Swedish University of Agricultural Sciences
Faculty of Natural Resources and Agricultural Sciences
Department of Economics

An econometric analysis of factors determining charcoal consumption by urban households: The case of Zambia

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ABSTRACT

The purpose of this thesis is to pin down the factors determining charcoal consumption by urban households in Zambia. These factors are important in facilitating smooth policy formulation in the areas of health, environment and energy planning. The thesis uses urban household consumption survey data collected during the dry and rainy seasons during the period 2007-2008. The data information being used is a product of an extensive survey on household monthly total expenditures in urban Zambia. The biprobit and the Heckman selection models were used to analyse the factors affecting the likelihood of consuming charcoal and demand for charcoal respectively. The results suggest that as household's per capita total expenditure rises, per capita charcoal consumption increases at a decreasing rate – implying that per capita consumption of charcoal increases in tandem with per capita expenditure until it reaches its maximum and thereafter starts falling. Price of charcoal was also found to be negatively related with per capita charcoal consumption. The notable socio-economic factors driving charcoal consumption were found to be low education, poverty factors such as low income, low wealth and poor household access to electricity. Given that policy formulation in the areas of health, energy and environment would be based on reducing charcoal consumption, mitigation measures on consumption of charcoal were identified. Among others were 1) to increase the income of poor households so that they can have access to electricity, 2) to increase the usage of energy efficient equipments such as the efficient charcoal stoves, 3) finding efficient less carbon fuel-substitutes for charcoal, 4) making electricity both accessible and affordable through investing in hydro-electricity generation. Adoption of the afore mentioned measures would help in reducing demand for charcoal leading to reduction in pollution, deforestation and on a more general level, mitigating adverse effects of charcoal consumption on the environment as a whole.

Key words: Determinants, Charcoal consumption, Household expenditure, Policy

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ACRONYMS

BVP	Bivariate Probit
COMESA	Common Market for Eastern and Southern Africa
CSO	Central Statistics Office
FSRP	Food Security Research Project
GDP	Gross National Product
GHG	Green House Gases
HA	Hectare
LPG	Liquid Petroleum Gas
ME	Marginal Effects
MLE	Maximum Likelihood Estimation
MVP	Multivariate Probit
OLS	Ordinary Least Squares
SADC	Southern Africa Development Cooperation
USD	United State of America Dollar
UVP	Univariate Probit
ZESCO	Zambia Electricity Supply Corporation
ZMK	Zambian Kwacha (the currency of Zambia)

CHAPTER 1
INTRODUCTION

1.1 Background and problem statement

In Zambia charcoal is one of the important energy sources. In as far as primary energy supply is concerned, it ranks second to firewood. For instance, in 1994 it accounted for about 33% of total primary energy supply whereas firewood accounted for 43%, petroleum 10%, electricity 10% and coal 4%. Taking into consideration the energy losses arising from converting wood into charcoal, charcoal contributes about 11% to final energy consumption and it is put at the same level with electricity and petroleum (Hibanjene *et al*, 2003).

Consumption of charcoal in Zambia has been progressively increasing for the past three decades both in urban and rural areas of Zambia. It is estimated to increase to 1.211 million tonnes in 2010 from 0.330 million tonnes in 1969 (Malambo *et al*, 1998). Charcoal consumption is higher in urban areas than in rural areas. It is estimated that 85% of charcoal is consumed by urban households whereas the rest (15%) is consumed by rural households. Charcoal production involves the felling of trees and then trees are cut into logs. The logs are used as inputs in the charcoal production process. The production of charcoal has caused widespread deforestation in the country. The Environmental Council of Zambia in 1994 estimated annual deforestation attributed to charcoal production to be 56 000 ha which represented 28% of the total annual deforestation rate. A considerable number of studies in developing countries suggest that consumption of biomass (charcoal, firewood, crop residues, animal dung) as a form of energy poses a considerable number of economic, social, health and environmental problems (Yamamoto *et al*, 2009) and charcoal consumption is no exception. When the whole process of charcoal production is examined, it becomes clear that it has adverse effects on the environment as reflected by deforestation, which leads to extinction of species, habitat destruction, ecosystem simplification, climate change and health problems. From an environmental point of view, adverse effects of charcoal production and consumption on the environment are further compounded by its enhancement of greenhouse gases (GHG) accumulation. For example; 1) at production there is release of GHG which continues even at consumption stage, 2) The cutting of trees causes deforestation (destruction of carbon sinks) and this increases the incidence of atmospheric carbon concentration resulting into global warming (climate change), degradation of biodiversity and soil fertility and 3) during transportation of charcoal from production areas to markets in urban areas GHG are released as well through combustion of fossil fuels (Parikh and Shukla, 1995). From the health point of view, at the household level the potential problem of charcoal consumption concerns the health of people who are exposed to indoor air pollution stemming from incomplete combustion of charcoal due to using inefficient-stoves. The consequences of this are respiratory diseases and lung cancer which culminate into unwarranted deaths (Smith, 2003) hence causing social and economic problems.

Various studies on the causes of deforestation in Africa have been conducted by various authors (see among others Benjaminsen, 1997; Hofstad, 1997; Alemu, 1999) and have pointed out that forest extraction for fuelwood is one of the leading causes of deforestation and Zambia is no exception. Population increase is said to put pressure on demand of energy in general. According to Curthbert and Dufoumaud (1996), as population expands, fuelwood demand rises while stocks of trees diminish. In the case of rapid urbanization in Zambia coupled with expensive and inadequate access to modern energy such as electricity, a large proportion of households use charcoal for cooking, leading to an increase in the demand for charcoal and eventually causing extensive wood deforestation in the country. Meanwhile Ehrhardt-Martinez (1998) reports that, deforestation accounts for 22.9 % of global carbon. The adverse effects on the environment of charcoal production come into play due to the fact that the carbon sinks are destroyed through deforestation. Thus there are no sinks to absorb the GHG and this aggravates the incidence of GHG concentration in the atmosphere.

Given that decisions concerning choice and demand for energy are made at household level, moreover such decisions can have important consequences as deliberated earlier; there is a need to estimate factors which may have influence on the choice and demand for energy. In the case of charcoal consumption, identification and estimation of the factors influencing its choice and demand by households would facilitate smooth formulation of policy from three dimensions- health, energy and environment. For example, in formulation of domestic energy policies, price and income elasticities play a very important role. Not only are they important for domestic energy policies but are regarded as useful in the context of greenhouse gas abatement energy-policies. Though price and income seem to be the major determinants of energy consumption, the fact that decisions of energy choice and demand are made by the household facing a number of different socio-economic characteristics, all other factors are equally important in the formulation of rigorous policies related to health, energy and environment as far as consumption of energy (charcoal) is concerned.

1.2 Aim and objectives

The overall objective of this thesis is to perform an econometric analysis of charcoal consumption by urban households in Zambia in order to estimate their demand functions, identify their determinants and measure price and expenditure elasticities. The specific objectives are:

- To determine the factors which significantly influence the likelihood of consuming charcoal by urban households in Zambia.
- To determine the factors which significantly influence demand for charcoal by urban households in Zambia.

There are a number of factors that affect choice and consumption of energy. In general energy demand is affected by demographics, socio-economic conditions, economic structure, technology, economic activity, substitutable energy, and equipment efficiencies (Kebede *et al,* 2010). In the same vein this thesis seeks to find factors affecting charcoal consumption in urban Zambia. Factors such as demographics/household characteristics (age, gender, household size, education level of household head), housing conditions as a measure of standard of living of the household (material used for floor, roofs, walls, if the house is electrified or not, modern plumbing – water and/or sewerage system), location of the household (low income, medium income and high income) and economic factors (price and total household expenditure as a proxy for income). These variables would be used in an econometric model to determine how significantly each influences the likelihood of using charcoal by the household as well as determining their significant effect on the quantity of charcoal consumed in urban Zambia by using urban household consumption survey data collected during the dry season-2007 and the rainy season-2008.

The significant determinants from the analysis would form a basis on which policies related to health, energy and environment in the face of charcoal consumption can be formulated. For instance price and income/expenditure elasticities of energy demand play an important role in energy projections and carbon dioxide simulations on which choice of domestic energy and formulation of green house gas abatement energy- policies are based (Gundimeda and Kohlin , 2006).

1.3 Delimitations of the study

The study is limited to charcoal consumption of urban households in Zambia. Given the fact that urban households in Zambia make their cooking-energy choices mainly between charcoal and electricity, the study should have carried out the econometric analysis of factors affecting electricity consumption in urban Zambia as well. However, since there was no complete quantity of electricity consumed in the data that are used for the econometric analysis of this thesis, only the households likelihood of consuming electricity was conducted to help in coming up with a rigorous policy on charcoal consumption mitigation. It is also noteworthy that the price of electricity was not considered because it was fixed in both surveys (2007 and 2008). Firewood is not used by urban households for cooking or heating, but it is mainly used during funerals and in a small degree it is used for brewing some traditional beers. Given that firewood is not an alternative energy source in urban areas, it was left out in this analysis.

Though the study uses data that was not exactly tailored to households' energy consumption, it paves the way for future studies of this kind given that there are no well known attempts to estimate factors determining households energy consumption in Zambia as far as the author's knowledge is concerned.

1.4 Thesis outline

The thesis is organized as follows. The first chapter has defined the problem this study is looking at. It also gives the objective of the study and the expected achievements at the end of it all. Chapter 2 continues shedding more light on the background of the study. It brings out to the fore the general economic and energy consumption status of Zambia.

Chapter 3 presents the theoretical framework of the study based on existing literature and economic theory. The household choice models are discussed in tandem with their theoretical variables and this gives a guide in selecting empirical variables relevant to this study. Overall this chapter gives a summary of previous studies' contribution on consumption of cooking energy by households in various countries. In the next chapter (4), the econometric models employed in the study are presented. It presents the estimation methods (note that the Bivariate probit and the Heckman selection models are employed) and specifies the models used and lastly defines the variables used in these models and their expected effects.

Chapter 5 presents the database of the urban consumption survey conducted in 2007 and 2008 by the Food Security Research Project (FSRP) in Zambia. It gives general statistics on household characteristics and consumption of charcoal by each expenditure group. Chapter 6 goes further to present econometric estimations of the factors affecting charcoal consumption in urban Zambia. The estimates give a basis on which the various policies related to health, energy and environment can be formulated. Finally, the study is wrapped up in chapter 7 by giving conclusions and recommendations.

CHAPTER 2
PROFILE OF THE REPUBLIC OF ZAMBIA

2.1 Location

Zambia is a landlocked country found in central Southern Africa. It is located between latitudes 8° and 18° South of the Equator, and longitudes 24° and 34° east, and has surface area of 752 600 km^2. It has eight neighbouring countries; Angola, Democratic Republic of Congo, Tanzania, Malawi, Mozambique, Zimbabwe, Botswana and Namibia. In 2000 the population stood at 9.9 million and registered growth rate of 2.5%. It was projected that in 2009 the population would be 12.9 million (www.zamstats.gov.zm, population projections report, 1, 2010). The average growth rate of 2.5 % makes Zambia to be grouped among countries with highest population growth rate in the world. The country is highly urbanized with 35% of the population living in urban areas making it one of the most urbanized countries in Sub-Sahara Africa. It has regional affiliation to the Southern Africa Development Cooperation (SADC) and the Common Market for Eastern and Southern Africa (COMESA).

2.2 Geographical features, climate and natural resources

Zambia has three main topographical features named according to their altitudes. (1) an altitude above sea level of at least 1 500 meters – mountains; (2) an altitude ranging from 900 to 1500 meters – Plateau; and (3) an altitude falling between 400 to 900 meters – low land or plain. The country has tropical climate and three different seasons namely:

- Cool and dry season from May to August
- Hot and dry season from September to November, and
- Warm and wet season from December to April

The vegetation of Zambia is mostly made up of savannah woodlands and grassland. The country has abundant natural resources including minerals (copper, zinc, cobalt, lead and precious stones such as emeralds), rivers, lakes, game reserves, forests and water falls (the most renowned is the might Victoria falls).

2.3 The economy of Zambia

Zambia got its independence from Great Britain in October 1964. From the inception of independence, the country adopted a controlled type of economy in order to foster socially-oriented development in the country. The economy is dependent on copper exports as the main source of foreign exchange. This over dependence of the economy on the mining industry has made it highly vulnerable to fluctuations in the price of copper on the international market, and since the 1970s when the price of copper started falling at the London Metal Exchange, the Zambian government has been experiencing budget deficits (www.sarpn.org.za, The Historical Role of Copper Mining in the Zambian Economy and Society, 2010).

In 1991 the economy of Zambia changed from controlled to a liberalized and deregulated economy which saw privatization and closure of mines and state-owned firms, and severe retrenchment of workers as a way of creating macro-economic stability in the economy in order to bring it back on to recovery as per International Monetary Fund (IMF) and World Bank (WB) Structural Adjustment Programmes (Harsch, 2000). Nevertheless, despite these programmes, the economy of Zambia has not recovered yet. Unemployment has been rising, in 2000 the overall unemployment rate stood at 13% and 26% in urban areas. Poverty levels are increasing and measured to be 68% in 2004 (CSO, Living Conditions Monitoring Survey in Zambia, 2004). The road infrastructure has deteriorated to unprecedented levels, education and health care services are poor. The country's per capita income is about USD 450 and its GDP was USD 833.23 million in 2009 (www. zamstats, Economic Activity Report, 2, 2010) and the GDP growth rate is at most 2 % as shown below (table 1). All these misfortunes have relegated the country to one of the poorest countries in the world.

Table 1: GDP at 1994 price (USD' Million)

	2006	2007	2008	2009
Real GDP at market price	699	742	784	833.23
Real Growth Rate	6.2	6.2	5.7	6.2

Source: C.S.O 2009, Zambia

2.4 Energy consumption in Zambia

As far as energy sources for the country are concerned, Zambia draws its energy from two major sources, the imported petroleum and the indigenous energy. Among the indigenous energy sources, the woodlands called the miombo woodland is the largest single source of energy in Zambia. The miombo woodland provides firewood and charcoal as the major products. There are other indigenous energy sources like hydropower (electricity) and coal. Above 80% of total energy demand in Zambia is met by the indigenous energy sources and the remainder is met by imported oil (Serenje *et al*, 1994). As pointed out earlier, charcoal and firewood make the bulk of indigenous energy and they come from woodlands. Fuelwood (charcoal and firewood) is Zambian's principle household's fuel and it is the largest single source of energy in Zambia.

When considering energy consumption at sectoral level, household consumption dominates and it accounts for over 60% of final energy consumption. The industrial, mining, commercial and transport sectors draw their energy from electricity (hydro- power), coal and petroleum products.

Household's cooking-energy consumption in Zambia consists of fuelwood and electricity (hydro-power) as the principle sources of energy. In the urban areas, charcoal and electricity are a major source of energy for cooking and heating whereas in the rural areas almost 100% of the energy used comes from fuelwood (firewood and charcoal) and other biomass such as crop residues. An insignificant percent of rural households use electricity.

As pointed out above, in urban Zambia, electricity and charcoal are the major if not the only two fuels used for cooking and heating. Firewood is not commonly used for cooking in urban areas but it is mostly if not solely used only when the household experiences a funeral and/or for brewing traditional beer (FAO, 1998). For lighting and igniting charcoal and fire wood, kerosene is used by households with no electricity while they supplement electricity for those households with electricity. These facts are authenticated by statistics from the urban consumption data (2007 and 2008) used in this study where on average 93% of households used charcoal whereas an average of 15 % of households consumed firewood. Meanwhile 39% of households used kerosene. Gas is not used for cooking nor for lighting in Zambia and this is evidenced by the low per cent of households that own gas cookers- equal to 0.6 % implying that, gas is not used by households in Zambia. Generally households in urban Zambia use electricity and charcoal as energy for cooking and they make their cooking energy choices between the two energy types.

In the last decade, Zambia has seen an unprecedented increase in the construction of housing units in urban areas due to shortage of accommodation after the government-housing units were sold to sitting tenants. Since accommodation is in private hands, rentals have been rising and this has caused some people to start building their own houses while others have seen it as an opportunity to enter into housing business. The population in urban areas is increasing as people from rural areas are coming to urban areas in search of jobs or trade. This has been caused among other things, due to lack of income generating activities in rural areas for since the time the economy was liberalized in 1991, almost all rural industries were closed down living rural people redundant and in addition to this agriculture has stagnated since then. Due to lack of jobs, many people have migrated to urban areas in search of jobs or trade. This has caused the population of the urban areas to surge to substantial proportions. There have been new mines opened in the Copperbelt Province and in the Northwestern

Province. The rising numbers of housing units in urban areas and the newly opening mines have put pressure on the supply of electricity in the country. The power distribution Company – Zambia Electricity Supply Corporation (ZESCO) has failed to cope up with this high demand of electricity and it has resorted to electricity shedding in favor of commercial entities and mines. Thus urban households have had no constant supply of electricity in this last decade. Despite the intermittent supply of electricity, ZESCO has been frequently increasing the price of electricity (see appendices 1and 2 for more information). This has caused households to use charcoal as a supplement to and substitute for electricity. Charcoal demand has increased to higher levels in this last decade and this has been a source of concern to many environmentalists in the country in view of the wide deforestation charcoal production is causing in the country.

There have been attempts to provide alternative sources of energy to charcoal in urban areas as a way of stopping deforestation caused by charcoal production. One of the renowned efforts is the manufacturing of coal briquette in Zambia. The pilot project of coal briquette production has been on-going since 1991 though it is not fully commercialized to start producing the coal briquettes due to lack of funding (www.hedon.info, energy and environmental concerns for Zambia, 2010). When commercialized, the coal briquettes would provide an alternative source of energy to charcoal.

Bio-fuel production has also been identified as another alternative source of energy to fossil oil though it is only in a proposal stage. Zambia has high potential for solar and wind energy for it has got prolonged periods of sunshine due to its nearness to the equator. However the solar and wind energy potentials have remained unharnessed.

CHAPTER 3
LITERATURE REVIEW

There are many and various studies that have examined factors determining consumption/use of household energy (firewood, charcoal, electricity, gas, kerosene, coal etc) in meeting their cooking needs in various countries. This chapter brings to the fore the models used, the variables employed and the findings of the various studies.

3.1 Households' energy choice models

In studying the household fuel choice, the model of "Energy Ladder" is employed. The energy ladder model puts more emphasis on income in explaining fuel choice and focuses more on fuel switching (Heltberg, 2003). According to Heltberg (2003), the energy ladder model is a three-stage fuel switching process. As the household's income increases, households move from biomass to transitional fuels such as kerosene, coal and charcoal, and eventually to liquid petroleum gas (LPG) and/or electricity once their income is sufficient. The ladder model is renowned for its ability to explain the income dependency of fuel choices. However, the model has a misleading implication that "a move up to a new fuel is simultaneously a move away from fuels used hitherto" (Heltberg, 2003). In the same vein, the counterpart model of fuel switching that postulates that the introduction of a new superior fuel will phase out a traditional fuel, has the same drawback as this is not always the case.

There are many evidences from a considerable number of studies that show that households consume a portfolio of energy sources at different stages of the energy ladder (see among others Davis, 1998; Hosier and Kipondya, 1993), the phenomenon called fuel stacking. From literature it has been difficult to find the relative importance of fuel stacking and fuel switching nor are the causes of fuel stacking well understood (Heltberg, 2003). The norm is that introduction of superior fuel would not necessarily displace traditional fuels like biomass and wood fuel. Likewise, an increase in the income of households would not necessarily result in the movement up from a traditional source of energy to a superior one. What is mainly observed is the multiple consumption of a portfolio of energy sources. In contending against the energy ladder model new studies have found that income alone is not sufficiently able to determine the household consumption of a particular energy type and as such other factors are also taken into consideration.

Given that income alone is not sufficient to determine the household consumption of a particular energy type (Heltberg, 2003), it has been considered to be imperative to look at other factors that may influence household's fuel choice. In doing this, there are two econometric models employed; the binary dependent variable model and the demand model. In the first model a binary dependent variable is employed – whether the household used or did not use a particular type of fuel, this analysis determines the maximum likelihood of consuming a fuel type.

In the second model- demand, the quantity of a particular type of fuel consumed is employed as a dependent and its independent variables indicating the factors that affect the quantity of a fuel type consumed by the household. This second model estimates factors affecting demand of an energy type. Further this model is also used to estimate the income/expenditure and price elasticities of household demand for different kinds of energy. Given different growth rates for different segments of a particular country's population, the income and price elasticities can be used for energy projections and carbon dioxide simulations. Gundimeda and Kohlin (2006) report that, "price and income elasticities of demand are important for the choice of domestic energy policies". They are as well useful for formulation of greenhouse gas abatement energy policies.

3.2 Factors included in the models and expected effects

From empirical studies carried out in various countries, numerous socio-economic variables have been identified as being important in influencing consumption of a particular fuel type. The socio-economic variables in question affect both the likelihood of consuming and demand of a particular fuel type. From theory, the variables are categorized into household characteristics, household living standards, the income status of the household and economic factors.

3.2.1 Household characteristics

Household characteristics have either a positive or negative correlation with both the likelihood of consuming and demand of household cooking energy. *Family size* is expected to have a positive correlation with use rate of less clean fuel. Ouedraogo (2005) in his study of household energy preferences for cooking in urban Ouagadougou in Burkina Faso showed the existence of significant relationships between the use rates of firewood, charcoal and liquid petroleum gas (LPG) and household size. He found that households with large family size were the poorest and were the main users of firewood. Conversely, the richest households had smallest family size and were the main user of charcoal. In general this depicted the fact that poor families have large family size and are likely to rather use firewood than charcoal whereas rich families are likely to use mainly charcoal at the expense of firewood. The same findings were arrived at by Mekonnen and Kohlin (2009) in their endeavor to find the determinants of household fuel choice in major cities of Ethiopia where households with large family size were found to be more likely to consume charcoal and wood and less likely to use kerosene. However they found that households with small family size consumed more kerosene whereas electricty consumption did not depend on family size. Interestingly, in determining factors affecting household fuel choice in Guatemala, Hetberg (2003) found that household size was associated with fuel stacking – larger households used more of both fuels – clean and less clean (LPG and firewood respectively).

Education level of the head of the household is postulated to have a negative relationship with rate of usage and demand of less clean fuels. The higher the level of education of the household head the higher is the probability of consuming/using clean fuels. Mekonnen and Kohlin (2009) in their attempt to find the determinants of household fuel choice in major cities of Ethiopia conjectured that higher education (secondary and post secondary) engendered households to more likely use electricity and kerosene than wood and charcoal as cooking energy. This finding was also confirmed by Ouedraogo (2005) in his study of household preferences for cooking in urban Ouagadougou in Burkina Faso. He found that households with a head that had higher education level had lower firewood adoption probability than the household with a head with lower education. Heltberg (2003) in his study of factors determining household fuel choice in Quatemala also found the same that education level of the household head had a very significant negative impact on wood consumption while at the same time encouraging demand for LPG (clean fuel).

