



# Application of an almost ideal demand system (AIDS) to Ethiopian rural residential energy use: Panel data evidence

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## HIGHLIGHTS

- ▶ Two step LAAIDS model and MLM were applied to analysis of residential fuel use.
- ▶ I examined issues of 'energy ladder' versus 'fuel stacking' behavior of households.
- ▶ Controlling other factors increase in welfare increases demand for modern fuel.
- ▶ Traditional fuels are income inelastic but not necessarily cheaper.
- ▶ Residential fuel choice is determined by intricate web of socio-economic factors.

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## ABSTRACT

It is well known that poor rural households in low-income economies are reliant on traditional fuels to meet basic domestic energy needs, but little is known about the specific underlying socio-economic drivers of residential fuel choices in Ethiopia. I used the linear approximation almost ideal demand system (LAAIDS) with normalized prices to compute expenditure elasticity and a multinomial logit model (MLM) to examine household fuel use. The LAAIDS model result showed that expenditure was elastic for modern fuels, but inelastic for traditional fuels. Regression results from the MLM indicated that fuel choice behaviour of rural households could be more accurately described as 'fuel stacking' behaviour as opposed to the 'energy ladder' hypothesis. In rural areas household fuel choice may be constrained by limited access to commercial fuels and efficient cook stoves, supply dependency and affordability, consumer preferences and a web of other intricate factors. Rural households had less incentive for fuel switching due to underlying factors and the availability of fuel wood without direct financial cost. With continued deforestation and receding forests, households are expected to develop inter fuel substitution and switching behaviour conditional on access to modern energy technologies.

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## 1. Introduction

I examined household energy use patterns in the context of rural Ethiopia with an exclusive focus on residential energy utilization (i.e., lighting, cooking and heating). The major constraint in this empirical analysis was that the data were not segregated on the basis of fuel end uses, however, local experiences indicate that modern fuels were consumed primarily for illumination, while biomass fuels (fuel wood and charcoal) were used primarily for cooking and heating residences. The major aim of this research was to describe household demand for different fuels. Main fuels consumed by rural households were categorized into two main groups: modern and traditional fuels. The term

'energy demand' is used in this article to refer to fuel choice as opposed to the intensity of energy consumption.

Very few studies have analysed energy utilization and optimization in the context of multiple fuel use behaviour of households in developing countries (Mekonnen and Köhlin, 2009; Campbell et al., 2003; Ouedraogo, 2006; Pachauri and Jiang, 2008; Reddy, 2003), typically in regard to rural residential fuel choice in Sub-Saharan Africa. In this article I examined the issue of 'energy ladder' versus 'fuel stacking' behaviours of households in rural Ethiopia based on panel data evidence.

The econometric tools used in this research are the almost ideal demand system (AIDS) and the multinomial logit model (MLM). The former was fitted for estimating the effects of income/wealth; whilst the latter was used to analyse the role of factors that determine fuel choices. More specifically I gave special attention to the analysis of the effects of an intricate web of factors on household fuel choice decisions.

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Although household energy demand analysis might appear intuitive enough in the existing economic literature, its theoretical and empirical underpinnings have not been sufficiently detailed, especially in rural contexts. Moreover it is fair to say that in the field many important issues remain controversial. For example different conclusions have been reached concerning the effects of factors that drive inter-fuel substitution and the income switching points where consumer transition to modern fuels occurs. There is debate in the energy literature about the impacts of energy prices on low-income rural energy consumers and about the efficiency and efficacy of different energy policies intended to encourage inter-fuel substitution. The lack of consensus partly stems from the fact that conclusions in the literature are generally drawn from extrapolating the results of individual studies conducted in a single city, village, or region or of relatively few cities, villages, or regions (Abebaw, 2007; Mekonnen, 1999; Masera et al., 2000). In the field there have been incredible micro-econometric studies on the determinants of residential energy use at household level (Mekonnen and Köhlin, 2009; Campbell et al., 2003; Chaudhuri and Pfaff, 2004; Foster and Rosenzweig, 2003; Ouedraogo, 2006; Pachauri and Jiang, 2008; Reddy, 2003), but rural residential fuel choice has been overlooked. In addition, within the literature some of the determinants of household energy demand were found to have an equivocal effect on the fuel stacking behaviour of households.

