent. However, the estimated mean WTP for TLC Rocket Stove ($3.98) is slightly lower than the TLC Rocket Stove market price (MK3000 or $4). Portable Rocket Stove estimated mean WTP is slightly higher than its market price by MK20.34 ($0.03).

Table 4.6 Estimates of WTP

Stove Type	Coefficient	Std. Error	z-value	p-value
Chitetezo Mbaula	1586.225	853.996	1.86	0.063*
TLC Rocket Stove	2838.06	66.893	42.08	0.000***
Portable Rocket Stove	12032.04	43.663	275.57	0.000***

* Significant at 10 percent level ** significant at 5 percent level and *** significant at 1 percent level

4.4 Determinants of WTP

The probit model was used in assessing the determinants of WTP for the different stoves. The probit model was chosen because the explained variable (WTP) is a dummy, taking the value of `1`if respondent is willing to pay and `0` if is not willing to pay. The study found that total number of adult female members in the household, sex of the household head, number of firewood collectors in the household and total time the household spend collecting firewood are the significant factors affecting WTP for Chitetezo Mbaula (Table 4-6). Total number of firewood collectors in the household was found to have a negative and significant relationship with the WTP for Chitetezo Mbaula. The results show that having one additional firewood collector in the household is associated with a 2.1 percent lower probability for the household`s WTP for Chitetezo Mbaula, *ceteris paribus*. The results are similar with what other researchers found that the households with more labour on firewood collection cannot appreciate energy saving characteristics of ICS (Kooser, 2012). Total time spent collecting firewood by the household significantly increases the probability for willingness to pay for Chitetezo Mbaula, holding other things constant. The results imply that an hour increase in time spent travelling to and from firewood source and collecting firewood, increases the probability of WTP for Chitetezo Mbaula by 0.05

percent. The findings meet prior expectation that people who spend much time in sourcing firewood or those with firewood scarcity problem are willing to pay for ICS so as to save time through reduced firewood trips.

Sex of the household head significantly determine WTP for Chitetezo Mbaula. The results indicate that having a male household head positively influences the probability of WTP for Chitetezo Mbaula by 8.4 percent, holding other things constant. The results are similar to the findings from Concern Universal (2014) that men are supportive of ICS and about 78 percent of household heads managed to buy Chitetezo Mbaula without NGOs` persuasion. The last but not the least significant determinant of WTP for Chitetezo Mbaula is number of adult female members in the household. The increase in the number of adult female members positively affects the probability of WTP for Chitetezo Mbaula by 3.7 percent. The Positive relationship might be revealing the important aspect that presence of female members in the household enhances the understanding of ICS benefits because females are mostly involved in cooking. The adult female members` experience with inefficient traditional three-stone firewood stove can make them pay for ICS such as Chitetezo Mbaula.

TLC Rocket Stove`s WTP is influenced by firewood source distance from home, primary cook age, total number of female adults in the household, firewood collection frequency and monthly household income. Out of these determinants, firewood source distance from home and age of the primary cook are significant determinants of WTP for TLC Rocket Stove at 1 percent and 10 percent, respectively. Results in Table 4-6 indicate that firewood source distance from home increases the probability of WTP for TLC Rocket Stove. The increase in distance to the firewood source from home by a Kilometer increases the probability of WTP for TLC Rocket Stove by 34 percent. The results are similar with findings from Mobarak et al. (2012), who found that households who take long and strenuous walks to collect firewood are willing to pay for firewood efficient cook stoves.

Furthermore, age of the primary cook negatively influenced the WTP for TLC Rocket Stove. Increase in age of the primary cook by a year is associated with reduction in the probability of WTP for TLC Rocket Stove by 0.6 percent, holding other things constant. The results support the findings of Nlom et al. (2015) that an increase in the age is negatively associated with the likelihood of adopting new technologies. In other words, the older primary cooks are more resistant to change while younger primary cooks are more willing to move from traditional Three-Stone Firewood Stove. This is the case because many years of experience in using traditional stoves and cultural beliefs associated with it may reduce ICS WTP.

Table 4.7 Determinants of WTP for ICS

Variable name	Chitetezo Mbaula (n=241)		TLC Rocket Stove (n=96)		Portable Rocket Stove (n=67)	
	Marginal Effects	Std. Error	Marginal Effects	Std. Error	Marginal Effects	Std. Error
Female adult in the household (number)	0.0382*	0.0210	0.0990	0.0851	-	-
Household head sex	0.0843**	0.0414	-	-	0.2534	0.1621
Monthly-household expenditure (ln)	-	-	0.0538	0.0456	-	-
Firewood collection help (number of people)	-0.0210**	0.0102	-	-	-	-
Firewood collection time (hours)	0.0283**	0.0121	-	-	-0.3589***	0.1005
Age of the primary cook	-	-	-0.0057*	0.0030	-	-
Firewood Collection Frequency (per week)	-	-	0.0281	0.0240	-	-
Firewood source distance (ln)	-	-	0.0823***	0.0219	0.1432***	0.0398
Montlhy Fuelwood Expenditure	-	-	-	-	0.0000	0.0000
Location (1 =T.A Chitera 0= T.A Likoswe	-0.0359	0.0232	-	-	0.1568	0.1547
	Log likelihood= -44.20474 LR ch2(5)= 29.16 Prob>0.0000		Log likelihood= -41.3750 LR ch2(5)= 22.41 Prob>0.0004		Log likelihood= -32.830903 LR ch2(5)= 24.31 Prob>0.0002	

*Significant at 10 percent level *** significant at 5 percent level ** Significant at 1 percent level.

