ADDIS ABABA UNIVERSITY
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ESTIMATING HOUSEHOLD ENERGY DEMAND OF RURAL ETHIOPIA USING AN ALMOST IDEAL DEMAND SYSTEM (AIDS)

BY
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"Estimating household energy demand for rural Ethiopia using an almost ideal demand system."

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ABSTRACT

The paper attempts to estimate household energy demand (fuel choice) using panel data for different sources of energy consumption. The study contributes to the contemporary literature a coherent view of energy demand (fuel choice) in rural setup. The result of the finding suggests that as household's total expenditure rises, fuel option widens and fuel mix may change. They respond by increasing the number of fuels they use exhibiting fuel stacking (multiple fuel use) behavior but traditional/inferior fuels are rarely entirely excluded from household energy mix. It also suggests that households do not simply substitute one fuel for another due only to income or expenditure increases, rather diversify their fuel consumption in a process of fuel stacking. To envisage this issue deeply, the study used econometric tool of the linear approximation almost ideal demand system (LAAIDS) with normalized prices to compute expenditure elasticities and the multinomial logit model of household fuel choice behavior.

The fuel stacking (energy mix) model is based on the fact that in any point in time, rural households use multiple sources of energy. Households make inter fuel switch and inter fuel substitution in optimizing their energy mix by adopting multiple fuel use (fuel stacking) strategy in response to expenditure change; rather than completely transiting to consumption of new fuels as the energy ladder hypothesis suggests. To prove this, we computed the expenditure or income elasticities of demand for inferior fuels and advanced fuels. The result of the study, that demand is expenditure elastic for advanced fuels and expenditure inelastic for traditional/inferior fuels provides solid and consistent argument/evidence to the economic literature that despite the income constraints, households prefer the normal good (advanced fuels) to the traditional (inferior fuels).

Furthermore, the study used multinomial logit estimate of the determinants of household choice between inferior fuels, advanced fuels and mix of the two fuels to scrutinize the fuel stacking (multiple fuel use) behavior of households in the energy mix model. Our result indicates that household's total expenditure, the fact that the household is female headed, total land owned by household (land holding size), total number of livestock

owned by household and family size square as predictor have positive coefficients of parameter estimate. This implies that the likelihood of household's choosing inferior fuels or mix of inferior and advanced fuels (except for total number of livestock owned) away from advanced fuels increases with increment in these predictors. However, family size, education of household head, age of household head, time spent on fuel collection and expenditure on advanced fuels have negative parameter estimates. This indicates that it is less likely that households choose inferior fuel or mix of inferior and advanced fuels compared to advanced fuel with increase in these variables as predictors. Our result indicates that fuel stacking or multiple fuel use is a more applicable hypothesis for rural households of Ethiopia than the simplistic energy ladder hypothesis.

In rural areas, however, energy choice of household is constrained by lack of access to commercial fuels, energy using equipments and appliances, energy supply dependency and affordability as well as consumer preferences and tastes. Therefore, rural households have less potential for fuel switching due to the aforementioned factors and the existence of fuel wood which is gathered without any financial payment.

1. INTRODUCTION

1.1 Background

Poverty is a multifaceted and complicated challenge for most African countries. In these countries population growth is shooting at an alarming rate; putting a great pressure on the natural environment and ultimately on people's life as they often depend directly on a wide range of natural resources and ecosystem services for their livelihood, health, and sense of empowerment [Bruce *et al.*, 2000., Arnold *et al.*, 2003, 2006].

With enormous rate of population growth, energy demand per capita grows rapidly. This creates a serious problem in countries like Ethiopia with population size of about 80 million, out of which about 85% is dwelling in rural areas with little or no access to modern energy. The country is the second most populous in sub-Saharan next to Nigeria. Access to advanced fuels such as Liquidifies Petroleum Gas (LPG) and electricity are totally lacking. Almost all fuel consumption of the rural poor is obtained mainly from the traditional biomass. This results in deforestation and disruption of the ecosystem.

This paper analyzes household energy demand (fuel choice) in a fuel stacking or multiple fuel use context for rural households of Ethiopia. It focuses exclusively on energy use and household energy consumption pattern for household purposes (i.e. for lighting, cooking, heating, etc). More specifically, it aims at estimating household energy demand using panel data for different sources of energy. Very few Studies exist on energy use optimization (fuel choice) and fuel stacking (multiple fuel use) behavior of household of

Sub-Saharan African countries. Households consume a portfolio of energies (mix of different energy sorts) rather than ascending from inferior fuels like fuel wood to modern energy sorts, which lays in the sprite of the energy ladder hypothesis. The issue of fuel stacking or multiple fuel use behavior by household for rural Ethiopia is scrutinized in this study using econometric model of panel data.

The econometric tool used for this study is the almost ideal demand system (AIDS) of computing income or expenditure elasticities and the multinomial logit model of household fuel choice decision. The paper estimates the income effect in an energy demand (fuel choice) system with household level panel data. It explores further the issue by providing a more in-depth analysis of the wealth or income effects of household energy consumption. Furthermore, it focuses on household fuel use patterns and assesses the potential and the constraints for welfare enhancement through policies to promote inter-fuel substitution. The study gave special consideration on the factors that guide households to optimize their fuel mix by switching between the different energy sources.

1. 2 Statement of the problem

The lack of adequate energy services in rural areas of developing countries has social and economic dimensions as well as serious environmental and health effects. Energy in rural areas, fuel wood collection as well as its use has strong implication for household labour allocation. When the environment is degraded forest recedes. So, spending more time and effort in collecting fuel wood becomes a tiring and arduous activity. Different studies conducted on natural resource degradation have focused on the impact of deforestation on household increasing time spent on fuel gathering [e.g. Heltberge et al.,2000; ESMAP, 2003). On the other hand, fuel wood collection has strong implication for child labor where the problem hurts the economic and social welfare children in less developed countries. . In this line, Dasgupta (1995) argued that Children are significantly involved in collecting firewood, so forest degradation may induce lower levels of schooling and child health. Moreover, various empirical works noted that cutting of trees, use of animal dung and agricultural crop residue for fuel and other purposes (building residential house, timber and so on), aggravate soil erosion, and thus affect agricultural productivity adversely [Dankleman and Davidson, 1989; Duraiappah, 1998; Shibru, 1996; Sinkhane, 1995].

Furthermore, shortage of energy supply can harm the environment. There is a strong trade-off between the objective of tackling energy poverty and the objective of improving the environmental problems linked to energy conversion and use. Poor rural households usually have fewer energy options. That is households with low levels of income will be unable to afford costly fuels. In this aspect, Bhagavan and Kapekez (1992) argued that rural energy crisis is rooted in poverty, under development and resultant ecological destruction. Hurst and Barnet (1990) also stated that deforestation can have severe environmental implication because of catastrophic destruction of natural forests with consequent environmental decay. Hence, rural households have less potential for fuel switching and energy transition.

This nexus between energy poverty and environment is sensible to our intuition in case of Ethiopia. Most rural households of Ethiopia have low and sporadic income, which influences their choice among different fuels. Unavailability of better energy option itself also hampers household energy switch in rural Ethiopia. The problem of supplying the rural poor with modern fuels thus appears daunting. However, the main focus of this study rests up on the demand side of rural household energy and how different energy types substitute each other or how households choose between different energies.

Poor rural households spend much time on income generating activities to secure other necessities for their livelihood. Thus, they tend to reduce time allotted to energy search, switch to traditional fuel alternatives, reduce leisure time or switch to the relatively easy to cook foods. But this reduces household nutrition status and according to Kgaithi et al., (1997), fuel switching results in to food switching.

In the existing economic literature, though household energy demand (fuel choice) might arise intuitive enough, neither its theoretical nor its empirical underpinnings have been deeply explored. Moreover, it is fair to say that in the field, there are controversies on many important issues. For example, different conclusions have been reached about the factors that drive inter fuel substitution and the income switching points at which of consumers' transition to higher grade fuels. There is also a debate in the energy literature about the impact of energy prices on low-income rural energy consumers, and the efficacy of different policies targeted at encouraging inter-fuel substitution. Part of the reason behind this lack of consensus is the fact that conclusions in the literature have generally arisen from extrapolating the results from individual studies of single city, village or region, or few cities, villages, regions [for example, Alam et al., 1985; Barnes, 1990; Dewees, 1995; Foley, 1987; Leach, 1987; Masera et al., 2000; Moges, 2006; Alemu, 1999; Faye, 2002]. In the field there are very few rigorous micro-econometric studies on the determinants of energy demand (fuel choice) at the micro household level, with a few recent exceptions [e.g. Chaudhuri and Pfaff, 2004; Foster and Rosenzweig, 2003]. Moreover, some of the determinants of household energy demand (fuel choice) appeared to have ambiguous effect on fuel stacking behavior of households in different literatures.

To this effect, household energy demand (fuel choice) in Ethiopia was examined by a number of empirical studies [CESEN, 1986; Asmerom, 1991; Alemu, 1999; Bereket et al., 2001; Faye, 2002]. But, there are several shortcomings in this studies that invite further studies in order to enrich the literature. None of these studies provide energy mix model capturing all energy sorts and some of them exhibited methodological problems. For instance, CESEN (1986) provides estimation of energy end-use demand functions, thus the result cannot be used as direct policy inputs. Asmerom (1991) results are not consistent and harmonious with the contemporary literature as it is based on the inherently flawed estimation technique. Bereket et al. (2001), Alemu (1999) and Faye (2002) are relatively better in terms of coverage of the various types of energy sources and the functional forms used for model specification of empirical study. However, the former two studies [Bereket et al., 2001; Alemu, 1999] used the Tobit model whose reliability is highly dependent on absence of heteroskedasticity and non-normality, both of which are almost always existent. The later used cross-sectional data, which suffers from the limitations of unobserved individual heterogeneity; which this study tries to control using panel data. Therefore, the central focus of this study is to bridge the observed gap by exploring the issues of multiple fuel use (fuel stacking) of household and to determine how different factors interplay to gear households towards such behavior.

Estimation of energy demand (fuel choice) in the context of fuel stacking (multiple fuel use) is nonexistent for the country in general and rural households in particular. Moreover, the use of panel data in estimating household energy demand in rural Ethiopia is the first attempt. The advantage of the longitudinal structure of the survey in this study is to control for unobserved individual heterogeneity using household random effects. This paper makes new contribution with respect to several important issues dealing with estimation of the household demand function for all sorts of energy consumption. It provides an almost ideal but complete and fully-specified energy demand system, including effectively all household expenditure on all energy types. The contribution of this study is to provide a coherent view of rural household energy demand (fuel choice) and energy transitions (fuel switch), and the associated policy options for intervening in the rural energy setup.

In general, the attempt of this study hinges on establishing causal relationship between micro-level consumption determining factors and energy demand (fuel choice) of household for rural Ethiopia in a fuel stacking (multiple fuel use) context. No study used an almost ideal demand system (AIDS) and multinomial logit model in estimating the energy demand (fuel choice) of rural households of Ethiopia in the context of fuel stacking (multiple fuel use).

The central questions that this paper engages are: how changes in ladder variables play role in shaping demand conditions of household energy?; what are the deterministic factors or deriving force for households to choose one form of energy to the other in the fuel stacking process?, how households optimize their energy demand (fuel choice) in the energy mix model when income or expenditure changes?.

1.3 Objective of the study

The principal objective of the study is to estimate household energy demand (fuel choice) in the context of fuel stacking (multiple fuel use). In this study, the concepts of income response, the inter fuel substitutability in the energy mix model are used in estimating energy demand of household. In particular, it examines household's energy demand response to their income progression. It specifically focuses on:

- Estimating the household demand (choice) for different sorts of energy.
- Determining and assessing roles of different factors that influence household energy demand (fuel choice).
- Computing the expenditure elasticities of different energies consumed by households; and examining whether demand is expenditure elastic or inelastic and whether the fuels are inferior or normal goods.

1.4 Hypothesis of the study

The study conducts a number of hypothesis tests. Some of the null hypotheses are:

- The demand of household for specific energy or energies on the same juncture of the energy ladder increases as income or expenditure of the family increases (horizontal energy/fuel diversification).

- Rise in income of household give rise to possibility of substituting more efficient (modern fuel) for the traditional or inferior fuel (vertical energy/fuel diversification).

1.5 Limitation and Significance of the study

The study utilizes panel data collected by Addis Ababa University in collaboration with center for study of African Economies, Oxford University. It was collected for last time in 2004. But the 2004 data is not made accessible for research use and this study used the 1994 and 2000 surveys. Therefore, it may fail to disclose the present situation. Despite all the benefits of panel data, it suffers from limitations such as attrition and panel imbalances. To collect primary data it is very costly and difficult to obtain sample from overall the country.

Almost none of the studies conducted on household energy demand explicitly dealt with the rural residents using panel data econometric model. This study contributes to the existing literature and lays an important benchmark for future researches to be conducted in the subject area. Its distinction from those of pioneer studies is that it attempts to use panel data and focus on energy demand of rural households in the context of fuel stacking (multiple fuel use) behavior. Bhagavan and Kapekez (1992) noted that assessment of present energy flow and energy requirement of rural areas is needed to incorporate rural population in to over all national energy development and in order to identify strategies and options.

The finding of the study is invaluable input for policy intervention that is intended to reduce the health impact of indoor air pollution resulting from use of inferior fuels and to rehabilitate the natural environment and the resulting ecological decay. Policy interventions in the energy sector especially rural household will encourage an effort of alleviating poverty. Therefore, despite all the limitations, the importance of this study is by no means ruled out.

1.6 Methodology

The aim of this paper is to model the relationship between energy demand (fuel choice) and the underlying factors for rural households of Ethiopia. In particular, we investigate the role of income/expenditure as a major deterministic force for energy transition and or fuel stacking.

Household fuel choice has often been conceptualized using the energy ladder model and fuel stacking (multiple fuel use) behavior of households. This study places heavy emphasis on income or expenditure in explaining fuel choice and fuel switching practices of households. To do this, we adopt a simple model of economic behavior called the linear approximation almost ideal demand system (LAAIDS) and then show how energy demand for each fuel types relate to the various variables in the model. We then specifically discuss the relationship between expenditure and energy demand in the economic model controlling for other factors. The ladder variables that are used for estimation of household energy demand (fuel choice) include; household total expenditure, assets such as Land, livestock, and household characteristics like family size, education of household head, gender of household head and total time spent on fuel collection … etc.

This paper aims at estimating expenditure elasticities of energy consumption using the standard demand concept, which includes income or total expenditure factors as major explanatory variable. The framework of the linear approximation Almost Ideal Demand System (LAAIDS) with normalized price is used in this study for modeling the energy consumption in rural household of Ethiopia.

The model is typically a kind of the agricultural household model. This is because in the model, households are thought to derive income from sale of agricultural produce, labor wage, non-labor (transfer) incomes and non- farm business activities. More specifically, the model is applied to analyze how changes in household income or expenditure affects household energy demand (fuel choice) in a fuel stacking or multiple fuels use context.

The non existence of monetized market for rural energy (traditional fuels) necessitates modeling of household labour time allocation between fuel wood and other tasks. Given the absence of markets for traditional fuels, and the importance of self-employment in these settings, household decision concerning labor supply, consumption and fuel collection are made jointly. This study will make an attempt to model household labor allocation decision and its effect on household energy demand. Then, estimate the shadow prices of traditional/inferior fuels collectable free of financial cost.

The study segregates the different household energies in to two: the traditional or inferior fuels (which in this study include fuel wood and charcoal), modern or advanced fuel sources (which mainly include kerosene, match, batteries and candle). Then LAAIDS model will be estimated separately for each of the two energy types. Moreover, for empirical investigation, the two panel data models, fixed effect and random effect estimates are conducted using pooled OLS and GLS estimations respectively. Haussmann test is employed to make distinction and comparison between the two parameter estimates.

Using a multi-stage budgeting approach, the share of energy in total household expenditure and the share of inferior fuel and advanced fuel in the total energy expenditure of rural households are estimated. Finally, the multinomial logit model is used to model the fuel choice decision of household among the aforementioned energy categories and mix of traditional and advanced fuels as a third alternative to examine the fuel stacking (multiple fuel use) behavior of households. Moreover, using the model results the study carries out simulations to show how the policy intervention handles to reduce the demand for firewood and to mitigate environmental degradation. Demand equations for inferior fuel and advanced fuel types are econometrically estimated and the elasticities are used to examine the income effects.

1.7 Organization of the study

The remaining part of the study is organized as follows. The immediate up coming chapter provides a literature review where theoretical as well as empirical works are precisely presented. The third chapter discusses methodology and model specification issues. Here, econometric model for energy demand of household is developed. The forth chapter briefly discusses the empirical models employed for the study. Chapter five presents data description and the results or findings. Finally, the study is winded up by drawing conclusion and recommendation for policy implication in the sixth chapter.

2. LITERATURE REVIEW

2.1. Theoretical Survey

2.1.1. General overview of Energy consumption of the world

Economic development and energy demand interact and co-evolve together over time. There is great disparity between energy demands across countries. This gap is widening rather than narrowing. Chipman (1999) observed that disparities in household energy use exist between rural and urban populations, between high and low income groups within a country, and among countries. Developed and developing countries shared similarity in that for both fuel woods played a dominant role until the mid 19 century. But with economic development, the former shifted to more efficient and convenient sources of energies such as electricity, LPG.

This created huge gap as the richer is continuing to use more and more advanced energy while the poor is stacked at consuming inefficient fuel as source of energy. A body of literature has been written on this issue. For example, a recent work by Douglas et al. (2007) supported this aspect arguing that the poorer half of the world's people have long relied for their energy needs on wood fuels. Fuel wood has therefore remained vital part of life in many developing countries [Arnold et al., 2003]. A study on trends in consumption and production of household energy by Chipman (1999) also showed that since oil price shocks of the 1970s, pressure on forest resources has increased and the costs of traditional use of fuel wood have been growing-to the householder, in cash or collection time, and to society in inefficient energy use, deforestation, and local and global harm to health and the environment.

Similar observation by Echolm et al. (1984) stated that while the richer half of human kind ponders the vagaries of oil price and the dilemmas of nuclear power, the poor half still rely on the most inefficient fuel. To meet the basic energy needs of poor rural households become scarce; and hundreds of millions of third world residents face crisis of their own. By adding to the drudgery and expense of daily survival, the energy crisis further degrades the well being of the already desperately poor.

Echolm et al. (1984) also argued that until the 1970s the fuel wood crisis was largely ignored by the third world governments and international aid agency alike. However, more recently, fire wood scarcity has become major topic of concern. Same study indicated that in these countries heavy reliance on wood for energy is of course, nothing new. As recently as 1850, the US used wood for 90% of its fuel. The same line of reasoning indicated that fire wood scarcity and resulting hardship for the poor is not a new thing. European countries also experienced acute shortage of fuel wood. These facts according Echolm et al. (1984) in an indirect way may have had epochal historical significance.

On the other hand at micro counterpart level a huge gap remains between household energy use in developed and developing countries. Average per capita household energy use in developed countries is about nine times higher than in developing countries, and in developing countries a large share of household energy is non-commercial fuels [Chipman, 1999]. The difference in per capita energy consumption is also inevitable within a particular country between the relatively rich household and the poor. With relatively little pain the better off can purchase what wood they need, obtain it from their own land or switch to alternative fuels. Something seldom changed. As in the Marx's time, today's firewood crisis reflects the disparities in income and power between rich and poor [Echolm et al., 1984].

Furthermore, Echolm et al. (1984) also indicated that technological change and economic development in advanced countries of the world like UK and Europe could solve the fuel wood problem by permitting large scale shift to new fuels. In contrast, in the third world countries household fuel wood crisis is reinforced by poverty and technological backwardness. In addition, in these countries unaided market force will not relieve the fuel wood problem soon enough to avert wide spread human sufferings and ecological disruption. Thus market for rural energy demand is distorted and cannot reflect the true demand for energy. Moreover, in Sub-Saharan African countries huge population growth, meager income of household and the high cost of alternative fuels provide no hope that the demand for fuel wood will shrink dramatically.