Gender of the household head is postulated to influence consumption of a particular fuel type. In major cities of Ethiopia, Mekonnen and Kohlin (2009) found that female-headed households were more likely to use wood than charcoal while charcoal consumption was higher in male-headed households. They attributed this to the fact that males are generally more mobile than females and thus have better access to larger quantity of charcoal.

Age of the household head is also said to have influence on the likelihood of consuming a particular fuel type. The households with older heads are more likely to consume wood fuel than non wood fuels. Mekonnen and Kohlin (2009) found that households with older heads in major Ethiopian cities were more likely to use wood and kerosene than electricity and charcoal while demand of wood increased with age. This finding was attributed to the role of habits on the part of older people reflected in their resistance to change if they grew up with wood as their main fuel as well as limited access to other energy types such as electricity.

3.2.2 Standard of living variables.

Mainly in the literature, household standards of living are mainly reflected in the housing conditions which are proxied by the following variables: material used for floor, roofs, walls, if the house is electrified or not, and modern plumbing – water and/or sewerage system (Abeyasekera, 2002).

Household standards of living are hypothesized to have a significant negative relationship with consumption of fuelwood. As standards of living for a particular household improve consumption of fuelwood declines and vice versa. Ouedraogo (2005) in his study of household energy preferences for cooking in urban Ouagadougou in Burkina Faso found that as standards of living improved, the use of firewood declined whereas the use of charcoal and LPG rose. In urban Ethiopia, Abebaw (2003) in his study of household determinants of fuelwood choice found that possession of a refrigerator increased the probability of consuming charcoal contrary to his *a priori* anticipation that the probability of charcoal consumption would be reduced since refrigerator reduces the frequency of cooking.

3.2.3 Economic variables (income/expenditure and price)

Income and price elasticities of energy demand are important for choice of domestic energy policies and for formulation of greenhouse gas abatement- energy policies. There is a general perception that household demand for fuelwood is characterized by low income and inelastic price elasticities-implying that quantity demanded responds less proportionately to price and income changes, however the direction of the relationship between income, price and energy demand give conflicting results. In estimating price and income elasticity of energy demand, three types of data are used; the cross-sectional data, pooled cross sectional, time series data and panel data.

Cuthbert and Defournaud (1996) by use of pooled cross-sectional - time series data, estimated income and price elastisties of fuelwood demand in Sub-Saharan Africa. They found that income and price elasticities conformed to conventional economic theory – income is positively related whereas price is negatively related to fuelwood demand. The income elasticity was found to be equal to 0.39 whereas the price elasticity was found to be equal to -0.28, suggesting that, an increase of 1 % in household income yielded a 0.39 % increase in fuelwood demand whereas an increase of 1% in price of fuelwood yielded a 0.28 % decrease in fuelwood demand.

There are so many studies which conform to the conventional economic theory of energy demand when modern and traditional fuels are studied. The urban and rural areas portray the same scenario though there are differences in income and price elasticity responsiveness. It is held that demand is more responsive to income in urban areas whereas demand is more responsive to price in rural areas (Pachauri, 1983; Zein-Elabdin, 1993).

Other studies have shown opposite results as opposed to the energy demand conventional economic theory. In the study conducted by Abakah(1990) in which he established trends in fuelwood consumption in Ghana, found that the demand of fuelwood was negatively and positively correlated with wages and price levels respectively. The negative income elasticity indicate the fact that fuelwood is a transitional fuel – implying that households are willing to switch to modern fuels as their income increases.

Ouedraogo (2005) in his study of household energy preferences for cooking in urban Ouagadougou in Burkina Faso found that the firewood utilization rate decreased with increasing household income whereas the charcoal utilization rate increased with increasing household income. This implied that firewood energy in Burkina Faso acted as a "transition energy source" towards other sources of energy for cooking that are more adaptable for urban consumption. The same trend is observed on total household expenditure when used as a proxy for income. Mekonnen and Kohlin (2009) found that as total household expenditure increased, households increased consumption of each fuel type except for charcoal in urban Ethiopia. To them, this suggested that wood was not an inferior good as postulated in literature by the energy- ladder hypothesis.

Price of energy also influences the household energy choice and the amount of energy consumed by both rural and urban households. The general observation is that price has a negative effect on the quantity of energy consumed. As price increases, the amount of energy consumed decreases. In Guatemala, Hetberg (2003) found that price of wood had a significant negative impact on firewood demand of both rural and urban sectors. Mean while Zein-Elabdin (1997) found that price had a negative significant effect on the demand of charcoal in Sudan.

3.2.4 Physical location and dynamic differences

Physical location of a household determines what and how much fuel type a household consumes. When rural and urban households' energy consumption patterns are compared, it is hypothesized that the rural households consumes more of fuelwood whereas the urban household consumes more of non fuelwood energy (clean fuels such as LPG, kerosene, electricity). This is authenticated by Heltberg (2003) study of factors determining household fuel choice in Guatemala in which it was found that in urban areas household consumption of fuelwood declined while consumption of LPG generally increased with the increase in expenditure. There are other studies undertaken by Mekonnen and Kohlin (2009) in major cities of Ethiopia that obtained the same finding – households in the capital city Addis Ababa consumed more electricity and less charcoal as compared to other cities.

Dynamic differences are also important in economic studies due to the fact that they show trends of variables being investigated over time. In as far as energy consumption is concerned, seasonal variations are important as they help to plan for rigorous energy policies.

Due to the fact that household energy demand and choices are influenced by many factors, both observed and unobserved (among others tastes and opportunity costs), there is a need to employing a holistic model that would integrate as many factors as possible in its modeling. Thus, in view of this, econometric models are deemed appropriate for determining the household's demand for and likelihood of consuming a given energy type. Among factors to consider are; household demographics, household living standards, economic and physical location of the household.

CHAPTER 4
ECONOMETRIC MODELS USED IN THE STUDY

As already pointed out, in order to rigorously determine the factors affecting household use and demand of a particular fuel type, two econometric models are employed. These are the models that determine the likelihood of consuming a fuel type and the estimation of the quantity of a fuel type consumed by a household. In this study bivariate probit and two-stage Heckman selection models were employed and STATA 11 programme was used for data analysis.

4.1 The Probit model for consumption of charcoal

Consumption of charcoal in this thesis will be modeled as a binary decision whereby a household either consumes or does not consume charcoal. Given this case of binary decision, the dependent variable is a discrete dummy variable (consume charcoal=1; and don't consume charcoal = 0). Further, linear estimation in this case is inappropriate due to the fact that 1) the error term is not normally distributed because it takes only two values (1 and 0), 2) the variance of the error term is not constant but it is heteroskedastic thus violating the assumption of the ordinary least squares regression (OLS) and 3) the probabilities estimated by the linear estimation don't necessarily fall between zero and one (Stock and Watson, 2007). Thus with linear estimation it is possible to have probabilities lying below zero or greater than one a thing which is unacceptable. For instance the consumption of charcoal can not be predicted with over one hundred percent certainty nor less than zero percent certainty. Because of these complications, other estimation methods are used when dealing with the dependent variable that is a discrete dummy variable.

Given the above pointed out reasons, to estimate a binary response model typically maximum likelihood estimation (MLE) technique (Stock and Watson, 2007) is employed. Thus the regression employed is nonlinear specifically designed for binary dependent variables. Commonly employed binary response models include the logit and probit models. There is insignificant difference between the two models as far as their marginal effects at the multivariate point of means are concerned (Baum, 2006). This study employs the probit model to analyze the factors affecting the likelihood of consuming charcoal among urban-households in Zambia. Below is the general form of the probit model :

$$Y_i = F(G_i) \qquad (1)$$

$$G_i = (b_0 + \sum^{n}_{j=1} \ b_j X_{ji}) \qquad (2)$$

Where: Y_i is the observed response (1 or 0) for the i^{th} household;

G_i is the underlying stimulus (reasons why the household consumed charcoal or not);

F is the functional relationship between observation (Y_i) and the stimulus index (G_i);

G = 1, 2, ……., k, is the index of observations, where k is the sample size;

X_{ji} is the j^{th} explanatory variable for the i^{th} observation;

b_0 is a constant;

b_j are unknown parameters ; and

j = 0, 1, 2, ……. , n, where n is the total number of explanatory variables.

For the probit model $F(*)$ is the standard normal cumulative distribution function (c.d.f) , thus the model becomes:

$$Pr(Y_i = 1 / X_{ji}) = F(G_i) = F(b_0 + \sum^n_{j=1} b_jX_{ji}) = Pr(Z =< z) \qquad (3)$$

where $z = b_0 + \sum^n_{j=1} b_jXji$

The estimated coefficient of each explanatory variable (b_j) is reported with a standard error and *t-test* just like in the OLS. Nevertheless, the interpretation of the probit coefficients (b_j) differs from the OLS as they are not directly interpreted due to the fact that they are not marginal effects (ME) associated with explanatory variables but are coefficients associated with the standard normal cumulative distribution *F(Z).* The coefficients are used to find the ME of each related explanatory variable by taking into account the density function of *Z*, *Φ(Z)*. If the probit coefficient (b_j) is positive, then an increase in the explanatory variable (X_{ji}) increases the probability that $Y_i = 1$ and vice versa other factors held constant (Stock and Watson, 2007). Given that the probit coefficients are difficult to interpret, they are best interpreted indirectly by computing probabilities and/or changes in probabilities which give the marginal effects of explanatory variables when a dependent variable is equal to one ($Y_i = 1$). Shown below is how the ME of the explanatory variables are computed:

$$P(Y_i) = F(b_0 + b_i X_i) = F\left(\bar{Z}\right)$$

$$\frac{\partial P(Y_i)}{\partial X_i} = \frac{\partial F}{\partial \bar{Z}} * \frac{\partial \bar{Z}}{\partial X_i}$$

$$= \phi\left(\bar{Z}\right) * \left[\frac{b_0}{X_i} + \frac{b_i X_i}{X_i}\right]$$

$$= \phi\left(\bar{Z}\right) * b_i = ME$$, where $\phi\left(\bar{Z}\right)$ is the density function.

However, due to the fact that the same household may consume a combination of different energy types (charcoal and electricity in our case but also other sources such as firewood and kerosene), a multivariate probit (MVP) model was employed in this study. MVP models give more-efficient estimations than univariate probit models when the same individual makes several binary choice decisions(Ramful and Zhao, 2008) and allow for examination of correlation across several binary choice decisions through both observable and unobservable characteristics (see among others Zellner and Lee, 1965., Ashford and Sowden, 1970). In this study the bivariate probit (BVP) model was used in order to examine the correlation between charcoal and electricity consumption through their error terms (unobserved characteristics of the household). The use of this approach facilitated the estimation of joint, conditional and marginal probabilities between charcoal and electricity which can not be estimated using the univariate probit (UVP) models. The bivariate probit model for charcoal and electricity took this form:

We assume a vector of latent variables for charcoal(*C*) and electricity (*E*) - (R_C^*, R_E^*), where the latent variable R_j^* is proportional to the unobserved demand of an energy type $j(-\infty < R_j^* < \infty, j = C, E)$. Further, R_j^* is related to a set of observed characteristics M'_j as shown below:

$$R_j^* = b_j M'_j + \varepsilon_j \quad (j = C, E), \qquad (4)$$

where, b_j and ε_j are vector of parameters to be estimated and random errors (unobserved characteristics) respectively. This latent variable R_j^* relates to the observed dummy variable R_j through;

$$R_j = \{ 1 \text{ if } R_j^* > 0, \text{ or } 0 \text{ if } R_j^* <= 0 \} \qquad (5)$$

Which is interpreted as $R_j = 1$ if the household consume energy *j* and $R_j = 0$ otherwise.
In order to model the correlation of two error terms in the two latent equations in equation (4), we assume that the two error terms jointly follow a bivariate normal (BVN) distribution in the form $(\varepsilon_C, \varepsilon_E)' \sim BVN(0, \sigma')$, and the covariance matrix σ' is given by;

$$\sigma' = \begin{bmatrix} 1 & \rho_{CE} \\ \rho_{EC} & 1 \end{bmatrix} \qquad (6)$$

where ρ_{ji} is the coefficient of correlation between error terms ε_j and ε_i *(j, i = C, E; j # i)*. Equations 4, 5 and 6 with all their assumptions explain the bivariate probit (BVP) model and it models the consumption choice decisions for charcoal and electricity. The correlation coefficients ρ_{ij} give correlation between the two error terms in the two latent equations and they represent unobserved characteristics of the same household. Thus, the knowledge of the household consumption of one energy type can be used to predict its probability of consuming another energy type. It should be noted that when $\rho_{ij} = 0$, the bivariate probit model defined above disintegrates into two UVP models and now the estimation of the two equations is done independently from the other as defined in the UVP model above.

From the BVP model defined above in equations 4, 5, and 6, univariate marginal, bivariate joint and conditional probabilities can be mathematically derived by using cumulative distribution functions (c.d.f) of univariate and bivariate normal distributions. Some of the examples are given below:

For *j, i = C* or *E* , and in each equation we have *j # i*.

$$P\left(R_j = 1/M_j\right) = F_1\left(\beta_j M'_j\right)$$

$$P\left(R_i = 1, R_j = 1/M_{i,} M_j\right) = F_2\left(\beta_i M'_i, \beta_j M'_{j,} \rho_{ij}\right) \qquad (7)$$

$$P(R_i = 1/R_j = 1, M_{i,} M_j) = \frac{F_2\left(\beta_i M'_{i,} \beta_j M'_j; \rho_{ij}\right)}{F_1\left(\beta_j M'_j\right)}$$

$$P\left(R_j = 1/R_i = 0, M_i, M_j\right) = \frac{F_2\left(\beta_i M'_i, \beta_j M'_j, -\rho_{ji}\right)}{F_1\left(\beta_i M'_i\right)}$$

Here, F_1 and F_2 represent the cumulative distribution functions of the standard univariate and bivariate normal distributions respectively. In this regard, conditional maximum likelihood is used to estimate both the parameters β_i *(i = C or E)* and correlation coefficients ρ_{ij} *(i , j = C, E ; j # i)* given a random sample of a number of households and conditioned on observed household characteristics (explanatory variables).

4.2 The two-stage demand model for charcoal.

To analyze the factors affecting the total quantity of charcoal demanded by the urban-household in Zambia, the Heckman selection model was also employed. The household charcoal demand was based on the utility model shown below, where U^* is the indirect utility function of the household which under here is assumed to be unobserved. We have the indirect utility that depends on the Income *C*, the price of charcoal *P* and the household's socioeconomic characteristics *H*, and is conditionally defined on the choice of charcoal use category. This therefore can be presented as:

$$U_i^* = V_i\,[P,\ C_i,\ H_i\,]\ +\ \varepsilon_i \qquad (8)$$

Where $i = 1, \ldots\ldots N,$ is the individual household and ε_i is the error term. From here we have the Roy's identity that gives us the household's marshallian demand function for charcoal as follows:

$$X_i(P,C_i,H_i) = \frac{\partial V_i(P,C_i,H_i)/\partial P}{\partial V_i(P,C_i,H_i)/\partial C_i} \qquad (9)$$

The marshallian demand function presented above in simplification can be presented as follows:

$$Y_i = b_0 + b_1 X_i\ + e_i \qquad (10)$$

where:

Y is a vector of the dependent variable (quantity/demand of charcoal by household)

X is a vector of independent explanatory variables (reasons that explain how much charcoal the household consumed);

b_1 is a vector of parameter estimates (marginal effects); and

e is the error term randomly distributed around a mean of zero, and it accounts for the effect of the unobserved variables.

In order to measure elasticities of demand of the regression model, the log-log linear regression model was employed in the form shown below;

$$ln(\,Y_i\,) = b_0 + \ b_1\, ln(\,X_i\,) + aD_i + e_i \qquad (11)$$

where b_1 is now elasticity of *Y* with respect to *X* which by interpretation is the percent change in dependent variable *Y* for a one per cent change in an independent variable *X* holding other factors constant. *D* is a vector of independent dummy variables and *a* is the percent change in *Y* when *D* moves away from 0 to 1.

However the above OLS model was modified in order to correct for the sample selection bias due to the unobservability of the dependent variable. This type of data is censored on the dependent variable. The dependent variable in our sample is quantity of charcoal consumed and some households had missing (zero) quantity of charcoal consumed. Thus, instead of the OLS model that should have given biased estimates, the Heckman selection model was used in order to correct for sample selection bias in estimating demand of charcoal by urban households in Zambia (Baum, 2006). The maximum likelihood estimation method of the Heckman selection model was employed in this thesis. The Heckman selection model took this form:

Assume two models, demand (Y_i) and selection (S_i = individual's probability of participation) of an energy category are modeled together as a way of accounting for sample selection bias.

$$Y_i = bX_i + u \qquad (12)$$

$$S_i = aZ_i + v \qquad (13)$$

Where $S_i = 1$, if there is participation and, = 0, if there is no participation.

X_i and Z_i are explanatory factors in demand and selection equations respectively, and X_i is a subset of Z_i.

u and v are error terms in demand and selection equations respectively. Assuming zero-conditional means of u and v, we have $E(uX) = E(vZ) = 0$, we get also $E(u/v) = \rho v$, where ρ is correlation of u and v. Thus from (12) we have;

$$E(Y/Z, v) = bX + \rho v \qquad (14)$$

Since v is unobservable but is related to S in equation (13), equation (14) becomes;

$$E(Y/Z,v) = bX + \rho E(v/Z,S) \qquad (15)$$

$\rho E(v/Z,S)$ is the additional term in the Heckman selection model. If $\rho = 0$ then the OLS regression gives consistent estimates otherwise the estimates are inconsistent.

Since electricity is an energy alternative to charcoal for urban households in Zambia, it would have been good to employ the same two models employed on charcoal on electricity as well so as to make reliable policy decisions on mitigation of charcoal consumption. However, in view of the data not capturing expenditure on electricity, only probity model was employed on electricity so as to determine the factors affecting the likelihood of the household's consumption of electricity.[1] Price of electricity was not considered as well because it was fixed and was the same through out the country in both seasons (dry-2007 and rainy-2008).

Note[1]: Electricity was not among the non food items consumed. Expenditure on electricity was captured in two parts, it was either included in the amount spend on housing rent or if not included, it was captured on its own. Thus not possible to capture the whole amount spend on electricity. Hence the estimation of electricity demand and factors affecting it was rendered irrelevant due to the fact that there was no complete data on the amount of electricity consumed.

4.3 Method and model specification

After explaining the econometric models to be employed in the analysis of factors determining the consumption of charcoal, this section will delineate how the bivariate probit and the Heckman selection models will be implemented. The implementation of the models shall be as follows: first the operational variables (X_j) to be used shall be identified. Then this shall be followed by discussion and outline of the models specification.

In the introductory discussion, categories of variables that affect household's consumption of energy are mentioned. These are; household characteristics (HHvar), housing conditions (HCONDvar), economic variables (ECONvar), and household physical location (LOCvar), and are used in the probit and demand models. The dependent and explanatory variables are defined as follows:

4.3.1 Dependent variables:

CCONSUM: this is a binary variable representing the decision of the household to consume or not to consume charcoal. The dependent variable CCONSUM is specified as a function of exogenous (explanatory) variables.

ELECTRIC: this is a binary variable representing the decision of the household to consume or not to consume hydro-electricity and it is specified as a function of exogenous variables.

QCHA: This is a quantitative variable representing the quantity (kg) of charcoal consumed in a month by the household.

4.3.2 Explanatory variables

Household characteristic variables (HHvar)

The household characteristic variables consist of data related to age and gender of the household head, the education level of the household head, and the family size of the household.

AGE: this is the age of the household head in years. In this study age is hypothesized to have an associated positive coefficient indicating that older household heads will have a higher probability of consuming charcoal due to resilient habit.

GENDER: this is a dummy variable representing the sex of the household head. From theory female-headed households are espoused to be more readily to consume charcoal than male-headed household due to the fact that male heads have more income/expenditure than female heads.

EDU: a dummy variable representing level of education of a household head. Households with heads with a maximum of primary education are hypothesized to have a higher probability of consuming charcoal than households with heads with secondary and post secondary education. This is because household heads with higher education may have better understanding of the costs and benefits of using modern energy thus they may change taste and preference in favor of modern energy.
FSIZE: this is the number of people of any age in the household. Large household sizes are commonly found in poor households (households with low income), thus large households will have higher probability of consuming charcoal than smaller households. Therefore, FSIZE will have a positive coefficient indicating that as household size increases, charcoal consumption increases as well.

Household living standard/housing condition (HCONDvar)
WALL: a dummy variable representing material used for the house's wall as a measure of household living standard. A wall made out of mud/grass is an indication of poor living standard as compared to a wall made from bricks/stone/wood/iron sheet. Thus the household with house's wall made from mud/grass will have higher probability of consuming charcoal than the household with house's wall made from bricks/stone/wood/iron sheet.
FLOOR: a dummy variable representing material used for a house's floor as a measure of household living standard. A floor made from earth/mud is an indicator of poor living standard as compared to a floor made from cement/ceramic tiles/wooden. Thus the household with house's floor made from earth/mud will have higher probability of consuming charcoal than the household with house's floor made from cement/ceramic tiles/wooden.
ROOF: this is a dummy variable representing material used for the house's roof as a measure of living standard. A roof made from grass is an indicator of poor living standard as compared to the roof made from iron sheet/ asbestos tiles/concrete. It is hypothesized that the household with a roof made from grass will have higher probability of consuming charcoal than the household with house's roof made from iron sheet/asbestos tiles/concrete.
PLUMB: it is a dummy variable indicating whether the household has modern plumbing-water and/or sewerage system or not as an indicator of household living standard. Lack of modern plumbing is an indicator of poor living standard. The household without modern plumbing will have higher probability of consuming charcoal than the household with modern plumbing.

REFRIG: It is a dummy variable showing whether the household possesses a refrigerator or not. It is an indicator of living standard among urban households. The household with a refrigerator will consume less charcoal or electricity due to the fact that the household does not cook food frequently instead it stores the cooked food in the refrigerator for future utilization, hence preserving energy.

ELECTRIC: it is a dummy variable indicating whether the household has electricity or not. It both indicates the household living standard and the alternative source of cooking energy. The household with electricity will have lower probability of consuming charcoal than the household without electricity.

Location and dynamic differences (LOCvar)

LUSAKA: this is a dummy variable representing the capital city Lusaka. This variable represents all spatial variations across the survey between the capital city and all other districts. These spatial variations include the opportunity cost for choosing one fuel type, level of education and level of affluence.

RESIDENCE: a dummy variable representing the residential area in which a household is located either in the low income, medium income or high income areas. A household located in the low income area is hypothesized to be more ready to consume charcoal than a household located in the medium or high income area.

SEASON: this is a dummy variable representing a season (1 = dry season-2007, 0 = rainy season-2008). SEASON is taking account of the seasonal variations between the dry season (August 2007) and the rain season (February 2008).

