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Alemu Mekonnen

Gunnar Köhlin

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Department of Economics
School of Business, Economics and Law at University of Gothenburg
Vasagatan 1, PO Box 640, SE 405 30 Göteborg, Sweden
+46 31 786 0000, +46 31 786 1326 (fax)
www.handels.gu.se   info@handels.gu.se

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Abstract

This paper looks at the fuel choice of urban households in major Ethiopian cities, using panel data collected in 2000 and 2004. It examines use of multiple fuels by households in some detail, a topic not much explored in the household fuel-choice literature in general, and in sub-Saharan Africa in particular. The results suggest that as households' total expenditures rise, they increase the number of fuels used, even in urban areas, and they also spend more on the fuels they consume (including charcoal but not wood). The results also show that even fuel types such as wood are not inferior goods. The results support more recent arguments in the literature (using Latin American and Asian data) that multiple fuel use (fuel stacking) better describes fuel-choice behavior of households in developing countries, as opposed to the idea that households switch (completely) to other (more expensive but cleaner) fuels as their incomes rise. This study shows the relevance of fuel stacking (multiple fuel use) in urban areas in sub-Saharan Africa. While income is an important variable, the results of this study suggest the need to consider other variables such as cooking and consumption habits, dependability of supply, cost, and household preferences and tastes to explain household fuel choice, as well as to recommend policies that address issues associated with household energy use.

Key Words: Household fuel, urban, Ethiopia

JEL Classification Numbers: D11, O12

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Alemu Mekonnen and Gunnar Köhlin*

1. Introduction

It is estimated that approximately 2.5 billion people in developing countries rely on biomass fuels to meet their cooking needs. For many of these countries, more than 90 percent of total household fuel is biomass. Without new policies, the number of people that rely on biomass fuels is expected to increase to 2.6 billion by 2015, and 2.7 million by 2030 (about one-third of the world's population) due to population growth (IEA 2006).

While rural households rely more on biomass fuels than those in urban areas, well over half of all urban households in sub-Saharan Africa rely on fuelwood, charcoal, or wood waste to meet their cooking needs (IEA 2006). With increasing population and urbanization over time, urban household energy is an important issue for developing countries in general, and for poorer developing countries, such as Ethiopia, in particular.

Heavy reliance of urban households in sub-Saharan Africa on biomass fuels (such as woody biomass and dung) contribute to deforestation, forest degradation, and land degradation. This is partly because use of these fuels in urban areas is an important source of cash income for people in both urban and rural areas. While use of woody biomass as fuel and as construction material contributes to deforestation and forest degradation,[1] use of dung as fuel implies that it might not be available for use as fertilizer—thus contributing to land degradation and consequent reduction in agricultural productivity.

Use of biomass fuels for cooking is a major cause of health problems in developing countries due to indoor air pollution (Bruce et al. 2000; Ezzati and Kammen 2001). For example, the World Health Organization (WHO) estimates that 1.5 million premature deaths per year are directly attributable to indoor air pollution from the use of solid fuels (IEA 2006). Recognizing the adverse effects of use of traditional biomass fuels, the United Nations Millennium Project

* Alemu Mekonnen, Department of Economics, Addis Ababa University, P.O. Box 150167, Addis Ababa, Ethiopia, (email) alemu_m2004@yahoo.com, (tel) +251 11 1223676, (fax) +251 11 1223674; and Gunnar Kohlin, Department of Economics, University of Gothenburg, P.O. Box 640, 405 30 Gothenburg, Sweden, (email) gunnar.kohlin@economics.gu.se, (tel) + 46 31 786 4426, (fax) +46 31 7861043.