WTP for Portable Rocket Stove is significantly influenced by time spent on collecting firewood and firewood source distance. Total time spent on sourcing firewood was found to be a negative influence of WTP for Portable Rocket Stove at 5 percent significance level. This means that one hour increase in time spent in collecting firewood decreases the probability of WTP for Portable Rocket Stove by 36 percent, holding other things constant. The results differ with prior expectation that the longer the time that one takes to collect firewood, the higher the probability of WTP for energy saving stoves. However, total time spent collecting firewood has a positive influence on Chitetezo Mbaula`s WTP. On the other hand, distance to the firewood source increases the probability of WTP for Portable Rocket Stove. The results in Table 4-6 show that increase in distance taken to collect firewood increases the WTP for Portable Rocket Stove, *ceteris paribus*. This implies that people are willing to pay for higher priced ICS in order to save energy so as to reduce the burden of walking long distances to source firewood.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Summary

The main aim of this study was to assess consumers` choice and WTP for ICS in Chiradzulu District using a contingent valuation method. Specifically, the study aimed at determining factors that influence households` choice and WTP for firewood ICS. To assess the determinants of ICS choice, Multinomial Logit model was estimated. Single bounded model was applied in eliciting mean WTP for ICS. Furthermore, probit model was estimated to assess determinants of WTP for ICS. The study findings summarized below review critical factors that need to be considered by government and other stakeholders involved in the promotions of ICS technologies in Malawi to achieve wider adoption.

5.2 Key Findings

5.2.1 Determinants of ICS Choice

Multinomial logit model results revealed that Chitetezo Mbaula is the most preferred ICS seconded by TLC Rocket Stove and lastly, Portable Rocket Stove. MNL results further revealed that household monthly income is positively associated with the probability of choosing Portable Rocket stove while negatively associated with probability of choosing Chitetezo Mbaula. Similarly, value of household assets negatively influence the choice of Chitetezo Mbaula. Distance to firewood source from home positively influence the probability of choosing Chitetezo Mbaula. Under-five children ratio positively influences the choice of Chitetezo Mbaula but negatively influence the probability of choosing TLC Rocket Stove. Furthermore, firewood collection frequency per week is positively associated with the probability of choosing Chitetezo Mbaula. Number of adult females postively influence the choice of Chitetezo Mbaula but negatively influence the choice of TLC Rocket Stove. Knowledge of negative environmental impacts of using Three-stone Firewood Stove was found to positively influence the choice of Chitetezo Mbaula but negatively influence the choice of TLC Rocket Stove. The choice of TLC Rocket Stove is also negatively influenced by age of the household head. Lastly, firewood source positively influences the choice TLC Rocket Stove but negatively influences the choice of Portable Rocket Stove. The results indicates that firewood availability, household cooking behavior and differences in household socioeconomic and demographic characteristics influence the choice of ICS in Chiradzulu District.

5.2.2 Estimated Mean WTP for ICS

Mean WTP for Chitetezo Mbaula, TLC Rocket Stove and Portable Rocket Stove were estimated using single bounded model. The mean WTP were estimated at MK1586 ($2.22), MK2838 ($3.98) and MK12032 ($16.87), respectively. Mean WTP value for Chitetezo Mbaula MK1586 ($2.22) is far above the market price of the stove MK650 ($0.9) while the estimated mean WTP for TLC Rocket stove MK2838 ($3.98) is slightly lower than the TLC Rocket Stove market price (MK3000 or $4). Portable Rocket Stove estimated mean WTP is slightly higher than its market price by MK20.34 ($0.03). The mean WTP results show that households in Chiradzulu are willing to pay about the market price of ICS.

5.2.3 Determinants of WTP for ICS

Based on each ICS, factors influencing household WTP (for presented price bids) was estimated using probit model. WTP for Chitetezo Mbaula was negatively influenced by number of firewood collection helpers in the household. While household head sex, total time spent collecting firewood, and number of adult female members in the households were found to positively influence the WTP for Chitetezo Mbaula. TLC Rocket Stove`s WTP was positively influenced by firewood source distance from home and negatively influenced by age of the primary cooks. Furthermore, WTP for Portable Rocket Stove was positively influenced by firewood source distance from home. Total time spent collecting firewood negatively influenced the WTP for Portable price bid. The results indicate that different socioeconomic and demographic factors affect households` WTP for different prices of ICS.

5.3 Recommendations

The Government of Malawi through various NGOs plans to distribute two million ICS in Malawian households by the year 2020 (Jagger and Jumbe, 2016). Following such plan, the study makes the following recommendations to foster wider adoption of ICS in the country.

Since Chitetezo Mbaula was most preferred stove seconded by fixed TLC Rocket Stove then Portable Rocket Stove, GoM and ICS dissemination partners should prioritize the distribution of Chitetezo Mbaula in the area.