Economic variables (ECOvar)

TEXP: this is total monthly expenditure of the household. It includes all food and non-food monthly expenditure by the household. Expenditure is also used as a proxy for monthly income of the household. It is hypothesized that household with large expenditure will have lower probability of charcoal consumption than household with small expenditure.

PRICE: price will represent the price of charcoal per kilo gram in Zambian kwacha. The coefficient of charcoal price is expected to be negative indicating that larger price of charcoal decreases consumption of charcoal.

4.4 The specific models employed

Six different model specifications were used to analyse the factors affecting charcoal consumption for both the probit and demand estimations. The likelihood of consuming electricity or charcoal was estimated by models 1, 3 and 2, 4 respectively by using the bivariate probit model in which CCONSUME and ELECTRIC were modeled together. In models 1 and 2 all the variables defined above were used except for the variable SEASON, and was done for each year (2007 and 2008). Models 3 and 4 are similar to models 1 and 2, and were formed by combining all households in each survey (2007 and 2008) into one data set and the variable SEASON was included. The purpose of including variable SEASON was to help differentiate households according to the season (dry-August 2007 or rainy-February 2008). The variable SEASON is important in showing the significance of all variables across the two survey periods analyzed. Further, the SEASON variable would depict how the consumption/demand of charcoal has changed between the two surveys. For the demand estimation, models 5 and 6 followed the Heckman selection model where the selection part consisted of all explanatory variables of models two (2) and four (4) respectively. However, in order for the explanatory variables in the demand part to be a subset of the explanatory variables in the selection part of models 5 and 6, explanatory variable LUSAKA was excluded from the demand part of models 5 and 6. The dependent variable of models 5 and 6 is per capita charcoal consumption (pc_qcha). The same procedure explained in the bivariate probit model estimation applies here as well. Model 5 was used to compare household per capita charcoal demand between the two seasons whereas model 6 was used to compare household per capita charcoal demand across the charcoal-only consumers (pcq_C), the Charcoal + Electricity consumers (pcq_CE) and lastly the General consumers (the charcoal-only and the charcoal + Electricity consumers). Model 6 was also used to compare price and per capita expenditure elasticities of household per capita charcoal demand across income groups (low, medium and high). The six models are specified below.

ELECTRIC = f(HHvar, HCONDvar, ECOvar, LOCvar) (Model 1)

CCONSUM = f(HHvar, HCONDvar, ECOvar, LOCvar) (Model 2)

ELECTRIC = f(HHvar, HCONDvar, ECOvar, LOCvar, SEASON) (Model 3)

CCONSUM = f(HHvar, HCONDvar, ECOvar, LOCvar, SEASON) (Model 4)

PC_QCHA = f(HHvar, HCONDvar, ECOvar, LOCvar) (Model 5)

PC_QCHA = f(HHvar, HCONDvar, ECOvar, LOCvar, SEASON) (Model 6)

Table 2 provides a summary of the variables and their accompanied definitions.

Table 2: Summary definition of variables employed

Variables	Variable definition	Variable Type
	Dependent and explanatory variables	
Dependent		
pc_qcha	Per capita Charcoal consumption per month (kg)	Quantitative
cconsum	Consumption of charcoal (yes=1, else=0)	Dummy
pcq_C	Per capita Charcoal consumption (Charcoal-only consumers) (kg)	Quantitative
pcq_CE	Per capita charcoal consumption (Charcoal + Electricity consumers) (kg)	Quantitative
electric	Consumption of electricity (yes =1, else=0)	Dummy
Explanatory		
	ECOvar : Economic variables	
pc_texp	Per capita household total expenditure per month (ZMK)	Quantitative
pc_texp^2	Per capita household total expenditure per month squared	Quantitative
price	Price of charcoal per kg (ZMK)	Quantitative
	LOCvar: Location	
Lusaka	Lusaka (1 = Lusaka, 0 = other areas)	Dummy
residence	Residential area (1= low income, 0= else)	Dummy
	HHvar: Household characteristics	
fsize	Household size	Quantitative
gender	Gender (1 if Male)	Dummy
age	Age of household head	Quantitative
edu	Maximum education of the household head (1=grade 12 and above)	Dummy
	HCONDvar: Household living standards	
roof	Material of roof (1 if grass thatched)	Dummy
wall	Material of wall (1 if earth/mud)	Dummy
floor	Material of floor (1 if earth/mud)	Dummy
refrig	Possession of a refrigerator (yes=1, else=0)	Dummy
plumb	Installed modern plumbing (1= yes, 0 = else)	Dummy
electric	Use of electricity (yes=1, 0=else)	Dummy
season	**Seasonality** (1= dry-2007, 0 = rainy-2008)	Dummy

Source: Author's Analysis of FSRP Urban Consumption Survey, 2007-2008

CHAPTER 5
DATA DESCRIPTION AND ANALYSIS

This chapter describes the data used and brings out the various statistics on various variables (Household characteristics, wealth status of the households, energy type of consumption and household expenditure).

In order to make the data suitable for analysis, data transformation was carried out in several ways. In the survey data there were no classes of income, the households were divided into three income groups (terciles) using household monthly total expenditure as a proxy – the low income , the medium income and the high income groups. Quantity consumed was derived by dividing consumption value by average price. Given the fact that cross-sectional data always suffers from limited variation in prices it was thought expedient to use the average price (Gundimeda and Kohlin, 2006). Although this sample was less affected by this problem, average price at constituency level was used. In Zambia a town is sub-divided into a number of constituencies (see table 3). The nominal exchange rate of a Zambian kwacha to a USD was 4005 ZMK and 3726 ZMK in 2007 and 2008, respectively, giving an average of 3865 ZMK per one USD during the period of the survey (2007-2008). The data description and analysis are based on the income groups, and it should be noted that this descriptive analysis is based on unadjusted data.

5.1 The survey data

The study uses the household urban consumption survey data collected from four urban areas of Zambia. The data is on a comprehensive survey on urban consumption of important commodities in urban Zambia. The survey was conducted in two cities (the capital city Lusaka and the city of Kitwe) and two Provincial Head Quarters (Mansa and Kasama) of the Republic of Zambia by Food Security Research Project (FSRP) through the Central Statistical Office.

Lusaka is the mostly populated (1.1 million in 2000) seconded by Kitwe whereas Mansa and Kasama have smaller populations (see table 3 for respective population of these towns in 2000). The two cities of Zambia are the economic hub of the Country. The data was randomly collected in two phases, in 2007-August (dry season) and the same households were interviewed in 2008-February (rainy season) in order to capture the seasonal effects. In 2007, in each city 720 households where interviewed whereas in each Provincial Head Quarters 360 households, bringing the total of households interviewed to 2160. However in 2008 due to attrition the total number of households interviewed declined to 1865. Table 3 shows the number of households interviewed in 2007 and in 2008 per district.

Table 3: Constituencies and households per district

	Constituencies	Households		Population ('000)
District		2007	2008	2000
Kitwe	5	720	632	363.7
Kasama	2	360	301	74.2
Lusaka	7	720	610	1084.7
Mansa	2	360	322	41.1
Total	16	2160	1865	1563.7

Source: Author's Analysis of FSRP Urban Consumption Survey, 2007-2008 & CS0 (2003b)

The urban consumption data contains information on household profile for consumption, household food and non food consumption by purchase or own production, general household expenditure on different items, participation in urban agriculture, household asset ownership and household food security.

5.2 Household characteristics

An overview of household characteristics of the sample is given in table 4. There are more male household heads than female household heads. About 79.7 per cent of the total number of households interviewed was male-headed. On average in both periods of interviews the family size remained the same at roughly 5.6 persons. Meanwhile the average age of household head increased to 43.61 in 2008 from 41.75 in 2007. About 46 per cent of household heads had maximum education of grade 12 and above.

5.3 Energy consumption and expenditure

From table 4 it is clearly noticeable that average total expenditure in both seasons is the same at 1.55 million ZMK (Zambian Kwacha) although there was an insignificant increase in the rainy season-2008. The average household expenditure on charcoal per month was higher in the rainy season as compared to the dry season-2007 giving 33,166 ZMK and 23,692 ZMK respectively. Average expenditure on firewood was higher in the dry season (2,381 ZMK) as compared to the rainy season (1,675 ZMK). 55.2 per cent of the households used electricity in the dry season whereas 58.2 per cent in the rainy season. The number of households that consumed charcoal in the rainy season was 94.7 per cent whereas in the dry season it was 90.8 per cent. The average household monthly consumption of charcoal was 35.9 kilograms in the rainy season higher than that was consumed in the dry season (31.8 kilograms). The cities of Lusaka and Kitwe had higher total monthly expenditure (though Lusaka's monthly expenditure is slightly higher than Kitwe) than Kasama and Mansa, this is portraying the postulation that people in cities have higher income compared to those in small towns.

Table 4: Descriptive statistics of continuous and dummy variables

	Year 2007		Year 2008	
	N = 2160		N = 1865	
Variables	Mean	Std.Dev	Mean	Std.Dev
Total household monthly expenditure(ZMK)	1545431	1825242	1554858	1599758
Expenditure on firewood per month(ZMK)	2381.597	7705.146	1675.335	6401.078
Expenditure on charcoal per month(ZMK)	23692.36	21534.18	33166.38	29280.88
Expenditure on kerosene per month(ZMK)	2969.907	6067.521	3112.075	7453.821
Use of electricity (yes=1, else=0)	.5523148	.4973708	.5817694	.4934007
Use of kerosene(yes=1,else=0)	.4101852	.4919811	.6294906	.4830707
Use of charcoal (yes=1, else=0)	.9083333	.2886216	.9469169	.2242594
Use of fire wood (yes=1, else=0)	.1726852	.3780624	.1233244	.3288974
Price of charcoal per kg (ZMK)	794.2984	229.5788	1000.352	402.6301
Charcoal consumption per month (kg)	31.76367	28.03146	35.92546	30.66755
Per capita Charcoal consumption (kg)	6.67	7.16	7.45	7.17
Family size	5.561806	2.691696	5.618141	2.704585
Gender (1 if Male)	.7967593	.4025033	.7896719	.4076513
Age of household head	41.7463	12.98731	43.61431	13.10167
Max. education of a Household head (1=grade 12 and above)	.4597222	.4984905	.4702413	.4992475
Material of roof (1 if grass thatched)	.1398148	.3468751	.1270777	.3331494
Material of wall (1 if earth/mud)	.1347222	.3415057	.2434316	.4292685
Material of floor (1 if earth/mud)	.1523148	.485292	.1345845	.3413707
Possession a refrigerator (yes=1, else=0)	.3791667	.485292	.4160858	.4930403
Installed modern plumbing (yes=1, else=0)	.3555556	.4787922	.3957105	.4891339

Source: Author's Analysis of FSRP Urban Consumption Survey, 2007-2008
Note: non-weighted descriptive statistics

The variations of charcoal consumption per month and expenditure per month between towns and expenditure (income) groups -treciles (low, medium and high) by interviewed households are reported in table 5. Kitwe and Kasama experienced an increase in average charcoal consumption whereas Mansa and Lusaka experienced a decrease. In tables 6 and 7, the medium income group in both years is the highest consumer of charcoal whereas the low income group is the least charcoal consumer and at the same time has the least monthly expenditure on charcoal. Though the high income group has the highest monthly total expenditure, it is second in charcoal consumption to the medium income group. The per capita charcoal consumption in table 7 is highest in the low income group and lowest in the high income group.

Table 5: Household average monthly charcoal consumption and total expenditure (ZMK)

	Year 2007	Year 2008	Year 2007	Year 2008
	N = 2160	N = 1865	N = 2160	N = 1865
Variables	Charcoal consumption per month (kg)		Expenditure per month(ZMK)	
Kitwe	26.91	39.04	1760112.29	1787273.25
Mansa	39.69	35.88	1031463.31	1119719.83
Lusaka	31.79	30.56	1905520.92	1808135.94
Kasama	33.49	40.31	909855.18	1019070.41
Low income	30.02	31.79	427937.03	461644.53
Medium income	36.82	40.12	1003188.35	1088564.67
High income	28.45	35.87	3205167.07	3117884.70
Sample	31.76	35.93	1545430.81	1554857.69

Source: Author's Analysis of FSRP Urban Consumption Survey, 2007-2008

Table 6: Average value of charcoal consumption in ZMK

Average Value of Charcoal Consumption: District by Expenditure Group								
	2007				2008			
District	Low	Medium	High	Sample	Low	Medium	High	Sample
Kitwe	22425	27889.54	23734.04	24895.83	35221.56	39571.03	38330.68	37929.11
Mansa	16947.61	23734.78	21775.64	20161.81	18035.95	26362.24	30471.83	23312.11
Lusaka	26578.04	31189.55	23409.24	26807.29	34178.86	44005.36	36725.39	38992.62
Kasama	15507.5	22019.42	23184.21	18586.11	17313.89	26113.16	33133.33	21900.66
Sample	20230.9	27504.51	23341.67	23692.36	25621.19	37503.3	36398.95	33166.38

Source: Author's Analysis of FSRP Urban Consumption Survey, 2007-2008

Table 7: Household charcoal consumption district by income group

Average Charcoal consumption (kg): District by Income Group								
	2007				2008			
District	Low	Medium	High	Total	Low	Medium	High	Sample
Kitwe	25.16	30.03	25.16	26.91	37.76	41.8	37.53	39.04
Mansa	33.24	46.73	43.13	39.69	28.02	40.47	46.49	35.88
Lusaka	33.03	38.4	25.75	31.79	27.3	36.03	27.13	30.56
Kasama	29.08	39.03	38.99	33.49	32.54	47.52	59.22	40.31
Sample	30.02	36.82	28.45	31.76	31.79	40.12	35.87	35.93
Average per capita charcoal consumption (kg): district by Income group								
Kitwe	6.41	5.64	4.15	5.25	10.18	6.99	6.27	7.55
Mansa	7.76	8.06	6.6	7.6	7	7.16	7.53	7.16
Lusaka	10.19	9.16	4.67	7.52	8.18	8.18	5.56	7.09
Kasama	6.89	7.22	6.08	6.85	8.31	7.82	8.95	8.28
Sample	7.76	7.44	4.79	6.66	8.46	7.56	6.32	7.45

Source: Author's Analysis of FSRP Urban Consumption Survey, 2007-2008

In table 8, of all the households that consumed electricity in both years, the high-income group has the majority whereas the low-income group has the minority. This is depicting the fact that the majority of households in the high-income group use electricity compared to other income groups. Charcoal usage has smallest number of households in the high-income group in both years although the difference in relation to other income groups is very small. However the high-income group has the biggest number of household who did not consume charcoal. This is showing that the high-income group prefers electricity to charcoal though they use both side by side. The other empirical evidence is that as income increases up to a certain level, majority of the households start consuming electricity than charcoal. Generally in table 8, it is observed that the number of households that used charcoal is almost the same in each income group whereas the number of those using electricity is greatest in the high income group and lowest in the low income group.

Table 8 : Number of households using electricity and charcoal

Number of households using electricity by Income Group								
Used electricity	2007				2008			
	Low	Medium	High	Total	Low	Medium	High	Total
Yes	137	394	662	1193	136	379	570	1085
No	583	326	58	967	487	242	51	780
Total	720	720	720	2160	623	621	621	1865
Number of households consuming charcoal by Income group								
Used charcoal								
Yes	667	674	621	1962	583	603	580	1766
No	53	46	99	198	40	18	41	99
Total	720	720	720	2160	623	621	621	1865

Source: Author's Analysis of FSRP Urban Consumption Survey, 2007-2008

Table 9 shows that in 2007, 1.76 per cent of households did not consume charcoal nor electricity while in 2008 the proportion was 1.66 per cent. Of the total sample 7.41 per cent consumed electricity- only in 2007 whereas in 2008 the proportion was 3.65 per cent. The proportion that consumed charcoal- only in 2007 was 43.01 per cent whereas in 2008 it was 40.16 per cent. The proportion of household that are consumers of both charcoal and electricity was 47.82 percent in 2007 whereas in 2008 it was 54.53 per cent.

Table 9: Proportion of households consuming an energy type

	Year of survey	
Energy Type	**2007** N=2160(%)	**2008** N=1865 (%)
Charcoal only	43.01	40.16
Electricity only	7.41	3.65
Charcoal + electricity	47.82	54.53
No charcoal no electricity	1.76	1.66
Total	100	100

Source: Author's Analysis of FSRP Urban Consumption Survey, 2007-2008

Table 10 shows the frequencies for 2007 and 2008 of interaction between households consuming charcoal and electricity within each income group. The majority of households using neither charcoal nor electricity are in the low income group while in the high income group there is no household not using charcoal or electricity. The number of households using charcoal-only decreases as you move from the low income group through to the high income group; whereas number of households using electricity increase as you move from the low income group to the high income group. It is interesting to note that the number of households using both charcoal and electricity are in the majority and increasing as you move from low income group through the high income group. It is also notable that the majority of charcoal-only consumers are in the low income group whereas the majority of electricity-only consumers are in the high income group.

Table 10: Number of household using charcoal & electricity by income group

Household consuming charcoal	Household has electricity by 3 Income groups of total expenditure-2007							
	No				Yes			
	Low	Medium	High	Total	Low	Medium	High	Total
No	33	5	.	38	20	41	99	160
Yes	550	321	58	929	117	353	563	1,033
Total	583	326	58	967	137	394	662	1,193
N = 2160								
	Household has electricity by 3 Income groups of total expenditure-2008							
No	26	5	.	31	14	13	41	68
Yes	461	237	51	749	122	366	529	1,017
Total	487	242	51	780	136	379	570	1,085
N = 1865								

Source: Author's Analysis of FSRP Urban Consumption Survey, 2007-2008

An overview of variation of family size in each income group by district is given in table 11. In both years of the survey, the average household size increases as you move from the low income group through the high income group. The low income group has the smallest family size of 4.8 in 2007 and 4.7 in 2008; whereas the high income group has the largest family size of 6.1 in 2007 and 6.2 in 2008. At district level, Lusaka (capital city) has the smallest family size in both years as compared to other districts.

Table 11: Average household size district by income group

Average household size: District by Expenditure Group

	2007				2008			
District	Low	Medium	High	Sample	Low	Medium	High	Sample
Kitwe	4.9	6.1	6.4	5.9	4.7	6.5	6.4	6
Mansa	5	6.4	6.9	5.9	5	6.1	7	5.8
Lusaka	4.2	5.1	5.5	5	4.2	5	5.7	5.2
Kasama	5	6	7.1	5.6	4.9	6.8	6.7	5.7
Sample	4.8	5.8	6.1	5.6	4.7	5.9	6.2	5.6

Source: Author's Analysis of FSRP Urban Consumption Survey, 2007-2008

5.4 Concluding remarks

From the data analysis, it is observed that household total monthly expenditure is higher in cities especially the capital city Lusaka. It is also interesting to notice that charcoal consumption and its expenditure by households are higher in the rainy season than in the dry season. Comparing charcoal expenditure and consumption across income groups, it is clearly observed that the medium income group has the highest whereas the low income group has the lowest. This is portraying the fact that the medium income group is the highest consumer of charcoal whereas the low income group is the least consumer of charcoal in terms of quantity. The majority of charcoal-only consumers are in the low income group and the number decreases as you move towards the high income group. Conversely, the majority of electricity consumers are in the high income group and the number decreases as you move towards the low income group. It is also well noted that charcoal and electricity are used side by side by the majority of the households in the medium and high income groups. The other fascinating finding is that per capita charcoal consumption is highest in the low income group and lowest in the high income group whereas the average household size is highest in the high income group and lowest in the low income group.

CHAPTER 6
MODEL ESTIMATIONS AND ANALYSIS

In this chapter, the bivariate probit choice models for specified models 1and 2, 3 and 4 are analyzed first before the charcoal demand models 5 and 6 are embarked on. It has to be noted that for the specified models 5 and 6, the Heckman selection model was used in estimating per capita charcoal demand in the quest to account for the sample selection bias in incidentally truncated data (where charcoal demand was observed only when a household participated in consumption of charcoal). This facilitated the use of the probit-choice model in the selection part of the Heckman selection model. The Maximum Likelihood estimation method was used for the Heckman selection model.

6.1 Estimation of the bivariate probit choice model

As explained in chapter 4, the bivariate probit-choice model was based on demographic characteristics, economic variables, housing conditions and location of the household. The two reference categories that were chosen were non consumption of charcoal and non consumption of electricity. In this regard the estimated parameters give the impact of the explanatory variable on the probability of choosing the category of use in relation to reference category (non-charcoal consumption or non-consumption of electricity). The estimated coefficients for the bivariate probit model and the resultant marginal effects (ME) of explanatory variables are given in tables 12 and 13 (see appendices 12, 13 and 14 as well). It should be noted that the ME reported in tables 12 and 13 correspond to those of univariate marginal probabilities, and are calculated at the sample mean of explanatory variables. For a continuous explanatory variable, the ME relates to the actual change in the unconditional probability of consuming a particular energy type in response to a unit change in the explanatory variable, whereas for the dummy variable the ME represents the change in the probability when the dummy variable changes from 0 to 1. The rho (ρ) relates the two binary outcomes (probability of consuming charcoal and electricity) via correlation of their error terms. If the rho is significant ($\rho \neq 0$) it implies that the two error terms are correlated and the bivariate probit model is an efficient model to use than the univariate probit model. Conversely, if the rho is not significant ($\rho = 0$) implies that the two error terms are not correlated and the bivariate probit model collapses to two univariate probit models.

The interpretation is limited to the variables that appear to have some significant impact on the consumption of charcoal or electricity. In table 12, we note that the rho coefficient (estimated at -0.542) for 2007 data is significant showing the fact that there is moderate negative-correlation between the two error terms of charcoal and electricity choice models, while for the 2008 data the rho coefficient is not significant and it shows that there is no correlation between the two error terms of charcoal and electricity choice models. For the overall data (2007 + 2008) in table 13, the rho coefficient (estimated at -0.366) is significant and it shows that there is low negative-correlation between the two error terms of charcoal and electricity choice models.

Economic variables (price and Income):

Price and income (expenditure in our case) affect the probability of choosing charcoal as a source of energy by households in urban Zambia. The price coefficient is negative, meaning that an increase in price decreases the probability of consuming charcoal. In 2008 the price coefficient was significant at a 5% level of significance where as in 2007 was not significant. Per capita monthly total expenditure had a positive impact on the probability of consuming charcoal. As per capita expenditure increases, the probability of consuming charcoal increases at a decreasing rate (the per capita expenditure squared coefficient is negative). The per capita total expenditure coefficient was significant at a 1% level of significance in both years (2007 and 2008).