[1] Note, however, that fuelwood may not be a primary cause of deforestation in general (e.g., see Arnold et al. 2006).

recommends halving the number of households that depend on traditional biomass for cooking by 2015, which involves about 1.3 billion people switching to other fuels (IEA 2006). One set of factors necessary for switching to other fuels particularly in poorer developing countries (like Ethiopia) is better availability of alternative fuels other than traditional biomass fuels. Such alternative fuels are generally available in the major cities of poorer countries, but access to such fuels is much more limited in rural areas and smaller cities in these countries.

Household fuel choice also depends on other factors, which makes knowledge of the determinants of urban households' choice of fuel important. In the literature on household energy demand and choice, it has been argued that households with low levels of income rely on biomass fuels, such as wood and dung, while those with higher incomes consume energy that is cleaner and more expensive, such as electricity. Those households in transition—between traditional and cleaner (and more efficient) energy sources—consume what are called transition fuels, such as kerosene and charcoal. While this is a simpler version of the "energy ladder hypothesis," it is also presented in the literature with more elaborate intermediate steps (Hosier and Dowd 1987; Barnes and Floor 1999; Heltberg 2005).

A related concept is fuel switching, where it is argued that introduction of superior fuels will phase out traditional fuels as households will switch to the former. ESMAP (2000) also presents a theory with a ladder of energy demand, rather than of fuel preferences, where more diversified demand for energy sources is explained in terms of the nature of appliances used and the purpose as incomes rise. Simple and linear associations between income and fuel preferences and demand (represented by a ladder) have been criticized as unrealistic because fuel preferences could be explained by other factors.

More recently, it has been argued that households in developing countries do not switch to modern energy sources but instead tend to consume a combination of fuels, which may include combining solid fuels with non-solid fuels as sources of energy. Thus, instead of moving up the ladder step by step as income rises, households choose different fuels as from a menu. They may choose a combination of high-cost and low-cost fuels, depending on their budgets, preferences, and needs (World Bank 2003). This led to the concept of fuel stacking (multiple fuel use), as opposed to fuel switching or an energy ladder (Masera et al. 2000; Heltberg 2005).

The relative importance of fuel stacking (multiple fuel use) and fuel switching has not been well established in the literature (Heltberg 2005). Rigorous analyses of urban household fuel choice and demand in sub-Saharan Africa are very limited. Studies that undertake a rigorous examination of fuel stacking in developing countries are very limited (Masera et al. 2000;

Heltberg 2005), and is, to our knowledge, non-existent in sub-Saharan Africa. As in the case of Mexico, as shown in Masera et al. (2000), fuel stacking could be important in urban Ethiopia because households there have limited options for fuel, as well as stoves to bake *injera*[2] (although there are more options for cooking other foods). Careful examination of fuel stacking could lead to a different set of conclusions and recommendations than what might result from the assumption that households will shift to modern and cleaner (but more expensive) fuels as incomes rise. For example, the nature and scale of new policy interventions may be much smaller if fuel stacking is significant, and the benefit of policies that ignore fuel stacking may be lesser than sometimes hypothesized (Heltberg 2005) Moreover, most empirical studies of household energy choice and demand in developing countries do not use panel data (e.g., Faye 2002; Kebede et al. 2002). Among other things, the use of panel data enables us to control for unobserved effects and explain energy choice and demand over time.

This paper attempts to examine the determinants of household fuel choice and demand in major Ethiopian cities using panel data. We also contribute to the literature by paying particular attention to the issue of fuel stacking (multiple fuel use).

The paper is structured as follows: section 2 presents the conceptual and empirical framework used. The data, results, and discussion are presented in section 3, while section 4 concludes the paper.

2. Conceptual and Empirical Framework

The energy-ladder model has emphasized the role of income in determining fuel choices. However, it appears to imply that a move up to a new fuel is simultaneously a move away from previously used fuels (Heltberg 2005). ESMAP (2000) and Foley (1995) suggested the idea of an energy-demand ladder, where they argued that, as incomes rise, households' demand for fuel is guided by the nature of appliances used and that fuel choice and demand depends on the purpose. This idea of an energy-demand ladder has also been criticized, since the widespread use of multiple fuels for a particular purpose (such as cooking) has suggested the presence of fuel stacking for a given purpose (Davis 1998; Heltberg 2005).