The study has established that household socioeconomic and demographic differences play an important role in determining choice and WTP for ICS. Specifically, household income, number of adult females, household head age, under-five children ratio, distance to firewood source and firewood source significantly influence the choice of ICS. However, the direction of influence to the probability of choosing particular ICS was different. Therefore, GoM and ICS dissemination partners should consider promoting various designs of ICS in Chiradzulu so that people are given a chance to choose their preferred stove design.

The study has also established a significant relationship between the choice of ICS and household knowledge of negative environmental impact of using three-stone firewood stove. Therefore, civic education and awareness campaigns on negative environmental impacts of using traditional Three-Stone Firewood Stove are needed prior to ICS dissemination for wider adoption and sustained usage.

From the mean WTP results, the study has proved that people value ICS and are willing to pay about the market price of the ICS and even more in Chiradzulu District. While there are programs that distribute ICS for free, households would manage to buy ICS if they are informed about health and environmental benefits of using ICS. Therefore to ensure stove availability, GoM and ICS dissemination partners must consider training local artisans for sustained production of ICS.

Furthermore, the study discovered that total distance to firewood source and total time taken to collect firewood increases the WTP for ICS in Chiradzulu District. This implies that ICS are appropriate technologies for areas with firewood scarcity, for instance, Chiradzulu District. Therefore, there is a need to extend and intensify the current ICS distribution efforts to all areas with firewood scarcity problem.

REFERENCES

Adkins, E., Tyler, Wang, J., Siriri, D. & Modi, V. 2010. Field testing and survey evaluation of household biomass cookstoves in rural Sub-Saharan Africa. *Energy for Sustainable Development.* Available at: http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwjbvL7jlP_YAhWLKMAKHY2uCgcQFggoMAA&url=http%3A%2F%2Fwww.millenniumvillages.org%2Fuploads%2FReportPaper%2FAdkins_HHstovepaper_9-28-101.pdf&usg=AOvVaw0lMCqQp2f56wUISLc2Nqww [Accessed on 19th December, 2015].

Concern Universal Malawi. 2012. *Socio-Cultural Acceptability of Improved Cook Stoves (ICS) in Rural Malawi*. Lilongwe, Malawi. Available at: http://united-purpose.org/files/cook_stoves_report_2012_summary.pdf [Accessed on 27th January, 2016]

Dlamini, N.M., Edriss, A.K., Jumbe, C.B.L. & Masuku, M.B., 2016. Households` Wilingness to Pay for Improved Water Services: A case of Semi-Urban Households in the Lobombo and Lowveld Regions of Swaziland. *Economics and Sustainable Development.* 7(3): 31-43.

Edriss, A.K. (2013). *Pearls of Applied Statistics: Theory and Stata Applications with real data for social sciences and professional consulting*. Canada: International *i*-Publishers.

Fullerton, D.G., Semple, S., Kalambo, F., Suseno, A., Malamba, R., Henderson, G., Ayres, J.G. & Gordon, S.B. 2009. Biomass Fuel Use and Indoor Air Pollution in Homes in Malawi. *Occupational Environmental Medicine.* Available at:

https://www.researchgate.net/publication/26733044_Biomass_fuel_use_and_indoor_air_pollution_in_homes_in_Malawi [Accessed on 10th January, 2016].

Government of Malawi, (GOM) 2015. *National Cookstove Program Roadmap*. Malawi.

Haab, T.C. & McConnell, K. E. 2002. *Valuing Environmental and Natural Resources. The Econometrics of Non-Market Valuation*. UK: Edward Elgar Publishing Limited.

Habermehl, H. 2008. *Costs and Benefits of Efficient Institutional Cook Stoves in Malawi; Economic Evaluation of the Component "Promotion of Efficient Institutional Cook Stoves" of the Programme for Biomass Energy Conservation (ProBEC) in Malawi in the Years 2004 to 2007*. Available at http://www.gtz.de/de/dokumente/en-costs-benefits-institutional-stove-malawi-2008.pdf [Accessed on 26th June, 2015].

Hassan, R. & Nhemachena, C. 2008. Determinants of African farmer's strategies for adapting to climate change: Multinomial choice analysis. *African Journal of Agricultural Resources*. 2(1): 83-104. Available at: https://www.researchgate.net/publication/46534644_Determinants_of_African_farmers%27_strategies_for_adapting_to_climate_change_Multinomial_choice_analysis [Accessed on 30 January, 2015].

Hausman, J. & McFadden, D. 1984. Specification tests for the multinomial logit model. *Econometrica* 52 (5), 1219–40. Available at: https://www.jstor.org/stable/1910997 [Accessed on 30 January, 2015].

Inayatullah, J., (2011). *What makes people adopt improved cookstoves? Empirical evidence from rural northwest Pakistan*. The Governance of Clean Development Working Paper 012. Available at:

http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwjL0IiUl__YAhVmJsAKHT65CgIQFggoMAA&url=http%3A%2F%2Fcleancookstoves.org%2Fresources_files%2Fwhat-makes-people-adopt.pdf&usg=AOvVaw14Aegg_DmCuUrh-lyBy7jd [Accessed on 2nd April, 2016]

Jagger, P. & Jumbe, C. 2016. Stoves or Sugar? Willingness to Adopt Improved Cookstoves in Malawi. *Energy Policy*. 92: 409-419.