For the overall estimation (combination of 2007 and 2008), the price coefficient was significant at a 10% level of significance whereas the per capita total expenditure and its square term were both significant at a 1% level of significance. The price variable has ME of -0.023 implying that when price of charcoal increases by 1%, the probability of consuming charcoal declines by 0.023%. Per capita expenditure has ME equal to 0.401 and it is also increasing at a decreasing rate of ME equal to -0.382 giving a total ME equal to 0.0195 (see appendix 11 for derivation of marginal effects). These results can be interpreted as follows: a high per capita expenditure increases (but at a decreasing rate) the probability of choosing charcoal as the source of energy for cooking by households in urban Zambia rather than not using charcoal at all. Further, an increase in average per capita expenditure by 1% would increase the probability of consuming charcoal by 0.0195 percentage points. For instance in the overall bivariate probit model, the predicted probability of choosing charcoal (C=1) as the source of energy is 95.28 % (for the average household), then the probability after per capita monthly expenditure has increased by 1% would increase by 0.0195% from 95.28 to 95.30%. It is well noted that electricity and charcoal are substitutes. Increasing the price of charcoal increases the probability of using electricity. In the same vein increasing per capita expenditure increases the probability of using electricity but at a decreasing rate as shown in table 13.

Household Characteristics

In both seasons (dry-2007 and rainy-2008) in table 12, age and gender did not have a significant effect on the probability of using charcoal. The household size variable was significant at a 1% level in both seasons and the same applies to education level of the household head, which was significant in both years at 1% level. In the overall bivariate probit regression in table 13, age and gender of the household head did not have significant effect on the probability of consuming charcoal, but household size and education had significant effect on the probability of consuming charcoal at a 1% level. The household size coefficient had a positive sign meaning that as the size of the household increases, the probability of consuming charcoal increases as well, education coefficient had a negative sign, meaning that a household with a head possessing secondary education and above has a lower probability of consuming charcoal than one with lower education. Thus the higher the education a head of the household possesses, the lower the probability of consuming charcoal would be. It is interesting to note that age negatively impact on the probability of using electricity. As age of the household increases, the probability of using electricity decreases. Education level of the household head impacts positively on the probability of using electricity. As you move from lower education to higher education, the probability of using electricity increases. The coefficient of education in the electricity probit regression was positive and significant at a 1% level in 2007, 2008 and in the overall probit regression in tables 12 and 13 respectively. In the overall bivariate probit model in table 13, residing in low income area increases the probability of consuming charcoal by 0.05 percentage points while it decreases the probability of using electricity by 0.16 percentage points.

Table 12: Econometric results of the bivariate probit models 1 and 2

	Dry season-2007						Dry season-2008					
	Charcoal			Electricity			Charcoal			Electricity		
Variable	Coef.	z	dy/dx	Coef.	z	dy/dx	Coef.	z	dy/dx	Coef.	z	dy/dx
Lprice	-0.0824	-0.44	-0.0098	0.3355	1.91***	0.1209	-0.4986	-2.18**	-0.0361	0.0260	0.13	0.0087
Lpc_texp	3.64	5.50*	0.4339	2.3523	2.11**	0.8473	5.1051	5.78*	0.3701	1.4571	0.82	0.4890
Lpc_texp2	-0.1407	-5.45*	-0.0168	-0.0800	-1.78***	-0.0288	-0.1975	-5.69*	-0.0143	-0.0449	-0.61	-0.0151
age	0.0029	0.80	0.0003	-0.0057	-1.77***	-0.0021	-0.0041	-0.98	-0.0003	-0.0061	-1.63	-0.0021
fsize	0.1674	7.26*	0.0199	0.0420	2.23**	0.0151	0.1349	4.68*	0.0099	0.0219	1.05	0.0073
gender	-0.0944	-0.89	-0.0108	-0.1097	-1.07	-0.0389	0.0112	0.09	0.0008	-0.0967	-0.84	-0.0319
edu	-0.3215	-2.89*	-0.0393	0.4173	4.75*	0.1483	-0.4584	-3.07*	-0.0348	0.4117	4.02*	0.1365
roof	0.0572	0.30	0.0065	-0.6148	-2.88*	-0.2353	-0.5371	-2.38**	-0.0564	-0.6874	-2.38**	-0.2551
wall	-0.1784	-1.10	-0.0235	-0.4083	-2.44**	-0.1546	0.2097	1.04	0.0138	-0.4472	-3.29*	-0.1585
floor	-0.1919	-1.24	-0.0254	-0.4944	-3.16*	-0.1879	-0.2652	-1.18	-0.0230	-0.9070	-3.30*	-0.3392
plumb	-0.3662	-2.90*	-0.0476	0.8627	7.60*	0.2855	0.0278	0.17	0.0020	1.2221	9.12*	0.3663
residence	0.5144	4.90*	0.0742	-0.5556	-4.85*	-0.1856	0.3843	2.82*	0.0331	-0.4239	-3.26*	-0.1332
refrig	-0.0861	-0.69	-0.0104	1.6838	13.05*	0.5068	-0.0860	-0.52	-0.0063	1.7643	12.72*	0.5057
Lusaka	-0.0184	-0.18	-0.0022	0.2311	2.55*	0.0816	0.0160	0.10	0.0012	0.4443	2.84*	0.1415
constant	-22.2382	-5.04*		-19.0025	-2.74*		-28.0821	-4.83*		-11.3983	-1.04	
Sample	2160			2160			1865			1865		
Observed P	0.91			0.55			0.95			0.58		
Predicted P	0.94			0.67			0.97			0.72		
Log likelihood	-1170.7446						-808.7644					
rho	-0.5423 (0.0820)						-0.1498 (0.1212)					

Source: Author's Analysis of FSRP Urban Consumption Survey, 2007-2008

Notes:

*, **, *** denote statistical significance at 1%, 5%, 10% level respectively

dy/dx is the marginal effect of the explanatory variable

Z is the standard normal distribution

Table 13: Econometric results of bivariate probit Models 3 and 4

Variable	Charcoal Coef.	z	dy/dx	Electricity Coef.	z	dy/dx
Lprice	-0.2331	-1.71***	-0.023	0.2273	1.86***	0.0796
Lpc_texp	4.0721	7.72*	0.401	2.0867	2.17**	0.7306
Lpc_texp2	-0.1578	-7.65*	-0.0155	-0.0698	-1.78***	-0.0244
season	-0.3403	-4.61*	-0.0331	0.0172	0.26	0.006
age	-0.0003	-0.11	-0.00003	-0.0061	-2.48**	-0.0021
fsize	0.1494	8.42*	0.0147	0.0331	2.37**	0.0116
gender	-0.0577	-0.71	-0.0055	-0.1064	-1.39	-0.0366
edu	-0.3693	-4.17*	-0.0375	0.408	6.13*	0.1410
roof	-0.1724	-1.23	-0.0189	-0.6594	-3.88*	-0.2495
wall	-0.082	-0.69	-0.0084	-0.4662	-4.51*	-0.1727
floor	-0.1978	-1.57	-0.0219	-0.5959	-4.43*	-0.2243
plumb	-0.2252	-2.29**	-0.0233	1.0252	12.18*	0.3248
residence	0.4634	5.61*	0.055	-0.4897	-5.69*	-0.1598
refrig	-0.0844	-0.86	-0.0084	1.7025	18.23*	0.5032
Lusaka	-0.044	-0.52	-0.0044	0.2759	3.58*	0.094
constant	-23.3887	-6.69*		-16.6268	-2.8*	
Sample	4019			4019		
Observed P	0.93			0.57		
Predicted P	0.95			0.69		
Log likelihood		-1998.1627				
Rho		-0.3656 (0.0675)				

Source: Author's Analysis of FSRP Urban Consumption Survey, 2007-2008
Notes:
*, **, *** denote statistical significance at 1%, 5%, 10% respectively
dy/dx is the marginal effect of the explanatory variable
Z is the standard normal distribution

Living standards (wealth of the household)

As living standards are reflected in the wealth of the household, the housing conditions (the materials with which a roof, wall and floor are made out of), possession of refrigerator and modern plumbing were considered. The results from the overall bivariate probit model (table 13) show that roof, floor and refrigerator were not significant at a10% level of significance, however their coefficients were negative portraying the fact that they decrease the probability of consuming charcoal. The ME of modern plumbing (plumb) was significant at a 5% level of significance and was negative implying that possession of a house with modern plumbing decreases the probability of consuming charcoal by 0.023 percentage points. Meanwhile the coefficient of refrigerator was not significant at a 10% level of significance but was negative implying that possession of a refrigerator decreases the probability of consuming charcoal. These results should be interpreted with caution due to the fact that they might be misleading. Since these variables have a connotation of the household's wealth, roof made of grass and floor made of soil reflect low wealth (income), hence low living standards. In the data analysis we found that the low income group consumes less charcoal as compared to the medium and high income group, in addition the low income group consumes more charcoal than electricity. Thus families with low living standards would have a low probability of consuming charcoal as they would consume firewood (see appendix 3 which shows that low wealth increases the probability of consuming firewood). In the same vein, possession of a refrigerator or modern plumbing are proxies for more wealth, hence decreases the probability of consuming charcoal in preference for electricity. These results are authenticated by the electricity part of the bivariate probit regression in tables 12 and 13 where it is found that a household with plumbing services and refrigerator has a higher probability of using electricity than a household without. If a household has a house with roof made of grass, floor made of soil and wall made of soil, it decreases the probability of using electricity. This is validating the fact that wealthier households have higher probability of using electricity than poor households.

Electricity and charcoal consumption are negatively correlated to each other as evidenced by the negative significant coefficient of the rho (estimated at -0.366). Implying that they are substitutes. Location was significant and had a positive sign in both seasons as well as in the overall estimation but the sign was negative in the electricity probit model. Thus a household in the low income residential area has higher probability of consuming charcoal than a household in the medium or high income residential areas. Conversely, a household in the low income area has lower probability of using electricity compared to a household in the medium or high income area. Living in Lusaka, the capital city has no significant effect on the probability of consuming charcoal but it increases the probability of using electricity than charcoal.

6.2 Predicted participation probabilities and elasticities with respect to per capita expenditure.

The expected participation probabilities and elasticities for the charcoal (C=1), charcoal-only(C=1,E=0) , electricity+charcoal(C=1,E=1), and the electricity(E=1) consumers are presented in table 14. The probability of participation gives the probability of consuming an energy type whereas the participation elasticity is the percentage change in the probability of participation (Yi =1) resulting from a percentage change in the per capita total expenditure or charcoal price (see appendix 11 for the derivation of the formulae). It should, however be noted that these values of per capita expenditure and price elasticities of participation are not equivalent nor can they be directly compared to their counterpart elaticities of demand measured in terms of quantity of consumption.

Participation in charcoal consumption has the highest probability followed by electricity consumption, third is charcoal+electricity consumption and lastly the charcoal-only consumption estimated at 0.953, 0.695, 0.652 and 0.301, respectively. The marginal effects (ME) of per capita expenditure and the price of charcoal on the probability of participation in different charcoal-electricity choices were converted to participation elasticities as presented in table 14. All the energy choices have inelastic participation elasticities and this implies that a one per cent change in per capita expenditure or charcoal price would cause a less than one per cent change in the probability of participation. The charcoal-only consumers (C=1, E=0) have a negative per capita expenditure participation elasticity while the rest are positive. As expected, the charcoal and charcoal-only consumers have negative own price elasticities of participation which are estimated at -0.031 and -0.268 respectively. This suggests that a percentage increase in the price of charcoal will induce a less than one per cent decline in probability of consuming charcoal. The positive inelastic cross price elasticities for the electricity (E=1) and the charcoal+electricity[2] (C=1,E=1) show that these two energy choices are substitutes to charcoal- a percentage increase in the price of charcoal will induce a less than one percent increase in their participation probabilities and vise versa.

Table 14: Price and per capita expenditure participation elasticities & probabilities

	C=1	E=1	C=1,E=1	C=1, E=0
Participation Probability	0.953	0.695	0.652	0.301
Per Capita Expenditure Participation Elasticity	0.021	0.188	0.222	-0.418
Price Participation Elasticity	-0.031	0.115	0.088	-0.268

Source: Author's Analysis of FSRP Urban Consumption Survey, 2007-2008

Note[2] : "charcoal+electricity" refers to simultaneous consumption of charcoal and electricity.

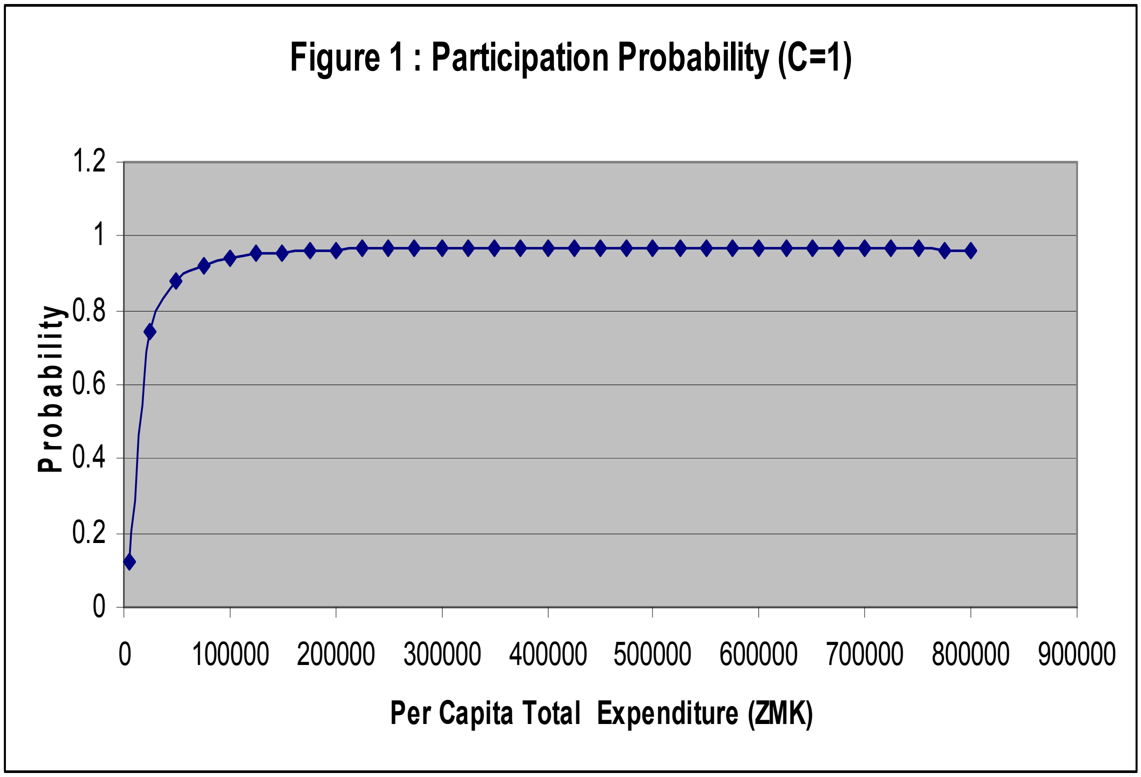
In order to have a clear understanding of the effect of per capita total household monthly expenditure on the probability of consuming charcoal and/or electricity, predictions of participation probabilities at different levels of per capita total expenditure were evaluated at the sample (overall sample) means of other explanatory variables. From these predicted participation probabilities, elasticities of participation were evaluated as well (see appendices 15, 16, 17 and 18 for predicted values). The predicted probabilities and their elasticities of participation are illustrated in figures 1, 2, 3, 4, 6, 7 and 8. As already discussed earlier, the probability of consuming charcoal (C=1) increases with per capita total expenditure at a decreasing rate up to a certain level of income and then it starts decreasing with income though at a very insignificant rate. From figures 1 and 2, it seems the increase in the probability of consuming charcoal is large below per capita total expenditure equal to 250 000 ZMK and there after it becomes increasingly small or constant as depicted by the elasticity of participation in figure 2. From the table of predictions in appendix 15 it is well shown that probability of participation reaches its maximum at per capita total expenditure equal to 400 000 ZMK and there after it starts decreasing. This is supported by the elasticity of participation which after per capita total expenditure equal to 400 000 ZMK becomes negative. As noted from the graphs, the probability of participation is almost constant after total expenditure 300 000 ZMK. The most important observation from figures 1 and 2 is that the poor households have lower probability of consuming charcoal but have larger elasticity of participation than the rich households. The rich households' elasticity of participation is almost zero.

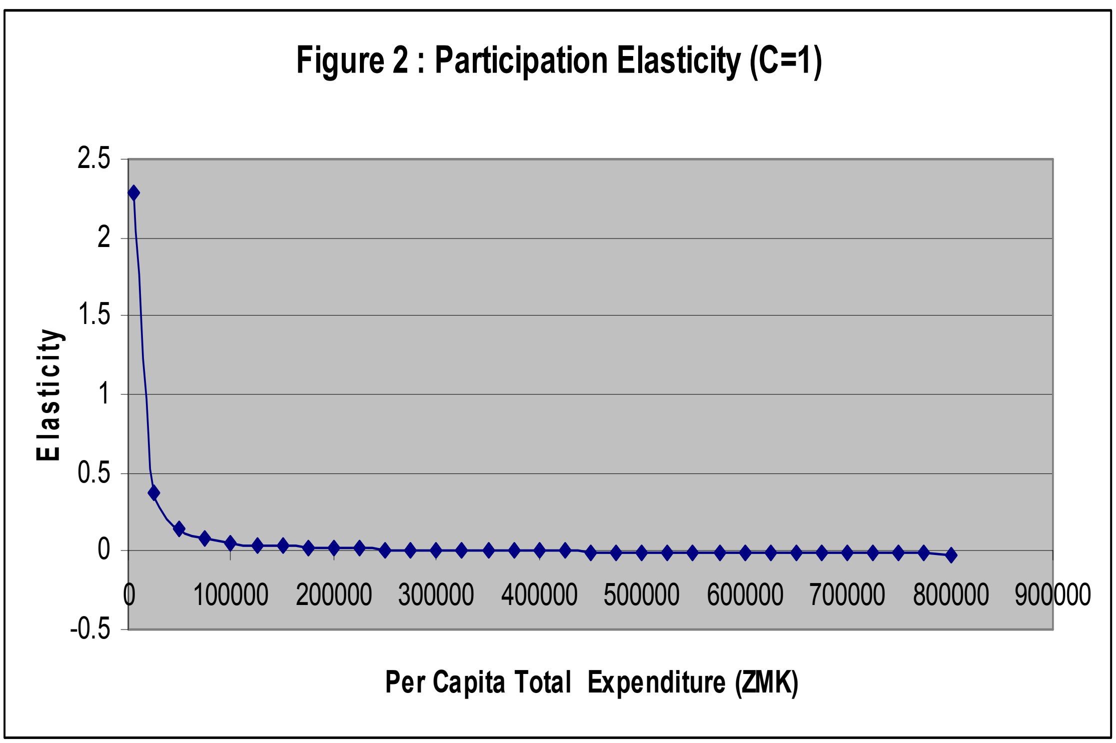
Participation probabilities and elasticities of consuming electricity (E=1) are illustrated in figures 3 and 4 (see appendix 16 for their predicted values). It is well noted that participation probability increases with the increase in the level of per capita total expenditure though at a decreasing rate. However the participation elasticity decreases with the increase in the level of per capita total expenditure. Below per capita total expenditure equal to 250 000 ZMK elasticity of participation is large whereas after this level, the participation elasticity becomes almost zero but positive still. This is portraying the fact that after per capita expenditure equal 250 000 ZMK, the marginal effect of a percentage increase in per capita total expenditure on the probability of consuming electricity becomes increasingly small.

Figures 5 and 6 show the participation probability and elasticity for charcoal-only consumers (C=1, E=0) respectively (see their predictions in appendix 18). The participation probability increases sharply as per capita total expenditure increases from zero to 25 000 ZMK and thereafter it starts declining at an increasing rate as per capita expenditure increases. This is authenticated by the elasticity of participation which sharply declines from 2.3 to zero at the level of expenditure equal to 25 000 ZMK and there after it becomes negative but inelastic. After the level of per capita expenditure equal to 100 000 ZMK, the participation elasticity starts increasing towards zero but still negative. This is portraying the fact that , for the low income households with per capita total expenditure below 100 000ZMK, probability of consuming charcoal-only increases with income but after the per capita expenditure 100 000ZMK, the probability of consuming charcoal-only starts declining and the participation elasticity is negative and inelastic; and increases towards zero as per capita expenditure increases. Thus, this further implies that after the per capita expenditure equal to 100 000 ZMK, a one per cent increase in per capita total expenditure causes a less than one per cent decline in the probability of consuming charcoal-only. As per capita expenditure increases the percentage decrease in probability of participation approaches zero.

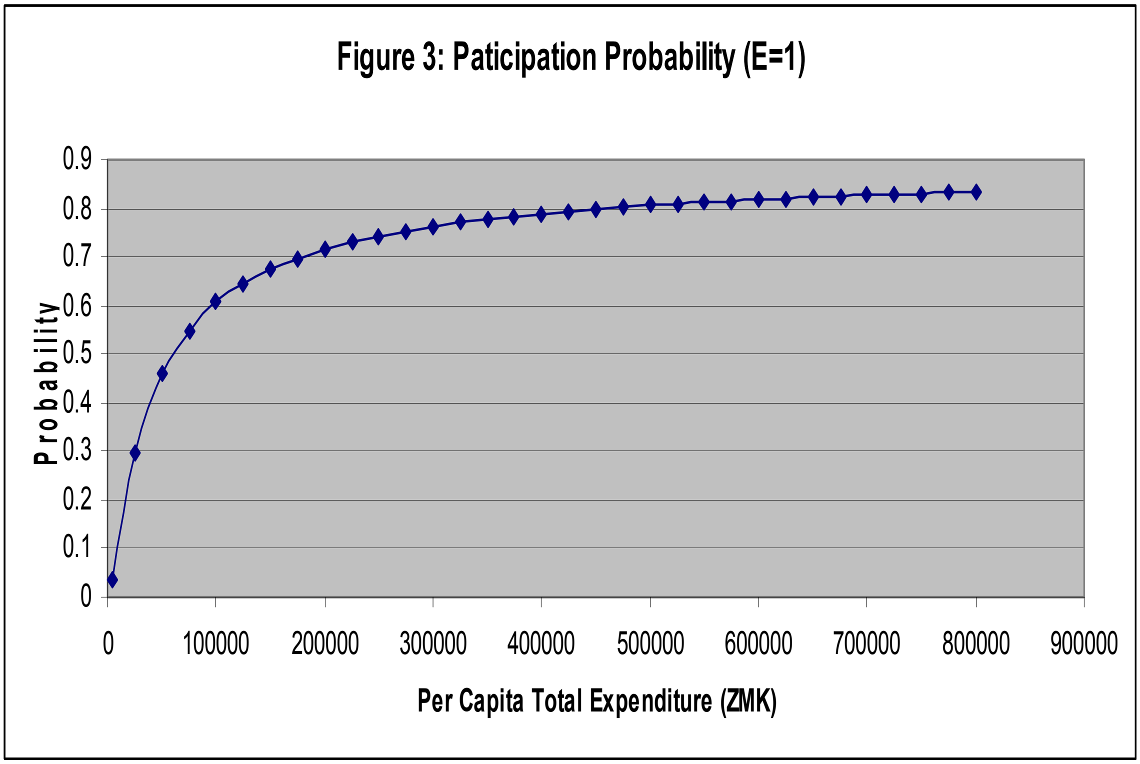
For the households consuming charcoal and electricity (C=1, E=1) simultaneously, their probability of participation increases with the increase in per capita total expenditure but at a decreasing rate as shown in figure 7 (see their predictions in appendix 17). From figure 8 it is well observed that below the per capita total expenditure equal to 35 000 ZMK the elasticity of participation is elastic and implies that a percentage increase in per capita expenditure causes a more than one per cent increase in the participation probability. After per capita expenditure equal to 35 000 ZMK, the participation elasticity becomes inelastic and approaches zero as per capita expenditure increases. This portrays the fact that after per capita expenditure equal to 35 000 ZMK, a percentage increase in per capita expenditure adds a less than one percent to the probability of participation and this additional effect approaches zero with successful increases in per capita expenditure.