Thus households in the rural areas of developing countries will face acute shortage of fuel wood and be able to cook their food only at the tragic costs for themselves and the environment. In addition for huge number of people, fuel wood will be increasingly scarce and expensive. This problem will be exacerbated by little effort by households to diversify their fuel choice or energy demand in to alternative fuels that can relieve the deepening crisis. In line with this argument, Kgaithi, et al. (1997) found that fuel switching is one of the strategies which household resort to in a situation of fuel wood scarcity.

Saddayoa (1985) noted that the demand for traditional fuels is heaviest in the rural areas and it is dominated by household use. Poverty and lack of human capital have left large segment of the population particularly the rural poor with no other recourse than extracting their livelihoods from the natural resource base around them. Thus poverty remains the driving force behind environmental degradation and ecological imbalances.

Deforestation is an important issue in the discussion of fuel consumption of rural households. Various literatures focused on this matter. Firewood gathered from commons forest is the major source of domestic energy in rural areas of many poor countries [Cecelski, Dunkerley and Ramsay, 1979; Heltberg et al., 2000]. Demand for fuel wood by subsistence agricultural households may be the leading cause of world deforestation [Amacher et al., 1993; 1996]. In recent decades, deforestation has come to be perceived as a global problem, because of the perception that the earth's resources are reaching the limits for supporting the world's population and economic systems [Schmink, 1994]. The recently growing empirical literature on firewood consumption and forest degradation focused mostly on India, Nepal, and china [Adhikari *et al.*, 2004, Amacher *et al.*, 1993, 1996; Heltberg *et al.*,2000; Chen *et al.*, 2006] and curiously, to our knowledge, only two paper dealt with this issue in a rural region of Ethiopia [Alemu ,1999; Moges, 2006].

2.1.2 General Overview of energy consumption in Ethiopia

The energy sector of Ethiopia is one of the least developed in the world despite the presence of an enormous energy resource endowment. This is reflected by the low per capita energy consumption of households. Furthermore, heavy reliance on traditional energy of rural households of Ethiopian has been focused by a number of studies. For example, Jargstorf (2004) stated that Ethiopia is the third largest user in the world of traditional fuels for household energy use, with 96% of the population dependent on traditional biomass (e.g., fuel wood and dung) to meet their energy needs. This is in comparison to 90% for Sub-Saharan Africa and approximately 60% for the African continent. The excessive deforestation, which led to the depletion of tree stock, caused what is known as the household energy crisis in Ethiopia. For the great majority of the population wood and other biomass fuels are the only source of energy which has negative environmental, ecological, and economic as well as health impacts on the life of the rural poor.

The cost of firewood increased, thus, challenging the already staggering living condition in the economy. This crisis led to consumption shift towards animal dung and crop residue as household fuels. These fuels are usually collected freely from farms. Hence, agricultural and crop residues have become important source of fuel for the rural mass, as fuel wood is becoming scarce. In this aspect, World Bank (1984) notes that although there is strong cultural preference in Ethiopia to use fire wood and charcoal for cooking, this preference had been affected by the scarcity of wood and hence, people started using dung and crop residue which accounted for over half of the total households' energy use. Increased burning of dung and crop residue, however, deprives the soil of important nutrients and hence reduces soil fertility. This adversely affects the agricultural sector which is the mainstay of the economy, and result in repercussion health problem and ecological imbalances.

Similar observation by Bhagavan and Kapekez (1999), on page 83 table 6.6, gives rural household energy use pattern of Ethiopia which is composed mainly of traditional fuels (98%). In addition, under the executive summary of report organized by S and T professional association (2002) on energy in Ethiopia; status, challenges and prospects; noted that overall energy profile of Ethiopia is characterized by heavy dependence on biomass with limited form of modern energy and generally low level of per capita energy consumption. The same summary also notes that in Ethiopia 96% of energy supply is from traditional energy, which is biomass and such consumption pattern created unbalanced ecosystem. It also stated that household is the major consumer of energy and almost entire energy demand of the sub sector is met from biomass sources and the ever increasing need existing for biomass energy is among the factors that constitute top causes of degradation. These studies and other complementary literatures suggest that Ethiopian households are stacked at consuming low grade energy types with all its repercussion effects.

2.1.3. Household economic frame work and energy demand (fuel choice)

Economics has traditionally taken the household to be the atomic unit of observation. So analysis of the consumption behavior and examination of decision-making within household unit requires its own field of inquiry. The household of agricultural sector is the predominant rural energy consumer. Household energy demand and energy choice in the past has often been understood through the lens of energy ladder.

Energy use of rural household is described by using economic framework. A study conducted by ESMAP (2003) argued in this line that the household economics framework clarifies that, in addition to income and market prices, the opportunity costs of firewood collection also need to be taken into account in shaping demand for all fuels. The opportunity costs to household of firewood collection are determined by factors such as household wealth, labor, and availability of wood resources.

Fuel diversification and inter-fuel substitution can help to discourage the use of traditional fuels and to optimize fuel mix (choice) in the energy portfolio. Since fuel wood is used mainly at household level, modeling household demand behavior is a critical issue. *A* study by IEA (2005) argued that the major goal of fuel diversification is to reduce dependence on traditional fuel and switch to modern fuel through increased fuel efficiency, as an alternative or complementary in end use. It is also noted that energy efficiency improvements enhance both energy security and environmental protection. In addition to energy security, environmental issues may provide a large part of impetus for introduction of alternative fuels in the rural household. Fuel choices therefore need to be understood in terms of relative household resource scarcities.

The household economics framework also makes it clear that it may be perfectly rational for households to use a portfolio of different energy sources (energy mix) at any point in time. This is often facilitated through policies to promote inter-fuel substitution and use of improved stoves. Most papers that compare firewood consumption with other energy sources emphasize the substitution patterns between fuel wood and lower substitutes, such as animal dung or crop residues. Although the use of such substitutes may be less detrimental to forests, there is a trade-off between using them as agricultural inputs and burning them for fuel [Heltberg et al., 2000].

Household fuels are defined as energy sources used for domestic cooking, space heating, and lighting and exclude fuels used for transportation or commercial purposes. However, bulk of the energy consumption in the household is directed towards cooking. The traditional view on fuel switching in the household sector of developing countries has been that households gradually ascend energy ladder and that there is a simple linear progression from relatively inefficient fuels and energy end-use equipment to more efficient fuels, electricity and equipment, with increasing income levels and urbanization [Leach, 1992; 1991 and Reddy, 1994]. However, recent literatures on household energy use in developing countries show that the energy ladder theory is too simplistic and that there are many other factors other than income that determine fuel choice of household [Davis, 1998 and Masera et al., 2000].

The study by Hosier and Dowd (1987) tests the energy ladder hypothesis empirically for household fuel choice in Zimbabwe using a multinomial logit model and also shows that although economic factors do affect fuel choice, a large number of other factors are also important in determining household fuel choice. In addition, much of the literature bears out that fuel switching is often not complete and it is a gradual process with many households often using multiple fuels. The reasons for multiple fuel use are varied and not dependent merely on economic factors, although the affordability or cost of the energy service also has an important bearing on the household's choice.

Household sector is the major consumer of rural energy. In rural areas, energy choices of households are constrained by lack of access to more commercial fuels and markets for energy using equipments and appliances. Often, the choice of fuel is determined more by local availability, transaction and opportunity costs involved in gathering the fuel (mostly wood, dung and other bio fuels) rather than by household budget constraints, prices and costs. In contrast to rural households, urban households have a wider choice and greater accessibility to modern commercial fuels, electricity, and energy end-use equipment and appliances. Therefore, they have greater potential influence on fuel switching ESMAP (2003).

2.1.4. Factors affecting energy demand of household (fuel choice)

No household wants energy for itself. It is needed for the purpose that it can do. Approaching development impacts from a demand side perspective, one wants to keep in mind, however, that what is specifically in demand is not fuels or access to energy sources. It is rather the services that the energy may provide, such as lighting, cooking, space heating, or pumped water [Muleguetta, Dunnet, Khennas, and Rai, 2006]. This means that it is a "derived demand". In this light, it is important to assess the factors that influence energy demand of household, especially in terms of demand management and end-use considerations.

In the household sector, the key determinants of energy demand or fuel choice are: (a) the relative price of the energy form and the appliance, (b) the disposable income of the household, (c) the availability of the alternative fuels and related appliance(s) in the market, (d) particular requirements related to each energy end-use, and (e) cultural preferences and the like.

In addition, household fuel consumption generally follows the "energy ladder"; the household moves from consuming less costly and less convenient fuels (wood, other biomass) to energy of intermediate price and quality (charcoal, kerosene) to more expensive, highly convenient types of energy (LPG, electricity), as their incomes rise and/or habits change over time. For example, World Bank (1993) point out that sharp increase in conventional energy prices and the need to develop substitutes for fuel wood have aroused considerable interests in renewable energy resources in developing countries.

Bhagavan and Kapekez (1992) found the following factors as reasons for variation of household energy consumption overtime:

- Fuel availability is influenced by seasonal variation (for example, during rainy season it is difficult to obtain fuel wood).
- Temperature variation affects amount of fuel consumed by household; since space heating may be required during cold day.
- Seasonal dietary change and festival that require more cooking may take place during certain period of the year.

An important consequence of the dynamics of the energy ladder is the shift in fuels used by rural household (and their related environmental problems) notably recognized in recent years. The consumption of energy and appliances by households, and the service industry has changed significantly. Growth in household incomes and urbanization has been accompanied by a change in the fuel mix to energies that can be used more efficiently. As incomes and urbanization continue, the share of traditional fuels used in cities will diminish while share of modern fuel consumption will increase.

Chipman (1999) identified the key determinants of energy demand in the household sector. These include: prices of fuels and appliances; disposable income of households; availability of fuels and appliances; particular requirements related to each; and cultural preferences. With increasing disposable income and changes in lifestyles, households tend to move from the cheapest and least convenient fuels (biomass) to more convenient and normally more expensive ones.

According to Chipman (1999), there is a strong positive relationship between growth in per capita income and growth in household demand for commercial fuels. Household energy transitions are often discussed in the literature as smoothly sequenced evolution from firewood, to charcoal and kerosene, and ultimately to LPG and electricity consumption. But according to Douglas, L. (2007), the converse is true. The energy transitions are in fact quite varied, in terms of the timing of the transition period, and the transition fuels consumed. In urban households of most developing countries, demand for commercial fuels has risen more rapidly than per capita incomes since 1970. This reflects the increasing desire for comfort and discretionary energy consumption Douglas, L. (2007).

Energy demand in rural household set up is quit different from that of urban because of the existence of fuel wood which is gathered without any financial payment. Barnett (2000) underlined this point and made distinction between different forms of energy types in his statement;

Clearly all modern fuels and some traditional fuels are traded (wood fuel is increasingly traded for money, and charcoal is almost always traded) and are therefore known as "commercial fuels" to distinguish them from "non-commercial fuels". While non commercial fuels are not traded for cash, they are not "free". This is because non-commercial fuels usually require considerable expenditure of time for their collection and processing (and this time can have a high opportunity cost in terms of other things that the collectors – usually women and children – could be doing, including going to school, if they were not collecting fuel). In addition, both non-commercial and commercial fuels may incur costs (often called "externalities") on society that is not necessarily reflected in their price (such as environmental damage). Some forms of energy from "traditional biomass" can be converted into more useful forms and are then known as "modern biomass fuels" (for instance biomass can be converted into liquid or gas fuels).

For households to switch to alternative fuels; availability of the fuel is a constraint. Access to electricity has often been found to be another important determinant of the energy transition [Campbell et al., 2003; Davis, 1998; Ouedraogo, 2006]. However, households in the rural area have no privileged to get electricity. Rather,they optimize their energy demand (fuel choice) which is mostly inferior form.

2.1.5. The Energy Ladder Hypothesis and fuel stacking by households

The general pattern of fuel use for cooking in developing countries dictates that with increasing income people move up the energy ladder from firewood to charcoal or kerosene and then to LPG, natural gas, or electricity. Analysts use a simple model, the 'energy ladder' [Leach and Mearns, 1988; Leach, 1992; Masera et al., 2000], to describe a hierarchy of household energy options characterized by attributes such as cost, energy efficiency, cleanness, and convenience. The energy ladder model has been shown to be strong in its emphasis on the role of income in determining fuel choices. The energy ladder states that households switch their fuel use from biomass to modern energy sources as a country develops and incomes increase, implying that firewood is an inferior good [Arnold *et al.*, 2006].

However, in rural areas inferior fuels such as firewood, dung and crop residue which are relatively dirtier and less convenient to use are available for free or at least cost. Thus, rural households have little incentive to shift to advanced energy forms. Even though the relatively richer households do so, they will not entirely give up the biomass fuel. But, Kammen & Lew (2005) showed that fuel wood, which is near the bottom of the cooking energy ladder, due to inconvenience and smoke emission, is not necessarily the cheapest of energy options. Cleaner and more convenient fuels tend to transfer heat more efficiently, are easily controlled over a range of heat outputs, and are much costlier. They may require large lump payments for the fuel as with LPG, or large up-front expenditure for the stove, as with gas and electric cookers.

Munasghe and Meier (1993) conceptualized the energy ladder hypothesis where they put array of the different energy sources in terms of increasing efficiency which they called a typical "*substitution ladder*". At the bottom of the ladder they identified low quality biomass fuel such as dung and crop residuals. This is followed as households move up the ladder by high quality fuel such as wood and charcoal; Kerosene; LPG and finally natural gas and electricity, respectively in that order. The core issue in this regard for policy makers is the threshold level of income at which transitions occur. This replacement of "*traditional sources*" of energy with "*commercialised*" fuels of increasing efficiency is known as "*the energy transition*"[Barnett, 2000]

Similarly, as cited in ESMAP (2003), Leach (1992) envisions the energy ladder model at three-stage fuel switching process. The first stage is marked by universal reliance on biomass. In the second stage, households move to "*transition*" or intermediate fuels such as kerosene, coal, and charcoal in response to higher incomes and factors such as deforestation and urbanization. In the third phase, households switch to LPG and electricity once their income is sufficient.

Problems with the energy ladder model arise from the simplified way that the model is applied to policy-making and the mistaken conclusion that fuel choice is determined by purely economic factors. However, as in the movement on a ladder, it appears to imply that a move up to a new fuel is simultaneously a move away from previously used fuels [Heltberg, 2005]. Moreover, ESMAP (2000) and Foley (1995) suggest the idea of the energy demand ladder, where it is argued that as income rises household's demand for fuel will be guided by the nature of appliances used and that fuel choice/demand depends on the purpose. An increase in household income will not necessarily be spent on cooking stoves or fuel. Complete and exclusive switching, where one fuel totally substituted for another is rare. It must be noted, however, that the transition may not be neat in the sense that at higher income, households may tend to use one or more of a particular traditional energy source together with the modern energy sources. The reason may be due to non-replaceable use of some of these energy sources and cultural preferences. This may cause a household to retain a particular fuel/stove combination to cook certain foods or to use on special occasions.

Evidences from a growing number of countries suggests that modern fuel adoption often results in multiple fuel use, where households consume a portfolio of energy sources at different points of the energy ladder [see for example Barnes and Qian , 1992; Hosier and Kipondya, 1993; Davis, 1998]. Ease of access and consistent availability of fuels are important factors that determine the extent and/or permanence of fuel switching in any household. Currently emerging literatures argued that households in developing countries do not switch to modern energy sources, but instead tend to consume a combination of fuels. This phenomenon has been termed fuel stacking [Masera et al., 2000; Heltberg, 2005].

Moreover, common observation indicates that household's energy demand (fuel choice) is end use specific under certain circumstances. For example, for rural households kerosene is mainly used for lightening while animal and plant residues largely used for baking bread. This fact gives rise to households retaining certain proportion of different kinds of energy in their energy mix (energy portfolio). Supporting argument was given by Barnett (2000) in his study indicating the energy transition is also driven by the fact that each end use needs to be matched by a particular energy source. Energy end uses range from subsistence needs like cooking, space heating, and lighting to income generating activities and entertainment. However, the relative importance of fuel stacking (multiple fuel use) and fuel switching has not been well established in the literature [Heltberg, 2005]

The mix of sources and quantity of energy that households use can change depending on domestic and international fuel markets, fluctuating household incomes, and seasonal conditions that affect labor markets and fuel availability. It gives the rational for the argument that households will not make complete transition from exclusive use of one form of energy to exclusive use of another. In this aspect, ESMAP (2003) noted that fuel interrelationships take two forms. On the one hand, individual cooking fuels compete in price, convenience, and other parameters. Furthermore, fuels are often consumed in conjunction.

Poor rural households often rely on a mix of traditional fuels such as animal dung and crop residues, and fuel wood and to very minimal extent on commercial energy sources, including, kerosene, liquefied petroleum gas (LPG) and electricity. They usually have fewer energy options. ESMAP (2003) in the study of household fuel use and fuel switching in Guatemala observed that as incomes grow people start to demand more diversified energy sources. This is because they can afford to purchase varieties of appliances each of which requires a specific energy source.

In contrast, households in rural areas are supposed to need only wood for basic cooking. Although undoubtedly true, the finding of widespread use of multiple fuels for cooking suggests genuine fuel stacking for a given purpose [see also Davis, 1998]. The higher cost of, and lack of access to commercial forms of energy, and the lower income characteristic of rural populations compel them to rely more heavily on traditional fuels, and limit the diversity of possible end-uses. According to World Bank (1993), shortage of energy is a factor for households to account for small proportion of the total commercial energy used in developing countries.

The energy ladder is a commonly used concept in models of domestic fuel choices in poor countries [Alam, Sathaye and Barnes, 1998; Campbell et al., 2003; Davis, 1998; Hosier and Dowd, 1987; Leach, 1992]. The principal notion underlying this concept is that households face a range of energy supply choices, which can be ordered from least to most technologically sophisticated. A transition from biomass fuels to more sophisticated alternatives occurs as part of the process of economic growth [Macht, Axinn and Ghimire, 2007].

More nuanced formulations of energy transition theory suggest that the scenario of households switching from exclusive use of one type of fuel to exclusive use of another is overly simplistic. For example, Barnes and Floor (1999) argued that the simple energy ladder model is sometimes extended with more elaborate intermediate steps. More accurately, steps on the energy ladder include households using various combinations of fuels. Although the use of biomass fuels may gradually decline from exclusive use by many households towards less use by fewer households, the use of biomass fuels may not be entirely abandoned as households climb the energy ladder [Campbell et al., 2003; Hosier and Dowd 1987]. Moreover, in his analysis of multiple fuel use patterns in South Africa, Davis (1998) noted that changes in fuel choice were not a smooth transition from biomass to commercial fuels, but a continual switching between different combinations. He found that while high-income households were more likely to rely only on electricity, low-income households were more likely to rely on four or more fuels even if they were electrified. Therefore, it is important to include non-wood fuels in households' fuel selection. The literature makes clear that observed patterns of energy production and utilization reflect a great deal of subtle optimizing behavior, given the constraints faced by the economic actors [Barnes and Floor, 1996].

From the energy ladder hypothesis, we may infer that shocks to the price of certain type of energy may result in to bidirectional move of different households along the ladder. The richer households are likely to increase the proportion of advanced energy in their energy mix while the relatively poor go down to consumption of inferior types. For example, the increase in price of fuel wood either in cash or in terms of time required to collect fuel wood may encourage the richer to substitute Kerosene or any other advanced fuel, while the poor increase consumption of animal dung and crop residue which are perceived to be inferior to fuel wood. A study by Toman and Jemelkova (2003) found in this aspect that, changes in relative opportunity costs as well as income can move households and other energy users up and down the ladder for different energy-related services.

However, in rural areas, the decision of household to switch from one form of energy to the other is very complicated. There appears to be no clear order of preference and progression in terms of the switching and substitution behavior of households in their choice of cooking fuel. Studies that have been done on the determinants of fuel transitions have linked factors such as income, access to electricity, and forest scarcity to fuel substitution [Alam, Sathaye and Barnes, 1998; Campbell et al.,2003; Davis, 1998;

Heltberg et al., 2000; Madubansi and Shackleton, 2007; Ouedraogo, 2006]. Although there have been few studies of changing household fuel choices, evidence of the energy transition is mounting [Macht, William and Ghimire, 2007].