Jeuland, M., Pattayanak, S.K. & Soo J.T. 2013. *Do Stated Preferences Provide Clues into Who Adopts Improved Cookstoves?* Available at https://www.google.com/search?client=firefox-a&rls=org.mozilla%3Aen-US%3Aofficial&channel=np&ei=7iBwWsuhKubMgAa-8qoQ&q=Do+Stated+Preferences+Provide+Clues+into+Who+Adopts+Improved+Cookstoves.+Jeuland.+2013.pdf&oq=Do+Stated+Preferences+Provide+Clues+into+Who+Adopts+Improved+Cookstoves.+Jeuland.+2013.pdf&gs_l=psy-ab.3...8024.30424.0.31138.0.0.0.0.0.0.0.0..0.0....0...1c.1j2.64.psy-ab..0.0.0....0.0GJjPUDAtv4 [Accessed on 6th June, 2015].

Jeuland, M.A., Bhojvaid, V., Kar, A., .Lewis J.J., Patange O., Pattanayak, S.K., Ramanathan, N., Rehman, I.H., Tan Soo, J.S. & Ramanathan V. (2015*)*. Preferences for Improved Cook Stoves: Evidence from Rural Villages in North India. *Energy Economics.* 52(2015): 287–298. Available at: https://www.google.com/search?client=firefox-a&rls=org.mozilla%3Aen-US%3Aofficial&channel=np&ei=JiJwWvvjLKzegAbxmp34Dw&q=Preferences+for+Improved+Cook+Stoves%3A+Evidence+from+Rural+Villages+in+North+India.+Jeuland.2015.pdf.&oq=Preferences+for+Improved+Cook+Stoves%3A+Evidence+from

+Rural+Villages+in+North+India.+Jeuland.2015.pdf.&gs_l=psy-ab.3...379859.392816.0.393138.0.0.0.0.0.0.0.0..0.0....0...1c.1j2.64.psy-ab..0.0.0....0.V0l0SHc7G90 [Accessed on 3rd June, 2016].

Jumbe, C.B.L. & Angelsen, A. 2011. Modelling choice of fuelwood source among rural households in Malawi: A multinomial probit analysis. *Energy Economics*. 33(5): 732-738.

Kamanga, P., Vedeld, P. & Sijaastad, E. 2009. Forest Incomes and Rural Livelihoods in Chiradzulu District, Malawi. *Ecological Economics*. 68(3): 613-624. Available at: https://www.researchgate.net/publication/223441255_Forest_Incomes_and_Rural_Livelihoods_in_Chiradzulu_District_Malawi [Accessed on 3rd Marcht, 2017].

Kooser, S.H. 2014. Clean Cooking: The Value of Clean Cookstoves in Ethiopia. *Environmental and Resource Economics at Colby*. 1(3):1. Available at: http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwiAs4Ghm__YAhVlIsAKHeIdBgYQFggoMAA&url=http%3A%2F%2Fdigitalcommons.colby.edu%2Fcgi%2Fviewcontent.cgi%3Farticle%3D1001%26context%3Djerec&usg=AOvVaw1mrx_A92KzqIHJAWe03KID [Accessed on 3rd August, 2017].

Lewis, J. & Pattanayak S. K. 2012. Who adopts improved stoves and cookstoves? A systematic review. *Environmental health perspectives*. 120 (5):637-645. Available at: http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwjO0Lrmm__YAhWiLsAKHTDeAgYQFggoMAA&url=http%3A%2F%2Fwww.tractionproject.org%2Fsites%2Fdefault%2Ffiles%2FLewis%2C%2520Pattanayak-%2520Who%2520adopts%2520clean%2520cookstoves.pdf&usg=AOvVaw06qrZhNPelw_mG24CZTOr7 [Accessed on 22nd May, 2016].

Lim, S., Vos T., Flaxman A.D., Danaei, G., Shibuya K. & Adair-Rohani H. 2012. *A Comparative Risk Assessment of Burden of Disease and Injury Attributable to 67 Risk. Factors and Risk Factor Clusters in 21 Regions, 1990–2010: a Systematic Analysis for the Global Burden of Disease Study 2010*. Available at http://www.thelancet.com/gbd/2010 [Accessed on 11th August, 2016].

Magrath, J., & Sukali, E. 2009. *The Winds of Change: Climate Change, Poverty and the Environment in Malawi. Oxfarm International.* Available at https://www.google.com/search?client=firefox-a&rls=org.mozilla%3Aen-US%3Aofficial&channel=np&ei=zSVwWo62DaLdgAawvIsw&q=The+Winds+of+Change%3A+Climate+Change%2C+Poverty+and+the+Environment+in+Malawi.+Oxfarm+International.+Magrath.2009.pdf&oq=The+Winds+of+Change%3A+Climate+Change%2C+Poverty+and+the+Environment+in+Malawi.+Oxfarm+International.+Magrath.2009.pdf&gs_l=psy-ab.3...4500.34524.0.35640.0.0.0.0.0.0.0.0..0.0....0...1c.1j2.64.psy-ab..0.0.0....0.RQzZslbi-4s [Accessed on 30th August, 2016].