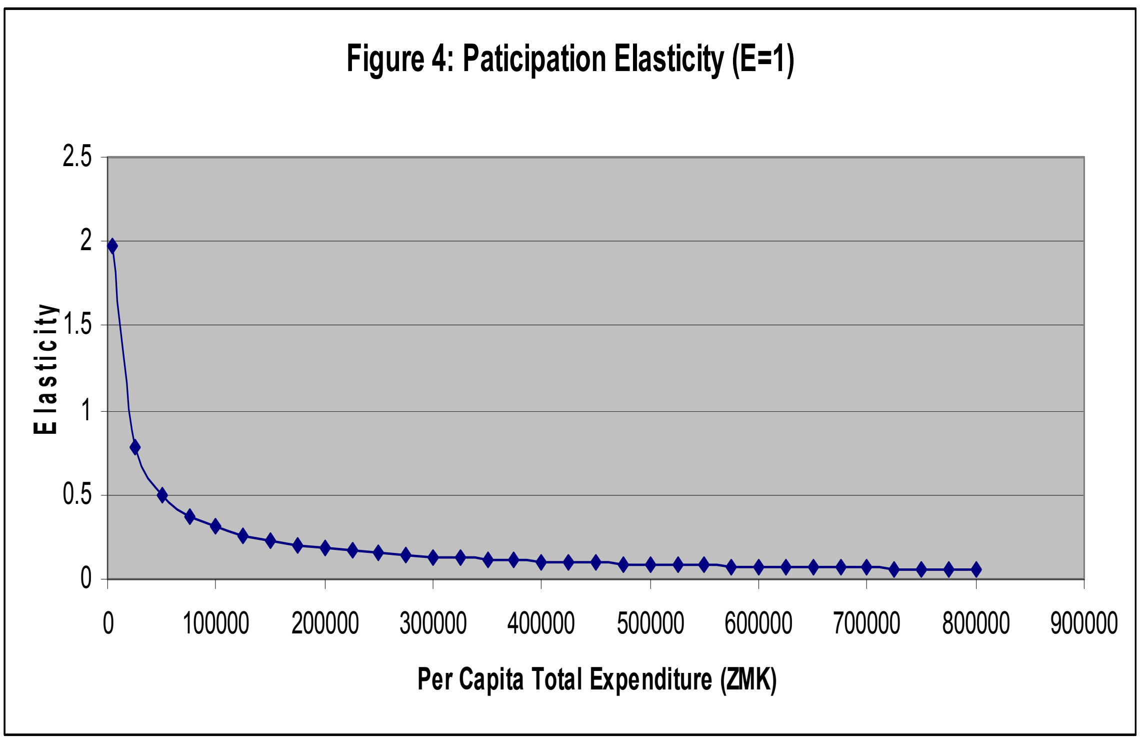
Figures 1 and 2: Effects of per capita total expenditure on predicted participation probabilities and elasticities for the charcoal consumers (C=1).



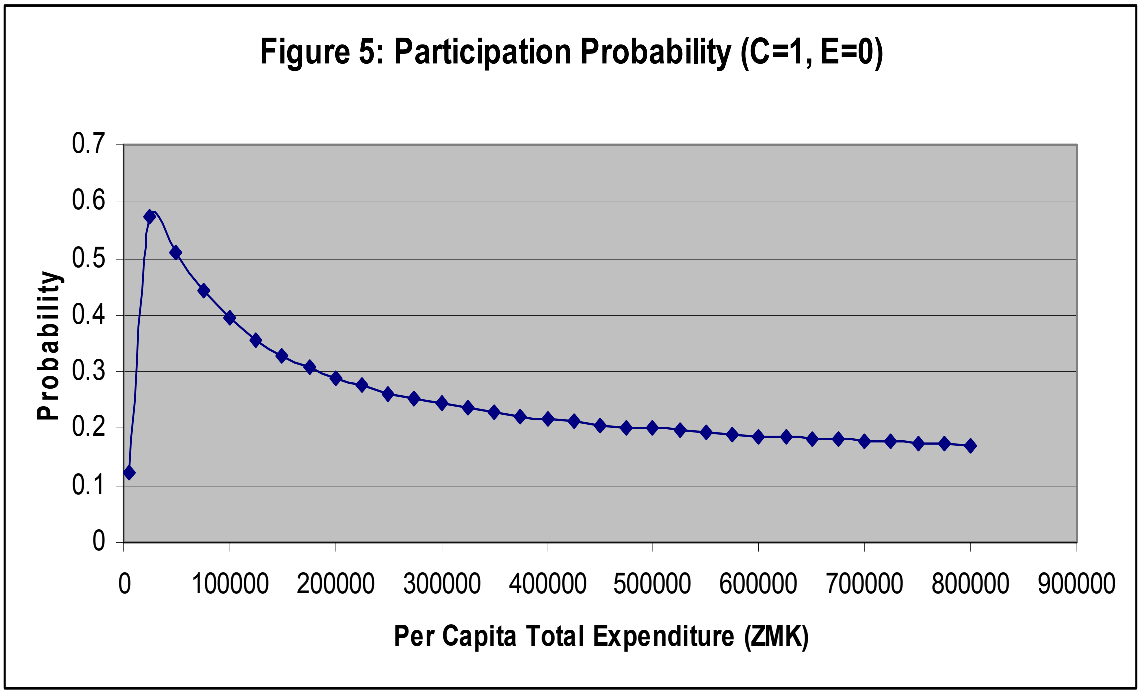


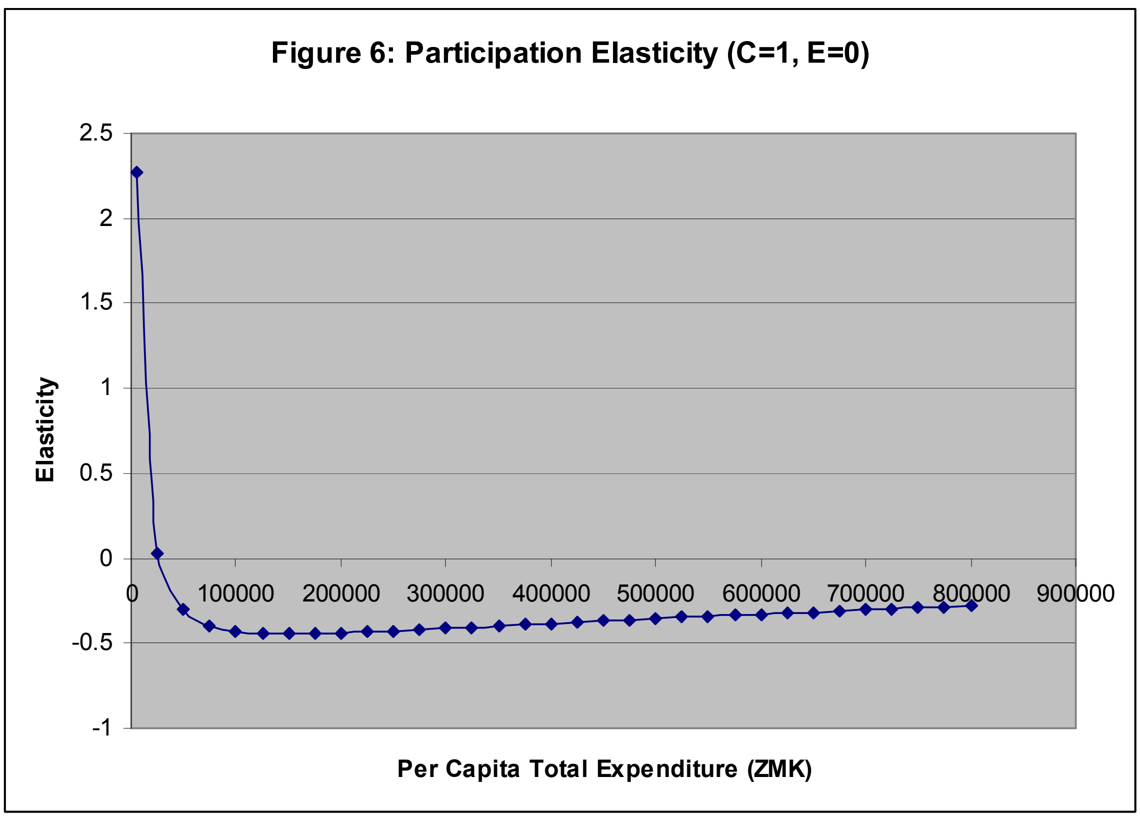
Figures 3 and 4: Effects of per capita total expenditure on predicted participation probabilities and elasticities for the electricity consumers (E=1).



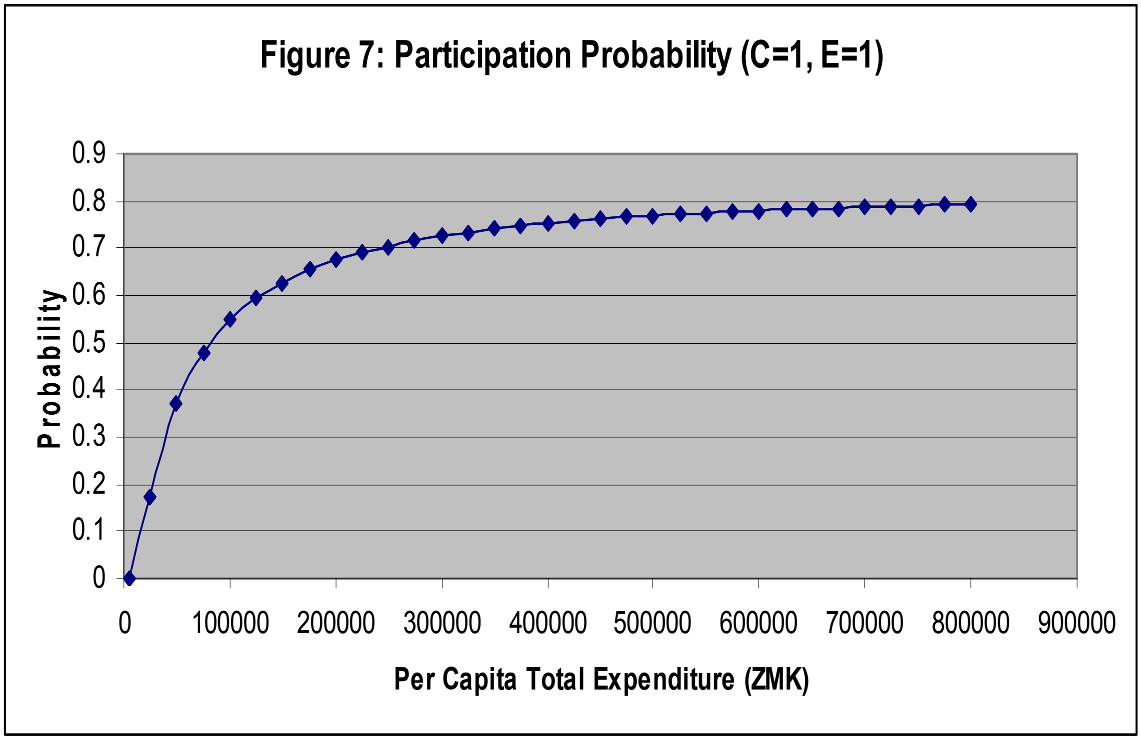


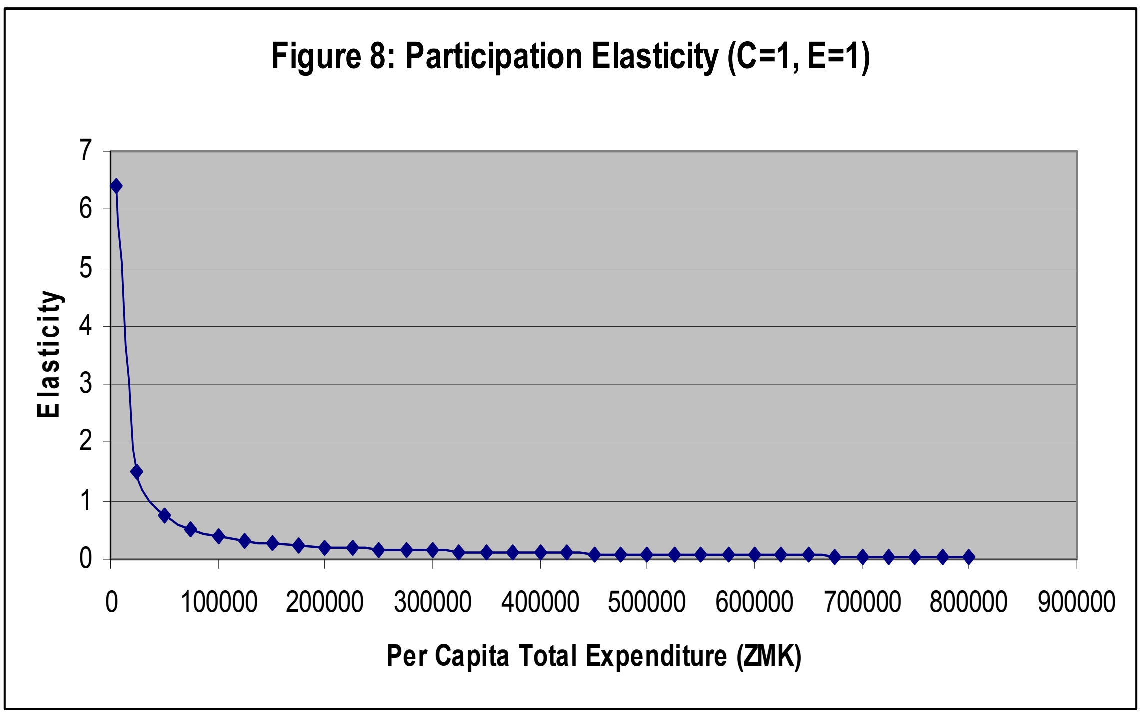
Figures 5 and 6: Effects of per capita total expenditure on predicted participation probabilities and elasticities for the charcoal-only consumers (C=1, E=0).





Figures 7 and 8: Effects of per capita total expenditure on predicted participation probabilities and elasticities for the charcoal+electricity consumers (C=1,E=1).





6.3 Estimation of charcoal demand using the Heckman selection model

In the introductory part of this chapter it was pointed out that per capita demand of charcoal would be estimated using the Heckman selection model in order to correct for sample selection bias of the incidentally truncated data (censored at zero). This is what was done here in estimating the demand for charcoal in that the data used was incidentally truncated- the charcoal demand was observed only when a household participated in the consumption of charcoal. The method of maximum likelihood estimation was employed for the Heckman selection model. The results for the per capita demand estimation for the general consumer group, the charcoal-only consumers and the charcoal+electricity consumers are presented in table 16. In order to compare the variations in per capita charcoal demand between dry and rainy seasons, regression was conducted on the dry season sample (2007) and rainy season sample (2008) and finally the combination of the two samples (the overall sample). The results of these regressions are presented in table 15 and appendices 4, 5 and 6.

Before presenting the estimated results, it should be noted that log transformation of the per capita quantity of charcoal consumed, price of charcoal and the household monthly per capita total expenditure was performed.

The Heckman selection model estimation of the per capita charcoal demand gave estimated rhos ($\rho = 0$) that were not significant for the dry season, rainy season and the overall samples, thus, implying that there was no sample selection bias for each of the three samples. Hence the demand and the selection models were independent from each other.

All the coefficients of the overall model in table 16 were significant at 1% level except for the wall variable that was significant at 10% level while the plumbing variable was not significant for a 10% level. In the dry season- 2007 all the coefficients were significant except for the wall variable which was not significant for a 10% level. In the rainy season- 2008 gender, wall and plumbing variables were not statistically significant. The estimated coefficients are the marginal effects (ME) and can be interpreted as follows: the coefficients for logged independent variables can be interpreted as constant elasticities. For example in the overall regression price coefficient of -0.834 is the percentage change of per capita charcoal consumption when price of charcoal increases by one per cent. For the non-logged continuous independent variables such as age of household head's coefficient equal to 0.00679 is 0.68 (0.00679 * 100) per cent increase in per capita charcoal consumption when age of the household head increases by one year. For the dummy independent variable, its coefficient is the percentage change in

Table 15: Econometric results of the Heckman selection models 5 and 6

variables	Dry season-2007	Rainy season-2008	Overall
Charcoal price (log)	-0.927*	-0.802*	-0.833*
	(-13.21)	(-14.75)	(-19.90)
Per capita expenditure per month (log)	2.860*	1.245**	2.129*
	(7.52)	(2.38)	(7.15)
Per capita expenditure per month square (log)	-0.101*	-0.033	-0.071*
	(-6.66)	(-1.56)	(-5.91)
Season (1 = dry)	-	-	-0.271*
			(-10.49)
Age	0.008*	0.005**	0.007*
	(5.7)	(3.860	(6.83)
Fsize	-0.0667*	-0.064**	-0.068*
	(-8.19)	(-7.36)	(-11.59)
Gender	-0.129*	-0.046	-0.089*
	(-3.05)	(-1.09)	(-2.95)
Edu	-0.083**	-0.169*	-0.119*
	(-2.03)	(-3.88)	(-4.03)
Roof	-0.173**	-0.394*	-0.244*
	(-2.53)	(-5.30)	(-4.96)
Wall	-0.096	0.022	-0.067***
	(-1.57)	(0.42)	(-1.68)
Floor	-0.151**	-0.111***	-0.130*
	(-2.57)	(-1.67)	(-2.94)
Plumb	-0.099**	-0.006	-0.054
	(-2.04)	(-0.14)	(-1.64)
Electric	-0.693*	-0.505*	-0.608*
	(-13.40)	(-9.38)	(-16.09)
Residence	0.126*	0.192*	0.152*
	(2.78)	(4.16)	(4.70)
Refrigerator	-0.167*	-0.277*	-0.217*
	(-3.11)	(-5.40)	(-5.83)
Constant	-11.318*	-2.548	-7.386*
	(-4.68)	(-0.79)	(-3.95)
Sample	2160	1859	4019
Censored obs	198	99	297
rho	-0.007	-0.030	-0.068
	(0.125)	(0.352)	(0.127)
Log likelihood	-2676.41	-2173.14	-4893.25

Source: Author's Analysis of FSRP Urban Consumption Survey, 2007-2008
Notes:
*, **, *** denote statistical significance at 1%, 5%, 10% respectively
In parentheses are student t -values, but for rho are standard errors

per capita charcoal consumption when the dummy variable changes from zero to one – in the case of a household possessing a refrigerator (refrig=1), charcoal consumption decreases by 0.22 per cent.

We focus on the overall estimation in analyzing the per capita charcoal consumption. As expected in table 15 economic variables; price and per capita expenditure respectively, have negative and positive marginal effect on per capita charcoal consumption. An increase in price decreases per capita charcoal consumption whereas an increase in per capita expenditure increases per capita charcoal consumption but at a decreasing rate (the per capita expenditure squared is negative) – implying that there is an expenditure level at which consumption of charcoal reaches its maximum and there after starts falling. As expected, per capita charcoal consumption in the dry season –2007 is less than per capita charcoal consumption in the rainy season- 2008. This is not surprising in that during the rainy season household use charcoal for heating more than in the dry season where there is enough sun shine. The household with a male head consumes less charcoal per capita than that headed by a female. This can be due to the fact that in Zambia more female headed households are poor compared to the male headed households (Kapungwe, 2004). The estimated results also show that education of the household head influences per capita charcoal consumption negatively. Households with heads possessing higher education consume less charcoal per capita and this finding is compatible with earlier findings by Israel (2002) and even the hypothesis of this thesis. This may be attributed to high income and inconvenience considerations in using charcoal as compared to electricity among the households with heads possessing higher education. In addition, the participation probability is pointing to the fact that highly educated people are likely to consume less charcoal.

The low living standards variables (roof, floor, and wall) decrease the per capita charcoal consumption, ceteris paribus but increase the probability of consuming charcoal-only (see select part of the regression in appendix 7). This is expected due to the fact that households with houses with thatched roofs, soil floor and soil walls posses little wealth hence low income. In view of this it is expected that their per capita charcoal consumption will be increasing with the increase in their wealth because charcoal is a normal good in this case. These households are those in the low income group and are frequently involved in both traditional and elicit bear brewing and firewood is used for brewing. See appendix 3 showing that the probability of using firewood increases with decrease in wealth of the household (the coefficients of roof, wall and floor variables are significant and positive). Having a refrigerator decreases per capita charcoal consumption. This is confirming the finding of other researchers among others Abebaw (2003) who postulated that refrigerator reduces the frequency of cooking food thereby conserving energy. It is also interesting to note that household size exerts a negative significant effect on per capita charcoal consumption. In relation to large households, small households use larger quantities of charcoal per capita and this is in support of the theory of economies of scale in fuel consumption. Living in low income residential areas increases per capita charcoal consumption by 0.15% whereas when the household has electricity would decrease per capita charcoal consumption by 0.61%.

An overview of variation in effects among the general consumers, the charcoal (lpcq_C) and the charcoal+electricity (Lpcq_CE) consumers is presented in table 16. The rho for the charcoal-only consumers is significant implying that there was a sample selection bias (see appendices 7 & 8 for more information on these models). Almost all coefficients of the three models have same sign. However some differ in their marginal effects. In all the three models per capita charcoal consumption is higher in the rainy season than in the dry season. A male headed household consumes less charcoal than a female headed household. Area of residence also has a positive significant effect on per capita charcoal consumption in the entire tree groups-living in a low income area increases per capita charcoal consumption. The charcoal-only consumers have inelastic price elasticity (-0.377) of per capita charcoal demand whereas the charcoal+electricity consumers have elastic price elasticity (-1.093) of per capita charcoal demand. The charcoal-only consumers and the charcoal+electricity consumers have elastic expenditure elasticity of per capita charcoal demand and almost of the same size. The implication of all these is that both groups of consumers respond to change in income almost in the same way but differ in their response to change in price of charcoal.

6.3.1 The Expenditure and Price Elasticities

The price and per capita expenditure elasticities for the general, charcoal-only(lpcq_C) and the charcoal+electricity (lpcq_CE) models, and in addition for the low, medium and high income groups are presented in table 17 (see appendix 10 for information on how they were derived).