However, in the context of rural households, Madubansi and Shackleton (2007) noted that the introduction of electricity into a rural region of South Africa had little impact on fuel wood consumption. Other factors associated with reduced consumption of fuel wood and instead use of alternative fuels are forest scarcity and increased fuel wood collection time [Heltberg et al., 2000] and household size [Alam, Sathaye and Barnes, 1998; Ouedraogo, 2006].

World Bank (1990) in its report on household energy handbook pointed out that to cope with deepening crisis of energy scarcity, households adopt two methods. First household energy should be made more efficient. Secondly, fuel substitution need to be encouraged. A stylized fact in the energy demand (fuel choice) and fuel use literature is the existence of a transition process whereby households gradually ascend energy ladder as the disposable income increases. This point is discerned by the model of energy ladder which is a complicated process than simply ascending from traditional energy sources to modern energy form. The ladder begins with biomass fuels (firewood and charcoal), moves to modern commercial fuels (kerosene and LPG), and culminates with electricity [see World Bank, 2000]. The principal notion underlying this concept is that households face a range of energy supply choices, which can be ordered from least to most technologically sophisticated, efficient and convenient energy forms.

2.2. Empirical Literature

In energy economics, there are some studies that have focused on the energy demand of household and how the economic unit responds to the change in various determinants of it. These papers gave special consideration on the factors that guide households to optimize their fuel mix by switching between the different energy sources. This study reviews literature surveys considered to be critical for building consistent and concrete knowledge in the area of household energy demand.

Jack (2004) used panel data on Peruvian household to compare point estimates of price and income elasticities of demand for clean fuels with pooled estimates. In the household fuel choice literature, the use of cross section data suggests that error introduced by unobserved heterogeneity is likely to lead to overestimating the effects of price and income. Raja and Bousquet (2003) also used panel data of French industrial plants and estimated empirical price elasticities of energy demand from the model. Farsi et al. (2004) noted that in the literature there are few studies that have tried to investigate factors affecting fuel choice using disaggregate household data. Baker et al. (1989) conducted study on an ideal demand system and Gorman polar form two stage to study household energy demand conditional on durables using family expenditure survey. In this work, the implied price and income elasticities are emphasized and it was the fuel category (gas and electricity that are used for the study) that where found to be inferior goods for over half of the sample.

2.2.1. Determinants of household energy demand

2.2.1.1. Household Size

Large families are an economic asset in the countryside, since child labor can be used for fuel wood collection and labor-intensive agricultural production [Dasgupta, 1998]. But large families become economically unsustainable as in rural household family members cannot generate income in formal markets. While immigrants to urban areas initially retain rural traditions, including large families, the economic realities of urban life gradually reduce household sizes. Correspondingly, the demand for traditional fuels falls, both because of the rising time opportunity costs for urban residents working in formal markets, and because of the availability and economy of alternative energy sources.

Démurger and Fournier (2006) identified that household size is an important explanatory variable in household energy demand and their estimated specification shows a concave effect of household size on fuel wood consumption. This result is consistent with expectations given the fact that, as the number of members in a household increases, energy demand also increases (and eventually also the supply of labour for collection). However, the additional member benefits from the firewood consumption of other members (for both heating and cooking) resulting in economies of scale.

Douglas et al. (2004) also observed that larger urban households tend to select traditional fuels to a great extent whereas smaller households tend to choose the relatively more of modern fuels. It also showed that although larger households generally choose traditional (and often less efficient) fuels in greater proportion, and they generally consume less total energy per household member than smaller households. Taylor and France (1989) also observed in this regard that family size influences per-capita fuel requirements. Large family cooking bigger meals and can be more efficient in their use of fuels. In assessing household energy consumption, one does not only have to identify the quantities of energy from of different sources which are allocated to specific end-use, but account for variation in household sizes and composition to reach standard consumption figure [Howes, 1984].

Household family size is expected to increase the fuel wood consumption because of increased energy demand and increased laborers available for fuel wood collection. The impact of household size on use of alternative fuels is ambiguous, because greater household size means increased demand for energy but also increased possibility of fuel substitution. The role of household size as one of the factors behind the variation in household expenditure is discerned by the use of per capita energy expenditure. We control for household size with a measure of the number of residents of the household.

2.2.1.2. Own price effect

One of the important determinants of household energy demand and fuel mix is the price of various fuels. Non cash payment consist mostly of time (e.g. for gathering fuel wood) and hence are opportunity costs. In general, policies that keep energy prices low lead to growth in latent or potential household energy demand. According to report of World Bank (1990), traditional fuels are either collected or traded outside the monetary economy, or bought and sold in a multiplicity of small markets. In general, policies that keep energy prices low lead to growth in latent or potential household energy demand.

Fuel wood from the commons is collected without financial cost. Foley and Mossa (1983) indicated that the question of whether people pay for wood fuel or not is an important factor determining their response to fuel wood scarcities. If prices go up those who already purchase fuel wood may be prepared to invest in an energy saving stove, alternatively they may switch to commercially available fuels. Pricing is an essential instrument of energy demand management not only because of its direct effect on the level of energy consumption but also it indirectly affects consumption by influencing choice of energy using technology World Bank (1993).

Chipman (1999) also observed that commercial energy prices are often used as a social policy instrument in developing countries. Among the most common subsidized energy sources for household is electricity, with the aim of making it accessible even to low income households. Moreover, Hurst and Barnet (1990) stated that no clear empirical evidence exist on the magnitude of rural energy price elasticities. A comprehensive study on the effect of own price on rural household energy demand for fuel wood was conducted by Hyde and Kohlin (2000) who reviewed not less than ten empirical studies. These works indicated that demand for fuel wood is inversely related to own price which demonstrate that fuel wood is price sensitive. Moreover, Teives (2006) made comparison of prices of available fuels in the market and observed that the relative prices are less important than the absolute ones for households in Portuguese.

Moreover, economic theory offers considerable guidance on how consumers will respond to nonlinear prices. The demand behavior of a utility- maximizing consumer thus depends not on the average price, nor any single marginal price, but on the entire price schedule. By doing so, one can express demand under nonlinear pricing in terms of the ordinary demand function of classical consumer theory, which assumes a linear budget constraint. The difficulty that arises in empirical work is how to incorporate a complex price schedule into a demand specification in a way that is consistent with economic theory yet tractable empirically [Reiss and White, 2002].

Some studies rely on market prices for fuel wood, which is appropriate when an active market exists (as in the Indonesia, empirical study by Pitt (1985)), but not when transactions are infrequent (as in case of Ethiopia), where most households collect their own firewood, provided such prices are observable at all.

Specifically, case study for Ethiopia in this regard was conducted by Alemu (1999). This study assesses whether fuel wood and animal dung (including crop residue) are substitute or complement and also made an attempt to estimate income and price elasticities. He estimated the non- separable agricultural household model, using data from a sample survey of 419 rural households in Ethiopia. The general Tobit model was used. In the model, since the price of fuel wood was endogenous in the demand equation, as captured by the marginal product of labour (derived from the fuel wood collection) multiplied by the amount of time spent in collection, instrumental variable estimation was employed by this study. The response of fuel price as expressed by price elasticity is -0.4 indicating fuel consumption is sensitive to its own price variation.

2.2.1.3. Cross price elasticities

We expect fuel substitution to be a rational economic agent's response to increased resource scarcity and increased wood collection time. Bhagavan and Kapekez (1992) argued that demand structure should be modified to incorporate the determinants of household energy consumption. The traditional econometric formulation of demand as a function of price and income frequently ignores quite aside from other assumptions cross price elasticities. Concerning price elasticities, they showed that energy products are rather inelastic in Spain.

Households are induced to substitute away from energy only if prices of energy exceed a certain threshold level and they reverse the technology only if energy prices are low enough. This threshold price level at which consumers make transition to alternative substitutes is a crucial issue in energy economics. For instance, Sadayoa (1985) observed that subsidized kerosene and electricity would not have significant effect on firewood price because market for firewood and commercial fuels are highly segmented and elasticity of substitution is probably quite low.

However, Chambwera (2004) applied the almost ideal demand system to analyze urban fuel (particularly firewood) demand in Harare town in an energy mix context. Their study by using a multi-stage budgeting approach in the model estimated the share of energy in total household expenditure and the shares of firewood, electricity and kerosene in total energy expenditure. It drew policy recommendation, that decreasing prices of alternative fuels, notably kerosene could induce households to shift from fire wood to kerosene and ease the problem of environmental degradation.

Fuel wood sold in market competes in price with petroleum for cooking fuels. It has therefore been suggested that the market price of the cheapest petroleum fuel imposes an upper limit on fuel wood prices. Price competition between fuel wood and petroleum is likely to be particularly intense where wood is relatively scarce or distant from the city ESMAP (2003).

Khazzoom (1973) in his study on an econometric model of the demand for energy in Canada argued that because of the required past investment in appliances by household, overall response of total demand to price variations will be much more restrained than economic theory would lead one to believe. According to him, this results in consumer's agility which in turn results in under expected response of demand to price change for such energy sources. He distinguished between two forms of demand: "free demand" and captive demand and noted that in measuring the impact of an economic stimulus on demand, one necessarily has to focus on the free demand. The study also indicated free demand depends on a price vector whose elements generally consist of the price of the commodity in question, as well as the price of its substitutes.

However as for this study, unfortunately information regarding the prices of different energy forms is not provided. In rural energy demand households do not know precisely how much it cost them to acquire fuel wood, dung and residue or charcoal as it is obtained without any financial outlay. The only cost incurred is the opportunity cost of foregone time.

2.2.1.4. Income effect

The budget and income constraint of household is an important determinant of its overall pattern of consumption expenditure. In line with this argument, Campbell, Vermeulen, Mangono and Mabugu (2003) conducted a study on energy transition and indicated that households switch from wood through kerosene to electricity occurred with a rising household income. According to Beamont and Keys (1982) observation, that Engel curve can be used to represent direct relationship between household income and expenditure; that is, in general as household income increases, expenditure on a particular commodity does not decrease in absolute terms. Household energy surveys have found income to be a major determinant of the energy transition [Alam et al., 1998; Campbell et al., 2003; Davis, 1998; Ouedraogo, 2006]. For example, Campbell et al. (2003) observed that in the four largest cities in Zimbabwe higher income households were less likely to use wood as their primary cooking fuel, witching to kerosene and electricity. Similarly, Ouedraogo (2006) noted that households' firewood utilization rate decreased with increasing household income in the capital city of Burkina Faso. Moreover, Hurst and Barnet (1990) indicated that as income increases there is a natural shift from wood to the so called modern fuels of coke and kerosene.

Taylor and France (1989) in their study titled energy issue and option in developing countries observed that wood crisis does not affect all equally. It is mainly crisis of the poor. Those with higher income can switch to other fuels. Furthermore, Kgait et al. (1997) in the study of biomass in Africa observed that households tend to find it convenient to switch to advanced energy sources if income is not a constraint. Thus, we infer that shocks such as increase in price of kerosene results in divergence in households move at a point on the energy ladder. That is while the households with high income are expected to switch to advanced fuels the poor moves down the ladder to the relatively less efficient fuels such as crop residue and animal dung. Thus, the rampant loss of forest now occurring in the third world countries without any doubt, since most of the households can not afford for advanced energy sources, cause a serious treat on their economic development. But households will not abandon or completely give up consumption of one form of fuel and switch to another. Rather, they exhibit subtle optimization decision where multitude of energy sources consumed simultaneously.

The strong link between energy demand and income in the energy ladder framework was also observed in study by ESMAP (2003). It indicated that the major achievement of the energy ladder model in its simplest form is the ability to capture the strong income dependency of fuel choices. Barnes, Krutilla, and Hyde (2004) on the other hand pointed out that the increase in incomes give rise to a decline in the percentage of consumers who choose to consume traditional fuels, as well as the kerosene, and an increase in the percentage of consumers who consume LPG and electricity. Specific to kerosene for instance, Dahl (1994) notes that the income elasticity of kerosene demand could be either positive or negative. That is, for the very poor, increase in income would switch his consumption from traditional fuel to kerosene, i.e. the demand is positively related with income. However, as income increases further, the demand may shift out of kerosene to electricity and other commercial fuels such as liquefied petroleum gas (LPG).

Foley (1995) made an interesting attempt of formulating energy transition theory, suggesting a ladder of energy demand rather than of fuel preferences. As income grows people start to demand more diversified energy sources as they can afford to purchase a variety of appliances each of which requires a specific energy source. The poor rural households, in contrast, are supposed to need only wood for basic cooking. Although undoubtedly true, the finding of widespread use of multiple fuels for cooking suggests genuine fuel stacking for a given purpose [see also Davis, 1998].

Khazzoom (1973) following Balestra and Nerlovels model (1996) used total expenditure, rather than income, as the appropriate constraint variable in studying energy demand model for Canada. The reason is because over short periods of time, consumers have more control over their expenditure than over their receipts of income. The literature on the determinants of firewood consumption in rural areas usually uses three different types of measures for the "income level": households (net) income, households total expenditures, and a measure of households' wealth. Heavy income dependence of household energy demand, however, was emphasized by many researchers [Démurger and Fournier, 2006].

In the case of Ethiopia, poverty appears to be the deriving force behind the problem. For instance, Bereket et al. (2001) indicated that electricity consumption is highly unaffordable for urban households in Ethiopia. Thus, from view point of economic theory, with no exception for Ethiopia high level of income is expected to induce increased consumption in per capita term and or switch towards more advanced energy sources. Higher incomes induce households to switch away from traditional fuels, such as cow dung and firewood, to higher quality but more expensive substitutes [Arnold *et al* ., 2003].

The theoretical assumption underlying the energy ladder model is that low living standards as the case in Ethiopia induce greater dependence on forest firewood owing to a combination of income and substitution effects. Poor households rely more on forest firewood *vis-à-vis* modern fuel substitutes purchased from the market, because the impact of the lower shadow cost of their time (the chief cost of collecting forest wood) dominates income effects (which may be positive, as higher food expenditures associated with higher income raise demand for cooking energy). The results of the study conducted by Baland et al. (2007) indicated that for Nepal the income and the substitution effects neutralize each other, so that firewood collections are essentially inelastic with respect to improvements in living standards. Some of literatures do not include income or consumption expenditures, and rely on proxies such as landholdings [e.g.Heltberg *et al.*, 2000].

2.2.1.5. Household labour allocation

Heltberge et al. (2000) noted that imperfections in rural labor markets-both seasonal and gender-based-make household labor supply and demand non-separable. The assumption of non-separability implies that household resource allocation, including energy supply, energy demand, and farm and off farm labor supply is decided simultaneously, rather than recursively. This means according to Sadoulet and de Janvry (1995) each household determines energy production and consumption by maximizing its utility subject to a "virtual" or "shadow" price of energy which is unobserved and unknown, except to the household itself, and which varies between households depending on household and village characteristics.

Some literature on household energy use in rural areas of developing countries discussed the issue of labour allocation for different energy search and other alternative tasks. For example, Kumar and Hotchkiss (1988), using data from Nepal, estimate the empirical links between deforestation, women's time allocation, and the effects on nutrition when women spend longer hours collecting fuel wood. Furthermore, following the same stand point, [Amacher et al., 1992; 1993] studied fuel wood supply and demand, and the decision to adopt improved stoves, respectively, both based on separable household models estimated on Nepali data.

Mackenzie (2007) conducted project study on development of energy for Africa which conceives that in the standard model, it is assumed that a household is endowed with fixed amounts of both agricultural land and of time available for labour. Based on notions of economic rationality and the prevailing prices of labour time, production inputs and final produce, the household time is optimally allocated into the three aforementioned activities. In the simplest version of the model it is furthermore assumed that the household can buy any amount of labour from outside or sell as it desires (from its fixed endowment) at a given wage rate.

Three papers come closer and put forward supporting arguments to the issues discussed in the above study. The first is Pitt (1985), who quantifies the substitution between firewood and kerosene (the major commercial fuel) by estimating expenditure equations for a large Indonesian sample. He finds that substitution between firewood and kerosene is very limited, and that the subsidy on kerosene therefore is an ineffective way to address deforestation, and in fact benefits urban and wealthier households. The second paper is done by Bluffstone (1995), who studies household labor allocation to fuel wood collection, agriculture and off-farm work. Simulation exercises of the time-path of deforestation, using parameter values for a typical Nepali hill village, demonstrate that the presence of off-farm labor opportunities are crucial for stabilizing forest levels. This is because off farm wages set a downward limit on the opportunity cost of time.

The third paper is by Amacher et al. (1996), who formulate and estimate a non-separable household model for fuel wood supply and demand, also using a Nepali data set. Its emphasis is on fuel wood purchase versus own collection and on estimation of the unobserved shadow wage using a two-step procedure. In addition, Baland et al. (2007) in the study of fire wood consumption in Nepal indicated that most households collect their own firewood, so we distinguish between the direct wealth effects of increased assets owned from induced effects on shadow cost of time spent collecting firewood.

The model presented by Heltberg et al. (2000) captures the situation of a agricultural farm household engaged in crop and livestock production, off-farm work, and energy collection. The main focus and novelty of this model is that the substitution of fuels from different sources is discussed and tested. Besides income, another important effect to be measured when exploring firewood consumption determinants is the price effect. And price of fuel wood in rural area depends on the time (opportunity cost of labor) to collect it.

As in most developing countries in Ethiopia, commercial fuels are widespread in urban areas but less in rural areas, where many fuels for home use are collected at zero financial cost by the household itself. The most important non-commercial domestic fuels are firewood collected from forests, common lands, roadsides, and private fields; crop residues from the farm; and dung gathered from domestic animals and charcoal. However, in many parts of Ethiopia, markets for domestic fuels are either absent or ill-functioning, making it reasonable to model household energy supply and demand as non-separable.

To this effect, Alemu (1999) tried to measure the shadow price of fuel collection for Ethiopia introducing firewood collection time (expressed in hours per kg) interacted with household wealth categories. The opportunity cost of firewood collection, used as a proxy for fuel wood price, therefore corresponds to the collection time multiplied by the opportunity (shadow) cost of time, which we assume here proportional to household wealth.

3. THEORETICAL SPECIFICATION OF THE MODEL

3.1. Economic model framework for estimating energy demand of agricultural household

In this section, we present the model underlying household labour allocation decision in modeling or estimating the energy demand of rural households. A recent and interesting model for household labour allocation for fire wood collection and the existence of substitutability between firewood and gas was modeled by [Baland et al., 2007].

This study adopts the model in estimating rural household energy demand in the energy mix or fuel choice context. It extends the model by including charcoal as possible source of household energy option. Hence the functional relationships are modified as households decide on labour allocated on collecting fuel wood and preparing charcoal which are the choice variables (used as substitute or complement) as we move along the energy ladder. Instead of only two alternatives we now have three substitutable energy sources. Then the model shows how households optimize their energy demand (fuel choice) in their energy portfolio (fuel mix) model.

Consider the total amount of cooking, lightening and heating energy used by household *i* in village v, H_{iv}. Energy is assumed to be obtained from three sources: firewood, charcoal, and advanced energies (which stand here for all energy sources that are sold in the market). Letting G_{iv} stand for the total amount of gas consumed in the household, F_{iv}, for the amount of firewood per capita, and R_{iv}, charcoal per capita, and n_{iv} for the number of members in the household, we have:

$$H_{iv} = \theta_g G_{iv} + \theta_f n_{iv} F_{iv} + \theta_r n_{iv} R_{iv} \text{ -- } (1)$$

So that θ_f/θ_g, $\theta r/\theta_g$ represents the gas energy equivalent of one unit of firewood, and charcoal respectively. Similarly, fire wood equivalence of charcoal is represented by the ratio of $\theta r/\theta f$. These ratios stand for the rate of substitutions between respective sources of energy forms.