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[2] *Injera* is a pancake-like bread, commonly used instead of a utensil to pick up the stew common at most Ethiopian meals, by people in urban areas and a substantial number of those in rural areas in general, and in the northern half of Ethiopia in particular. Typically, either wood or electricity is used to bake injera, given existing technologies; however, other alternative fuels (and technologies), such as kerosene and charcoal, are available for other cooking.

Heltberg (2005) noted that while earlier literature on household energy focused on the energy-ladder model and the related idea of fuel switching, the relative importance of fuel stacking versus fuel switching is not generally known.

To analyse fuel choice and demand, we used both descriptive and more rigorous analyses. In the descriptive analysis, in addition to presenting the nature of fuel choice in general, we used graphs to examine unconditional correlation between the decision and intensity of fuel use (including fuel stacking behavior), on one hand, and household expenditure on the other.

For the more rigorous analysis, we used random utility theory to analyze household fuel choice. In particular, we looked into the factors that determine choice of a particular fuel type, using random effects logit models. Moreover, we analyzed fuel-stacking behavior, using a multinomial logit model by grouping consumers into three categories according to the main fuel used by the household: those whose main fuel was only solid fuel (fuelwood and/or charcoal), only non-solid fuel (kerosene and/or electricity), and a mixture of solid and non-solid fuels.

The analysis in this paper also includes estimation of an Engle curve to look into the determinants of fuel consumption in a more rigorous fashion. This analysis controlled for a number of other factors that can influence consumption of wood, charcoal, kerosene, and electricity, in addition to total expenditure. To exploit the panel nature of the data, we used random effects in the estimation. Since we considered only those households that consumed a positive quantity of the fuel type considered, we took into account possible sample selection bias that might arise by using Heckman’s two-step estimator. Standard errors were bootstrapped to take into account the use of estimates from the first step in the second step estimation.

3. Data, Results, and Discussion

This section starts by presenting the data source and descriptive statistics where we also discuss unconditional relations between fuel choice and total expenditure. This is followed by presentation and discussion of more rigorous empirical results.

3.1 Data Source and Descriptive Statistics

We used panel data collected in the years 2000 and 2004 from seven major cities in Ethiopia by Addis Ababa University’s department of economics, in collaboration with the University of Gothenburg. We included 1,500 households in each survey, with about 60 percent of them from Addis Ababa, the capital city.

Table 1 presents the descriptive statistics for the years 2000 and 2004, which include the dependent and explanatory variables used in this study. We see from table 1 that, on average, the share of household energy expenditure in total energy ranged 15–18 percent over the two years. Households spent 85–90 ETB[3] per month on electricity, kerosene, charcoal, and wood, which are the most important energy sources. Wood and kerosene were the two most important fuels in the year 2000, in terms of their share in total energy expenditure (31 and 32 percent, respectively), while electricity was the most important in 2004 (33 percent). The proportion of households that used electricity as an energy source increased from 46 percent in 2000 to 87 percent in 2004. This is perhaps a key reason for the significant increase in the share of electricity in total energy expenditure. While the percentage of households using kerosene and charcoal did not change over the two survey years, use of wood decreased from 69 percent in 2000 to 63 percent in 2004.

We grouped the primary fuels used by households into solid fuels (charcoal and wood), non-solid fuels (kerosene and electricity), and a mixture of these (when households reported both solid and non-solid fuels as their main fuel). We note from table 1 that the proportion of households that used solid, non-solid, and a mixture as main fuels basically remained the same over the period 2000–2004.

Both nominal and deflated prices of each of the four fuel types increased over the period 2000–2004, with the exception of electricity for which the deflated price declined slightly. The 2004 survey had a larger percentage of household members with a maximum education of post-secondary education (34 percent) compared with 2000 (23 percent).