Table 16: Econometric results of the Heckman selection model 6

variables	lpcq_C	Lpcq_CE	General
Charcoal price (log)	-0.377*	-1.093*	-0.833*
	(-6.42)	(-19.26)	(-19.90)
Per capita expenditure per month (log)	1.168**	1.309**	2.129*
	(2.55)	(2.17)	(7.15)
Per capita expenditure per month square (log)	-0.0304	-0.039	-0.071*
	(-1.57)	(-1.65)	(-5.91)
Season (1 = dry)	-0.0968*	-0.418*	-0.271*
	(-3.15)	(-10.92)	(-10.49)
Age	0.0017	0.013*	0.007*
	(1.59)	(7.98)	(6.83)
Fsize	-0.075*	-0.063*	-0.068*
	(-11.60)	(-7.20)	(-11.59)
Gender	-0.103*	-0.087***	-0.089*
	(-2.90)	(-1.91)	(-2.95)
Edu	-0.027	-0.145*	-0.119*
	(-0.70)	(-3.35)	(-4.03)
Roof	-0.143*	0.157	-0.244*
	(-3.09)	(0.96)	(-4.96)
Wall	0.0052	-0.023	-0.067***
	(0.14)	(-0.23)	(-1.68)
Floor	-0.067***	-0.195	-0.130*
	(-1.72)	(-1.23)	(-2.94)
Plumb	-0.132***	-0.046	-0.054
	(-1.92)	(-0.95)	(-1.64)
Electric	-	-	-0.608*
			(-16.09)
Residence	0.117**	0.182*	0.152*
	(2.10)	(4.54)	(4.70)
Refrig	-0.362*	-0.213*	-0.217*
	(-2.86)	(-2.71)	(-5.83)
Constant	-4.623***	-1.263	-7.386*
	(-1.69)	(-0.32)	(-3.95)
Sample	4019	419	4019
Censored obs	2345	1971	-4893.25
	0.277	0.011	-0.068
rho	(0.084)	(0.145)	(0.127)
Log likelihood	-2744.01	-4033.54	-4893.25

Source: Author's Analysis of FSRP Urban Consumption Survey, 2007-2008
Notes:
*, **, *** denote statistical significance at 1%, 5%, 10% respectively
In parentheses are student t -values, but for rho are standard errors

They were estimated according to the category of households of charcoal consumption-i) those who consumed charcoal only, ii) those who consumed both charcoal and electricity simultaneously and lastly, iii) the general consumption without dividing the consumers into specific groups. In general the own price elasticity of per capita charcoal demand is less than unity in absolute values and equal to -0.834, thus meaning that as price of charcoal increases by 1 per cent, per capita charcoal consumption would reduce by 0.834 per cent. The price elasticity is more responsive in the dry season (-0.928) than in the rainy season (-0.802). This implies that the same percentage increase in the price of charcoal would induce a larger decrease in per capita charcoal consumption in the dry season than in the rainy season and vice versa, though the difference between the two seasons is small. Those households consuming charcoal-only (group (i)) are less responsive to changes in price than those consuming both charcoal and electricity simultaneously (group (ii)). The electricity and charcoal consumers have elastic price elasticity whereas the charcoal-only consumers have inelastic price elasticity. They both respond more to price changes in the dry season than in the rainy season.

Per capita expenditure elasticity of per capita charcoal demand is equal to 0.395 and its response is almost the same in the dry season and in the rainy season. This means that a 1 per cent increase in per capita expenditure would cause a 0.395 per cent increase in per capita charcoal consumption and vice versa .The charcoal-only consumers are more responsive to per capita expenditure change than the charcoal+electricity consumers in the order 0.421 and 0.362, respectively. The per capita expenditure elasticities for the charcoal-only and for the charcoal+electricity seem to be the same between the two seasons. The elasticities are a bit different from those found in earlier studies. For

Table 17: Price and expenditure elasticities of per capita charcoal consumption

ELASTICITY	Dry season-2007	Rainy season-2008	Overall
PRICE ELASTICITIES			
General consumers	-0.928	-0.802	-0.834
Charcoal-only consumers	-0.589	-0.19	-0.377
Charcoal + Electricity consumers	-1.162	-1.061	-1.093
PER CAPITA EXPENDITURE ELASTICITIES			
General consumers	0.373	0.439	0.395
Charcoal-only consumers	0.454	0.387	0.421
Charcoal + Electricity consumers	0.333	0.417	0.362

Source: Author's Analysis of FSRP Urban Consumption Survey, 2007-2008

instance Zein-Elabdin (1997) by using time series data for estimating charcoal demand in Sub-Saharan Africa found -0.55 and 0.87 as the price and income elasticities of charcoal demand respectively. Though slightly different, both the elasticities of this study and Zein-Elabdin (1997)'s study are inelastic. Other studies such as the one conducted by Gundimeda and Kohlin (2006) by using cross sectional data gave totally different elastic fuelwood price and income elasticities equal to 1.02 and 1.2 respectively.

It is no strange that per capita charcoal consumption is more responsive to price in the dry season than in the rainy season which can be attributed to the fact that households do not use charcoal for heating in dry season since there is enough sun shine to substitute for charcoal heating. As expected the charcoal+electricity's price elasticities are larger than the charcoal-only elasticities due to the fact that consumers of both charcoal and electricity can choose between the two depending on their costs (price)- hence their elastic price elasticity as compared to the charcoal-only consumers whose price elasticity is inelastic in that they do not have any alternative to charcoal.

Per capita expenditure and price elasticities of per capita charcoal demand for the low-income, medium-income and high-income groups are given in table 18 (see appendix 10 for more information on how they were derived). The price elasticities for the three income groups are negative and inelastic though the high-income group's elasticity is closer to one. The price elasticity is increasing as you move away from the low-income group towards the high-income group. The low-income group has elasticity equal to -0.683 whereas the high-income group has price elasticity equal to -0.947. Thus it is noticeable that there is increasing response to price as you move from the low-income to the high-income group which can be attributed to substitution effect. From the data analysis it is well noted that charcoal consumption decreases as you move away from the low-income group to the high-income group whereas electricity consumption increases as you move from low-income group to the high-income group. Given this fact, it is expected that substitution of charcoal for electricity will increase as you move away from the low-income group to the high-income group. Thus the response to price is also expected to increase in that holder – the biggest price elasticity will be with the high-income group. These price elasticities are slightly lower than those found by Gundimeda and Kohlin(2006) on fuelwood equal to -1.04, -1.02 and -1.05 for the low-income, medium-income and high-income groups respectively.

The per capita expenditure elasticities shown in table 18 are positive and inelastic for all the three income groups. This means that as per capita expenditure increases, per capita charcoal demand increases but less proportionally to the increase in price. The per capita expenditure elasticity is decreasing as you move away from the low-income group to the high-income group. The low-income group has the highest expenditure elasticity

Tabe 18: Price and expenditure elasticities by income groups

	Elasticity	
	Price	Expenditure
Overall	-0.834	0.395
Low Income	-0.683	0.503
Medium Income	-0.845	0.406
High Income	-0.947	0.275

Source: Author's Analysis of FSRP Urban Consumption Survey, 2007-2008

equal to 0.503 whereas the high-income group has the lowest expenditure elasticity equal to 0.275. Thus the high-income group has the least response to changes in income as far as charcoal demand is concerned. This is also attributed to substitution effect (charcoal for electricity and vice versa). These expenditure elasticities are lower than those found by Gundimeda and Kohlin(2006) on fuelwood equal to 1.242, 0.912 and 0.846 for the low-income, medium-income and high-income groups respectively.

6.4 Concluding remarks

In a nutshell, it is noted that factors that influence probability of consuming charcoal also influence demand for charcoal. The mostly notable are the price of charcoal, household expenditure, education of the household head and the wealth of the household. Probability of consuming and demand for charcoal both decrease with the increase in the price of charcoal. Per capita household expenditure has a positive effect on the probability of consuming and demand for charcoal. As per capita expenditure increases, probability of consuming charcoal or electricity increases at a decreasing rate. Demand of charcoal also increases with the increase in per capita expenditure though at a decreasing rate. It has been noted that education plays an important role in influencing the probability of consuming charcoal and electricity. Higher education reduces the probability of consuming and demand for charcoal while it increases the probability of consuming and demand for electricity. In general terms households with poor living standards have higher probability of consuming charcoal than electricity. It is also interesting to note that the charcoal-only consumers are less responsive to price (with price elasticity equal to -0.377) whereas the charcoal+electricity consumers are more responsive to price (with price elasticity equal to -1.093). However the charcoal-only and the charcoal+electricity consumers' responsiveness to income invariably differ from each other. When the price and income elasticities for the three income groups (low, medium and high) are examined, one finds that the low income group has the highest income elasticity (0.503) while the high income group has the lowest income elasticity equal to 0.275. Responsiveness to the price of charcoal for the three income groups increases as you move from the low to the high income groups in the order -0.683, -0.845 and -0.947 for the low, medium and high income groups respectively.

CHAPTER 7
CONCLUSION AND RECOMENDATIONS

7.1 Main findings of the study

The study has found that socio-economic factors affect the consumption of charcoal in urban Zambia. Among the socio-economic factors are the economic (price and income), the housing conditions (the type of material the roof, floor is made out of; and if the house has modern plumbing), the wealth of the household (having a refrigerator) and the household characteristics (household size, age, gender and education of the household head). Other variables the study looked into as determinants of charcoal consumption are seasonality (if in the dry or rainy seasons), if the household had electricity and in which residential area (low income, medium income and high income) the household was located.

There were three estimated demand models for the general, the charcoal-only and the charcoal + electricity consumers. In the general demand model it is clear that price of charcoal is negatively related to per capita charcoal consumption whereas per capita expenditure is positively related to per capita charcoal consumption. The square of per capita charcoal expenditure is negatively related to per capita charcoal consumption implying that per capita charcoal consumption increases at a decreasing rate as income increases. This further indicates the fact that charcoal is a normal good in urban Zambia and this conforms to the economic theory of household energy demand. This scenario observed for the general demand model was also observed for the other two disaggregated demand models (charcoal-only and charcoal + electricity).

The housing conditions show that urban households with poor housing conditions as specified above would consume more charcoal in preference for electricity. Conversely, wealthier household (those with refrigerators and modern plumbing) consume less charcoal in preference for electricity. It is also interesting to note that all characteristics of the household head influence per capita charcoal consumption. Higher education, large household size and a male household head have a negative effect on per capita charcoal consumption whereas older age of the household head increases per capita charcoal consumption.

Seasonality is also an important factor to consider as far as per capita charcoal consumption is concerned. Households consume less charcoal in dry season than in the rainy season. As expected, the households with electricity consume less charcoal while those living in lower income residential areas consume more charcoal than electricity.

As stated in the introduction, the results of this undertaking can be used in a number of ways related to policy formulation in the areas of health, environment and energy planning. For instance, due to health impacts or pollution at both local and global levels, government's objective would be transition towards clean fuel such as hydro-electricity in the case of Zambia. Thus policies that facilitate the move towards clean fuel and mitigation of charcoal consumption would be appropriate. From our results, these are economic factors such as price and income. The price and income elasticities of demand would play an important role in identifying the cost-efficient policy. As own-price elasticity is closer to unity (-0.834) in absolute value, it can play an important role in reducing the consumption of charcoal but only with the charcoal+electricity group. This is so because this group has elastic price elasticity (equal to -1.093) of charcoal demand, hence highly responsive to changes in the price of charcoal as they have electricity and charcoal as substitutes for each other. Unlike the charcoal-only consumers who are less responsive to changes in the price of charcoal (with price elasticity equal to -0.377), the charcoal+electricity consumers would switch to electricity when the price of charcoal increases relative to the price of electricity. Thus if tax was chosen as an instrument for effecting both substitution of electricity for charcoal and reduction in charcoal consumption, the charcoal-only consumers -who also are poor households (see appendix 9) would be regressively affected. In order to compensate for the regressive effects of tax as well as making the poor households have access to electricity as their income increases, increasing the income of poor households is advisable. With high price of charcoal due to tax on it, accessible and affordable electricity (as electricity is not very accessible and affordable in Zambia, see appendices 1 and 2) and an improved income base for the poor households, would pave way for substantial reduction in charcoal consumption and an increase in electricity consumption by majority of households in urban Zambia.

Taking the expenditure (income) elasticity point of view, we note that elasticity is positive and less than unity (0.395) implying that charcoal is a normal good. Thus, as income increases, consumption of charcoal increases but less proportionately to the increase in income of the household depicting that charcoal is a normal good in urban Zambia whose consumption increases with increase in income. Though an increase in the income of households is increasing consumption of charcoal, however, we know from our data analysis, demand estimations and charcoal consumption participation probabilities that charcoal consumption increases in tandem with income up to a certain level and there after starts declining. Electricity consumption also is increasing asymptotically with income, thus there is need to move the low income group up so that they start consuming more electricity and less charcoal as there is no complete switch to electricity. What is being observed in the urban Zambia is a multiple energy consumption system and not as stipulated by the traditional energy ladder model. Household would not leave charcoal when their income increases but would consume it less than they used to previously when they had smaller income. This is authenticated by the fact that in the data analysis there are some households in the high-income group which do not consume charcoal. It should be noted that in the last decade, Zambia has experienced inadequate electricity supply to households (see appendices 1 and 2), and this has caused an increase in the number of households in the high income group that are consuming charcoal. Thus if there is improvement in power supply and more household are brought into the high income group, there would be a substantial increase in an overall reduction in charcoal consumption.

As the households would not completely leave charcoal for electricity but still consume both types of energy despite reaching the baseline income level, energy-efficient technology can be useful in both reducing pollution and charcoal consumption. Thus, increased income of the poor households would facilitate purchasing of modern efficient-technology (improved charcoal stoves) and the use of electricity. Given that charcoal consumption is less responsive to income (income elasticity equal to 0.395), the energy-efficient charcoal stoves are a valid and attractive policy measure to employ in reducing charcoal consumption and pollution. This is good policy as improved charcoal stoves are not widely used in Zambia. In the survey data this thesis has used, about 1.8 %

(39 out of 2160) in 2007 and 1.5% (28 out of 1865) in 2008 households possessed improved charcoal stoves. Hence promotion of these improved stoves would go a long way in reducing charcoal consumption in Zambia. Furthermore, as the low income households find it difficult to switch from charcoal to electricity due to high cost of electricity and the high start up costs for electricity, improved charcoal stoves coupled with education of their importance to the households, can play an important role in reducing charcoal consumption and pollution while at the same time raising the real income and standard of living of the poor households.

Given that there are no well known attempts if any, to study the factors determining the choice and demand for energy (charcoal) in Zambia, this study sets a good foundation on which formulation of a number of policies related to health, environment and energy planning can be based as far as charcoal consumption is concerned. The different analyses, for example the aggregated and disaggregated demand models for each income group (low, medium, high) and the consumer groups (charcoal-only, and charcoal+electricity), the participation probabilities and participation elasticities of income, are very vital for identifying the most cost-efficient policy depending on the desired policy under consideration.

7.2 Recommendations

- It is clear that increased level of education is an important factor in reducing charcoal consumption. Thus there is a need for the Zambian government and other Non- Governmental Organisations (NGO) to embark on education programmes tailored to charcoal production and its consumption. In these programmes the following issues should be discussed with the households:
    - The adverse effects of charcoal production and consumption on the environment as a whole.
    - The importance of using energy efficient equipments such as the improved charcoal stoves in energy saving and reduction in emission of compounds that are detrimental to both health and the environment.

- Since improved (efficient) charcoal stoves are almost non existent in Zambia, there should be a deliberate policy to promote them among households in the entire country.
- From the study it is clear that poverty increases consumption of charcoal than electricity. Thus there is a need to accelerate economic growth of poor households in Zambia.
- There is an urgent need of increasing hydro-electricity supply to households in urban Zambia by investing in its generation. The government can take advantage of the carbon compensation criterion and the clean development mechanism of the climate change convention which provide funds for clean energy investments.
- Other clean and less carbon emitting alternatives form of energy to charcoal such as solar and coal briquettes should be promoted.
- Last but not the least, in view of the interesting findings of this study, a comprehensive nation-wide study can be carried out by including both the rural and urban areas so as to highlight their differences in energy consumption and the factors that influence demand and choice of energy. This would set a stage for better economic, health, energy and environmental policies formulation in Zambia.

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Appendices

Appendix 1: Complaints on electricity hikes in Zambia.

Reported by the Post News paper on 22, July 2009

Rupiah is leading Zambia on a path of economic disaster – Nawakwi 22/jully/2009

Written by Patson Chilemba and Nchima Nchito Jr

FDD president Edith Nawakwi yesterday charged that President Rupiah Banda is leading the nation on a path towards economic disaster as a result of his government's reckless hike in electricity tariffs by 35 per cent.

And economic consultant Professor Oliver Saasa has warned that the 35 per cent increment revised electricity tariffs on residential use by Zesco might lead to an increase in poverty levels.

Commenting on the Energy Regulation Board (ERB) who on Monday approved an average of 35 per cent electricity tariff increase for Zesco with effect from August 1, 2009, Nawakwi said the increase in tariffs was heightened after President Banda made a public pronouncement in support of the hike.

She said it was completely premature and reckless for the President to have come out in support of the hike.

"It was premature and ill-timed for the President to come out in support of the increase in energy. If you go to court over a national issue, you can't speak as a President. They have proceeded to increase because in effect, President Banda said 'increase'. But that increase will not induce any investment in the electricity sector. It will just be spent on supporting the top heavy at Zesco," Nawakwi said. "This is completely reckless behaviour, he [President Banda] needs to explain where he is leading this country to. But it is not on a path to economic growth. It is a path to economic disaster."

Nawakwi said as a result of the hike, deforestation would increase in that more people would resort to using charcoal as an alternative. She said it was sad that while governments in other countries were providing stimulus packages, leaders in this country were increasing electricity tariffs, which should be used as a stimulus.

Nawakwi said President Banda's government had come to kill the little of what was left of Zambia's economy.

"It is completely misguided. Energy is to an economy what blood is to the body. This government wants to suck the little blood left. This economy is in intensive care and we need a lot of support from government. The cost of production has skyrocketed because energy is expensive and labour is ill-motivated. On the other hand you are saying you can't pay nurses because of the global recession but on the other hand you increase electricity tariffs," Nawakwi said. "This economy is going to shrink. I would have accepted it if it was another person in State House, but it is an economist like me who has done this. We should not pander to the World Bank demands but go to them with our solutions. This is something that could easily be done by floating shares on the Lusaka Stock Exchange. NAPSA should buy shares in Zesco instead of talking about lotto. All the local pension houses can be requested to assist Zesco by buying shares in Zesco."

Nawakwi said it was risky to increase tariffs in the midst of a recession.

"For us who are in farming, we shall reduce the hectarage. If I was spending six per cent on electricity, that increment will now push it to 10 per cent, meaning I will reduce on the hectares," Nawakwi said.

Nawakwi said the same government had allowed National Milling Corporation Limited to import wheat, when the local farmers had failed to sell their produce for two years in the running.

ERB awarded the increment in two phases.

During the first phase, between 2009 and 2010, there will be an increment of 35 per cent effective August 1.

The second phase of 2010 to 2011 would see a further increment of 26 per cent.

And in an interview, Prof Saasa said the current economic circumstances had to be taken into consideration.

"The effects of this increment on the poor will be quite significant. With the revised tariffs most people would have to pay more than they can budget for," he said. "This will mean that expenditure in other products will also have to be reduced in most home budgets to accommodate the tariff hikes."

Prof Saasa cautioned that there were also other hidden costs to the revised electricity tariffs.

"The majority of people will be forced to cut down on their consumption of electricity turning to charcoal as an alternative source of energy. With this happening it will have an adverse effect on our forest conservation plans as there will be a hike in the demand for charcoal," he said.

Prof Saasa said while bringing economic gains to Zesco, this would greatly compromise conservation efforts.

However, he commended Zesco for introducing the revised electricity tariffs in two phases as this would reduce shocks in the economy.

And Zambia Chamber of Small and Medium Business Association (ZCSMBA) called for an improvement on the services offered by Zesco.

Organisation president Maxwell Sichula said the increment was expected.

"It is understood that the sector has to be made more attractive if it is to attract more investments though the cost of business will also go up," said Sichula. "However, with this increase in tariff we expect that there shall be improvements in the operations of Zesco."

Sichula said as things stood, Zesco provided services that where below standards.

"Our people are suffering with the erratic supply of power that we are currently experiencing in the country. Should Zesco fail to account for the increased revenues they will have from the revised tariffs, we expect that heads will roll," he said.

Asked on the fact that with revised tariffs commercial power users would pay less than residential users per kilo watt hour, Sichula said this might have been done to encourage the industrial sector.

"...We all know that for the economy to grow, we need to encourage the industrial sector. This might have been the motive behind the pricing," said Sichula.

Appendix 2 : Zambians' opposition to electricity tariff increase.

Reported at http://www.postzambia.com/post-read_article.php?articleId=10860, 26, June 2010.

Residents oppose Zesco's proposed tariff increase
By Mutale Kapekele
Sat 26 June 2010, 17:20 CAT [148 Reads, 0 Comment(s)] Text size Print

ZESCO customers in Lusaka and Southern provinces have opposed the proposed 36 per cent tariff increase for all consumer categories.

And Energy regulations Board (ERB) chairperson Sikota Wina has assured customers that the board will make a reasonable tariff decision.

Making submissions at a public hearing on the Zesco tariff review held in Lusaka on Friday, several organisations and individual customers observed that the proposed tariff increments favoured the mines, who consume 50 per cent of power, and disadvantaged ordinary customers.

Green Enviro-watch technical advisor Maarten Elffers submitted that Zesco was 'badly-motivated' and made incorrect statements on the matter.

He said last year Zesco justified the tariff increment with the depreciation of the kwacha, the global recession and increased power import charges, a situation which he said had been reversed.

"Why is it that Zesco has not adjusted tariffs downward when economic performances improved? Zesco consistently manipulates figures as to appear more acceptable," Elffers charged. "Average price increase is advertised as 36 per cent yet for 90 per cent of users (residential) the increase is 69 per cent. Year on year the increase for residential is 346 per cent not the advertised 17.6 percent."

Margret Whitehead of Livingstone also submitted that it was not fair for ordinary Zambians to subsidise the mines through electricity tariffs.

According to Zesco, it was currently supplying power to the mines at a cost that was 28 per cent less than production costs.

On 21 April 2010, Zesco applied for the ERB to increase electricity tariffs by 36 per cent for all customer categories.

Speaking when he officially opened the public hearing, Wina said the ERB would arrive at a reasonable decision for the tariff increase application.

"In its last application, Zesco provided a tariff path towards cost reflective levels. However, as the economic fundamentals are dynamic, Zesco's current application indicates a tariff path different from that earlier envisaged.

That notwithstanding, it remains ERB's responsibility to ensure that all relevant factors are taken into account before arriving at a decision," Wina said. "Our commitment to effective regulation demands that we make a just and reasonable tariff decision. Our decision will take into account the public submissions from the customers."