The utility function of a representative member of household i in village v is given as follows:

$$U_{iv} = U\left(H_{iv}, C_{iv}, l_{iv}, S_{iv}\left(n_{iv}F_{iv}\right), \psi_{iv}\left(n_{iv}\, R_{iv}\right), a_v\right)) \text{ ----------------- } (2)$$

Where C_{iv} denotes per capita expenditures on all other goods consumed, l_{iv}, per capita leisure time (including time devoted to domestic tasks), $S_{iv}(n_{iv}F_{iv})$ and $\psi_{iv}(n_{iv}R_{iv})$ stand for the total amount of smoke produced by the use of firewood and charcoal, respectively in the household, and a_v stands for the relevant village characteristics, such as village climate and infrastructure. The inclusion of the total amount of energy in the utility function reflects the fact that the energy used for heating and cooking is to a large extent a public good within the household (and smoke health hazardous a public bad) while consumption expenditures or leisure are not.

Household income is the sum of fixed income (pensions, salaries of permanently employed members and wage employment earnings), denoted by P_{iv}, and (income from livestock, sell of crops and other produces); all summarized as self employment income denoted by Y_{iv}. The latter is in turn determined by the value of household production, given by a Cobb-Douglas production function of household labour hours, L_{iv}, the productive assets owned by the household: land, A_{iv}, livestock, Ls_{iv}, seed, fertilizer and other agricultural inputs, J_{iv}, education, E_{iv} and non-farm business assets, B_{iv}; and village level variables, b_v:

$$Y_{iv} = e^{b_v} L_{iv}^{\Phi_1} J_{iv}^{\Phi_2} A_{iv}^{\Phi_3} Ls_{iv}^{\Phi_4} E_{iv}^{\Phi_5} B_{iv}^{\Phi_6} \text{-------------------------------} (3)$$

Let us define N_{iv} as the household labour stock available for self-employment activities. It is obtained by multiplying it by 16 hours per day the number of adults (plus an adult equivalent scale of 0.25 for children) that are available for household activities, productive self-employment and forest collection and charcoal preparation. We can then define the household potential income, λ_{iv}, as the self-employment income that the household would earn if it were to fully utilize its labor stock. It is given by:

$$\lambda_{iv} = e^{b_v} N_{iv}^{\Phi_1} J_{iv}^{\Phi_2} A_{iv}^{\Phi_3} Ls_{iv}^{\Phi_4} E_{iv}^{\Phi_5} B_{iv}^{\Phi_6} = \frac{L_{iv}^{\Phi_1} Y_{iv}}{N_{iv}^{\Phi_1}} \text{---------------} (4)$$

By construction, it always exceeds the actual self-employment income. Owing to data limitations we will ignore the possibility of fuel wood and charcoal markets within the village. We therefore assume that firewood and charcoal used is entirely collected and or prepared by the household itself. The cost of using firewood and the alternative (charcoal) corresponds to the opportunity cost of time involved in collecting it. Since ownership of different assets affect allocation of household time between different occupations, some of which are complementary with firewood collection and charcoal preparation, while others are substitutes, the time taken to collect firewood, t_{iv}^{f}, and time taken to prepare charcoal t_{iv}^{c} also depend on the assets owned by the household. As household's occupational choices are endogenously determined by labour allocation decisions within the household. We use as proxies, the corresponding assets owned by the household that influence their occupational choices.

Letting t_v^c represent total time taken to collect firewood, and prepare charcoal for a household with no assets in village v, we assume:

$$t_{iv}^f + t_{iv}^r = K_{iv} = t_v^c (1 + \tau_1 A_{iv} + \tau_2 Ls_{iv} + \tau_3 J_{iv} + \tau_4 E_{iv} + \tau_5 B_{iv}) \text{----}(5)$$

Where τ_i measures the degree of complementarily between the activity associated with asset i and firewood collection and/or charcoal preparation. For instance, it might be hypothesized that grazing livestock reduces the time taken to collect fuel ($\tau_2 < 0$) while running a non farm business increases it ($\tau_5 > 0$).

Finally, the labour allocation constraint is given by:

$$N_{iv} = L_{iv} + n_{iv} t_{iv}^f F_{iv} + n_{iv} l_{iv} + n_{iv} t_{iv}^r R_{iv} \text{------------------------------}(6)$$

Letting $\omega_{G,v}$ represent the average price of gas in region v, the budget constraint can be written as:

$$n_{iv} C_{iv} + \omega_{G,v} G_{iv} = p_{iv} + Y_{iv}. \text{--}(7)$$

In this model, we incorporated the family size as a determinant of household energy demand. It appears in the equation with a linear and an inverse term. Identical results are obtained if a linear and quadratic terms yield are used instead. The use of an inverse here allows us a direct comparison to the results obtained for India in Baland et.al (2007a) where the specification is based on a linear expenditure system which yields an inverse term in household size. This transformed form of family size is used as an instrument in estimation of household energy demand.

So taking equation (4), and incorporating household size, equation (7) becomes:

$$n_{iv}C_{iv} + \omega_{G,v}\, G_{iv} = p_{iv} + \frac{L_{iv}^{\Phi 1}}{N_{iv}^{\Phi 1}}\lambda_{iv} \quad \text{-----(8)}$$

From (6), we get budget constraint equation given as:

$$n_{iv}C_{iv} + \omega_{G,v}G_{iv} = p_{iv} + \left\{1 - \frac{n_{iv}t_{iv}^{f}F_{iv} - n_{iv}l_{iv} - n_{iv}t_{iv}^{r}R_{iv}}{N_{iv}}\right\}^{\Phi 1}\lambda_{iv}. \quad \text{------ (9)}$$

The household maximizes utility function given in (2) by choosing gas, fuel wood, charcoal ,leisure and consumption expenditures under the budget constraint (9), taking assets, fixed income, demographics and the time taken to collect fuel as given in the short run. The Lagrange function is formulated as:

$$L = U(H_{iv}, C_{iv}, l_{iv}, S_{iv}(n_{iv}F_{iv}), \psi_{iv}(n_{iv} R_{iv}), a_v)) + \mu(p_{iv} +$$

$$\left\{1 - \frac{n_{iv}t_{iv}^{f}F_{iv} - n_{iv}l_{iv} - n_{iv}t_{iv}^{r}R_{iv}}{N_{iv}} - n_{iv}C_{iv} + \omega_{G,v}G_{iv}\right\}^{\Phi 1}\lambda_{iv}. \quad \text{---------- (10)}$$

Substituting H_{iv} from equation (1), and optimizing the Lagrange with respect to each of the variables yields equilibrium outcomes. That means maximizing the household utility function subject to the budget constraint stated above nests demand equation for fuel wood, charcoal, leisure and other consumer goods in terms of household assets which is embodied in time for fuel collection, family size, labour stock, fixed and potential income.

This yields the following first-order condition for gas, which takes into account the non-negativity constraint. Accordingly, for gas first order optimal condition is given as:

$$\frac{\partial L}{\partial G_{iv}} = 0 \text{ -- } (11a)$$

$$G_{iv}\,(U'_{iv,g}\theta_g - \mu\omega_{G,v}) = 0.\text{--}(11b)$$

For fuel wood collection the optimization equation is given by:

$$\frac{\partial L}{\partial F_{iv}} = 0\text{-- } (12a)$$

$$F_{iv}\{U'_{iv,f}\theta_f m_{iv} + U'_{iv,1}S'_{iv}n_{iv} - \mu\Phi_1\left(\frac{N_{iv} - n_{iv}t^f_{iv}F_{iv} - n_{iv}l_{iv} - n_{iv}t^r_{iv}R_{iv}}{N_{iv}}\right)^{\Phi_f - 1} n_{iv}t^f_{iv}\lambda_{iv}\}$$

$$= 0, \text{ -- } (12b)$$

This can be expressed as:

$$F_{iv}\,(U'_{iv,f}\theta_f + U'_{iv,2}S'_{iv} - \mu\Phi_1\left(\frac{N_{iv} - n_{iv}t^f_{iv}F_{iv} - n_{iv}l_{iv}\ n_{iv}t^r_{iv}R_{iv}}{N_{iv}}\right)^{\Phi_f - 1} t^f_{iv}\lambda_{iv}$$

$$=0, \text{ -- } (12.c)$$

Similarly, for charcoal:

$$\frac{\partial L}{\partial R_{iv}} = 0, \text{ -- } (12.a)$$

$$R_{iv}\{U'_{iv,r}\theta_r n_{iv}+U'_{iv,3}S'_{iv}n_{iv}-\mu\Phi_1\left(\frac{N_{iv}-n_{iv}t^f_{iv}F_{iv}-n_{iv}l_{iv}-n_{iv}t_{iv}^r R_{iv}}{N_{iv}}\right)^{\Phi_1-1}n_{iv}t^r_{iv}\lambda_{iv}\}$$

$$= 0, \text{--} (12.b)$$

This can be re-written as:

$$R_{iv}\left(U'_{iv,r}\theta_r + U'_{iv,3}S'_{iv} - \mu\Phi_1\left(\frac{N_{iv}-n_{iv}t^f_{iv}F_{iv}-n_{iv}l_{iv}-n_{iv}t_{iv}^r R_{iv}}{N_{iv}}\right)^{\Phi_1-1}t_{iv}^r\lambda_{iv}\right)$$

$$= 0, \text{--} (12.c)$$

The first order condition for consumption expenditures and for leisure (assuming interior solutions) are:

$$U'_{iv,c} - \mu = 0, \text{---} (13)$$

And,

$$U'_{iv,l}-\mu\Phi_1\left(\frac{N_{iv}-n_{iv}t^f_{iv}F_{iv}-n_{iv}l_{iv}-n_{iv}t_{iv}^r R_{iv}}{N_{iv}}\right)^{\Phi_1-1}t^f_{iv}n_{iv}\frac{\lambda_{iv}}{N_{iv}} = 0.\text{------}(14)$$

The aforementioned four first -order conditions, together with the budget constraint (9), implicitly define the demand functions, which can be written as function of potential income λ_{iv}, fixed income p_{iv}, the cost of firewood (equal to the time required to collect one bundle of firewood (standardized by amount of fuel wood collected in a single trip) or the alternative multiplied by the shadow value of time Ξ_{iv}), household demographics (represented by family size of household n_{iv} in adult equivalent consumption units) and the price of gas (which is omitted in what follows as being given at the village level, it is absorbed by the village level fixed effect). The shadow value of time, Ξ_{iv}, corresponds to the marginal productivity of labour in self-employment occupations (determined in turn by the labour supply choice and household assets) and is equal to:

$$\Xi_{iv} = \Phi_1\left(\frac{N_{iv} - n_{iv}t^f_{iv}F_{iv} - n_{iv}l_{iv} - n_{iv}t^r_{iv}R_{iv}}{N_{iv}}\right)^{\Phi_1-1} \frac{n_{iv}\lambda_{iv}}{N_{iv}} \text{---------------} \quad (15)$$

Taking a Taylor expansion, allowing for higher order terms in income and demographics, we obtain the following equation for firewood per capita within the household.

$$f_{iv} = \Theta_0 + \Theta_1\lambda_{iv} + \Theta_2\lambda_{iv}^2 + \Theta_3P_{iv} + \Theta_4\Xi_{iv}t^r_{iv} + \Theta_5\Xi_{iv}t^f_{iv} + \Theta_6n_{iv} + \Theta_7(1/n_{iv}) + \Theta_8a_v + \varepsilon_{iv}. \text{-----} \quad (16)$$

Where, $f_{iv} \equiv \dfrac{F_{iv}}{n_{iv}}$

Similarly, per capita demand for charcoal with in the household is given by equation:

$$r_{iv} = \pi_0 + \pi_1\lambda_{iv} + \pi_2\lambda_{iv}^2 + \pi_3p_{iv} + \pi_4\Xi_{iv}t^f_{iv} + \pi_5\Xi_{iv}t^r_{iv} + \pi_6n_{iv} + \pi_7(1/n_{iv}) + \pi_8a_v + \varepsilon_{iv}. \text{-----} \quad (17)$$

Where, $r_{iv} \equiv \dfrac{R_{iv}}{n_{iv}}$

We can allow for censoring by estimating truncated version of equation (16) and (17) above. From (15), per capita potential income is a major determinant of the shadow value of time. Therefore, we shall use λ_{iv}/N_{iv} as a proxy for the shadow wage rate Ξ_{iv}.)

Recalling the formulation of collection time t^f_{iv} above as a function of household assets, the firewood demand equation can now be entirely written as a function of fixed household characteristics as follows:

$$f_{iv} = \max [0, \Theta_0 + \Theta_1\lambda_{iv} + \Theta_2\lambda_{iv}^2 + \Theta_3 p_{iv} + \frac{\Theta_4\lambda_{iv}t_{iv}^f}{N_{iv}} + \frac{\Theta_5\lambda_{iv}(K_{iv} - t_{iv}^f)}{N_{iv}} + \Theta_6 n_{iv} + \Theta_7(1/n_{iv}) + \Theta_8 a_v + \varepsilon_{iv}] \text{ ---------- } (18.a)$$

Similarly, per capita demand equation for charcoal can also be written entirely as a function of fixed household characteristics as follows:

$$r_{iv} = \max [0, \pi_0 + \pi_1\lambda_{iv} + \pi_2\lambda_{iv}^2 + \pi_3 p_{iv} + \frac{\pi_4\lambda_{iv}t_{iv}^r}{N_{iv}} + \frac{\pi_5\lambda_{iv}(K_{iv} - t_{iv}^r)}{N_{iv}} + \pi_6 n_{iv} + \pi_7(1/n_{iv}) + \pi_8 a_v + \varepsilon_{iv}]. \text{ ---------- } (19.a)$$

Adopting this model for panel data we have to introduce the time series component, which yields demand equation for fuel wood by individual i, from village v, in period t is given by:

$$f_{ivt} = \max [0, \Theta_0 + \Theta_1\lambda_{ivt} + \Theta_2\lambda_{ivt}^2 + \Theta_3 p_{ivt} + \frac{\Theta_4\lambda_{ivt}t^f_{ivt}}{N_{iv}} + \frac{\Theta_5\lambda_{ivt}}{N_{iv}}(K_{ivt} - t^f_{ivt}) + \Theta_6 n_{ivt} + \Theta_7 (1/n_{ivt}) + \Theta_8 a_{vt} + \varepsilon_{ivt}]. \text{ ---------- } (18.b)$$

Similarly, equation for charcoal consumption per-capita is given as:

$$r_{ivt} = \max [0, \pi_0 + \pi_1\lambda_{ivt} + \pi_2\lambda_{ivt}^2 + \pi_3 p_{ivt} + \frac{\pi_4\lambda_{ivt}t^r_{ivt}}{N_{ivt}} + \frac{\pi_5\lambda_{ivt}}{N_{ivt}}(K_{ivt} - t^f_{ivt}) + \pi_6 n_{ivt} + \pi_7(1/n_{ivt}) + \pi_8 a_{vt} + \varepsilon_{ivt}]. \text{ ---------- } (19.b)$$

The substitution effects are now identified (separately from the income effect) by the interactions between per capita potential income (λ_{iv}/N_{iv}) of the household, average collection time in the village (proxied by t_v^c) and assets owned by the household.

3.2. Definition of variables

Potential income

Potential income as defined above provides a single measure of wealth which values and aggregates the different assets owned by the household. The main benefit of using potential income is that it is independent of short run labour allocation choices made by the household. It aggregates the assets of households into a single measure of wealth. Estimations based on reported income rather than potential income are subject to an endogeneity bias, as labour used in self-employment is a decision variable. For instance, it is likely that more dynamic or better skilled farmers will simultaneously choose to work more and to collect more firewood and/ or charcoal. Our measure of potential income is not subject to this type of bias. Moreover, this measure also removes sources of transitory shocks and measurement error in reported self-employed income. By contrast, fixed income can be considered exogenous in the short run, given the low development of labour markets in the rural area. We introduce fixed income separately from self-employment income as it represents a much more regular and certain source of income, which may affect the demand for a substitute such as LPG and electricity. This is a more general model than the one in which one parameter is estimated for income defined as the sum of the two types of income.

In equation (16) and (17), the second and third terms on the right-hand side represent the wealth effect on fuel wood, and charcoal demand respectively. This wealth effect can be positive or negative, as it will include on the one hand rising demand for household energy, and a rising concern with indoor smoke. The later may tend to reduce demand for traditional (firewood and charcoal) by households and provoke to switch to available substitutes. The fourth term is estimated separately from self-employment income as fixed income represents a much more regular and certain source of income, which may affect the demand for a substitute such as gas. This is a more general model than the one in which one parameter is estimated for income defined as the sum of the two types of income. However, the parameter estimate turns out to be surprisingly similar. That is as wealth of household increase advanced fuel will be favored to inferior ones.

Shadow value of time

In rural areas, where fuel wood and charcoal are accessed by any household without any financial cost from common forests the only payment incurred in acquiring fuel is the opportunity cost (shadow price of time) spent in collecting it. This shadow value of time Ξ_{iv} increases with potential income λ_{iv} because the marginal productivity of self-employed labour is an increasing function of the assets owned by the household that are complementary to labour supply. Wealthier households have a higher value of time, and a higher shadow price of using firewood or the alternative (charcoal). This implies that the substitution effects also rise with λ_{iv}. To the extent that the wealth effects are positive, and the substitution effects are negative, a rise in wealth of the household will tend to raise both at the same time, so the overall effect is theoretically indeterminate. However, in sub-Saharan African countries cheap labor availability tend to reduce the wealth effect and the net effect turns out more likely negative i.e. the substitution effect outweighs the wealth effect.

If labour markets were perfect, the valuation of household time would simply be the market wage rate. Here, however, the shadow value of time is the marginal productivity of household time, estimated using the household production function. One problem with using the measured shadow wage as a determinant of the shadow price of fuel wood or the alternative fuel is that it depends on endogenous labour supply decisions of the household. One source of imperfection is the existence of no pecuniary costs for family members, especially women and children, to work outside the home or own farm.

Another source of divergence between (measured) market wages and the value of time arises due to seasonal fluctuations in the labor market. Wage employment arises for a few months in the year (e.g., during harvesting and sowing seasons), when market wage rates rise above the value of time in household production. In rural area we observe that all households participating in wage employment were also involved in home production. For this reason reported market wage rates (which pertain to the high demand periods) turned out to be substantially above shadow wages (which pertain to year-round labour). Hence wage employment earnings were intra marginal, and the margin of labour-leisure choices operated solely with respect to home production.

Household family size

Energy demand of household is expected to increase with household size. With availability of more human power, labour force allotted to secure fuel wood and or charcoal increases. However, with increasing family size households exploit economies of scale in fuel utilization (i.e. the same amount of fuel is used to cook or prepare meal for large household). Thus, even if large family consumes large amount of fuel in absolute term, they use small amount of fuel in relative term. But various empirical works conducted on this issue have not exhaustively dealt in depth to come up with conclusive knowledge.

Village level fixed effects

This includes such factors as infrastructural facilities, forest availability, climatic conditions (heat required for space heating depends on the village climate). For instance availability of abundant forest results in households to depend on fire wood and charcoal while availability of infrastructural facility that link the household to the market will acculturate them to utilization of advanced energy forms such as kerosene. And if the climatic condition is cold households need more energy to heat space. Thus, these various village level variables influence household's energy demand differently and their effect is indeterminate.

4. EMPERICAL SPECIFICATION OF THE MODEL

Under this section, our emphasis lays on formulation of econometric models that are used for manipulation of empirical findings. The first part is devoted to specification of the almost ideal demand system used for estimating the income elasticity of household energy demand. For this purpose we use aggregate household expenditure, household expenditure on different sorts of energy and other covariates or determinants of household energy demand (fuel choice). Under the second section, the multinomial logit model is specified for modeling household choice decision among different energy categories. In fact, for simplicity of our empirical investigation energy used by households are classified in to three major groups. These are: traditional/inferior fuel, advanced or modern fuel and mix of the two fuels.