In this regard analysis of residential energy demand in Ethiopia was studied by a number of empirical studies (Mekonnen, 1999; Bereket et al., 2002; Faye, 2002). Nonetheless estimation of energy demand in the context of fuel stacking is non-existent for the country in general, and for rural households in particular. Moreover this use of panel data in describing household energy demand in rural Ethiopia is a first attempt. The use of panel data allows for controlling individual household heterogeneity and provides a good estimation of both cross-sectional and temporal variation of energy demand. These analyses provided complete and fully specified energy demand systems, effectively including all household expenditures on all energy sources in an attempt to develop a comprehensive view of rural household residential fuel choice.

The central questions that I tried to address were: 'what are the major factors that determine household residential fuel use behaviour?' and, 'how do households optimize energy consumption in response to income and expenditure changes?' Therefore the three research objectives were to: (1) examine the expenditure elasticity of household energy demand (2) investigate the role of factors that affect residential fuel source choices (3) scrutinize the concept of 'energy ladder' versus 'fuel stacking' among households.

## 2. Literature review

### 2.1. Theoretical literature

Economic development and energy demand interact and co-evolve together over time. Regarding rural biomass energy consumption, deforestation is formidable problem. Fuel wood gathered from communal forests supply a major portion of domestic energy in rural areas of many poor countries (Heltberg et al., 2000). Recent empirical research on fuel wood consumption and forest degradation have focused mainly on India, Nepal and China (Adhikari et al., 2004; Chen et al., 2006; Heltberg et al., 2000), although a very limited number of papers have dealt with this issue in Ethiopia (Mekonnen, 1999). Massive reliance on traditional fuels in Ethiopian has been underscored (Mekonnen, 1999; Bereket et al., 2002; Faye, 2002). For example Jargstorf (2004)

stated that Ethiopia is the third largest user of traditional fuels for household energy use in the world, with 96% of the population dependent on traditional biomass (e.g., fuelwood and dung) to meet their energy needs.

#### 2.1.1. Agricultural household economic framework and fuel choice

Agricultural households are predominantly solid biofuel consumers. Energy use among rural households can be described by using an agricultural household economic optimization framework. The opportunity costs to a household for firewood collection are presumed to be determined by factors such as household wealth, labour, and the availability of wood stock. Fuel wood is used mainly at the household level. Modelling household energy demand behaviour is thus a major focus in energy economics.

The energy problem of rural households is rooted in their over-reliance on few and low-grade energy sources. To mitigate the problem fuel diversification and inter-fuel substitution are important for discouraging the use of traditional fuels and to optimize fuel consumption. In fact a study by the International Energy Agency (IEA) (2005) argued that the major goal of fuel diversification is to reduce dependence on traditional fuels, to promote the switch to modern fuels, and to increase the efficiency of fuel use. It was also noted that energy efficiency enhances both energy security and environmental protection. In addition to energy security, environmental issues may provide a large part of the impetus for intervention in rural energy problems. Fuel choices therefore need to be understood in terms of relative household resource scarcities. Although the use of low-grade fuels (dung and residues) may be less detrimental to forests, there exists a trade-off between using them as agricultural inputs and burning them for fuel (Heltberg et al., 2000).

In rural areas household energy choices are constrained by the lack of access to alternative fuels and efficient cook stoves or appliances. Often household fuel choice is determined more by local availability, transaction and opportunity costs involved in gathering the fuel (mostly wood, dung and other biofuels), rather than by household budget constraints, prices and costs. In contrast to rural households, urban households generally have a wider choice of and greater access to modern commercial fuels, electricity, and energy end-use equipment and appliances. Therefore urban households have relatively greater potential for fuel switching than their rural counterparts (Energy Sector Management Assistant Program (ESMAP), 2003).

#### 2.1.2. Factors affecting household fuel choices

Energy is needed by households for the functions that it serves, such as lighting, cooking and heating. Among rural households there are key factors that underlay energy demand or fuel choice: (1) the relative price of energy and appliances, (2) the disposable income of the household, (3) the availability of alternative fuels and related appliance(s) in the market, (4) particular requirements related to end-use, and (e) cultural and other preference factors. Access to modern fuels has often been found to be another important determinant of the transition from traditional fuels (Campbell et al., 2003; Ouedraogo, 2006; Pachauri and Jiang, 2008), however, households in rural areas often have limited access to electricity.

#### 2.1.3. Energy ladder and household fuel stacking behaviours

Household energy demand in the past has often been understood through the concept of the energy ladder. This concept maintains that households switch their fuel consumption from traditional to modern energies as countries develop and incomes increase, implying that firewood becomes less desirable (Arnold et al., 2006) at higher income levels. Furthermore studies like

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