Malakini, M., Mwase, W., Maganga, A.M & Khonje, T. 2014. Fuelwood Use Efficiency in Cooking Technologies for Low Income Households in Malawi. *Middle-East Journal of Scientific Research*.19(10): 1328-1333.

Malinski, B. 2008. *Impact Assessment of Chitetezo Mbaula; Improved Household Firewood Stove in Rural Malawi.* A paper prepared for Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH Programme for Basic Energy and Conservation (ProBEC). Available at: https://www.google.com/search?client=firefox-a&rls=org.mozilla%3Aen-

US%3Aofficial&channel=np&ei=AylwWo6cG8nBzgL0hYXQCg&q=Impact+Assessment+of+Chitetezo+Mbaula%3B+Improved+Household+Firewood+Stove+in+Rural+Malawi.+Malinski.2008.pdf&oq=Impact+Assessment+of+Chitetezo+Mbaula%3B+Improved+Household+Firewood+Stove+in+Rural+Malawi.+Malinski.2008.pdf&gs_l=psy-ab.3...14277.16370.0.17632.0.0.0.0.0.0.0.0..0.0....0...1c.1.64.psy-ab..0.0.0....0.Yi_ytE5l7fEn [Accessed on 2nd January, 2016].

Malla, S. & Timilsina. 2014. *Household Cooking Fuel Choice and Adoption of Improved Cookstoves in Developing Countries.* Policy Research Working Paper 6903. The World Bank. Available at http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwiG3oWFoP_YAhXqIMAKHVY3BwYQFggoMAA&url=http%3A%2F%2Fdocuments.worldbank.org%2Fcurated%2Fen%2F542071468331032496%2Fpdf%2FWPS6903.pdf&usg=AOvVaw0_6VVONkoLjg1PPwctYEuR [Accessed on 15th August, 2016].

MBAULA. 2014. *Malawi cookstoves projects survey report*. MBAULA Secretariate. Malawi.

Meyer, S., Kato E., Nkonya E. & Smith V.H. 2015. *Stated Preference of Smallholder Farmers for Improved Cookstoves in Malawi and Mozambique*. International Food Policy Research Institute, Lilongwe, Malawi. Available at: http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwjjrbz3oP_YAhWEA8AKHYHxBgcQFggoMAA&url=http%3A%2F%2Fwww.tropentag.de%2F2015%2Fabstracts%2Flinks%2FMeyer_SMVwc0tQ.pdf&usg=AOvVaw3LGb6oj4Z5-QW2TtwO-6Ha [Accessed on 2nd April, 2016].

Mobarak, A.M., Dwivedi, P., Bailis, R., Hildemann, L. & Miller G. 2012. Low demand for nontraditional cookstove technologies. *Proceedings of National Academy Sciences* 109 (27): 10815–10820. Available at: https://www.google.com/search?client=firefox-a&rls=org.mozilla%3Aen-US%3Aofficial&channel=np&ei=di1wWrCxNc7XzwKXvqPoCw&q=Low+demand+for+nontraditional+cookstove+technologies.PNAS.+Mobarak.2012.pdf&oq=Low+demand+for+nontraditional+cookstove+technologies.PNAS.+Mobarak.2012.pdf&gs_l=psy-ab.3...10282.13219.0.13696.0.0.0.0.0.0.0.0..0.0....0...1c.1.64.psy-ab..0.0.0....0.Xi-_g5wUe1M [Accessed on 17th April, 2016].

National Statistical Office. 2012. *Statistical Year Book*. National Statistical Office. Zomba, Malawi.

Nlom, G.H. & Karimov, A.A. 2015. Modeling Fuel Choice among Households in Northern Cameroon. *Sustainability*. 10 (7): 9989-9999. Available at: http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwignJrEpP_YAhXJKsAKHas7Av8QFggoMAA&url=http%3A%2F%2Fwww.mdpi.com%2F2071-1050%2F7%2F8%2F9989%2Fpdf&usg=AOvVaw0--iY1UAVtUOc2Gw65Ll-d [Accessed on 7th June, 2016].

Roth, C., Michel, A. & Messinger, C.2007. *Getting Technologies to the Market-The Case of the Rocket Stove in Malawi*. Boiling Point No 53. Available at: http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwiZ67zFhoDZAhVD21MKHZtWAFIQFggoMAA&url=http%3A%2F%2Fwww.hedon.info%2Fdocs%2FBP53-Roth-11.pdf&usg=AOvVaw2hOytRpekZ_52ypx0nCehQ [Accessed on 18th October, 2017].

Sagbo, N.S. 2014. *Economic Analysis and Willingness to Pay for Alternative Charcoal and Clean Cook Stoves in Haiti*. Agricultural Economics Thesis. University of Kentucky. UK. Available at: http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwj207ihh4DZAhWQtlMKHX3MBwsQFggoMAA&url=http%3A%2F%2Fuknowledge.uky.edu%2Fcgi%2Fviewcontent.cgi%3Farticle%3D1029%26context%3Dagecon_etds&usg=AOvVaw0B6S5tM9iw6v-cq2nJjCi [Accessed on 12th August, 2016].