Table 1. Descriptive Statistics

	Year 2004 (N=1156)		Year 2000 (N=981)	
Variable label	**Mean**	**Std. dev.**	**Mean**	**Std. dev.**
Share of energy in total expenditure	0.15	0.12	0.18	0.16
Share of electricity in energy expenditure	0.33	0.24	0.17	0.26
Share of kerosene in energy expenditure	0.24	0.23	0.32	0.31
Share of charcoal in energy expenditure	0.19	0.20	0.18	0.22

[3] ETB = Ethiopian birr; 1 USD = about 8.5 ETB at the time of the surveys.

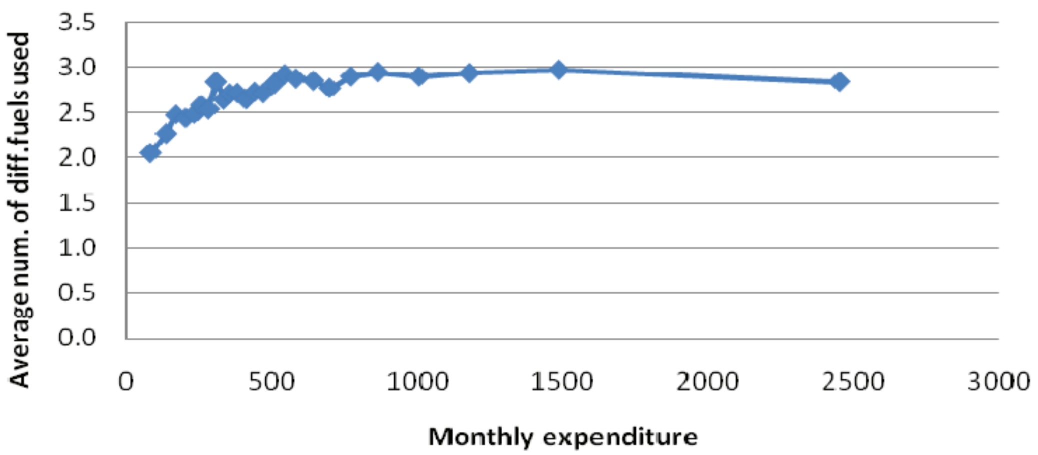
Variable label	Year 2004 (N=1156) Mean	Year 2004 (N=1156) Std. dev.	Year 2000 (N=981) Mean	Year 2000 (N=981) Std. dev.
Share of wood in energy expenditure	0.23	0.25	0.31	0.31
Expenditure on electricity per month	31.12	48.94	21.11	58.60
Expenditure on kerosene per month	19.55	35.91	34.91	86.49
Expenditure on charcoal per month	17.18	47.88	12.26	22.32
Expenditure on wood per month	17.17	29.94	21.82	44.72
Energy expenditure per month	85.03	85.87	90.11	123.82
Uses electricity (yes=1, else=0)	0.87	0.34	0.46	0.50
Uses kerosene (yes=1, else=0)	0.70	0.46	0.70	0.46
Uses charcoal (yes=1, else=0)	0.65	0.48	0.65	0.48
Uses wood (yes=1, else=0)	0.63	0.48	0.69	0.46
Main fuel solid (yes=1, else=0)	0.28	0.45	0.29	0.45
Main fuel mixed (yes=1, else=0)	0.28	0.45	0.28	0.45
Main fuel non-solid (yes=1, else=0)	0.43	0.50	0.42	0.49
Price of wood	91.52	32.35	75.57	18.65
Price of charcoal	1.78	0.32	1.34	0.21
Price of kerosene	2.07	0.07	1.48	0.06
Price of electricity	0.40	0.07	0.36	0.06
Price of wood (deflated)	81.13	28.68	75.57	18.65
Price of charcoal (deflated)	1.58	0.29	1.34	0.21
Price of kerosene (deflated)	1.83	0.06	1.48	0.06
Price of electricity(deflated)	0.35	0.07	0.36	0.06
Family size	5.70	2.51	5.76	2.61
Share of women in household	0.44	0.22	0.42	0.21
Max. education of a household member (1 if has secondary education, else=0)	0.33	0.47	0.34	0.47
Max. education of a household member (1 if post-secondary education., else=0)	0.34	0.47	0.23	0.42
Sex of household head (1 if male)	0.55	0.50	0.59	0.49
Age of household head	50.68	13.70	48.90	13.39
Expenditure per month	736.16	647.29	566.59	560.36
Expenditure per month(deflated)	611.42	537.62	566.59	560.36