Wina said the electricity sector still faced supply challenges owing to the electricity power deficit being experienced by the southern African region.
“The power deficit underscores the need for increased infrastructural investment in the country’s power sector,” he said.

“It should also be noted that the application comes at a time when the world is recovering from a recession and major consumers such as the mines were back to full production. I wish to implore Zesco to articulate their proposals and provide clear and concise responses to the consumer submissions. We are also mindful of the concerns of the public regarding the performance of the utility, especially in light of the relatively higher tariffs following the 2008 and 2009 tariff adjustments.”

He also said future tariff increase awards will be influenced by the utility’s performance.
“ I wish to emphasise our commitment to implementing the key performance indicators in 2011 with a view to equating utility performance to the award of tariff increases. In this regard, Zesco’s performance will directly influence the subsequent tariffs to be awarded,” he said. “Zesco has made some progress in meeting the key performance indicators benchmarks since they were introduced in 2008.”

Appendix 3: Probit model for consumption of firewood (2007 + 2008 data).

```
Probit regression                                 Number of obs   =       4019
                                                  LR chi2(15)     =    1172.51
                                                  Prob > chi2     =     0.0000
Log likelihood = -1112.8714                       Pseudo R2       =     0.3450

------------------------------------------------------------------------------
     wconsum |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       price |  -.0015422   .0001814    -8.50   0.000    -.0018977   -.0011867
     pc_texp |  -4.17e-07   1.85e-07    -2.26   0.024    -7.79e-07   -5.52e-08
    pc_texp2 |   4.70e-14   1.79e-14     2.62   0.009     1.18e-14    8.22e-14
      season |    .216273   .0651293     3.32   0.001      .088622     .343924
         age |   .0186033   .0022533     8.26   0.000      .014187    .0230196
       fsize |   .0229472   .0124053     1.85   0.064    -.0013667     .047261
      gender |   .1335785   .0762151     1.75   0.080    -.0158004    .2829574
         edu |  -.2128344   .0777155    -2.74   0.006     -.365154   -.0605148
        roof |   .1994074   .0970017     2.06   0.040     .0092875    .3895272
        wall |   .0920393   .0898879     1.02   0.306    -.0841377    .2682164
       floor |   .5454168   .0838547     6.50   0.000     .3810646    .7097689
       plumb |  -.2652359   .1026026    -2.59   0.010    -.4663333   -.0641384
    electric |   -.336463   .1010959    -3.33   0.001    -.5346074   -.1383187
   residence |   -.194667   .0882332    -2.21   0.027    -.3676009    -.021733
      refrig |  -.1726994   .1113435    -1.55   0.121    -.3909287      .04553
      lusaka |   -.575211   .1065676    -5.40   0.000    -.7840797   -.3663423
       _cons |  -.5805509    .216109    -2.69   0.007    -1.004117    -.156985
------------------------------------------------------------------------------
```

Appendix 4: Heckman selection model for the overall data (2007 + 2008 data).

```
Heckman selection model                         Number of obs      =      4019
(regression model with sample selection)        Censored obs       =       297
                                                Uncensored obs     =      3722

                                                Wald chi2(15)      =   2022.92
Log likelihood =  -4893.25                      Prob > chi2        =    0.0000

------------------------------------------------------------------------------
    lpc_qcha |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lpc_qcha     |
      lprice |  -.8335228   .0418879   -19.90   0.000    -.9156215   -.7514241
    lpc_texp |   2.128977   .2979087     7.15   0.000     1.545087    2.712868
   lpc_texp2 |  -.0706411   .0119499    -5.91   0.000    -.0940624   -.0472198
      season |  -.2712732   .0258614   -10.49   0.000    -.3219606   -.2205859
         age |   .0067921   .0009938     6.83   0.000     .0048444    .0087399
       fsize |  -.0677331   .0058429   -11.59   0.000     -.079185   -.0562812
      gender |  -.0886045   .0300667    -2.95   0.003     -.147534   -.0296749
         edu |  -.1193587   .0295989    -4.03   0.000    -.1773715   -.0613459
        roof |  -.2440992   .0491833    -4.96   0.000    -.3404966   -.1477018
        wall |  -.0668634   .0397912    -1.68   0.093    -.1448526    .0111259
       floor |  -.1303914    .044313    -2.94   0.003    -.2172433   -.0435395
       plumb |  -.0543301   .0331108    -1.64   0.101    -.1192261    .0105658
    electric |  -.6079292    .037786   -16.09   0.000    -.6819884     -.53387
   residence |   .1523764   .0324405     4.70   0.000     .0887942    .2159585
      refrig |  -.2175294   .0373424    -5.83   0.000    -.2907192   -.1443396
       _cons |   -7.38617   1.871205    -3.95   0.000    -11.05366   -3.718675
-------------+----------------------------------------------------------------
select       |
      lprice |  -.2477323   .1383797    -1.79   0.073    -.5189514    .0234869
    lpc_texp |    4.56675   .5422697     8.42   0.000     3.503921    5.629579
   lpc_texp2 |    -.17605   .0211552    -8.32   0.000    -.2175135   -.1345865
      season |  -.3603203   .0751533    -4.79   0.000    -.5076181   -.2130224
         age |  -.0011829   .0027642    -0.43   0.669    -.0066007    .0042349
       fsize |   .1528541   .0180243     8.48   0.000     .1175272     .188181
      gender |   -.059613   .0826444    -0.72   0.471    -.2215929     .102367
         edu |  -.3208226    .090106    -3.56   0.000    -.4974271   -.1442181
        roof |  -.2645625   .1474707    -1.79   0.073    -.5535998    .0244747
        wall |  -.1875702   .1246989    -1.50   0.133    -.4319755    .0568351
       floor |  -.3158206   .1338369    -2.36   0.018    -.5781362    -.053505
       plumb |  -.1098726   .0992359    -1.11   0.268    -.3043714    .0846263
    electric |  -.7066805   .1213762    -5.82   0.000    -.9445735   -.4687876
   residence |   .4442016   .0825959     5.38   0.000     .2823166    .6060867
      refrig |   .0925841   .0997697     0.93   0.353    -.1029608    .2881291
      lusaka |  -.0168381   .0866134    -0.19   0.846    -.1865971     .152921
       _cons |  -26.20633   3.584204    -7.31   0.000    -33.23124   -19.18142
-------------+----------------------------------------------------------------
     /athrho |   -.067667   .1281251    -0.53   0.597    -.3187876    .1834536
    /lnsigma |  -.3357818   .0117061   -28.68   0.000    -.3587254   -.3128383
-------------+----------------------------------------------------------------
         rho |  -.0675639   .1275402                     -.3084102    .1814228
       sigma |    .714779   .0083673                      .6985662    .7313682
      lambda |  -.0482933   .0912442                     -.2271286     .130542
------------------------------------------------------------------------------
LR test of indep. eqns. (rho = 0):   chi2(1) =     0.32   Prob > chi2 = 0.5718
------------------------------------------------------------------------------
```

Appendix 5: Heckman selection model for dry season - 2007 data.

Heckman selection model	Number of obs = 2160
(regression model with sample selection)	Censored obs = 198
	Uncensored obs = 1962
	Wald chi2(14) = 1120.05
Log likelihood = -2676.411	Prob > chi2 = 0.0000

lpc_qcha	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lpc_qcha						
lprice	-.9275204	.0701884	-13.21	0.000	-1.065087	-.7899536
lpc_texp	2.859683	.3801156	7.52	0.000	2.114671	3.604696
lpc_texp2	-.101486	.0152292	-6.66	0.000	-.1313346	-.0716375
age	.007901	.0013857	5.70	0.000	.005185	.010617
fsize	-.0666793	.0081424	-8.19	0.000	-.0826381	-.0507205
gender	-.1290433	.0422726	-3.05	0.002	-.211896	-.0461906
edu	-.0828194	.0408259	-2.03	0.042	-.1628367	-.002802
roof	-.1732604	.0684194	-2.53	0.011	-.3073599	-.0391609
wall	-.0956129	.0608433	-1.57	0.116	-.2148636	.0236378
floor	-.1507214	.0587281	-2.57	0.010	-.2658264	-.0356164
plumb	-.0993599	.0486846	-2.04	0.041	-.1947799	-.00394
electric	-.6932874	.0517508	-13.40	0.000	-.7947172	-.5918576
residence	.126447	.0455175	2.78	0.005	.0372343	.2156596
refrig	-.16676	.0536454	-3.11	0.002	-.2719031	-.061617
_cons	-11.3185	2.419196	-4.68	0.000	-16.06003	-6.57696
select						
lprice	-.0974285	.1950742	-0.50	0.617	-.4797669	.28491
lpc_texp	4.310866	.6894722	6.25	0.000	2.959526	5.662207
lpc_texp2	-.1651519	.0267787	-6.17	0.000	-.2176372	-.1126666
age	.0012603	.0037462	0.34	0.737	-.0060821	.0086026
fsize	.1779366	.0237955	7.48	0.000	.1312983	.2245749
gender	-.1088245	.1092768	-1.00	0.319	-.3230032	.1053541
edu	-.2553142	.1149595	-2.22	0.026	-.4806307	-.0299977
roof	-.0992429	.2022862	-0.49	0.624	-.4957166	.2972308
wall	-.3003851	.1723183	-1.74	0.081	-.6381228	.0373526
floor	-.3555822	.1688638	-2.11	0.035	-.6865491	-.0246153
plumb	-.2308947	.129101	-1.79	0.074	-.4839279	.0221386
electric	-.9482837	.1606942	-5.90	0.000	-1.263238	-.6333288
residence	.4838387	.1061028	4.56	0.000	.2758811	.6917962
refrig	.1276827	.1263272	1.01	0.312	-.1199141	.3752795
lusaka	.0270623	.1047543	0.26	0.796	-.1782524	.232377
_cons	-26.12672	4.600097	-5.68	0.000	-35.14274	-17.1107
/athrho	-.0065404	.1246315	-0.05	0.958	-.2508136	.2377328
/lnsigma	-.3233231	.0159647	-20.25	0.000	-.3546134	-.2920328
rho	-.0065403	.1246261			-.2456833	.2333531
sigma	.72374	.0115543			.7014446	.746744
lambda	-.0047335	.0901978			-.1815179	.1720509

LR test of indep. eqns. (rho = 0): chi2(1) = 0.00 Prob > chi2 = 0.9580

Appendix 6: Heckman selection model for rainy season - 2008 data.

```
Heckman selection model                          Number of obs      =      1859
(regression model with sample selection)         Censored obs       =        99
                                                 Uncensored obs     =      1760

                                                 Wald chi2(14)      =    971.07
Log likelihood = -2173.139                       Prob > chi2        =    0.0000

------------------------------------------------------------------------------
    lpc_qcha |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lpc_qcha     |
      lprice |  -.8024428   .0544115   -14.75   0.000    -.9090874   -.6957981
    lpc_texp |   1.245057   .5229755     2.38   0.017      .220044     2.27007
   lpc_texp2 |  -.0327775   .0209474    -1.56   0.118    -.0738336    .0082786
         age |   .0054378   .0014105     3.86   0.000     .0026733    .0082024
       fsize |  -.0637244   .0086559    -7.36   0.000    -.0806897    -.046759
      gender |   -.045808   .0420726    -1.09   0.276    -.1282687    .0366527
         edu |  -.1695871   .0437036    -3.88   0.000    -.2552446   -.0839296
        roof |  -.3938779   .0743088    -5.30   0.000    -.5395204   -.2482354
        wall |   .0224855   .0537965     0.42   0.676    -.0829537    .1279247
       floor |  -.1119968   .0672291    -1.67   0.096    -.2437633    .0197697
       plumb |  -.0063299   .0454037    -0.14   0.889    -.0953195    .0826597
    electric |  -.5049808   .0538266    -9.38   0.000    -.6104791   -.3994825
   residence |   .1923484   .0462141     4.16   0.000     .1017704    .2829263
      refrig |  -.2767024   .0512556    -5.40   0.000    -.3771615   -.1762433
       _cons |  -2.547941   3.221593    -0.79   0.429    -8.862146    3.766265
-------------+----------------------------------------------------------------
select       |
      lprice |  -.4995224   .2325293    -2.15   0.032    -.9552714   -.0437734
    lpc_texp |   5.290372   .8944675     5.91   0.000     3.537248    7.043496
   lpc_texp2 |  -.2044915   .0351851    -5.81   0.000     -.273453     -.13553
         age |  -.0043888   .0042022    -1.04   0.296     -.012625    .0038474
       fsize |   .1339453   .0288954     4.64   0.000     .0773114    .1905792
      gender |   .0147052    .129444     0.11   0.910    -.2390005    .2684108
         edu |  -.4364849   .1531916    -2.85   0.004     -.736735   -.1362348
        roof |  -.5641434    .230741    -2.44   0.014    -1.016387   -.1118994
        wall |   .1571834   .2083028     0.75   0.450    -.2510826    .5654494
       floor |   -.304598   .2309704    -1.32   0.187    -.7572916    .1480956
       plumb |   .0798512   .1675538     0.48   0.634    -.2485483    .4082506
    electric |  -.2996298   .1973272    -1.52   0.129     -.686384    .0871244
   residence |   .3767456   .1360386     2.77   0.006     .1101149    .6433762
      refrig |   .0059148   .1712035     0.03   0.972    -.3296379    .3414674
      lusaka |   .0257107   .1686104     0.15   0.879    -.3047596     .356181
       _cons |  -29.13776   5.884222    -4.95   0.000    -40.67063    -17.6049
-------------+----------------------------------------------------------------
     /athrho |  -.0298906   .3527819    -0.08   0.932    -.7213305    .6615492
    /lnsigma |  -.3677887   .0169359   -21.72   0.000    -.4009825   -.3345949
-------------+----------------------------------------------------------------
         rho |  -.0298817   .3524669                     -.6177328    .5793935
       sigma |   .6922634   .0117241                      .6696618    .7156279
      lambda |   -.020686   .2440344                     -.4989847    .4576126
------------------------------------------------------------------------------
LR test of indep. eqns. (rho = 0):   chi2(1) =     0.01   Prob > chi2 = 0.9260
------------------------------------------------------------------------------
```

Appendix 7: Heckman selection model for charcoal-only consumers (2007+2008) data.

```
Heckman selection model                           Number of obs      =      4019
(regression model with sample selection)          Censored obs       =      2345
                                                  Uncensored obs     =      1674

                                                  Wald chi2(14)      =    968.40
Log likelihood = -2744.015                        Prob > chi2        =    0.0000

------------------------------------------------------------------------------
      lpcq_C |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lpcq_C       |
      lprice |  -.3770851   .0587702    -6.42   0.000    -.4922726   -.2618977
    lpc_texp |   1.167737   .4577498     2.55   0.011     .2705638     2.06491
   lpc_texp2 |  -.0304347   .0193928    -1.57   0.117    -.0684439    .0075745
      season |  -.0967723   .0307173    -3.15   0.002    -.1569771   -.0365676
         age |   .0016794   .0010594     1.59   0.113     -.000397    .0037558
       fsize |  -.0755983    .006516   -11.60   0.000    -.0883694   -.0628273
      gender |  -.1025557   .0353051    -2.90   0.004    -.1717524    -.033359
         edu |   -.026818   .0385005    -0.70   0.486    -.1022777    .0486416
        roof |  -.1431422   .0462556    -3.09   0.002    -.2338016   -.0524828
        wall |   .0051903   .0379791     0.14   0.891    -.0692473    .0796278
       floor |  -.0661228   .0383979    -1.72   0.085    -.1413813    .0091356
       plumb |  -.1322146   .0687819    -1.92   0.055    -.2670248    .0025955
   residence |   .1169008   .0556223     2.10   0.036     .0078831    .2259185
      refrig |  -.3616166    .126445    -2.86   0.004    -.6094443    -.113789
       _cons |  -4.622806    2.73277    -1.69   0.091    -9.978937    .7333255
-------------+----------------------------------------------------------------
select       |
      lprice |  -.0341677   .1170761    -0.29   0.770    -.2636327    .1952972
    lpc_texp |   2.540986   .8096164     3.14   0.002      .954167    4.127805
   lpc_texp2 |  -.1136429   .0336762    -3.37   0.001     -.179647   -.0476388
      season |   .0354521   .0602767     0.59   0.556     -.082688    .1535921
         age |   .0005735   .0021837     0.26   0.793    -.0037063    .0048534
       fsize |   .0069616   .0127372     0.55   0.585    -.0180029     .031926
      gender |   .0772292   .0702232     1.10   0.271    -.0604057    .2148642
         edu |   -.435323   .0635034    -6.86   0.000    -.5597873   -.3108586
        roof |   .1292293   .1151574     1.12   0.262    -.0964749    .3549336
        wall |   .2624303   .0886651     2.96   0.003     .0886499    .4362107
       floor |   .1843206   .0987245     1.87   0.062    -.0091759    .3778171
       plumb |  -1.066906   .0837668   -12.74   0.000    -1.231086   -.9027259
   residence |   .4495474   .0836591     5.37   0.000     .2855785    .6135163
      refrig |  -1.795647   .0938085   -19.14   0.000    -1.979508   -1.611785
      lusaka |  -.4413083   .0765859    -5.76   0.000    -.5914139   -.2912026
       _cons |   -13.5833   4.919102    -2.76   0.006    -23.22456   -3.942036
-------------+----------------------------------------------------------------
     /athrho |   .2845938   .0906921     3.14   0.002     .1068406    .4623471
    /lnsigma |  -.5532189   .0204487   -27.05   0.000    -.5932975   -.5131403
-------------+----------------------------------------------------------------
         rho |   .2771514   .0837258                      .1064359    .4319952
       sigma |   .5750957   .0117599                      .5525024    .5986128
      lambda |   .1593886    .049973                      .0614433    .2573339
------------------------------------------------------------------------------
LR test of indep. eqns. (rho = 0):   chi2(1) =     6.60   Prob > chi2 = 0.0102
------------------------------------------------------------------------------
```

Appendix 8: Heckman selection model for charcoal+electricity consumers (2007 + 2008) data.

Heckman selection model	Number of obs	=	4019
(regression model with sample selection)	Censored obs	=	1971
	Uncensored obs	=	2048
	Wald chi2(14)	=	714.12
Log likelihood = -4033.543	Prob > chi2	=	0.0000

lpcq_CE	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lpcq_CE						
lprice	-1.092772	.0567348	-19.26	0.000	-1.20397	-.9815739
lpc_texp	1.30884	.6043731	2.17	0.030	.1242904	2.493389
lpc_texp2	-.0385626	.0234389	-1.65	0.100	-.084502	.0073767
season	-.4180784	.038282	-10.92	0.000	-.4931097	-.3430471
age	.013298	.001667	7.98	0.000	.0100307	.0165653
fsize	-.0629541	.0087467	-7.20	0.000	-.0800974	-.0458109
gender	-.0873916	.0457812	-1.91	0.056	-.1771211	.0023379
edu	-.1446227	.043144	-3.35	0.001	-.2291833	-.0600621
roof	.1566058	.1623979	0.96	0.335	-.1616882	.4748999
wall	-.0230057	.1014266	-0.23	0.821	-.2217982	.1757868
floor	-.1953173	.1586684	-1.23	0.218	-.5063017	.1156671
plumb	-.0457654	.0482971	-0.95	0.343	-.1404261	.0488952
residence	.1816781	.040007	4.54	0.000	.1032658	.2600904
refrig	-.2131279	.0786154	-2.71	0.007	-.3672113	-.0590445
_cons	-1.263007	3.965784	-0.32	0.750	-9.035802	6.509787
select						
lprice	-.1462267	.102682	-1.42	0.154	-.3474798	.0550264
lpc_texp	6.469716	.5629224	11.49	0.000	5.366409	7.573024
lpc_texp2	-.2516894	.0220297	-11.42	0.000	-.2948669	-.2085119
season	-.2235655	.0550814	-4.06	0.000	-.331523	-.1156081
age	-.0012493	.002155	-0.58	0.562	-.0054729	.0029744
fsize	.0686027	.0119258	5.75	0.000	.0452286	.0919768
gender	-.1018973	.0636347	-1.60	0.109	-.2266191	.0228244
edu	.1925011	.0594181	3.24	0.001	.0760438	.3089584
roof	-.7206135	.1464974	-4.92	0.000	-1.007743	-.4334839
wall	-.5192878	.0947522	-5.48	0.000	-.7049988	-.3335768
floor	-.6792739	.126094	-5.39	0.000	-.9264136	-.4321342
plumb	.5971598	.0679548	8.79	0.000	.4639708	.7303488
residence	.1521395	.0652907	2.33	0.020	.0241722	.2801069
refrig	1.155428	.0676375	17.08	0.000	1.022861	1.287995
lusaka	.1878384	.0656376	2.86	0.004	.059191	.3164858
_cons	-41.13609	3.65155	-11.27	0.000	-48.293	-33.97918
/athrho	.0107901	.1448435	0.07	0.941	-.2730979	.2946782
/lnsigma	-.240276	.015638	-15.36	0.000	-.2709259	-.2096262
rho	.0107897	.1448266			-.266505	.2864349
sigma	.7864108	.0122979			.762673	.8108873
lambda	.0084852	.1138987			-.2147522	.2317225

LR test of indep. eqns. (rho = 0): chi2(1) = 0.01 Prob > chi2 = 0.9410

Appendix 9: Charcoal-only (C), charcoal + electricity (CE) consumption by income groups (1= low, 2=medium, 3=high).

Charcoal - only consumption (Number of households)

Cosume consum_C	Income group 1	2	3	Total
No	332	783	1,232	2,347
Yes	1,011	558	109	1,678
Total	1,343	1,341	1,341	4,025

Charcoal+ Electricity (Number of households)

consum_CE	Income group 1	2	3	Total
No	1,104	622	249	1,975
Yes	239	719	1,092	2,050
Total	1,343	1,341	1,341	4,025

Appendix 10: Calculation of expenditure elasticities.