SSGHM 2013. *The Commissioning of the First 725 Envirofit Clean Cook Stoves in Malawi was a Superb Success*. Available at www.stichtingstgabriel.nl/pdfs [Accessed on 22nd March, 2016].

Stanturf, J., Karia, R., Evans, D., & Chisale, M. 2011. *Sustainable Landscapes Assessment: Malawi*. A report prepared for USAID –Malawi, Lilongwe. Available at: https://www.google.com/search?q=Sustainable+Landscapes+Assessment.stanturf.2011.pdf&ie=utf-8&oe=utf-8&aq=t&rls=org.mozilla:en-US:official&client=firefox-a&channel=fflb [Accessed on 7th December, 2016]

Varian, H.R. 1992. *Microeconomic Analysis*. USA: Norton & Company, Inc.

Wanjohi, D., & Smyser, B. 2013. *Malawi Cookstove Market Assessment; Enhancing Capacity for Low Emission Development Strategies.* Malawi National Cookstove Task Force. Malawi.

World Bank. 2011. *Household Cookstoves, Environment, Health, and Climate Change: A New Look at an Old Problem*. Available at *http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwjsr9-*

WioDZAhWSzlMKHSWGDdwQFggoMAA&url=http%3A%2F%2Fcleancookstoves.org%2Fresources_files%2Fhousehold-cookstoves.pdf&usg=AOvVaw1ZjowZ9biOIIUVsfMHodel [Accessed on 22nd September,2016].

Whittington, D., Jeuland, M., Barker, K .& Yuen, Y. 2012. Setting priorities, targeting subsidies among water, sanitation, and health interventions in developing countries. *World Development.* 40(3):1546–1556. Available at: https://www.google.com/search?client=firefox-a&rls=org.mozilla%3Aen-US%3Aofficial&channel=fflb&ei=iplwWuzCF5KdzwKljLbgDQ&q=Setting+priorities%2C+targeting+subsidies+among+water%2C+sanitation%2C+and+health+interventions+in+developing+countries.+Whittington.2012.pdf&oq=Setting+priorities%2C+targeting+subsidies+among+water%2C+sanitation%2C+and+health+interventions+in+developing+countries.+Whittington.2012.pdf&gs_l=psy-ab.3...28218.58490.0.60227.0.0.0.0.0.0.0.0..0.0....0...1c.1j2.64.psy-ab..0.0.0....0.2ZJ6c41dsU0 [accessed on 19June, 2017].

APPENDICES

Appendix A. Household Questionnaire

HOUSEHOLD SURVEY QUESTIONNAIRE

CONSUMER CHOICE AND WILLINGNESS TO PAY FOR IMPROVED COOKSTOVES IN MALAWI: A CASE OF CHIRADZULU DISTRICT

Research conducted by;

Joyce Angela Grevulo (MSc student)

Lilongwe University of Agriculture and Natural Resources

P. O Box 219, Lilongwe.

Cellphone number: +256 995 645 089

INTRODUCTION

Government of Malawi in January 2013 embarked on National Cookstoves Program with a goal of distributing two million improved cookstoves in households by 2020. The government is working with various NGOs who are promoting different ICS in Malawi. Some of the stoves promoted are locally made namely, Chitetezo Mbaula, Total Landcare Rocket Stove and Portable Rocket Stove. The current study seeks to investigate consumer choice and WTP for these three improved firewood cooking stoves. This is an academic study to be submitted at Lilongwe University of Agriculture and Natural Resources as a partial fulfilment for the Master's Degree Program in Agricultural and Applied Economics.

This study is being conducted only in Chiradzulu district where households` head like you are randomly surveyed. The survey is voluntary and you can choose not to participate. The information you give will remain completely confidential and will only be used to prepare an academic paper without including any specific names.

Could you please spare some time (maximum of 30 minutes) for the interview?

MODULE A. HOUSEHOLD AND VILLAGE IDENTIFICATION

Household Identification	**Code**		**Interview details**	**Code**
A1. Region:			**B7**. Date of interview (dd/mm/yyyy):	/ / 2016
B2. District			**B8** Time started (24 HR)	
B3. Traditional Authority (TA):			**B9**. Name of enumerator	
B5. Group Village headman:			**B10**. Name of supervisor:	
B6. Village name:			**B11.** Name of data entry clerk	

MODULE B. HOUSEHOLD COMPOSITION AND CHARACTERISTICS (Household members: Persons who live together and eat together from the same pot (share food), including hired labour, students and spouse living and working in another location but excluding visitors)

ID CODE	Name of household member [Start with respondent]	Sex 1 = M 0 = F	Relation ship to the househol d head **CODE 1**	Age (complete years)	Marita l status? **CODE 2**	Education (years) **CODE 3**	Primary occupation **CODE 4**	Contribution to household firewood collection **CODE 5**	Whether the person cooks (if yes how many times per week) 1-Primary Cook 2–Casually cooks (once in a month or if primary cook is absent)

									3 - Does not cook
	B1	B2	B3	B4	B5	B6	B7	B9	B10
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									