4.1. The Almost Ideal Demand system (AIDS) for estimating price elasticities of energy demand

The Almost Ideal Demand System (AIDS) was first introduced by Deaton and Muellbauer (1980) and it has become very popular in recent economic literature [for example, Chambwera, 2004; Asche and Wessells, 1997; Green 1990; and Alston; Foster and Gree, 1994]. Its applicability for household energy demand was demonstrated in the work by Chambwera (2004) on household survey data collected from Harare Town, Zimbabwe. AIDS is one of the most widely used flexible and standard demand specifications. While this model possesses many desirable properties, it may be difficult to estimate. A variety of approaches to computing elasticities has been used, and some of the approaches may lead to significant errors. To simplify the estimation problem, Deaton and Muellbauer (1980) (p. 316) suggested using a linear approximation. The linear approximate almost ideal demand system (LAAIDS) has been employed in the vast majority of empirical applications of the AIDS model, with a variety of formulas to compute elasticities.

This study develops the energy mix (fuel choice) model as the conceptual framework, using the household energy demand or fuel choice as a starting point. The energy mix model is based on the fact that in any one period, rural households use multiple sources of energy. Consumer theory is used to underpin this reality, and link it to the analysis that follows. System of demand is used in the empirical analysis. In the applied work, the Almost Ideal Demand System (AIDS model), in linear approximate form, as the empirical model, incorporates the effects of other household characteristics in addition to income and prices. A multi-stage budgeting process is used in the analysis, which assumes that households first decide on how much of their total expenditures to allocate to energy, among other household goods. In the second stage, they decide how much of their total energy outlays to allocate on a specific fuels.

The model

The AIDS budget share equations for estimation of household energy demand for different energy types was first introduced in to economic literature by Deaton and Muellbauer (1980) as mentioned above. AIDS Model in this context provides a clue on the share of a given energy in household energy demand in household budget outlay. The equation is specified as:

$$w_{it} = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_{jt} + \beta_i \ln(x_t/P_t) + u_{it} \qquad (20)$$

where, in time t, $w_{it} = P_iQi/X$ is the budget share of good i, u_{it}, is a random disturbance, p_j, is the price of commodity j, x_t is total expenditure, and P_t is a price index defined by:

$$\ln P_t = \alpha_0 + \sum_{k=1}^{n} \alpha_k \ln p_{kt} + \frac{1}{2} \sum_{j=1}^{n} \sum_{k=1}^{n} \gamma_{jk} \ln p_{jt} \ln p_{kt} \qquad (21)$$

Usually in the estimation of demand system using AIDS, we approximate this price index by the stone's index, which is given by:

$$\ln P^* = \sum_k w_k \ln P_k. \qquad (22)$$

When this Stone's index is used in modeling household energy demand the model is called the "linear approximate AIDS" (LAAIDS). This is because we used linear approximation of the price level. If prices are highly collinear, P may be approximately proportional to P*, i.e., P $=\zeta$P*. Where ζ denotes proportionality constant. In the extreme case when P is exactly (linearly) proportional to P*, the LAAIDS model can be used to estimate the parameters of the AIDS model because, then, the LAAIDS can be written (in terms of the AIDS model parameters) as:

$$w_i = (\alpha_i - \beta_i \ln \zeta) + \sum_j \gamma_{ij} \ln P_j + \beta_i \ln\left(\frac{X}{P*}\right). \quad \text{------------ (23)}$$

However, the relationship between the parameters of the AIDS and its corresponding linear approximation parameters is not known. In addition, it is not known whether the LAAIDS has satisfactory theoretical properties. These issues notwithstanding, and the LAAIDS is very popular for estimating household energy demand [Green and Alston, 1990].

Estimation of Price Elasticities using LAAIDS

A general definition of the uncompensated elasticities of demand from the AIDS and LAAIDS η_{ij} according to Green and Alston given as:

$$\eta_{ij} = \frac{d\ln Q_i}{d\ln P_j} = -\delta_{ij} + \frac{d\ln w_i}{d\ln P_j} = -\delta_{ij} + \left\{\gamma_{ij} - \beta_i \frac{d\ln P}{d\ln P_j}\right\} \Big/ w_i, \quad \text{------------------------ (24)}$$

Where these elasticities refer to allocations within the group holding constant total group expenditures (X) and all other prices (P_k, k # j), δ_{ij} is the Kronecker delta

The above equation satisfies a number of important properties:

- Adding-up conditions are $\delta_{ij} = 1, \Sigma_i \gamma_{ij} = 0$ and $\Sigma_i \beta_i = 0$
- The homogeneity condition is $\Sigma_i \gamma_{ij} = 0$; and

- Symmetry is reflected by $\gamma_{ij} = \gamma_{ji}$

The price index in (21) renders non linear system of equation for price elasticities of demand. Different literatures came up with different expressions for the elasticity of the group price index with respect to the j[th] price (i.e., $d\ln P/d\ln P_j$ or $d\ln P^*/d\ln P_j$). These differences carry over directly into the computation of compensated elasticities (η_{ij}), which is given:

$$\eta_{ij}^{*} = \eta_{ij} + w_j\left(1 + \frac{\beta_i}{w_i}\right). \qquad \text{-------------------------- (25)}$$

For instance, in the basic AIDS model, the correct expression for the elasticity of the group price with respect to the j[th] price is

$$\frac{d\ln P}{d\ln P_j} = \alpha_j + \sum_k \gamma_{kj} \ln P_k. \qquad \text{-------------------------------- (26)}$$

Substituting (26) into (24) yields the correct elasticities for the AIDS model. The use of resulting computing formula for AIDS elasticities with parameters from the LAAIDS helps to simplify the estimation problem. To obtain the correct formula for the LAAIDS, we differentiate Stone's price index with respect to the j[th] commodity price and get.

$$d\ln P^*/d\ln P_j = w_j + \sum_k w_k \ln P_k \frac{d\ln w_k}{d\ln P_j}. \qquad (27)$$

From (5) we have $d\ln w_j/d\ln P_i = \delta_{ij} + \eta_{ij}$, so that (4) may be written as:

$$d\ln P^*/d\ln P_j = w_j + \sum_k w_k \ln P_k(\eta_{kj} + \delta_{kj}) \qquad (28)$$

The Stone price index has recently been shown by several authors to make the parameter estimates inconsistent. Most authors attribute this problem to the fact that the Stone index introduces a measurement error because prices are not perfectly collinear, which must be for the Stone price index to equal the translog price index in (21).

4.2. Effect of Price Normalization on the AIDS and LAAIDS Models

The effect of price normalization on the estimation of the price elasticities of AIDS and LAAIDS was examined by Asche and Wessells (1997). Given the above model by Deaton and Muellbauer (1980), it can be shown that when all the prices are normalized to unity, the two representations, AIDS and LAAIDS, are equal when evaluated at that point of normalization. The nonlinear version of the AIDS model, with all prices normalized to one at some arbitrary point in the data set, reduces at point of normalization to;

$$w_{it} = \alpha_i + \beta_i \ln x_t - \beta_i \alpha_0. \qquad (29)$$

Where $\alpha_0 = \ln \zeta$

However, at all other data points, the AIDS specification remains (20). If the subsistence expenditure in the formulation of the demand system (which includes aggregate goods that cover most of the consumer's bundle) is set equal to expenditure in the base period, α_0 equals the predicted budget share at the point of normalization. This is done in some empirical studies at the point where the elasticities are computed. In a similar fashion, at the point of normalization, each equation in LAAIDS model (23) reduces to

$$w_{it} = \alpha_i^* + \beta_i \ln x_t = \alpha_i + \beta_i \ln x_t - \beta_i \alpha_0 \qquad \text{---------------- (30)}$$

this is identical to (29). However, note that when the Stone price index is used, there may be differences between (29) and (30) in applied work, as the estimated parameters in the LAAIDS model are inconsistent. This problem is avoided if one of the alternative indices suggested by Moschini (1995) is used.

According to Asche and Wessells (1997) the uncompensated elasticity for the AIDS model under price normalization condition is given as:

$$\epsilon_{ijt} = -\delta + \left(\frac{\gamma_{ij}}{w_{it}}\right) - \left(\frac{\beta_i}{w_{it}}\right)\left(\alpha_j + \sum_{j=1}^{n} \gamma_{ij} \ln p_{jt}\right) \qquad \text{-------------------------- (31)}$$

Where δ is the Kroenecker delta. At the point of normalization, and when α_0, is set equal to expenditure in the base period such that α_i equals the predicted budget share, (31) reduces to:

$$\epsilon_{ijt} = -\delta + \left(\frac{\gamma_{ij}}{w_{it}}\right) - \left(\frac{\beta_i}{w_{it}}\right) w_{jt}. \qquad \text{-------------------- (32)}$$

This expression is identical to the formula used by Chalfant (1987) in the LAAIDS model. Buse (1994) shows that the correct uncompensated elasticities for the LAAIDS model as computed by Green and Alston (1990) can be written as

$$\begin{aligned}\epsilon_{ijt} = & -\delta + \left(\frac{\gamma_{ij}}{w_{it}}\right) \\ & - \left(\frac{\beta_i}{w_{it}}\right)\left(w_{jt} + \sum_{j=1}^{n} \gamma_{ij} \ln p_{jt}\right) \\ & \times \left(1 + \sum_{j=1}^{n} \beta_j \ln p_{jt}\right)^{-1}. \qquad \text{-------------------- (33)}\end{aligned}$$

However, at the point of normalization, equation (33) reduces to (32). Thus, at the point of normalization where prices are unity, the formulas for the uncompensated elasticities are equal for both the AIDS model and its linear approximation if α_0 is set equal to expenditure in the base period. Finally, the reduced expenditure elasticity for the AIDS model is given as:

$$\eta_{it} = 1 + \frac{\beta_i}{w_{it}}. \qquad \text{---------------------------- (34)}$$

Green and Alston (1991) showed that this expression is not correct for the LAAIDS model. In Buse's (1994) notation, the correct expression is given as:

$$\eta_{it} = 1 + \left(\frac{\beta_i}{w_{it}}\right)\left(1 - \frac{\sum_{j=1}^{n} \beta_j \ln p_{jt}}{1 + \sum_{j=1}^{n} \beta_j \ln p_{jt}}\right). \quad \text{-------------} \quad (35)$$

However, at the point of normalization, (35) reduces to (34). As the expressions for the uncompensated elasticities and the expenditure elasticities are equal in both models at the point of normalization, the expressions for the compensated elasticities, which can be found using the Slutsky equation, are also equal:

$$\epsilon^{*}_{ijt} = -\delta + \frac{\gamma_{ij}}{w_{it}} + w_{jt}. \quad \text{-------------------------} \quad (36)$$

Equation (34) gives us the expenditure elasticities at the point of normalization. This is essential for our analysis of household energy demand in rural areas where market for fuel wood and charcoal are distorted and obtained for free. Since, the pricing system is non existent; the budget share provides better mechanism of estimation for the income or expenditure elasticities.

4.3. The multinomial logit model for estimation of household energy choice

The multinomial logit model is used in this study to estimate the significance of the factors believed to influence household's choice among different fuels in rural energy demand system. Multinomial logit model describes the behavior of consumers when they are faced with a variety of goods with a common consumption objective. If only two discrete choices have to be analyzed, the multinomial logit model reduces to a logit model.

Suppose we have j possible alternative energy forms each consumed by household sector with some probability q_{mj}, m=1, 2, 3..., M, and j = 1, 2, 3..., J. The multinomial logit notation expresses these probabilities relative to some bench mark out come, say q_{Mj} as function of linear combination of a set of i explanatory variables, Zi.

If we suppress the subscript j for the case of exposition, letting

$$\frac{q_m}{q_m + q_M} = F\,(Z`b_m) \text{ -- } (37)$$

For m= 1, 2, 3,...M-1. Property of probability indicates that

$$q_m = \frac{F\,(Z`bm)}{q_M} = \frac{F(Z`b_m)}{1-F\,(Z`bm)} \text{ ------------------------------------ } (38)$$

Where the function F (.) is a monotone increasing function in its arguments, because $q_m \in (0, 1)$. Because the probability that a household chooses one type of cooking fuel is restricted to lie between zero and one. This in turn implies that

$\sum_{m=1}^{M} q_m = 1$, we have that:

$$\sum_{j=1}^{M-1} \frac{q_j}{q_m} = \frac{1-q_M}{q_M} = \frac{1}{q_M} - 1, \text{ ---------------------------------- } (39)$$

This thus defines the j[th] probability (bench mark probability) as:

$$q_m = \{1+\sum_{j=1}^{M-1} \frac{q_j}{q_m}\}^{-1} = \{1+\sum_{j=1}^{M-1} Q(Z`b_j)\}^{-1} \text{-----------------------------}(40)$$

The model assumes that households make fuel choice that maximizes their utility.

More generally,

$$Q_m = \frac{Q(Z`bm)}{1+\sum_{j=1}^{M-1} Q(Z`bj)} = \frac{exp\ Q(Z`b_m)}{1+\sum_{j=1}^{M-1} \exp Q(Z`b_j)} \text{---------------------}(41)$$

For all m=1, 2, 3…, M-1

This implies that each probability can be expressed in terms of set of explanatory variables and an unknown set of parameter vectors $b_{1,}\, b_{2,}\, b_3 ,\ldots\ b_{M-1}$. Estimation of the model requires specification of ***Q(.)*** in which case it turns out to be ***Q(u)*** = exp***Q(u)*** such that the specification of ***Q(.)*** is logistic.

When the logit equation above is rearranged using algebra, the regression equation is written as:

$$q_m = \frac{e^{(b_0 + b_1x_1 + b_2x_2 + \ldots\ b_Mx_M)}}{1 + e^{(b_0 + b_1x_1 + b_2x_2 + \ldots\ b_Mx_M)}} \text{-------------------------------------}(42)$$

The equation used to estimate the coefficients is specified as:

$$\ln \left(\frac{q_m}{1 - q_m} \right) = b_0 + b_1x_1 + b_2x_2 + \ldots\ b_Mx_M \text{--------------------------------}(43)$$

From the equation qm/ (1 – qm) indicates the odd ratios. In fact, equation 43 has expressed the logit (log odds) as a linear function of the explanatory variables (Xs). Equation 43 allows for the interpretation of the logit weights for variables in the same way as in linear regressions. For example, the variable weights refer to the degree to which the probability of choosing one firewood alternative would change with a one-year change in age of household head. For example, e^{bv} (in equation 4) is the multiplicative factor by which the odds ratio would change if X changes by one unit.

Econometric formulation of log likelihood function is used in multinomial logit for a given sample data. Particularly, we formulate the log likelihood as a product of the probabilities of each of the observations in the sample; the likelihood contribution is given as:

$$l = \prod_{m=1}^{M} pr(z_i = m/z_i)^{h_{im}} = \prod_{m=1}^{M} q_{im}^{h_{im}} \text{ -------------------------------- } (44)$$

Where **him** = 1(**z**i =**m**) for **m = 1, 2, 3 ...M** and where q_{im} stand for the probability of that the i^{th} dependent variable takes the m^{th} value.

Generally, the overall likelihood can be written as:

$$l(b_1, b_2, b_3, \ldots b_{J-1}) = \prod_{i=1}^{N} \prod_{m=1}^{M} q_{im}^{h_{im}} \text{ -------------------------------- } (45)$$

With the probability defined using the formula defined above. The model assumes no reallocation in the alternative set and no changes in fuel prices or fuel attributes. Finally maximization of the (log) likelihood will yield the multinomial logit estimator which does replicate the observed data.

The multinomial logit model has good computational properties except it suffers from the problem of independence of irrelevant alternatives. That is, in the model, the ratio of the probabilities of any two outcomes is independent of the probability of any other outcome. This follows from the initial assumption that the disturbances are independent and homoscedastic.

Remedial measure for this problem is omitting from the model choice sets that are truly irrelevant. And the action will not change the parameter estimates systematically. That is exclusion of these variables will be inefficient but not inconsistent. This is the usual Haussmann specification test.

The model follows from the assumption that the random disturbance terms are independently and identically distributed [McFadden, 1974]. In addition, Judge *et al.* (1985) shows that even if the number of alternatives are increased (from 2 to 3 to 4 etc) the odds of choosing an alternative fuel does not change.

5. EMPIRICAL ANALYSIS

5.1. Description of data survey

The data used for empirical discussion of this study is compiled from the longitudinal rural household survey conducted by Addis Ababa University, Department of Economics in collaboration with Center for Studies of African Economies, Oxford University. It provides detailed information on multitude of socio-economic variables of rural households. The survey touches up on all regions of the country. About 65 percent of the sample was drawn mainly from two regions (Oromia, 37.2% and Amhara, 27.7%) while Tigrai, and remaining regions together accounted for 8.9% and 26.2% of the sample surveyed, respectively. At grass root level households from each region were selected from different villages. The survey has broad outreach coverage and possesses all the desirable characteristics of panel data.

The questioner is organized in to three principal parts. The first part dealt with household demographics, assets and non-agricultural income. The second section is devoted to questions regarding agricultural production and livestock. The last section inquires information on food, energy and non food expenditures, health, women's activities and the like. In each of these parts a number of crucial information were inculcated. To conduct empirical investigation, the study used the 1994 and 2000 surveys. Total households interviewed and included in this survey in the year 1994 is 1479, while in the year 2000 the number of respondents grew to 1681 households.

The rationale for using expenditure rather than total income of household is that while the later is seasonally fluctuating for rural agricultural household, the former is more or less stable in the short run. In the short time span, total expenditure is a better indicator of household's welfare status. Hence instead of income, expenditure outlay is used interchangeably as a main ladder variable as households make progressive move up or regressive move down along the energy ladder. Households make inter fuel switch and inter fuel substitution in optimizing their energy mix in multiple fuel use (fuel stacking) system in response to income or expenditure changes. The change could be progressive in which case income or expenditure grows and households respond by introducing new, diversified and advanced fuels in to their energy portfolio (fuel mix). It could be regressive in a sense that income or expenditure of household goes down to which they respond by picking more inferior fuels in to their energy mix. In the estimation process a rigorous econometric methods of data discussions are employed.

Multistage budgeting of household decision making is used whereby households first decide on how much to spend on energy in their total expenditure. In the successive stages they decide on how to apportion the total energy expenditure on each category of fuels. Energy consumption of household is classified in to two major categories: modern or advanced energy sources like kerosene, match, batteries and candles, and traditional or inferior fuels such as fuel wood and charcoal.

However, information on rural energy price is not readily available rendering deterrence to our attempt of estimating the own and cross price elasticities of energy demand. This emanates from the ill-functioning of rural energy market. That is experience of rural households of Ethiopia reveals that market prices are insufficient indicators of fuel choice as some fuels can be consumed without being bought in the market. The cost of using firewood is determined by the opportunity cost of household member's labour time used to gather it from forests or woodlots. Such information on cost or expenditure on fuel wood is known only to the householders. Rural agricultural households may collect firewood from their own private woodlots, or from the common property forests at no financial cost. This implies that for such households fuel choice is affected only by the opportunity cost forgone in securing it. This is why we incorporated time spent on fuel collection as a major determinant of household energy demand (fuel choice) in examining the fuel stacking (multiple fuel use) behavior of households.

The study used expenditure on energies and total household expenditure outlays for estimating the income or expenditure elasticities of energy demand (fuel choice) to discuss the hypothesis of energy ladder and fuel stacking (multiple fuel use) practices by households. For rural households, the decision over which fuel to use or how much of the fuel to use, requires consideration of several important factors. These variables are incorporated in to the functional specification of the regression equation.

5.2. Descriptive statistics of variables used in analysis

Table 1 gives descriptive statistics of the dependent variables and covariates used for this study. It discerns that the average share of inferior fuels in total household energy expenditure varied in a range of 48 percent in the year 1994 to 36 percent in the year 2000 exhibiting about 12 percent decline. To the collar opposite, for the stated period range the share of advanced fuels out of total household energy expenditure rose from 52 percent to 64 percent showing equal 12 percent increment. This indicates increasing average share of advanced energy and decreasing average share of the alternative in trend over time. The difference in the share of the two sorts of fuels in household total energy expenditure widened from 4 percent in the base year (1994) to 28 percent in the terminal year (2000).