3.2 Energy Use and Expenditure Pattern versus Total Expenditure

The graphs in figures 1-4 examine fuel use and demand pattern in relation to total monthly household expenditure. In all the figures, we divided households in the sample into 25 groups of equal size and similar total expenditure—thus they were divided into 4-percent quantiles. In all the graphs, the average total monthly expenditure of the households in each group is presented on the horizontal axis.

Figure 1 shows the average number of different fuels that households used by total monthly expenditure. It can seen that the average number of fuels used by each of the 25 expenditure categories (groups) is between 2 and 3, with many households using 4 different fuel types. It also shows that households generally used more fuel types as their incomes increased, instead of (completely) switching to another fuel type. Such behavior is associated with the fact that while households were more likely to afford to buy additional cooking stoves if new fuel types required them, there were also various other reasons to do so, including preferences for a particular fuel type used for a particular type of food, for a particular time or occasion, for convenience, or due to uncertainty about the supply of a fuel type.

Fig. 1. Average number of different fuels used by monthly expenditure



We also note from figure 2 that the proportion of households using wood, kerosene, electricity, and charcoal was between 40 percent and more than 80 percent for all expenditure categories. This also confirms the result that households generally used different fuel types. Figure 2 also shows that the proportion of households using one fuel type changed in a nonlinear way as expenditure increased. In particular, there was a tendency for the proportion of households using charcoal, kerosene, and electricity to increase initially as expenditure rose. However, this trend changed with charcoal and electricity, where a slight decline was observed for the richest group. On the other hand, the proportion of households using wood—although it fluctuated—tended to decrease as expenditure rose. This provides some support to the energy-ladder hypothesis, since there was a reduction in the proportion of households using wood as expenditure rose. (This is not a complete shift, as well over 40 percent of the households in the sample used wood, even in the richest group.) We cannot, however, comment on the relative importance of a fuel type from figure 2, as it only indicates whether a household used a fuel type—but not the intensity of use—for example, in terms of quantity of expenditure.