CODE 1	CODE 2	CODE 3	CODE 4	CODE5
1.Household head 2.Spouse 3.Son/daughter 4.Parent 5.Son/daughter-in-law 6.Grandson/granddaughter 7.Other relative 8.Hired worker 9. Other, specify……………	1.Married living with spouse 2.Married living without spouse 3.Divorced/separated 4.Widow/widower 5.Never married	0. None/Illiterate 100. Religious education 1. Adult education or 1 year of education 2. Junior primary or 5 years of education 3. Senior primary or 8 years of education 4. Junior secondary or 10 years of education 5. Senior secondary or 12 years of education 6. Tertiary or over 13 years of education	1.Farming (crop+ livestock) 2.Salaried employment 3.Self-employed off-farm 4.Casual labourer on-farm 5.Casual labourer off-farm 6.School/college child 7.Non-school child 8. Other, specify…………..	1. Full time 2. Part time 3. Nothing

MODULE C. HOUSEHOLD SOCIOECONOMIC CHARACTERISTICS

Assets Ownership 1 = Own 0 = Does not own		Values of the assets [present value of asset in C1]	Earnings from Livelihood sources (For the past twelve months or growing season)		Land holding size (Acres)	Monthly income expenditure [for the past 30 days]	
Assets	**C1**	**C2**	**Livelihood sources**	**C3**	**C4**	**Item**	**C5 Expenditure**

Cell phone			Crop Sales			Food items	
Furniture (including beds/cots, sofa set, cupboard etc.)			Livestock Sales			Non-food staple items	
bicycle			Own business			Firewood/charcoal	
Motorcycle			Wage/salaried employment			Health/medicines	
car			Piece work-ganyu			Church/mosque donations	
Ox cart			Remittances			Village contributions	
plough			Pension			Beer	
Hoes						Furniture	
axe						Ceremonies	
Torch/lamp						Clothing	
Refrigerator						School fees and	
Radio						Land renting	
Television						Other	
Solar panel							
Other							

MODULE D. HOUSEHOLD FUEL USE PATTERN

Household firewood source(s) **CODE 6**	Distance to collection source from home (In KM)	Frequency of firewood collection per week	How many days does the firewood collected per trip lasts	Total time spent collecting firewood per week (walking plus firewood collection time)

D1	D2	D3	D4	D5

CODE 6
1. Forest reserve 2. Private land 3.Communal forest

MODULE E. COOKING TECHNOLOGIES (Ask the primary cook)

List all the cooking devices you use in this household	How frequently (in a week) do you use cooking device in E1?	How did you obtain cooking device (s) in E1? **CODE 7**	For how many years have you been using cooking device in E1?	Where do you do most of the cooking? **CODE 8**	How many windows or ventilation holes does the cooking area have?

E1	E2	E3	E4	E5	E7

CODE 7	CODE 8
1.Own construction 2.Bought (ask amount) 3.Received 4. Other	1. Primary dwelling 2.Kitchen (separate building) 3.Veranda/khonde 4. Open space

MODULE F. HOUSEHOLD COOKING BEHAVIOUR (Ask primary cook or wife if married or worker for unmarried)

Who makes cooking decisions in this household? [in relation to head] **CODE 9**	Do you prepare dishes concurently?	If yes, how many dishes?

	1 = Yes 0 = No>>F5	
F1	**F2**	**F3**

CODE 9	
1.Household head 2.Spouse 3.Son/daughter 4.Parent	5.Son/daughter-in-law 6.Grandson/granddaughter 7.Other relative 8.Hired worker

MODULE G. HOUSEHOLD PERCEPTIONS ABOUT COOKING TECHNOLOGIES

What are the best two attributes of cooking devices used in this household? [refer to E1 for stoves]	What are the worst two attributes of cooking devices used in this household? [refer to E1 for stoves]	Do you think that there are some better stoves that use less firewood and produce less smoke than what you are using now? 1 = Yes>>G4 0 = No	If yes, are you willing to adopt the better cooking devices? 1 = Yes 0 = No
G1	**G2**	**G3**	**G4**

Do you know how cooking on three-stone firewood stove negatively affect your family's health, especially young children? 1=Yes 0=No>>G8	If yes, what do you do to reduce the negative health impacts? **CODE 10**	Do you know how cooking on three-stone firewood stove negatively impact forests, watersheds and climate change? 1 = Yes 0 = No>>G11	If yes, what can you do to reduce the negative environmental impacts? **CODE 11**	Where did you get information on health and environmental effects of three-stone firewood stove? **CODE 12**
G5	**G7**	**G8**	**G9**	**G10**

CODE 10	CODE 11	CODE 12	
1.Cooking outside 2.Using other cleaner technologies (specify) 3.Keep children out of kitchen 99.Nothing	1. Plant fast growing trees 2. Use less firewood 3.Use cleaner fuels (specify) 99. Nothing	1.Realized by one`s self 2.Posters 3.Radio 4.Health worker 5.School lessons	6.Family 7.members/friends 8. Newspaper 9.NGOs (specify) 10. Other (specify)

MODULE H. CHOICE EXPERIMENTS AND WILLINGNESS TO PAY FOR IMPROVED COOKSTOVES

As a household, you can reduce the number of firewood collection trips or firewood expenditures, household air pollution (which result into negative health impacts) and control deforestation in your area by using improved cookstoves (ICS).