This increasing share of modern energy and reverse trend observed for inferior fuel might be due to fuel wood scarcity and the consequent rising opportunity cost of fuel collection (as reflected in the time spent on fuel collection which rose acceleratory at high rate over this period range), response of household to health hazards problem associated with use of inferior fuels or several other factors. This difference is diverging because share of advanced fuel is rising sharply while that of inferior fuel is declining steadily. The gap between the average shares of the two energy categories is widened by 75% over the period range 1994 to 2000.

Households spent on average between birr 6 and birr 15 per month on inferior fuels over the period1994-2000. A relatively higher average amount of money per month (9 birr in 1994 and 28 birr in the year 2000) was spent on advanced fuels. This implies that average expenditure per month on advanced fuels increased by 19 birr, while that of inferior fuels showed only 9 birr increment in between these periods. The gap (divergence) in expenditure on these two fuel types increased from 3 birr in 1994 to 13 birr in 2000. This does not, however, tell us the change in the magnitude (quantity) of fuel consumption. Since expenditure is a function of quantity and price of fuels, this expanding gap in expenditure between the two fuel categories can be attributed to change in either or both of these variables.

The proportion of household that used advanced fuels increased from 83 percent in the year 1994 to 99 percent in the year 2000. This may perhaps be the main reason for the significant increase in the share of advanced fuels in the average total energy expenditure of households. The proportion of households that used inferior fuels also increased slightly from 93 percent to 99.9 percent over that period range. That is in the year 2000 almost all households consumed inferior fuels in a typical month at least ones. But this does not tell us the intensity of fuel utilization (i.e. in terms of quantity of fuel consumption); rather it indicates whether or not households used the corresponding fuel in a particular month.

Households who reported that they consume both inferior and advanced fuels are grouped under mix of inferior and advanced fuels. Their proportion significantly escalated from 79 percent in 1994 to 92 percent in the year 2000 exhibiting about 23% increment. This indicates that there is significant increasing tendency of household's fuel stacking behavior at consuming multiple fuels over the period range considered. Comparing variations in the proportion of households that consume inferior fuels, advanced fuels and mix of the two fuels, it was increased by 4 percent, 15 percent and 23 percent, respectively over the time range considered. This shows that fuel stacking practices by household has demonstrated remarkable increment in trend over time. It also implies the tendency of household's energy consumption inclining over time towards diversity of fuels and gradual shift to advanced energies in trend.

Households respond to scarcity of one fuel by adopting the alternative in to their energy mix (fuel choice). The tendency of households to use mix of advanced and inferior fuels might perhaps be attributed to various economic, social and environmental factors. Economic factors are welfare improvements that derive energy demand of household in favor of better fuel alternatives. Social dimension arises from household's developed cultural preferences, loyalty and familiarity especially for fuel wood. Environmental concern results from effort to avoid forest degradation and desertification arising from mass destruction of forests. Moreover, fuel specific end use, cooking or consumption habits, affordability of fuels or dependency of cost, and taste or preferences of household together with the aforementioned factors play critical role in guiding household to move for best mix of various energies chosen from fuel menu.

The growth of proportion of households consuming mix of inferior and advanced fuels implies increasing trend in diversity of fuels in household energy portfolio (fuel mix) over time. Rather than completely transiting from consumption of inferior fuels to cleaner and efficient modern energy alternatives, households make the best choice of mix of fuels. This confirms to the hypothesis that households generally used different fuels as their welfare improves which acts as a neutralizing case for the simplistic assumption of the energy ladder hypothesis.

The average time spent on collecting fuel wood increased from 29 minutes to 51 minutes over the period 1994-2000. This might be attributed to deforestation which caused forest to recede and so households have to travel relatively longer distances to get fuel from forest. The opportunity cost of collecting fuel wood increased as reflected in increased household expenditure on inferior fuels over the time range under consideration. As a result, over time fuel wood scarcities may develop which in turn leads to deepening crisis of energy poverty nexus for poor rural households of Ethiopia.

Although average total household expenditure per month slightly decreased from 190 birr to 188 birr, average energy expenditure rose from 15 birr to 43 birr over the period range 1994 to 2000. Average total monthly energy expenditure of household assumed higher share in average total monthly expenditure with share of 17 percent and 27 percent respectively in 1994 and 2000, exhibiting 10 percent rise. This implies that energy consumption for home use purpose claimed increasing trend of share in household total expenditure. The reason could perhaps be rising per unit price (expenditure on fuels) for household to secure fuel to meet their demand and or increased opportunity cost as reflected in escalated time spent on fuel collection. On the other hand, selection of energy sorts that are relatively more expensive in to their energy mix (fuel choice) might provide part of the justification.

When we consider the min and the max values of share of household energy in total household expenditure, the min value increased from 0 percent in the year 1994 to 0.01percent in the year 2000 while the max value decreased from 1percent in year 1994 to 0.90 percent in 2000. This indicates convergence over time of household expenditure share on energies. It might arise from increasing cost of energy to households with least energy to total expenditure share and cost effective and efficient fuel selection behavior of households with large energy to expenditure share over time.

In optimizing their fuel combination in an energy mix model rural households tend to move towards some optimality point over time. Those with high expenditure share on energies seek ways of cutting back on their expenditure by devising cost wisely strategy (i.e. by choosing to consume best mix of different energies were fuels are selected simultaneously from both inferior fuels and advanced fuels). On the other hand, overtime households make learning process to adopt fuel saving stove technologies. Reason for consuming no energy in the base year (1994) may be due to the fact that they consumed only low grade fuels like dung and residues which are not incorporated in this survey. However, in the terminal year (2000) those very households started demanding relatively more efficient inferior fuels like fuel wood and charcoal and/ or perhaps modern energies. This provides supportive evidence for increasing fuel stacking (multiple fuel use) behavior of households over time in trend which definitely seizes the sprite of this study.

Total number of livestock owned by household showed a slightly less than doubled increment on average from 4.7 to 8.4 in that period gap. But, land holding size (total hector of land owned by households) has shown slight change over the period. The increase in wealth possession of household gave rise to increase in the opportunity cost of collecting fuel wood from forest resulting in to shift towards advanced fuels as a consequence. Perhaps shift might have occurred towards lower grade fuels which are not included in this study.

Table1 descriptive statistics of variables

Variable label	Year 2000(N=1681)				Year 1994 (N=1479)			
	Mean	Std dev	Min value	Max value	Mean	Std dev	Min value	Max value
Total energy expenditure per month(in birr)	42.96	28.11	3	191	15.39	15.33	0	142
Total expenditure per month (in birr)	188.12	135.60	15	2651	190.39	465.36	0	1633
Share of energy in total expenditure	0.27	2.47	0.01	0.90	0.17	0.75	0	1
Expenditure on advanced fuels per month (in birr)	28.34	23.39	0	166	8.98	13.57	0	130
Expenditure on inferior fuel per month (in birr)	15.07	14.79	0	123	6.54	8.20	0	64
Share of advanced fuel in total energy	0.64	0.24	0	1	0.52	0.34	0	1
Share of inferior fuel in total energy	0.36	0.24	0	1	0.48	0.34	0	1
Use advanced fuel(yes=1, else 0)	0.99	0.19	0	1	0.83	0.38	0	1
Use inferior fuel(yes=1, else 0)	0.999	0.26	0	1	0.95	0.22	0	1
Use mix of advanced and inferior fuel(yes=1,else 0)	0.92	0.28	0	1	0.79	0.40	0	1
Education of household head(never any school=0 else 1)	0.30	0.46	0	1	0.30	0.46	0	1
Total time spent on fuel collection per month (in minute)	50.92	61.93	0.30	230	28.85	28.14	0	480
Total number of live stock owned by household	8.36	9.76	0	83	4.71	5.93	0	91
Total land owned by household (in hector)	1.41	1.17	0	8	1.38	1.15	0	8
Family size	6.88	3.53	2	26	6.00	3.05	1	23
Family size square	59.76	63.78	4	676	45.33	48.96	1	159
Age of household head (in year)	49.25	15.53	21	98	49.70	15.58	18	95
Age square	2667.16	1655.58	451	9604	2712.48	1664.65	324	9025
Sex of household head(male=1,else 2)	1.23	0.42	1	2	1.24	0.43	1	2
Male headed household(yes=1,else=0)	0.71	0.45	0	1	0.64	0.48	0	1

Source: computed from the ERHS (Ethiopian Rural Household survey 1994, and 2000)

5.3. Discussion of regression results

5.3.1. Elasticities of energy demand

Expenditure on different energy forms and total household expenditure outlay are used to estimate the expenditure elasticities of household energy demand (fuel choice). We are also interested in estimating the own and cross price elasticities of demand for different energies consumed by household but lack of information renders obstacle to our effort. The only information we have at hand is expenditure on different energies. Hence, under this section, we deal exclusively with the income/expenditure elasticities of inferior and advanced fuels. This is because the major indicator of household economic power is their income or expenditure outlay. However, we incorporated in the regression equation other determinants of household energy demand (fuel choice) [see appendix 1 and appendix 2].

For this purpose, the study used logarithm of share of the two fuels out of total household energy expenditure as dependent variables and logarithm of total household expenditure and other determinants of household energy demand (fuel choice) as explanatory variables. To examine the income effect by computing the expenditure or income elasticities, we controlled for other factors which entered in to our specified regression equation for parameter estimation in level (non logarithmic form). We are estimating the linear approximation almost ideal demand system (LAAIDS) with normalized prices. Hence, we done away with estimation of own and cross price elasticities as energy prices are set to unity. This would enable us to inspect the fuel use and energy demand (fuel choice) pattern in relation to household's monthly total expenditure.

It provides a systematic way for examining the energy ladder hypothesis as well as fuel stacking (multiple fuel use) behavior by the respondents. The former hypothesis states that households move ascending the energy ladder from consumption of low grade, inefficient, inconvenient and inferior fuels to consumption of modern or advanced, cleaner and efficient energies as their income or expenditure increases. The central question we are trying to reckon here is do households respond to income or expenditure increment by adding better, cleaner, efficient and modern fuel categories in to their energy mix?.

But the hypothesis of fuel stacking (multiple fuel use) states that households respond to increased income or expenditure by subtle optimization behavior where by both advanced and inferior fuels are consumed concurrently and simultaneously. This meant that, they draw or introduce new diversities of energies which include combination of inferior and modern fuels at any point in time in to their energy mix while retaining previously fuels in use as their income or expenditure improves. This in turn means that households do not simply make absolute, complete and exclusive switch but partial and gradual shift as allowed by their budget limit.

In the case of the energy ladder hypothesis, fuel consumption behavior of households exhibits vertical fuel diversification. That is they make complete switch from exclusive use of one fuel to exclusive use of alternatives. This fuel diversification occurs up the energy ladder when income or expenditure increases and down the ladder if this ladder variable/s[1] decreases. However, in fuel stacking (multiple fuel use) we get elements of both vertical and horizontal fuel diversification. Horizontal fuel diversification in this study is said to occur when households draw more fuels of assumed equal level of efficiency, cleanness and cost at a given point (stage) on the energy ladder as their income or expenditure rises. This could perhaps happen due to household`s better preference for the new fuel/s to be added from diverse angles such as: social, cultural and ecological factors. However, vertical fuel diversification involves adding or introducing a new fuel type either as absolute substitute or partial substitute for the energy perceived inferior as their income or expenditure progresses. In this case, households make best use of what they can afford as well as what they have at their disposal. The later seems more realistic for poor rural households of Ethiopia as they use the marginal increase in their income or expenditure more likely for unsatisfied basic necessities based on its urgency and priorities and least likely for energies.

We carried out the random effect (RE) and fixed effect (FE) estimations and conducted the Haussmann test for making comparison between the two parameter estimates. Our decision is reject the null hypothesis[2] as the test returns out a significant result (see appendix1.2 and appendix 2.2). Our conclusion is that there is a systematic difference between the parameter estimates of the random effect and the fixed effect models. Thus we can fit the fixed effect for our data in computing the expenditure or income elasticities for both types of energy in this empirical study.

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[1] The ladder variables are the explanatory variables used in this study (refer to appendix 1 and 2). But here to compute the income or expenditure elasticities we controlled for non-expenditure determinants of household energy demand. And coefficient on logarithm of total household expenditure is used for our empirical study.

[2] The null hypothesis states that the difference between coefficients of fixed effect and random effect models is not systematic.

variable/s[1] decreases. However, in fuel stacking (multiple fuel use) we get elements of both vertical and horizontal fuel diversification. Horizontal fuel diversification in this study is said to occur when households draw more fuels of assumed equal level of efficiency, cleanness and cost at a given point (stage) on the energy ladder as their income or expenditure rises. This could perhaps happen due to household's better preference for the new fuel/s to be added from diverse angles such as: social, cultural and ecological factors. However, vertical fuel diversification involves adding or introducing a new fuel type either as absolute substitute or partial substitute for the energy perceived inferior as their income or expenditure progresses. In this case, households make best use of what they can afford as well as what they have at their disposal. The later seems more realistic for poor rural households of Ethiopia as they use the marginal increase in their income or expenditure more likely for unsatisfied basic necessities based on its urgency and priorities and least likely for energies.

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[1] The ladder variables are the explanatory variables used in this study (refer to appendix 1 and 2). But here to compute the income or expenditure elasticities we controlled for non-expenditure determinants of household energy demand. And coefficient on logarithm of total household expenditure is used for our empirical study.

[2] The null hypothesis states that the difference between coefficients of fixed effect and random effect models is not systematic.

The overall F-statistics is significant for all the twelve variables included in to the regression equations (refer to appendix 1.2 and appendix 2.2). That means we reject the null hypotheses that states that all the coefficients are jointly statistically not significantly different from zero. Our conclusion is that the demand equation is statistically significantly defined jointly by all the variables incorporated in to the model. We tried to incorporate more predictors in to our regression equation but Haussmann test turns out inaccurate as degree of freedom exceeds twelve. Thus, the functional specifications of the demand equation for the two fuels include only twelve predictors. Non expenditure predictors are mainly household characteristics like household head's age, household head's sex, and household head's education, household family size etc. Village level effects like time required for fuel collection (access to fuels) and household's wealth such as total number of livestock and land holding size are also included in the equations specified for estimation of the demand system.

The parameter estimate of household demand for inferior fuels are obtained by regressing log expenditure share of the fuel out of household total monthly energy expenditure on household's log total monthly expenditure. The negative sign of the parameter estimate on inferior fuels (referring to appendix 1.2) reveals that demand for these sorts of energy declines with rising household total expenditure. This implies that these fuels which mainly include fuel wood and charcoal are in fact inferior goods. Households are gradually shifting away from use of inferior fuels towards modern fuels but they are not making a complete, absolute and exclusive switch from one fuel use to alternatives. That means fuel switching and inter fuel substitution takes place as part of household's smoothing their interim total consumption expenditure over time and depends on the interaction between diverse factors described above. Energy transition occurs as part of household economic transition.

However, they make a progressive move towards using multiple fuels chosen from array of fuels (energy mix). This underpins the reality of economic theory that consumers maximize their utility by choosing to consume the best mix of goods with upper bound limit set by their budget. It provides justification for household's fuel stacking (multiple fuel use) strategy in which case households first look in to their money in pocket and choose affordable fuel types from the menu of energy array. Otherwise, as a last resort they switch their fuel consumption to firewood which is freely collectible but with all the repercussion health and environmental effects associated with its use.

In contrast, the parameter estimate of advanced fuels which is obtained in a similar fashion is positive testimony that these fuels are normal goods (refer to appendix 2.2). Their demand increases with rising household total expenditure or income. With advance in economic welfare of households, we observe that they switch in favor of modern and cleaner fuels. This result boosts some support to the energy ladder hypothesis as households respond to progress of their income or expenditure by adopting modern energy forms in to their energy mix. However, households generally lean to use more fuel types as their income or expenditure increases instead of completely switching to cleaner alternatives. That means they diversify their fuel both vertically and horizontally to make best use of their resources. This in turn implies that households switch between different fuels in optimizing their energy mix as their income or expenditure progresses. Here they more likely diversify their energy towards advanced fuels as their economic welfare improves.

Driving force behind such behavior of households is that inclusion of more advanced, modern and cleaner fuels in to their energy portfolio (energy mix) requires purchase of additional and perhaps new appliances suitable for the new energy introduced. Moreover, preferences of household towards energy specific end use also play a vital role for households being stacked at consuming mix of inferior and advanced fuels simultaneously rather than abandoning the former completely in response to welfare progression. Under certain circumstances, certain types of foods are cooked using mainly a particular fuel type and fuel combinations. To this effect, in the rural part of Ethiopia for example baking of bread is done using animal dung and crop residue while enjera is prepared using fuel wood, leaf or crop residues. It is not possible to use kerosene to bake bread or prepare enjera which is merely used for lightening purpose. The reason may be due to non-replaceable use of some of these energy sources and cultural preferences and tastes of households.

In addition, uncertainty about the supply of the fuel, affordability of the fuel and convenience or expedience of fuel use by consumers also play pervasive crucial role for household fuel stacking (multiple fuel use) practices exhibited in this empirical study. These factors preclude household's complete switch decision from use of inferior fuels to advanced alternatives as their income or expenditure grows; rather it allows partial shift to modern fuels while retaining inferior fuels still in their energy or fuel mix. To put precisely, progression of income or expenditure is not the only factor defining household energy demand (fuel choice). Hypothesis of fuel stacking (multiple fuel use) appears a neutralizing case for the extreme position held by the energy ladder hypothesis. Therefore, hypothesis of fuel stacking or multiple fuel use sounds more applicable as well as plausible for explaining the household energy demand (fuel choice) of rural part of Ethiopia than the energy ladder hypothesis.

We computed the expenditure or income elasticity of inferior fuel using equation (34), whereby the mean share of inferior fuels out of total household energy expenditure from table1 above was used in place of W_{it} and coefficient of log total household expenditure as a predictor in the fixed effect model given in appendix 1.2 substituted for β_i. Applying this formulation to our regression result, the expenditure or income elasticity of demand for inferior fuel is calculated and stood at 0.90 in 1994 and 0.87 in the year 2000 which are less than unity. This indicates that demand for inferior fuel is expenditure or income inelastic. A given percentage increase in household total expenditure gave rise to less than proportionate percentage increase in household demand for inferior fuels. That means fire wood collection is essentially inelastic with respect to improvement in living standard of households even in rural areas. Interestingly enough, this result is consistent with the finding obtained by Baland et al. (2007) for Nepali's households which states that firewood collection is essentially inelastic with respect to improvement in living standard (which we approximated in this study by total household income or expenditure).

The decrease in the computed elasticity over the period range considered indicates that the response of household energy demand for inferior fuels to the total expenditure of household dynamically dwindled over time. That means these fuels are becoming less and less important in sharing household budget or total expenditure allocation. The acute shortage of fuel wood due to the prolonged and rapid deforestation together with the consequent rampant forest degradation that the country is recently experiencing may give part of explanation for such outcomes. This argument provides some support to the energy ladder hypothesis as demand for fuel wood and charcoal which are considered inferior or traditional fuels shrank with increased total household expenditure.

Table2 Expenditure or Income elasticities of inferior and advanced fuels

Energy Category	Parameters	Year	
		1994	2000
Traditional (Inferior fuels)	W_{it}	0.52	0.64
	B_i	-0.047	-0.047
	η_{it}	**0.90**	**0.87**
Advanced fuels	W_{it}	0.48	0.36
	B_i	0.033	0.033
	η_{it}	**1.06**	**1.05**

Source: computed from ERHS (Ethiopian Rural Household Survey, 1994 and 2000, based on descriptive statistics given above and Appendix 1.2 and 2.2)

Where the parameters are defined as: W_{it} is the budget share of energy type i in total household energy expenditure. Bi is the coefficient of total household expenditure as predictor in estimation of demand for inferior fuels and advanced fuel in the fixed effect model. η_{it} is the elasticity of energy demand for each of the fuel categories.

Similarly, applying the same rule we computed the income or expenditure elasticity of demand for advanced fuels. As we expect it is greater that unity indicating that demand for advanced fuel is elastic with respect to household's total expenditure. A given percentage increase in household log total expenditure gave rise to more than proportionate percentage increase in demand for advanced fuels. That means as income or expenditure of household increases, they will respond by adopting or introducing more and more modern energy types in to their energy portfolio (energy mix). The absolute magnitude of the elasticity stood at 1.06 in the year 1994 and 1.05 in the year 2000. Households are stepping up the energy ladder with rise in their income or expenditure but various other factors hamper complete and exclusive switch between different fuels.