Fig. 2. Proportion of households using a fuel type by monthly expenditure

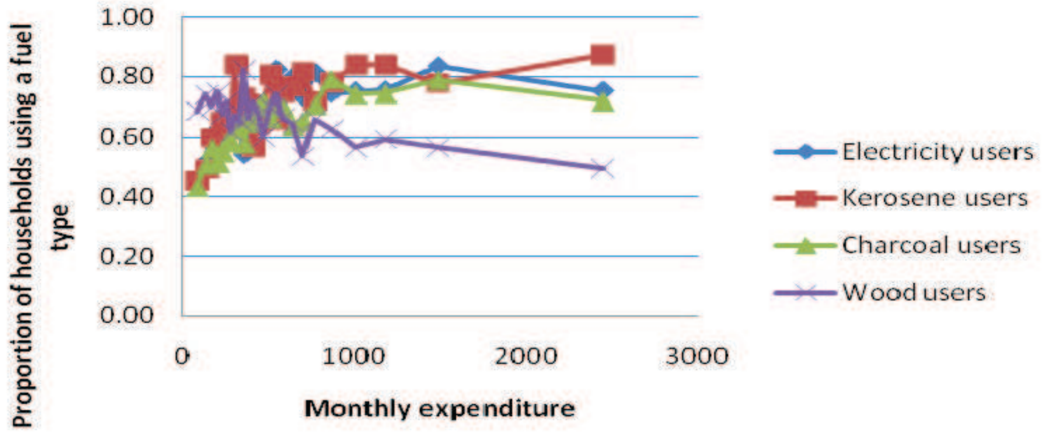


Figure 3 shows the share of each of the four fuel types in total energy expenditure by monthly expenditure. We note that the share of expenditure on wood and charcoal in total energy expenditure for the richest group is more or less the same. Note, too, that these shares for this group are much less than its shares of kerosene and electricity. Thus, although there is no complete shift, this supports the hypothesis that households tend to use more of the cleaner fuels and less of the traditional fuels as total household expenditure rises. The trend in the share of a fuel type in total energy expenditure is, however, far from linear and varies across fuel types. While there is a tendency for the share of wood expenditure to decline as household total expenditure rises, the fluctuation in the share of charcoal with changes in expenditure appears to be much less than is the case for the other fuel types.

Fig. 3. Share of a fuel type in energy expenditure by monthly expenditure

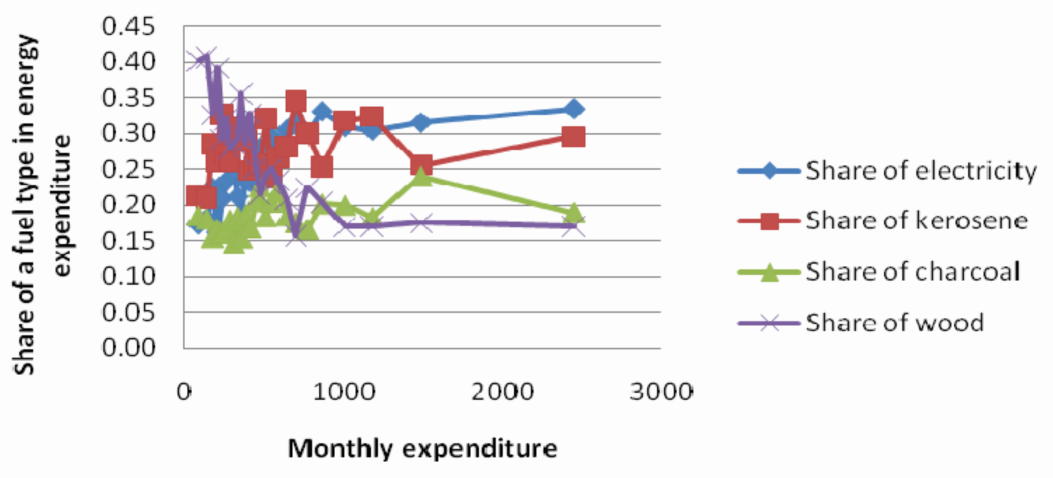
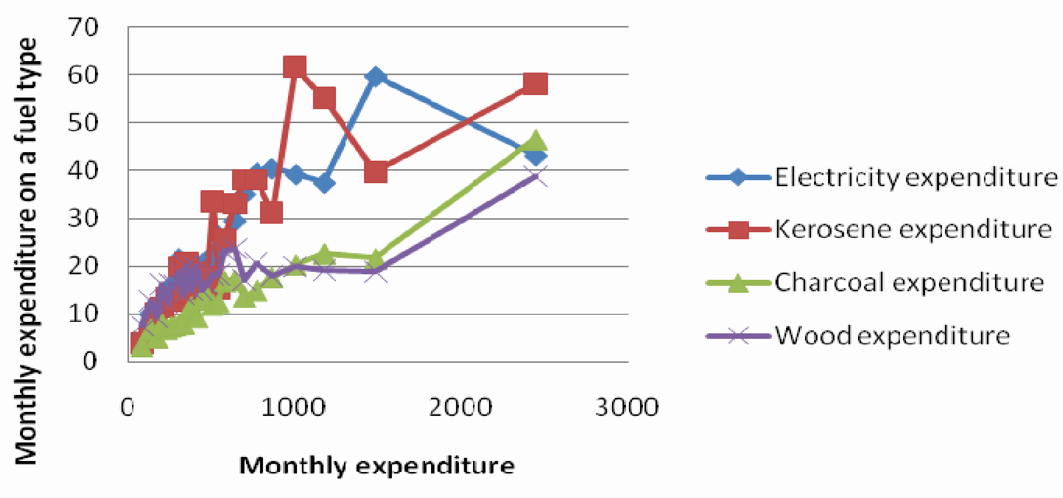