For the Low , Medium and High Income Groups ; the following general formular of log per capita charcoal consumption was differentiated with respect to per capita total expenditure,

$$\ln(pc\_qcha) = \beta_0 + \beta_1 \ln(pc\_t\exp) + \beta_2 [\ln(pc\_t\exp]^2$$

$$\frac{\partial \ln(pc\_qcha)}{\partial \ln(pc\_t\exp)} = \beta_1 + 2 * \beta_2 [\ln(pc\_t\exp]$$

Where pc_qcha : is mean per capita charcoal consumption

$pc\_t\exp$: is mean per capita total household expenditure

From our econometric per capita charcoal consumption analysis in appendix 6 we have β_1 = 2.128977, β_2 = -0.0706411 thus the general equation becomes:

$$\frac{\partial \ln(pc\_qcha)}{\partial \ln(pc\_t\exp)} = 2.128977 - \{2 * 0.0706411 * [\ln(pc\_t\exp)]\}$$

Finding the per capita expenditure elasticities of per capita charcoal consumption for the Low , Medium and High Income groups was just a matter of replacing $pc\_t\exp$ on the right hand side with their means. The means where as follows:

	Mean pc_texp(ZMK)
Agregate(overall)	349898.3
Low Income	127281.5
Medium Income	235414.5
High Income	687331.0

The same procedure was used for calculating the expenditure elasticities for the Charcoal only and the charcoal+Electricity consumer groups. These two groups had different β_1 and β_2 :

	β_1	β_2	Mean pc_texp(ZMK**)**
Charcoal- only	1.167737	-0.0304347	162 736.4
Charcoal+Electricity	1.30884	-0.0385626	439 774.8

Appendix 11: Derivation of the participation probability and elasticity

$$\Pr ob_i(Y=1) = F(Z) + u_i = F\left(\alpha_0 + \beta_1 \ln(T\exp_i) + \beta_2[\ln(T\exp_i)]^2 + \ldots\ldots\ldots\ldots\right) + u_i$$

(1)

Where $Z = \alpha_0 + \beta_1 \ln(T\exp) + \beta_2[\ln(T\exp)]^2 + \ldots\ldots.$

(2)

Marginal effect

$$\frac{\partial \Pr ob_i(Y=1)}{\partial Ln(T\exp_i)} = \phi(\overline{Z})\frac{\partial Z}{\partial \ln(T\exp_i)} = \phi(\overline{Z})[\beta_1 + 2\beta_2 \ln(T\exp_i)] = \phi(\overline{Z})(\beta_1) + \phi(\overline{Z})(\beta_2 \ln(T\exp_i))$$

(3)

where $\phi(\overline{Z})$ represents the normal density function.

In expression (3), the marginal effect consists of two components. The first one $\phi(\overline{Z})(\beta_1)$ is the marginal effect that is reported in STATA, corresponding to the variable associated with ln(Texp). The second component is associated with the ln(Texp) expressed in a quadratic form. This second effect takes into account the nonlinearity of the Texp variable and it explains why this second term is equal to $\phi(\overline{Z})(\beta_2 \ln(T\exp_i))$

The marginal effect can be interpreted as some kind of "semi" elasticity because it gives the change in the Prob(Yi=1) resulting from a percentage change in the household expenditures.

Participation elasticity

$$\frac{\partial \ln[\Pr ob_i(Y=1)]}{\partial \ln(T\exp_i)} = \left(\frac{\partial \Pr ob_i(Y=1))}{\partial T\exp_i}\right)\left(\frac{T\exp_i}{\Pr ob_i(Y=1)}\right) = \left(\frac{\partial \Pr ob_i(Y=1)}{\partial \ln(T\exp i)}\right)\left(\frac{1}{\Pr ob_i(Y=1)}\right) =$$

$$= \frac{\phi(\overline{Z})[\beta_1 + 2\beta_2 \ln(T\exp_i)]}{\Pr ob_i(Y=1)}$$

$$= \frac{\phi(\overline{Z})[\beta_1 + 2\beta_2 \ln(T\exp_i)]}{\mathrm{F}(\overline{\mathrm{Z}})}$$

This participation elasticity can be interpreted as the percentage change in the Prob(Y=1) resulting from a percentage change in the variable Texpi. An inspection of expression (3) shows that this elasticity is made up of two terms. The first one o of two terms In this expression defining the elasticity of participation with respect to the variable Texpi.

Appendix 12: The Bivariate probit regression for the consumption of charcoal and electricity.

Overall data (2007 + 2008)

```
Bivariate probit regression                       Number of obs   =       4019
                                                  Wald chi2(30)   =    1353.74
Log likelihood = -1998.1627                       Prob > chi2     =     0.0000

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
cconsum      |
      lprice |  -.2331267   .1360215    -1.71   0.087     -.499724    .0334705
   lpc_texp |   4.072103   .5275548     7.72   0.000     3.038115    5.106092
  lpc_texp2 |  -.1578278   .0206423    -7.65   0.000    -.1982859   -.1173696
      season |  -.3402665   .0737771    -4.61   0.000     -.484867    -.195666
         age |   -.000305      .0027    -0.11   0.910    -.0055968    .0049868
       fsize |   .1493825   .0177398     8.42   0.000      .114613    .1841519
      gender |  -.0576678   .0815717    -0.71   0.480    -.2175453    .1022097
         edu |  -.3693076   .0885303    -4.17   0.000    -.5428238   -.1957915
        roof |  -.1724036   .1405129    -1.23   0.220    -.4478038    .1029966
        wall |  -.0819754   .1189814    -0.69   0.491    -.3151747    .1512238
       floor |  -.1977946   .1261173    -1.57   0.117      -.44498    .0493908
       plumb |  -.2251968   .0982872    -2.29   0.022    -.4178362   -.0325573
   residence |   .4634131   .0825343     5.61   0.000     .3016489    .6251773
      refrig |  -.0844533   .0985891    -0.86   0.392    -.2776844    .1087778
      lusaka |  -.0440293   .0844535    -0.52   0.602    -.2095552    .1214966
       _cons |  -23.38875   3.493901    -6.69   0.000    -30.23666   -16.54083
-------------+----------------------------------------------------------------
electric     |
      lprice |   .2273024   .1225026     1.86   0.064    -.0127983     .467403
   lpc_texp |   2.086792   .9618399     2.17   0.030     .2016203    3.971963
  lpc_texp2 |  -.0698023   .0391095    -1.78   0.074    -.1464554    .0068509
      season |    .017196   .0654964     0.26   0.793    -.1111746    .1455665
         age |  -.0060731   .0024466    -2.48   0.013    -.0108684   -.0012779
       fsize |   .0330668   .0139621     2.37   0.018     .0057015     .060432
      gender |  -.1063773   .0763235    -1.39   0.163    -.2559686     .043214
         edu |   .4079844   .0665315     6.13   0.000     .2775851    .5383837
        roof |  -.6594589   .1699455    -3.88   0.000     -.992546   -.3263718
        wall |   -.466204   .1033843    -4.51   0.000    -.6688335   -.2635745
       floor |  -.5959522   .1345254    -4.43   0.000    -.8596172   -.3322872
       plumb |   1.025185   .0841471    12.18   0.000     .8602601    1.190111
   residence |  -.4896963    .086124    -5.69   0.000    -.6584963   -.3208963
      refrig |   1.702489   .0934138    18.23   0.000     1.519401    1.885577
      lusaka |   .2759203   .0771604     3.58   0.000     .1246887    .4271519
       _cons |  -16.62678   5.946918    -2.80   0.005    -28.28253   -4.971038
-------------+----------------------------------------------------------------
     /athrho |  -.3833204   .0779602    -4.92   0.000    -.5361195   -.2305212
-------------+----------------------------------------------------------------
         rho |  -.3655875   .0675405                      -.490045   -.2265229
------------------------------------------------------------------------------
Likelihood-ratio test of rho=0:     chi2(1) =  26.2322    Prob > chi2 = 0.0000
```

Appendix 13: The Bivariate probit rregression for the consumption of charcoal and electricity-2008 data.

Bivariate probit regression — Number of obs = 1859
Wald chi2(28) = 579.66
Log likelihood = -808.76444 — Prob > chi2 = 0.0000

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
cconsum						
lprice	-.498585	.2290929	-2.18	0.030	-.9475989	-.049571
lpc_texp	5.105075	.8826122	5.78	0.000	3.375186	6.834963
lpc_texp2	-.1974942	.0347197	-5.69	0.000	-.2655436	-.1294448
age	-.0040782	.0041694	-0.98	0.328	-.0122501	.0040937
fsize	.1349477	.0288495	4.68	0.000	.0784037	.1914917
gender	.0111661	.1292116	0.09	0.931	-.2420841	.2644162
edu	-.4583647	.1492288	-3.07	0.002	-.7508478	-.1658816
roof	-.537135	.2257757	-2.38	0.017	-.9796472	-.0946228
wall	.2096882	.2017907	1.04	0.299	-.1858144	.6051907
floor	-.2651942	.2242781	-1.18	0.237	-.7047711	.1743827
plumb	.0278268	.1645626	0.17	0.866	-.29471	.3503635
residence	.3843539	.1364368	2.82	0.005	.1169427	.6517652
refrig	-.0860359	.1652094	-0.52	0.603	-.4098403	.2377685
lusaka	.0160468	.1673016	0.10	0.924	-.3118584	.343952
_cons	-28.08212	5.816987	-4.83	0.000	-39.48321	-16.68104
electric						
lprice	.0260293	.2066742	0.13	0.900	-.3790447	.4311034
lpc_texp	1.457069	1.786773	0.82	0.415	-2.044942	4.959079
lpc_texp2	-.0448631	.0732904	-0.61	0.540	-.1885096	.0987835
age	-.0061174	.0037463	-1.63	0.102	-.01346	.0012252
fsize	.0218935	.0209417	1.05	0.296	-.0191515	.0629386
gender	-.0966608	.1151327	-0.84	0.401	-.3223169	.1289952
edu	.4115849	.102339	4.02	0.000	.2110042	.6121656
roof	-.6873641	.2882434	-2.38	0.017	-1.252311	-.1224174
wall	-.4472277	.1360523	-3.29	0.001	-.7138853	-.1805702
floor	-.9070031	.2745348	-3.30	0.001	-1.445081	-.3689248
plumb	1.222059	.133998	9.12	0.000	.9594273	1.48469
residence	-.4239204	.1302259	-3.26	0.001	-.6791584	-.1686824
refrig	1.764349	.1387426	12.72	0.000	1.492418	2.036279
lusaka	.4442783	.1562389	2.84	0.004	.1380557	.7505009
_cons	-11.39828	10.94624	-1.04	0.298	-32.85252	10.05596
/athrho	-.1509735	.1239324	-1.22	0.223	-.3938764	.0919295
rho	-.1498368	.1211499			-.3746972	.0916714

Likelihood-ratio test of rho=0: chi2(1) = 1.50565 Prob > chi2 = 0.2198

Appendix 14: The Bivariate probit regression for the consumption of charcoal and electricity-2007 data.

```
Bivariate probit regression                       Number of obs   =       2160
                                                  Wald chi2(28)   =     760.84
Log likelihood = -1170.7446                       Prob > chi2     =     0.0000

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
cconsum      |
      lprice |  -.0823736   .1890171    -0.44   0.663    -.4528402     .288093
    lpc_texp |   3.639963   .6622301     5.50   0.000     2.342015     4.93791
   lpc_texp2 |  -.1407048   .0258379    -5.45   0.000     -.191346   -.0900635
         age |   .0028874   .0036082     0.80   0.424    -.0041845    .0099593
       fsize |   .1674348   .0230545     7.26   0.000     .1222489    .2126208
      gender |  -.0943698   .1062718    -0.89   0.375    -.3026587     .113919
         edu |  -.3215411   .1111307    -2.89   0.004    -.5393532   -.1037289
        roof |   .0571677   .1898973     0.30   0.763    -.3150242    .4293597
        wall |  -.1783797   .1621722    -1.10   0.271    -.4962314     .139472
       floor |  -.1919264   .1551947    -1.24   0.216    -.4961024    .1122497
       plumb |    -.36618   .1262924    -2.90   0.004    -.6137085   -.1186515
   residence |     .51437   .1049799     4.90   0.000     .3086131    .7201269
      refrig |  -.0860717   .1246779    -0.69   0.490    -.3304358    .1582924
      lusaka |   -.018421   .1003306    -0.18   0.854    -.2150653    .1782233
       _cons |  -22.23821   4.415645    -5.04   0.000    -30.89272   -13.58371
-------------+----------------------------------------------------------------
electric     |
      lprice |   .3355383   .1752384     1.91   0.056    -.0079228    .6789993
    lpc_texp |   2.352185   1.113132     2.11   0.035      .170486    4.533884
   lpc_texp2 |  -.0800384   .0449611    -1.78   0.075    -.1681606    .0080837
         age |  -.0057524   .0032421    -1.77   0.076    -.0121068     .000602
       fsize |   .0419937   .0188279     2.23   0.026     .0050917    .0788958
      gender |  -.1097224   .1021486    -1.07   0.283      -.30993    .0904852
         edu |   .4172757   .0877751     4.75   0.000     .2452397    .5893118
        roof |  -.6146702   .2133849    -2.88   0.004    -1.032897   -.1964434
        wall |  -.4083634   .1674134    -2.44   0.015    -.7364877   -.0802391
       floor |  -.4944177   .1564701    -3.16   0.002    -.8010935    -.187742
       plumb |   .8627009   .1135472     7.60   0.000     .6401524    1.085249
   residence |  -.5555659   .1144468    -4.85   0.000    -.7798775   -.3312544
      refrig |   1.683863   .1290091    13.05   0.000     1.431009    1.936716
      lusaka |   .2311424   .0904731     2.55   0.011     .0538183    .4084664
       _cons |  -19.00246   6.936798    -2.74   0.006    -32.59834   -5.406587
-------------+----------------------------------------------------------------
     /athrho |   -.607381   .1161865    -5.23   0.000    -.8351023   -.3796597
-------------+----------------------------------------------------------------
         rho |  -.5422809   .0820197                     -.6832062   -.3624119
------------------------------------------------------------------------------
Likelihood-ratio test of rho=0:     chi2(1) =  34.2748    Prob > chi2 = 0.0000
```

Appendix 15: Predicted participation probabilities and elasticities for charcoal (C=1) consumers

Pc_texp(ZMK)	ln(pc_texp)	Participation Probability (C=1)	Total ME of ln(pc_texp)	Participation Elasticity (C=1)
5000	8.517193191	0.122801	0.281302897	2.29072255
25000	10.1266311	0.744379	0.281513106	0.378185123
50000	10.81977828	0.882579	0.12938099	0.146594205
75000	11.22524339	0.923402	0.076064992	0.082374734
100000	11.51292546	0.941489	0.051155927	0.054335142
125000	11.73606902	0.951267	0.037138004	0.039040548
150000	11.91839057	0.957196	0.028221392	0.0294834
175000	12.07254125	0.961056	0.022035726	0.022928667
200000	12.20607265	0.963685	0.017456321	0.018114129
225000	12.32385568	0.965528	0.01388953	0.014385431
250000	12.4292162	0.966836	0.010995786	0.011372955
275000	12.52452638	0.967767	0.008568294	0.008853671
300000	12.61153775	0.968421	0.006474632	0.006685761
325000	12.69158046	0.968865	0.004626448	0.004775122
350000	12.76568843	0.969146	0.002962744	0.003057066
375000	12.8346813	0.969298	0.001440171	0.001485788
400000	12.89921983	0.969345	2.71559E-05	2.80147E-05
425000	12.95984445	0.969306	-0.001299793	-0.001340951
450000	13.01700286	0.969196	-0.002558481	-0.002639797
475000	13.07107008	0.969025	-0.003762626	-0.003882897
500000	13.12236338	0.968803	-0.004922947	-0.005081475
525000	13.17115354	0.968535	-0.006047926	-0.006244405
550000	13.21767356	0.968228	-0.007144353	-0.007378788
575000	13.26212532	0.967887	-0.008217717	-0.008490366
600000	13.30468493	0.967515	-0.009272494	-0.009583824
625000	13.34550693	0.967115	-0.010312368	-0.010663017
650000	13.38472764	0.966691	-0.011340386	-0.01173114
675000	13.42246797	0.966244	-0.012359091	-0.012790862
700000	13.45883561	0.965776	-0.013370613	-0.013844424
725000	13.49392693	0.965289	-0.014376747	-0.014893719
750000	13.52782849	0.964785	-0.015379013	-0.015940354
775000	13.56061831	0.964264	-0.016378702	-0.016985697
800000	13.59236701	0.963729	-0.017376914	-0.018030921

Appendix 16: Predicted participation probabilities and elasticities for electricity (E=1) consumers

Pc_texp (ZMK)	ln(pc_texp)	Participation Probability (E=1)	Total ME of ln(pc_texp)	Participation Elstisty (E=1)
5000	8.517193191	0.035945791	0.071051678	1.976634172
25000	10.1266311	0.29712139	0.233649637	0.786377704
50000	10.81977828	0.460810735	0.229549707	0.49814314
75000	11.22524339	0.549567273	0.206473325	0.375701639
100000	11.51292546	0.605974164	0.185242602	0.305693895
125000	11.73606902	0.645348368	0.167573275	0.259663282
150000	11.91839057	0.674569215	0.152980596	0.226782653
175000	12.07254125	0.697209943	0.14080875	0.201960329
200000	12.20607265	0.715322252	0.130520055	0.182463295
225000	12.32385568	0.730173717	0.121708376	0.166684137
250000	12.4292162	0.742592496	0.114070821	0.1536116
275000	12.52452638	0.753144065	0.107379995	0.142575638
300000	12.61153775	0.762228584	0.101462999	0.13311361
325000	12.69158046	0.770137715	0.096186482	0.124895172
350000	12.76568843	0.777089394	0.091446138	0.117677758
375000	12.8346813	0.783249951	0.087159279	0.11127901
400000	12.89921983	0.788748673	0.083259543	0.105559028
425000	12.95984445	0.793687677	0.07969306	0.10040859
450000	13.01700286	0.798148754	0.076415643	0.095741105
475000	13.07107008	0.802198238	0.073390703	0.091486991
500000	13.12236338	0.805890529	0.070587673	0.087589655
525000	13.17115354	0.809270689	0.067980816	0.084002568
550000	13.21767356	0.812376382	0.0655483	0.080687107
575000	13.26212532	0.815239348	0.063271478	0.077610923
600000	13.30468493	0.817886536	0.061134326	0.074746708
625000	13.34550693	0.820340983	0.05912299	0.072071237
650000	13.38472764	0.822622509	0.057225431	0.069564631
675000	13.42246797	0.824748263	0.055431134	0.067209761
700000	13.45883561	0.826733163	0.053730869	0.064991791
725000	13.49392693	0.828590252	0.052116501	0.062897797
750000	13.52782849	0.830330988	0.050580832	0.060916469
775000	13.56061831	0.831965476	0.049117465	0.059037864
800000	13.59236701	0.833502669	0.047720695	0.057253201

Appendix 17: Predicted participation probabilities and elasticities for the charcoal+electricity consumers (C=1,E=1).

pc_texp (ZMK)	ln(pc_texp)	Participation Probability(C=1, E=1)	Total ME of ln(pc_texp)	Participation Elasticity(C=1,E=1)
5000	8.517193191	0.00062315	0.003981431	6.389201402
25000	10.1266311	0.17274717	0.262396072	1.518960175
50000	10.81977828	0.3705513	0.285171874	0.769588109
75000	11.22524339	0.479955	0.251335143	0.523663976
100000	11.51292546	0.54782713	0.220086718	0.401744832
125000	11.73606902	0.59414498	0.195072977	0.328325549
150000	11.91839057	0.62787727	0.175067126	0.278823799
175000	12.07254125	0.65359734	0.158760853	0.242903151
200000	12.20607265	0.6738833	0.14518829	0.215450198
225000	12.32385568	0.6903048	0.133679679	0.193653121
250000	12.4292162	0.7038629	0.123753999	0.175821171
275000	12.52452638	0.71524214	0.115079188	0.160895424
300000	12.61153775	0.724922	0.107395835	0.148148126
325000	12.69158046	0.733234	0.100525041	0.137098172
350000	12.76568843	0.7404601	0.094316058	0.127374936
375000	12.8346813	0.7467705	0.088666314	0.118733017
400000	12.89921983	0.7523337	0.083471647	0.110950296
425000	12.95984445	0.7572	0.078695044	0.103929007
450000	13.01700286	0.761608	0.074241525	0.09747997
475000	13.07107008	0.765537	0.070076198	0.091538617
500000	13.12236338	0.769004	0.06618443	0.086065131
525000	13.17115354	0.772143	0.062509345	0.080955659
550000	13.21767356	0.77496698	0.05903213	0.076173736
575000	13.26212532	0.777501	0.055722629	0.071668884
600000	13.30468493	0.77982714	0.052563832	0.067404466
625000	13.34550693	0.78191128	0.049548729	0.063368735
650000	13.38472764	0.78379775	0.046654856	0.059524101
675000	13.42246797	0.78550596	0.04387076	0.055850321
700000	13.45883561	0.78705263	0.041186366	0.052329875
725000	13.49392693	0.78845243	0.038593329	0.048948202
750000	13.52782849	0.78971822	0.036079948	0.045687116
775000	13.56061831	0.79086134	0.033640789	0.042536899
800000	13.59236701	0.79189184	0.031270991	0.039488967

Appendix 18: Predicted participation probabilities and elasticities for charcoal-only (C=1,E=0) Consumers

pc_texp (ZMK)	ln(pc_texp)	Participation Probability (C=1, E=0)	Total ME of ln(pc_texp)	Participation Elasticity (C=1,E=0)
5000	8.517193191	0.12217974	0.277325758	2.269817879
25000	10.1266311	0.57163533	0.019116966	0.033442589
50000	10.81977828	0.5120299	-0.155791672	-0.30426284
75000	11.22524339	0.443448	-0.175268565	-0.3952404
100000	11.51292546	0.393663	-0.168930649	-0.429125036
125000	11.73606902	0.357124	-0.157935162	-0.442241804
150000	11.91839057	0.32932	-0.146849381	-0.445916983
175000	12.07254125	0.307459	-0.13671471	-0.444659971
200000	12.20607265	0.2898022	-0.127733692	-0.440761635
225000	12.32385568	0.275224	-0.119794179	-0.435260658
250000	12.4292162	0.262974	-0.112758701	-0.428782696
275000	12.52452638	0.252526	-0.106509678	-0.421777077
300000	12.61153775	0.243501	-0.10093183	-0.414502731
325000	12.69158046	0.235624	-0.095896165	-0.406988104
350000	12.76568843	0.228687	-0.09136374	-0.399514358
375000	12.8346813	0.222528	-0.087225425	-0.391975056
400000	12.89921983	0.217015	-0.083455189	-0.384559541
425000	12.95984445	0.212094	-0.079993022	-0.377158347
450000	13.01700286	0.207588	-0.076792186	-0.369925939
475000	13.07107008	0.203498	-0.073852793	-0.362916556
500000	13.12236338	0.199799	-0.071101837	-0.355866833
525000	13.17115354	0.196392	-0.068550658	-0.349050152
550000	13.21767356	0.193259	-0.066171574	-0.342398409
575000	13.26212532	0.1903797	-0.063938037	-0.335844823
600000	13.30468493	0.18768891	-0.061837377	-0.329467402
625000	13.34550693	0.18520512	-0.059858601	-0.323201651
650000	13.38472764	0.18289412	-0.057992923	-0.31708468
675000	13.42246797	0.1807388	-0.056229543	-0.311109417
700000	13.45883561	0.17872437	-0.054558076	-0.305263777
725000	13.49392693	0.17683783	-0.052967813	-0.299527611
750000	13.52782849	0.17506776	-0.051458107	-0.293932517
775000	13.56061831	0.17340407	-0.050019517	-0.28845642
800000	13.59236701	0.17183783	-0.048647196	-0.283099452