Here too we observe decline in the calculated elasticity in trend over time but the gap is small compared to that of inferior fuels. As the result indicates, this emanates from diminishing share of advanced fuels in total household expenditure. Though we are not explicitly dealing with the issue in this study, the decline in the expenditure elasticities might perhaps be attributed to increase in income or expenditure elasticity of demand for mix of inferior and advanced fuels.

This result provides consistent, solid and supportive evidence/argument to the economic literature that despite the income constraint, households prefer the normal good (advanced fuels) to the inferior goods (inferior fuels). Although there is no complete switch or shift this supports the hypothesis that households tend to use more of cleaner fuel alternatives and less of traditional fuels as their total expenditure rises. They may perhaps substituted advanced fuels for inferior fuels as their income or expenditure increases while retaining certain portion of inferior fuels in their energy portfolio (fuel mix).

More generally, the study's result depicting elastic demand for advanced fuels and inelastic demand for inferior fuels indicates the increasing desire for comfort and discretionary in household energy consumption pattern with improvement in living standard. It reflects households' altruistic and instinct behavior of maximizing pleasure (associated with using advanced fuels) and minimizing pain (associated with using of inferior fuels) as their welfare improves. To this effect, Arnold et al .(2006) obtained similar observations arguing that households switch their fuel use from biomass to modern energy sources as a country develops and incomes increase, implying that firewood is an inferior good.

Consumption of inferior fuel has two opposite effects on household welfare when it is used for home purposes. The utility it delivers such services as cooking, heating and lightening gives it a characteristic of public good; while the smoke emission with health risk, environmental degradation, deforestation and ecological destruction makes it a public bad. The later is the pain we referred to above which households seek to minimize. Therefore, the weighted net out come of these contrasting effects determines household demand or choice for such fuels as firewood and charcoal.

However, we should have to bear in mind that though the expenditure elasticity of demand for inferior fuels are inelastic, the descriptive statistics discussed in the last section reveals that almost all households are consuming inferior fuels. This means inferior fuels particularly fuel wood shares significant part and parcel of rural household energy consumption. On the other hand, the household's expenditure elastic demand for advanced fuel and expenditure inelastic demand for inferior fuel testimonies that had there been a pave way for generating high income, rural households prefer advanced fuels to inferior fuels. But non expenditure or non income factors mentioned above come in to play for households to retain inferior fuels still in their fuel choice or energy mix. This argument affirms our stand point explained above that fuel stacking (multiple fuel use) is a better working hypothesis describing the energy demand (fuel choice) of rural households of Ethiopia. This issue of fuel staking (multiple fuel use) is illustrated more deeply in the forthcoming section.

5.3.2. Multinomial logit estimate to analyze household fuel stacking (multiple fuel use)

The multinomial logit model provides systematic means of studying a complicated economic agent's choice decision when choices are made from more than two alternatives. In this case ordering of alternatives does not bear influence on decision of economic agents. This paper uses multinomial logit estimate of the determinants of household choice decision between different energy sorts consumed for household home use purposes like cooking, heating and lightening. It is used thus to scrutinize empirically and test the subject of household fuel stacking (multiple fuel use) strategy in a more rigorous fashion.

Household fuel choice decision in this case is made between inferior fuels which include firewood and charcoal as a basic fuel, and advanced fuels like kerosene, match, batteries and candles, and a combination of the two energy categories as a third alternative. Here, however, we cannot comment on the relative importance of fuel types as it only indicates which fuel is preferred to which by household and not the intensity of fuel consumption as expressed for example in terms of amount of expenditure incurred by households on each of the fuel category. Therefore, for simplicity of empirically analyzing and testing of fuel stacking (multiple fuel use) behavior of household, multinomial logit model is used where we grouped consumers in to three major categories in terms of main fuel consumed by households. Namely, those whose main fuel is inferior fuels, advanced fuels only and a mix of advanced and inferior fuels.

The dependent variable is the fuel choice (inferior fuel and mix of inferior and advanced fuels) with advanced fuel taken as the reference choice. Estimated coefficients measure the estimated change in the logit for a one-unit change in the predictor variable while the other reference (omitted) variables (advanced fuels) are held constant. A positive estimated coefficient of predictors in the model implies an increase in the likelihood of household's choosing the alternative fuel. A negative estimated coefficient indicates that there is less likelihood that household will change to alternative fuel. P-value indicates whether or not a change in the predictor significantly changes the logit at the specified acceptance level. That is, does a change in the corresponding predictor variable significantly affect the choice of the response category compared to the reference category? If p-value is greater than the accepted confidence level, then there is insufficient evidence that a change in the predictor affects the choice of response category from reference category. These p-values are denoted with stars on the coefficients of respective predictors (refer to table3).

For our illustration the multinomial logit estimates are presented in table3 below. Advanced fuels are the base category (omitted or reference category) with which the estimated coefficients are to be compared. Here the response categories are inferior fuel and mix of inferior and advanced fuels where as the advanced fuel is the reference category. To obtain efficient estimators of the model, this study used Robust standard errors reported in brackets.

Table 3 multinomial logit estimate of the choices of household between inferior, advanced and mix of inferior and advanced fuels (advanced fuel taken as base category)

Explanatory variables	Dependent variables	
	Inferior fuels	Mix of inferior and advanced fuels
Total monthly expenditure	-0.01 (0.002)	-0.001 (0.002)
Monthly expenditure on advanced fuels	0.34** (2.71)	2.53 (1.41)
Monthly expenditure on inferior fuels	5.62 (2.69)	3.37 (1.32)
Sex of head (1 if male otherwise zero)	-0.21** (0.51)	0.16** (0.43)
Education of household head(attended =1, else=0)	-2.85 (0.66)	-0.20** (0.43)
Time spent on fuel collection	-2.42 (0.38)	-0.45 (0.18)
Total number of livestock	0.10** (0.17)	-0.02** (0.05)
Land holding size	-3.42** (10.77)	-0.02*** (0.05)
Family size	-0.08** (0.24)	-0.32*** (0.23)
Family size square	0.006** (0.014)	0.02*** (0.02)
Age of household head	-0.28 (0.08)	-0.05*** (0.04)
Age of head square	0.003 (0.001)	0.001*** (0.001)
dummy2000	-4.36*** (2.82)	2.36 (0.47)
Constant	6.17 (2.42)	-1.30*** (0.96)
Wald chi2(22)	6243.12	
Number of observation	2713	2713

Source: computed from ERHS (Ethiopian rural Household survey 1994 and 2000)

Robust z statistics in parenthesis.

** Significant at 5%, *** significant at 1%

The dependent variable is 0 if the main fuel consumed by household is inferior fuel; 1 if the main fuel is mix of inferior and advanced fuel and 2 if it is advanced fuel.

Household total expenditure

Household total expenditure or income reflects their economic power or welfare status. The energy ladder hypothesis states that households make progression from consumption of inferior fuel to wards cleaner, efficient and advanced or modern energy forms as their economic welfare improves. Hence household total income or expenditure is theoretically expected to negatively influence their choice decision for inferior fuel in comparison to advanced fuel alternatives.

In this study, the negative sign of coefficient on inferior fuels and mix of inferior and advanced fuels corresponding to total household expenditure as predictor suggests that households with high total expenditure are less likely to select either inferior fuels or the mix of inferior and advanced fuels away from advanced fuels. The estimators are statistically insignificant even at 1% level of precision. Our result suggests that households are more inclined to wards selection of advanced fuels as compared to inferior fuels only or mix of inferior and advanced fuels as main fuel when their total expenditure rises. In this light, supportive evidence was given by Barnes, Kruntilla and Hyde (2004) and Faye (2002), who pointed out that the increase in income of household, give rise to decline in the percentage of consumers who choose to consume traditional fuels and increase in percentage of consumers who consume advanced fuels. .

However, as the descriptive statistics implied inferior fuel is rarely entirely excluded from the energy mix of rural households. This indicates that rather than giving up totally the inferior fuels; households are stacked at consuming multiple fuel types (both inferior and modern fuel forms) at any stage of their economic development. This finding thus supports both the energy ladder hypothesis as households go for modern energy form as their expenditure or income increases, and fuel stacking (multiple fuel use) pattern as they opt to increase proportion of modern fuels and never give up consumption of inferior fuels all in all.

That is to say, as expenditure or income of household increases they will not completely abandon inferior fuels but make progress to wards consumption of mix of inferior and advanced fuels. In addition to factors stated in the previous section, fuel stove or appliance which is mostly traditional in rural areas constrains household's demand to flexibly switch completely from inferior fuels to modern fuels. Moreover, various other factors discussed above accounted for this result.

Here controlling for all other factors, we observe that with rise in the income or expenditure of households, they will increase the proportion of advanced fuels in their energy portfolio (energy mix) but will not completely switch away from inferior fuels. Households in developing countries like Ethiopia do not switch to modern energy sources but instead tend to consume a combination of fuels which in this case may include inferior and advanced fuels as main sources of energy. However, while income or expenditure is an important variable, there are numerous other factors that we need to consider in discussing household energy demand (fuel choice). Discussion on some of these variables follows suit below.

Monthly expenditure on inferior and advanced fuels

The estimation result suggests that higher monthly expenditure on advanced fuels increases the likelihood that households choose either solely inferior fuels or mix of inferior and advanced fuels to advanced fuel itself. At 5% precision level, the likelihood of household to select inferior fuel away from advanced fuels as expenditure on the latter increases is statistically significant but for the mix of inferior and advanced fuels it is insignificant at all precision level, however.

This result suggests that there is some degree of substitutability between the two energy categories. But we cannot comment on the extent of substitution effect as this issue needs energy prices to examine the cross price elasticities. But shortage of information on rural energy prices deters such attempt. This results from deficiency or ill-functioning rural energy market reflected in non availability of energy pricing instrument and it varies from village to village and from region to region making it difficult to use common price index. For rural agriculture household the market is not smoothly and efficiently working. Hence energy demand is not easily understandable as advanced fuels are sold in multiplicities of small and fragmented markets and inferior fuels are collected at zero financial cost. In addition, the opportunity cost of gathering fuel wood depends on wealth possession of households and accessibility of forests (firewood) which varies from place to place.

The positive coefficient corresponding to monthly expenditure on inferior fuels as a predictor suggests that the likelihood of household to select inferior fuels or mix of inferior and advanced fuels away from advanced fuel increases with increase in amount of budget allotted on inferior fuels. But it is insignificant at influencing the choice decision of household at all precision level.

Gender of household head

Men and women have different views regarding household fuel choice issues in the rural part of Ethiopia. Hence, for empirical analysis, the paper emphasizes gender differences as central to our understanding of household fuel choice between the three alternative energy forms for household home use purposes. In Sub- Saharan African countries as in other developing countries fuel collection is traditionally considered as the task performed by female and children. This conversional division of labour between different occupations makes us to expect female headed households to more likely prefer inferior fuels to advanced ones.

The study's result given in table3 conforms to this argument as the coefficient on the sex of household head is negative and significant. That means male headed households are less likely to choose inferior fuels compared to advanced fuels. However, positive and significant coefficient corresponding to mix of inferior and advanced fuels suggests that male headed households are more likely to choose mix of inferior and advanced fuels rather than advanced fuels. The other side of the coin conveys the fact that female headed households tend to prefer inferior fuels while male headed households tend to prefer mix of inferior and advanced fuels compared to the base category (advanced fuels). Sex of household head is statistically significant at 5% level of precision in influencing the likelihood of household choice decision for inferior fuels only or mix of inferior and advanced fuels away from advanced fuels. This implies that there is sufficient evidence to argue that gender of household bears effect on choice decision of household among different energy sorts.

Education of household head

The level of education of household head is expected to have a negative effect on the preference of household towards inferior fuels. We expect that the more educated the household head is, the less likely is the probability of choosing inferior fuels as main fuel compared to advanced fuels. This is because high level of education improves knowledge of household on fuel attributes, and changes their tastes and preferences for better fuel alternatives. It also increases income of household which then can be used to purchase modern fuels and appliances which are comparatively more expensive. In addition, a highly educated household head is more likely to lack time to collect firewood and may prefer to use the alternatives.

Education also improves awareness of household about the impact of using inferior fuels on forest degradation and deforestation, and effect of smoke emission hazard on health of female and children while cooking. These and various other factors interplay a critical role in diverting demand of households with educated heads towards consuming advanced fuels. Citrus paribus, the more educated the household heads are, the less is likelihood that they prefer inferior fuel or mix of inferior and advanced fuels as main fuel in comparison to advanced fuel.

From our estimation result reported in table3 above, the negative sign of the coefficient of education of household head corresponding to the dependent variable inferior fuel indicates that the more educated the household head is, the less likely that inferior fuel is chosen as a main fuel away from advanced fuel. This also holds for the likelihood of choosing a mix of inferior and advanced fuels but here the coefficient is statistically significant at 5% level of precision.

Household family size

Household family size is theoretically expected to positively affect choice of household for inferior fuels. This is because larger household family size may mean larger labour input, which is needed for firewood collection. The impact of household family size on their preference for alternative fuels is ambiguous, because greater household family size means increased demand for energy but also increased possibility of fuel substitution. It is also assumed that it is cheaper to cook for many people using firewood than using its alternatives. This is because per unit price of inferior fuel is lower than per unit prices of its alternatives. Other things being equal, to feed many people requires a lot of fuel on aggregate. Hence, the expectation is that households with larger family size will prefer to use more inferior fuels. The reason could perhaps be it is comparatively cheaper to use these fuels to cook for many people and it has a lower consumption rate per unit of time compared to the alternatives.

However, from table3, we see that the negative and significant coefficients of inferior fuels only and mix of inferior and advanced fuels suggests that households are less likely to choose inferior or mix of inferior and advanced fuels away from advanced fuels as family size increases. Part of the reason may lay in the exploitation of economies of scale associated with relatively less per capita energy demand for larger household family size. That means additional members of households benefit from the fuel consumption of other members resulting in exploitation of economies of scale.

Households with larger family size are more efficient in their fuel utilization as same amount of fuel can be used to cook large amount of food. However, the negative coefficient on household family size is not a reasonable outcome and we have no supportive argument on such outcomes. Rather according to Démurger and Martin (2006) household family size has concave effect on fuel wood collection. In this study, however, the positive and significant coefficient of family size square implies that there is nonlinearity were by as family size increases the likelihood of household to choose inferior fuels only or mix of inferior and advanced fuels as a dominant fuel away from advanced fuels increases at an increasing rate.

From view point of economic theory, it is expected that the likelihood of households choosing inferior fuel only or mix of inferior and advanced fuels in comparison to advanced fuels increases with increasing family size (more labour available for fuel collection). The out come of this study, the negative coefficient on the household family size as a predictor is consistent with Alem et al. (1998) and Ouedraogo (2006) who observed that household family size is one factor for reduced consumption of fuel wood and instead increased use of alternative fuels. The result of this empirical study indicates that though positive correlation between family size and choice in favor of inferior fuels or the mix of inferior and advanced fuels is violated, the family size square conform to this truth.

AGE OF HOUSEHOLD HEAD

The negative coefficient in our study's result on age of household head as a predictor suggests that the older are the heads, the less are the likelihood that households choose inferior fuels only or mix of inferior and advanced fuels as a main fuel away from advanced fuels. The reason may perhaps be due to heads being themselves aged and incapable to collect fuel wood from forest. The local experience of Ethiopia reveals that old aged households are dependent on their children for farming and other tasks. But household chores like water fetching and fuel collection are performed by their grand children which in most cases is unlikely as they go to school or serve their own parents. So they may substitute lower grade alternatives like dung and residue which they can obtain at least effort and are not reported in this survey or perhaps switch to advanced fuels.

However, younger household heads can them selves collect fuel from forest to reduce (save) their expenditure on advanced fuels which are relatively more expensive. Contrasting argument is that the age of household head is expected to influence fuel choice through developed loyalty and familiarity for inferior fuels. Old aged households have long history of using firewood (traditional fuels) and therefore lack flexibility to give up those fuels and switch to available alternatives. The older the household head citrus paribus, the more likely households will continue using firewood as their main fuel.

The result of the finding indicates that age of household head is not significant at explaining the choice of inferior fuel away from advanced fuel. But it is significant at explaining the likelihood that households choose mix of inferior and advanced fuels away from advanced fuels. On a sharp contrast, however, the positive coefficient of age square of household head indicates that choice of household for inferior fuels increases non-linearly at an increasing rate as compared to advanced fuels as age of household increases. The same reason holds for the probability that household choose a mix of inferior and advanced fuels compared to advanced fuels but in this case the coefficient is significant at 1% precision level and for the former not, however.

Time for fuel collection

The negative sign of coefficients on time for fuel collection in the study's result indicates that the more is the time required to collect fuel wood and or preparing charcoal, the less likely it is that households select inferior fuels or mix of inferior and advanced fuels as main fuel compared to advanced fuels. That is as opportunity cost of collecting fuel wood increases, households are more likely to switch towards the better available energy alternatives or perhaps switch to wards low grade fuels. This implies that the two fuels are substitutes as well as complementary to some extent. The cost of firewood increased, thus, challenging the already staggering living condition of households in rural Ethiopia. To cope with the situation households keep on diversifying their fuel towards a least cost combination of fuels in the energy mix model and they exhibit multiple fuel use (fuel stacking) strategy.

That is as scarcity of fuel wood sets in (develops), household's labor time required to collect it increases to which they respond by substituting the alternative fuel in to their energy mix. This may perhaps give a reasonable explanation for significant shift of household energy demand (fuel choice) from consumption of inferior fuels only or mix of inferior and advanced fuels as compared to advanced fuels with increment in time for fual collection as predictor. In this light, Heltberg et al. (2000) put supportive argument for this perspective stating that forest scarcity and increased time for fuel wood collection is among the major factors causing reduced consumption of fuel wood and instead use of alternative fuels.

Dummy 2000

The negative and significant coefficient estimate on dummy 2000 suggests that households are less likely to choose inferior fuels away from advanced fuels in the year 2000 compared to the year 1994. It indicates that overtime household's demand or preference shifted from consumption of inferior fuels towards advanced or modern fuels as main fuel other things kept intact.

However, the positive coefficient corresponding to the mix of inferior and advanced fuels suggests that households are more likely to choose mix of inferior and advanced fuels compared to advanced fuels in the year 2000 than 1994. This suggests a shift towards mix of inferior and advanced fuels over time. The likelihood of choosing inferior fuel away from advanced fuel is significant at 1% level of precision but insignificant for mix of inferior and advanced fuels at all level of significance. This indicates that the fuel stacking (multiple fuel use) practices by house hold has demonstrated remarkable improvement in the year 2000 compared to the base period. Households tend to shift gradually towards consumption of different energy mix chosen from energy array (fuel menu) than solely inferior fuels or advanced fuels.

Household wealth

The more livestock households possess, the more time allotted to its rearing thus reducing time for fuel collection. However, two facts negate this idea. First, households with more livestock can obtain more animal dung that serves as a substitute for fuel wood or charcoal reducing demand (preference) for fuel wood. Secondly, time for fuel wood collection and charcoal preparation may be complementary to cattle rearing. That is households can obtain these fuels while they are grazing livestock. Moreover, fuel wood and charcoal may be obtained while clearing forest or bushes for farming activities. In general, to put in a more precise language fuel collection or charcoal preparation can be performed complementarily together with other farming and non farming activities, making it difficult to estimate expenditure (opportunity cost) or shadow price of inferior fuels.

We expect that the more land owned by households, the more likely that households use inferior fuels. This is due to possibility of obtaining fuel wood from own private trees at their disposal and probably at a relatively least cost. The result of the finding is consistent with our expectation. The positive and statistically significant parameter estimate suggests that the larger is land holding size of household, the more is the likelihood of choosing inferior fuels or mix of inferior and advanced fuels compared to advanced fuels.