ICS are energy efficient cooking technologies that consume less firewood, reduce cooking time and allow a more complete combustion of firewood. Less firewood consumption reduces the frequencies of firewood collection or expenditures on firewood purchases and controls deforestation. The complete combustion minimizes the emission of black carbon particles that are detrimental to human health and environment.

To acquire the ICS, the household has to pay a market price. NGOs such as Concern Universal and Total land care are promoting Chitetezo Mbaula, TLC rocket stove and Portable rocket stove to achieve Government of Malawi`s goal of distribution 2 million ICS to households by 2020. Chiradzulu is one of the district where the program is expected to be implemented in the future. This survey therefore seeks to understand your preferences among these stoves before the program starts in your area. Stove pictures and their attributes are shown in table below.

COOKING TECHNOLOGIES AND THEIR ATTRIBUTES

STOVE ATTRIBUTES	 **CHITETEZO MBAULA**	 **TLC ROCKET STOVE**	 **PORTABLE ROCKET STOVE**
Flexibility	Portable	Fixed	portable
Material	Ceramic	Clay, bricks and metal	Steel and insulated bricks
Durability	3 years	2 years	>3years
Fuel saving	60 percent	50 percent	60 to 75 percent
Firewood collection time savings	44 percent	50 percent	75 percent
Market Price	MK650	MK3000	MK12,000

Which ICS would you choose? **CODE 13**	Why would you choose the stove in H1?	If the stove chosen above is on the market, will you be willing to pay for it? 1=Yes 0=No>>H5	If yes, will you be willing to pay _______ for it? **[Note: Randomly choose initial bid from table I]**	What about if the stove price has doubled due to market factors, would you be willing to pay _____________ for it? **[Note: Choose corresponding higher second bid from table I]**	What if through market circumstances the stove price has been reduced by half, would you be willing to pay ____________ for ICS? **[Note: Choose corresponding lower second bid from table I]**	If you are not willing to pay for ICS described above, what are the reasons? **CODE 14**
H1	**H2**	**H3**	**H4**	**H5**	**H6**	**H7**

CODE 13	**CODE 14**
1.Chitetezo Mbaula 2.TLC Rocket Stove 3.Portable Rocket Stove 99.None	1. I cannot afford it 2. It is not worthy that much 3.It is government responsibility 4. Other (specify)

I. Initial and second bids for ICS

Chitetezo Mbaula		**Total Landcare Rocket Stove**		**Portable Rocket Stove**	
Initial bid (MK)	Second bid (MK)	Initial bid (MK)	Second bid (MK)	Initial bid (MK)	Second bid (MK)
750 750	375 1,500	3,100 3,100	1,550 6,200	12,100 12,100	6,050 24,100
700 700	350 1,400	3,050 3,050	1,525 6,100	12,050 12,050	6,025 24,100
650* 650*	325 1,300	3,000* 3,000*	1,500 6,000	12,000* 12,000*	6,000 24,000
600 600	300 1,200	2,950 2,950	1,475 5,900	11,950 11,950	5,975 23,900
550 550	275 1,100	2,900 2,900	1,450 5,800	11,900 11,900	5,950 23,800

*stove market price.

I would like to thank you for participating in this survey.

Appendix B. Focus Group Discussion`s Checklist

CONSUMER CHOICE AND WILLINGNESS TO PAY FOR IMPROVED COOKSTOVES IN MALAWI: A CASE OF CHIRADZULU DISTRICT

Question 1.

What are the common sources of cooking energy in this community or village?

Question 2.

What are the characteristics of your main sources of firewood? (Characteristics include; distance, forest type, market, forest cover changes etc).

Question 3.

What common cooking technologies do you use? And why? (Indicate the most preferred attributes and worst attributes of the common cooking technologies)

Question 4.

What do you know about negative effects of cooking on three-stone firewood stove on family's health, forests and watershed?

Question 5.

If better stoves are introduced that use less firewood and produce less smoke than what you are using now, what attributes would you want them to have?

Table 1: Focus Group Discussion Participants` List

ID	First Name	Surname	Village name
1	Frolence	Charles	Njelemba
2	Annie	Kachulu	Njelemba
3	Faless	Kausiwa	Lopa
4	Jessie	Godeni	Njelemba
5	Evelyn	Abati	Njelemba
6	Ruth	Kachipapa	Mkucha
7	Chifundo	Thomas	Njelemba
8	Esther	Jakasi	Njelemba
9	Sellina	Benedicto	Njelemba

Appendix C Key-Informant Interviews

Question 1.

Which ICS do you promote and why?

Question 2.

What are your target districts in Malawi?

Question 3.

What dissemination strategies do you use?

Question 4.

If you sell the stoves, how much is the market price?

Question 5.

Approximately, how many ICS have you distributed so far?

Table 1: Key-Informant Attendance List

Interview Number	Name	Interview Date	Organization Represented	Resignation	contacts
1.	Ms. Regina Kulugomba	11TH February, 2016	Department of Energy Affairs	Energy Officer	rginakulugomba@yahoo.co.uk
2.	Mr. Yamungu Botha	15th May, 2015	Concern Universal, Balaka Office	Program Manager	y.a.botha@gmail.com
3.	Mr. Vincent Gondwe	30th March, 2016	Total Land Care Green	Marketing Manager	vitegondwe@gmail.com