The parameter estimate of coefficients corresponding to total number of livestock is positive and significant indicating that the more livestock owned by household, the more likely it is that households choose inferior fuels away from advanced fuels. However, the negative coefficient corresponding to mix of inferior and advanced fuels implies that the more livestock owned by household the less is the likely hood that they prefer mix of inferior and advanced fuels to advanced fuels. Both parameters are statistically significant at 5 percent level of precision pointing out that there is sufficient evidence that these predictors bear effect on choice decision of households.

6. CONCLUSION AND POLICY IMPLICATION

Environment matters greatly to the poor. They directly or indirectly derive their livelihood from the environment. But there is a need to assure sustainability of such services for the future generation. What makes things worse is communal accessibility of such services in which case no one bears incentive to preserve. Particularly fuel collection from forest exhibits such characteristics as it is freely accessible to many rural households. Furthermore, the concomitant impoverishment of quality of life of the rural society leaves them with no recourse than deriving their basic necessities from the environment. This results in to energy poverty nexus and consequent ecological damp and environmental decay which developing countries are currently experiencing.

Fuel wood collection from common forest may perhaps be the leading cause of forest degradation and deforestation in Sub Saharan African in general and Ethiopia in particular. Due to growing pressure on forests and consequent fuel wood scarcities, the cost of firewood increased, either in collection time or health problem creating challenges for the already staggering living condition in such economies.

Most households of Ethiopia have sporadic and seasonally fluctuating income which creates disincentive to diversify their energy demand (fuel choice) particularly to modern and costlier energy alternatives. This combined with prolonged human settlement and clearing of forest resources for agricultural expansion and fuel wood purpose disturbed the natural ecological balance profoundly.

In an attempt to deeply envisage the issues of energy demand (fuel choice) of rural household of Ethiopia, this study used panel survey collected in the year 1994 and in the year 2000. Previously conducted studies used data from only one locality (village), few cities or regions and extrapolated a generalized conclusion. However, in this paper we used all region inclusive data, appropriate and data admissible as well as fully specified econometric model to boost concrete and solid evidences for contemporary household energy demand (fuel choice) literature.

As presented in the literature review, pioneer studies dealt with the issue of fuel stacking (multiple fuel use) in various other parts of the world. But the subject is not adequately explored for Sub-Saharan African countries in general and rural Ethiopia in particular. The result of this study supports the hypothesis that households tend to use multiple fuels in optimizing their energy demand as a response to increase in their income or expenditure. This means households draw more and new diversity of fuels from energy menu in to their energy mix (fuel choice) as their expenditure grows rather than abandoning previously fuels in use. They are said to exhibit fuel stacking or multiple fuel use behavior where by both advanced and inferior fuels are used concurrently and simultaneously at any stage of economic development and at any given point in time.

As the computed elasticities imply households are inclined to choose more clean, efficient and advanced fuels than inferior fuels in to their energy mix as their total expenditure increases. This implies that with improvement in quality of life, households exhibit increasing desire for comfort and discretionary in their energy consumption or fuel choice. They are trying to step up in to consumption of advanced fuels but never abandon inferior fuels completely. This meant that they make best use of what they can afford (advanced fuels) and what they can obtain at their disposal (inferior fuels). One possible area of policy intervention thus is concentrating on encouraging rural residents to substitute advanced fuels for fuel wood.

Households will not make a complete transition from exclusive use of one fuel to exclusive use of the alternative. That is to say that change in fuel consumption by household is not a smooth transition from biomass fuel to commercial fuels, but continual switching between different combinations of fuels in a process of fuel sacking (multiple fuel use). This fuel diversification and inter-fuel substitution practices by households can help them to discourage use of traditional fuels and to optimize their fuel choice in their energy mix.

Household expenditure depends on their purchasing power. However, purchasing power is dependent on the income, quantity of the fuel consumed as well as the relative prices of fuels. Rural households have meager income which they use to cover various expenditures based on its urgency and priorities. Shocks like the sky rocketing price of oil currently the world is experiencing leaves poor rural households with no option rather than picking more inferior fuels which they can obtain at free of any financial cost in to their energy mix. Furthermore, inflation degrades the purchasing power of households to which they respond by making inter fuel switch and inter fuel substitution, in this case to lower grade fuels.

Inferior fuel is not necessarily cheap due to the health smoke problem, environmental and ecological imbalances resulting from fuel wood consumption. Fuel collection also reduces education enrolment of rural societies especially children as it competes in time for such activities. Therefore, excessive dependence of household on biomass and other inferior fuels ends up in sever ecological destruction and resultant global warming, climatic change and drought leading to famine lastly. Hence government policy makers and concerned organs should create protective scheme to cut back on the bad resultant cost on environment.

To relief the growing pressure on natural forest and combat deepening crisis resulting from fuel wood consumption, policy makers should intervene in rural energy sector. But this is rarely performed in developing countries as rural households are marginalized and largely ignored. Such segmentation, however, creates imbalanced growth of the economy. There is pessimistic attitude regarding policy interventions targeting on remedying rural energy crisis in poor countries like Ethiopia. This is because energy demand in rural set up is not easily influenced by policies as fuel wood is collectible at zero financial cost. So, government policy instruments like subsidizing advanced fuels have less efficacy and effectiveness at influencing household energy demand (fuel choice).

As a result, households may have little incentive to diversify their energy consumption to available alternatives only due to income or expenditure growth. Thus policy makers should have to devise appropriate strategies that can actively address the problem. For instance, keeping the prices of modern energies lower could to some extent shift household demand to those sorts of fuels. But inaccessibility of modern energies may preclude such flexible inter fuel substitution decision by households ending up in subsidizing richer households with probably better access to modern energies. Moreover, energy end use specificity for household consumption also bears deterrence to such flexible fuel shift and fuel switch. Households cannot easily substitute away from consumption of one fuel to available alternatives. Therefore, rural households have less potential for fuel switching.

The income or expenditure level at which households make inter fuel switch is very critical for policy intervention. To achieve energy transition by household it takes time lag. That is energy transitions are varied in terms of timings of transition period and transitional fuels consumed. It is not a one time sudden switch but needs long time horizon. Complete transition from consumption of inferior fuels to modern fuels requires holistic social, economic, cultural as well as ideological changes of the whole society. However, for rural Sub-Saharan African countries this is a very long term dream to be achieved.

As stated in the literature review section, even in the developed countries like USA and European countries fuel wood (inferior fuel) played a dominant role until the mid 19^{th} century. However, economic development and technological progress made possible transition to modern energies. But for rural Sub-Saharan African countries it may take a long unforeseeable time to make complete switch to modern fuels.

The lack of adequate energy services in rural areas of developing countries has social and economic dimensions as well as serious environmental and health effects. The problem is further exacerbated by the use of simple technologies characterized by low energy efficiency and harmful emissions. Use of inferior (dirty) fuel bears health hazards from smoke particles especially on children and women while cooking meal. For developing countries in general and rural Sub-Saharan African countries in particular health problem arising from smoke of fuel wood is among the leading causes of early childhood and women death. With increasing scarcity of quality fuel, traveling relatively longer distance as well as use of inferior fuels such as dung and residues has different implications on women health. Thus policy makers should take precaution intervention to mitigate the resulting bad consequences.

Poverty remains one of the driving forces behind environmental degradation and ecological imbalances. Improving energy services for poor rural households in developing countries thus remains one of the most pressing challenges. Since there are multifarious links between poverty and energy; effort to alleviate poverty is impossible without first alleviating energy poverty. And this could be done through the economic empowerment of households.

In addition, the use of advanced energy source is inhibited by inability of households to afford the price. In addition, inaccessibility of the service acts as the major deterring force. Tradition, religion, lack of stove and the like also interplay a critical role as well. Therefore, ease of access and consistent availability of fuels are important factor that determine the extent of and or permanence of fuel switching in rural households.

The negative sign on time for fuel collection indicates that fuel wood scarcity forces households to switch either to lower grade fuels like animal dung and crop residues or advanced fuels. Increased burning of dung and crop residue, however, deprives the soil of important nutrients and hence reduces soil fertility. This adversely affects the productivity of agricultural sector which is the mainstay of the economy. Hence such kind of fuel switch is not promising and may cause deterioration of economic performance.

At the household level, clean energy can improve health and general well-being, particularly of women and children, by lowering indoor-air pollution levels associated with the use of biomass and solid fuels. But the inadequate energy accessibility to rural households of third world countries (like Sub-Saharan African countries) threatens to dampen economic growth, hobbles development, and keeps living standards low. In general, thus for low-income rural households, energy is a crucial factor for getting out of poverty traps.

In this study the demand for advanced fuel is expenditure elastic and for inferior fuel it is expenditure inelastic. This lays concrete ground for policy makers to intervene in rural energy setup. Targeting on increasing income of households will cause shift of their energy demand towards modern fuels. Here, however, issue of energy supply comes in to focus. Hence balanced energy demand and supply growth is a paramount important. Fuel diversification and inter-fuel substitution by households can therefore help them to discourage use of traditional fuels and optimize their fuel choice in the energy mix (fuel portfolio).

Sub-Saharan African countries, typically Ethiopia in this case have huge potential in natural resources. The country has enormous potential to generate hydroelectric power which could avert the deepening crisis in the energy sector. However, it demands huge capital investment to spread the electric power service to rural society at large scale. Even demand of urban and semi urban areas is still unmet. This is where supply dependency comes into play as a deterministic variable for household energy demand or fuel choice of rural Ethiopia. Access to electricity is for instance, totally lacking though the country has tremendous potential for hydroelectric power generation.

Poor countries are therefore handicapped by financial, infrastructural, and technological factors to mobilize resources and realize potentialities. Building technological capabilities and innovations are very key ingredients to success for these countries by enabling them to fully utilize resources and make progressive move or transition of the entire economy. Here, energy transition or fuel switch to modern form will occur as part of transition of the economies.

The other promising area of policy intervention is encouraging the bio fuel (biogas) generation and its adoption by rural households. That means some traditional forms of energy can be converted into more efficient and useful modern energy forms. For instance, biomass can be converted into liquid or gas fuels. This could be done at relatively modest financial cost but needs provision of training and knowledge creation among the vast majority of the society. It also requires high financial outlay for purchasing equipment and implementing the project. So, careful examination of all these factors should be accomplished to effectively implement the program.

Widespread bio fuel generation and its consumption practices by large segment of the society acts as a panacea for the devastating deforestation we currently experience. Therefore, bio fuel (biogas) could be one area of fuel diversification for rural households. The surpassing performance of this sort of fuel is its ability to relief ecological disturbances and health hazards attributed to fuel wood consumption and generation of fertilizer as a residue. Therefore, it sounds and proves very economical to diversify into bio fuel than in to more advanced and costlier fuel alternatives.

The result of this study stating that educated households prefer advanced fuels to inferior fuels create loop for educational policy intervention in rural areas of the country. Equipping rural residents with education specifically targeting on environmental issues like afforestation, own private land forestry or tree planting will acquaint households with awareness of the effect of their action on the natural environment. It also casts an insight in to win-win effect of education of household head in alleviating rural energy poverty nexus. Since education of household head increases the opportunity cost of labour, households can shift their labour from fuel wood collection to income generating activities. Moreover, for addressing the rampant loss of natural forest, enacting forest protection law proves better applicable policy instrument.

Fuel switching is gradual and time taking process with households exhibiting fuel stacking (multiple fuel use) behavior in response to changes in the underplaying factors. Policy makers have an option of economically empowering rural poor households to diversify their fuel use (fuel consumption). This enables them to tackle the consequences of fire wood consumption on health and ecological imbalances and global climatic warmth and thereby rehabilitate the environment. In this regard, policies should be geared to wards promoting inter fuel substitution and inter fuel switch by supporting households financially and technically to adopt improved stoves that can save fuel and reduce health problem associated with smokes besides assuring availability of diversity of fuels to rural energy users.

In light of this argument, in Ethiopia energy saving stoves like mirte and Lakech has a proven advantage for reducing the amount of fuel consumed and to avoid the health hazard problem arising from smoke emissions. However, distribution of these stoves to large segment of rural society demands huge capital investment as it is made up of cement which is costly. Moreover, in rural area there is information asymmetries and dissemination problem for households to adopt improved stove technologies.

Furthermore, fuel switching may sometimes lead to food switching. In response to fuel scarcity households switch to easy to cook foods. Energy demand or fuel choice of household has strong implication for their nutrition status. This could result in to malnutrition that ends up in various diseases. Therefore, policy interventions targeting on food security and eradication of those diseases should give due attention to this liaison between energy switching and food switching heading in to malnutrition.

As presented in the above paragraphs, the results of this empirical study have important policy implications and recommendations. Hence design of appropriate policy instrument and its implementation is critically indispensable in the energy sector of rural economies to rehabilitate the environment and reduce health risks as well as to tackle global climatic change which is devastating the contemporary world scientists. It is also important for implementation of the United Nation millennium development project which recommends halving number of households using traditional biomass for cooking by 2015 which would involve about 1.3 billion people switching to other fuel alternatives. More studies are therefore needed to be conducted in the areas of household fuel stacking (multiple fuel use) to examine the importance of the issue pertaining to house hold choice decision between different energies in various other parts of the world.

To sum up, the result of the finding indicates that as income of households grows they start to demand more diversified energy sources. Therefore, policy intervention is deemed critical to facilitate household welfare growth and assuring sustainable availability of diversity of energies for rural households.

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APPENDIXES

APPENDEX 1: FIXED AND RANDOM EFFECT ESTIMATES FOR INFERIOR FUELS

Appendix 1.1: Fixed Effect Estimates for Inferior Fuels

Fixed-effects (within) regression Number of obs = 2560
Number of groups = 246

R-sq: within = 0.7304 Obs per group: min = 1
between = 0.8595 avg = 0.4
overall = 0.7383 max = 35
F(12,2302) = 519.78

Explanatory variables	ln share of inferior fuel	
	Coefficient	Str.err
lnmonthlyenergy	-.8119996	.0165506
lntotalexpenditure	-.0470962	.0116358
female headed	.00046	.0276682**
age of head	-.0089387	.0039443
family size	-.013232	.0116327***
family size sqr	.0002368	.0006794**
neducation	.0294649	.0246991***
time for fuel collection	.0124562	.0002164
tot livestock	-.000197	.0014871**
age sqr	.0000906	.0000387
land owned	.0941549	.0303061
dummy 2000	-.0532409	.0269939
Constant	.7860843	.1215487

sigma_u | .27944905
sigma_e | .53362452
rho | .21521963 (fraction of variance due to u_i)
F test that all u_i=0:
F (245, 2302) = 0.88
Prob > F = 0.9119

** Significant at 5% and *** significant at 1%

Definition of Variables

lnshareofinferiorfuel = logarithm of share of expenditure on inferior fuels out of total household energy expenditure.

lnmonthlyenergy = logarithm of total monthly expenditure on energy out of total household energy expenditure.

lntotalexpenditure = logarithm of household total monthly expenditure.
female headed = households that are headed by female
age of head = age of household head.
family size = household family size family size
family size sqr = household family size square.

neducation = households whose head is literate.
time for fuel collection = time spend by household on fuel collection.
tot livestock = total number of live stock possessed by household.
land owned = land holding of households
age sqr = age of household head square.
dummy2000 = dummy for households who used inferior fuel in year 2000.

Appendix 1.2: Random Effect Estimates for Inferior Fuels

Random-effects GLS regression | Number of obs = 2560
Number of groups = 246

R-sq: within = 0.7303 | Obs per group: min = 1
between = 0.8605 | avg = 10.4
overall = 0.7384 | max = 35
Random effects u_i ~ Gaussian | Wald chi2(12) = 7187.72
corr(u_i, X) = 0 (assumed) | Prob > chi2 = 0.0000

Explanatory variables	ln share of inferior fuels	
	Coefficient	Str.err
lnmonthlyenergy	-.8255888	.0155376
lntotalexpenditure	-.0453582	.0109917
female headed	.0002066	.0263359 **
age of head	-.0066476	.0037293
family size	-.0168062	.0106483***
family size sqr	.0004318	.0006226***
neducation	.021553	.0233052***
time for fuel collection	.012697	.0002038
tot livestock	-.0004068	.0014054**
land owned	.0927403	.0279223
age sqr	.0000672	.0000367
dummy 2000	-.045149	.0261302
Constant	.7674038	.1144678

sigma_u | 0
igma_e | .53362452
rho | 0 (fraction of variance due to u_i)

** significant at 5% and *** significant at 1%

Appendix 1.3: Haussmann Test for Inferior Fuels

Explanatory variables	Coefficients			
	(b) Fixed	(B) random	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
lnmonthlyenergy	-.8119996	-.8255888	.0135892	.0057014
lntotalexpenditure	-.0470962	-.0453582	-.0017379	.0038175
female headed	.00046	.0002066	.0002534	.0084822
age of head	-.0089387	-.0066476	-.0022911	.0012847
family size	-.013232	-.0168062	.0035742	.0046834
family size sqr	.0002368	.0004318	-.000195	.000272
neducation	.0294649	.021553	.0079119	.0081802
time for fuel collection	.0124562	.012697	-.0002408	.0000725
tot livestock	-.000197	-.0004068	.0002098	.0004859
land owned	.0000906	.0927403	.0014147	.0117816
age sqr	-.0532409	.0000672	.0000234	.0000122
dummy 2000	.7860843	-.045149	-.0080919	.0067738

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(12) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 15.85
prob>chi2 = 0.1982

APPENDIX 2: FIXED AND RANDOM EFFECT ESTIMATES FOR ADVANCED FUELS

APPENDIX 2.1: Fixed Effect Estimates for Advanced Fuels

Fixed-effects (within) regression Number of obs = 2371
Number of groups = 240

R-sq: within = 0.6292 Obs per group: min = 1
between = 0.6046 avg = 9.9
overall = 0.6252 max = 34

F(12,2119) = 299.58
corr(u_i, Xb) = 0.0666 Prob > F = 0.0000

explanatory variable	ln share of advanced fuel	
	Coefficient	Str.err
lnmonthlyenergy	.2869822	.0114427
lntotalexpenditure	.0334927	.0077424
female headed	.0036893	.0182804**
age of head	.0059101	.002595
family size	.0139915	.0076144
family size sqr	-. 0004723	.00044***
neducation	-.0097838	.0162094**
time for fuel collection	-.0072449	.0001414
tot livestock	.0007589	.000987***
land owned	-.0063106	.0199975**
age sqr	-.0000505	.0000253
dummy 2000	.1116942	.0174502
Constant	-1.464849	.0800813

sigma_u | .27209945
igma_e | .33685992
rho | .39484315 (fraction of variance due to u_i)
F test that all u_i=0:
F(239, 2119) = 1.32
Prob > F = 0.0014

** Significant at 5% and *** significant at 1%

Definition of Variables

lnshareofadvancedfuelinenergy: - logarithm of share of expenditure on advanced fuels out of total household energy expenditure

APPENDIX 2.3: Haussmann Test for Advanced Fuels

Explanatory variables	Coefficients			
	(b) fixed	(B) random	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
lnmonthlyenergy	.2869822	.2997362	-.012754	.0033938
lntotalexpenditure	.0334927	.0326502	0008425	.0021746
female headed	.0036893	.0058304	-.0021411	.0048836
age of head	.0059101	.0054426	.0004675	.0006975
family size	.0139915	.0103532	.0036383	.0024965
family size sqr	-. 0004723	-.0002585	-.0002137	.0001437
neducation	-.0097838	-.005256	-.0045278	.0044696
Time for fuel collection	-.0072449	-.0073893	.0001444	.0000387
tot livestock	.0007589	.0194326	.0000355	.0002622
Land owned	-.0063106	-.0000478	.013122	.0064991
age sqr	-.0000505	-.0000478	2.70e-06	6.58e-06
dummy 2000	.1116942	.1001085	.0115856	.0041599

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(12) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 33.25
Prob>chi2 = 0.0009

Declaration

I, the undersigned, declare that this thesis is my original work and has not been presented, in part or whole, in any other university or collage. All sources of materials used for the thesis have been duly acknowledged.

Name Dawit Diriba

Signature__________

Date 15/07/08

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Signature__________

Date 11/07/08

Place and date of Submission ____________________