Figure 4 presents total monthly expenditure for each of the four fuel types by monthly total household expenditure. We note that the total expenditure for each fuel type generally increased as total household expenditure rose, with some significant fluctuation for some of the expenditure categories—particularly electricity and kerosene. It is interesting that although the share of expenditure on wood declined and the proportion of households using wood declined as expenditure rose, the total expenditure on wood increased as expenditure rose. What this

Fig. 4. Monthly expenditure on a fuel type by total monthly expenditure (in Birr)



suggests is that households generally increased their spending on all fuel types as their incomes rose, but they spent more on electricity and kerosene in relative terms, compared to wood, as their incomes rose.

3.3 Results and Discussion

Since the graphs represent unconditional relations, we further examined these relationships in a more rigorous fashion by controlling for other factors (in addition to expenditure and income) that could influence fuel choice and demand.

3.3.1 Multinomial logit estimates to analyze fuel stacking

Multinomial logit estimates of the determinants of households' choice between solid, non-solid, and a mix of solid and non-solid fuels are presented in table 2. Non-solid fuels are the omitted category (the base outcome), with which the estimated coefficients are to be compared.[4] Model diagnostics are presented towards the end of the table. Robust standard errors are used.

The results suggest that higher kerosene prices made households choose either solid fuels only or a mix of solid and non-solid fuels, moving away from non-solid fuels. Households were also more likely to choose a mix of solid and non-solid fuels with higher wood prices, with a similar but statistically weaker result for choice of solid fuels. This suggests, perhaps, that one needs to look at other factors in addition to prices to explain fuel choice, such as the role of equipment cost, preferences, and habit.

Family size made the choice of non-solid fuels less likely, and the negative and significant coefficient for the square of the family size variable suggests that there is non-linearity, whereby as family size increased, the likelihood of a household using solid fuels only—or a mix of solid and non-solid fuels—as the main fuel increased, but at a decreasing rate. The likelihood of a household choosing one of the three groups of fuels did not depend on the proportion of women in the household. One may expect that larger family size and a greater proportion of women could increase the likelihood of choosing in favor of solid fuels and a mix of solid and non-solid fuels, since these fuel types require more labor for collection. The results suggest that this is not the case.

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[4] The choice of the omitted category does not change the basic results; it only influences the way the results are interpreted.

Households with a more educated member were more likely to have non-solid fuels as their main fuel. A comparison of the coefficients for secondary education and post-secondary education shows that while households who had members with either of these two education levels were more likely to choose non-solid fuels, households with members that had post-secondary education were even more likely to choose non-solid fuels than those with secondary education.

Female-headed households were more likely to choose either solid fuels only or a mix of solid and non-solid fuels as their main fuel. Older household heads were more likely to choose solid fuels only as their main fuel, perhaps from habit as non-solid fuels are relatively more recent and younger household heads are more likely to adopt them. Age of the household head was, however, not significant in explaining the choice between non-solid fuels and a mix of solid and non-solid fuels, suggesting that it is not important for this particular choice.

Households with larger expenditure were less likely to choose only solid fuels as their main fuel. However, there is no statistically significant difference between those who chose only non-solid fuels and those who mixed solid and non-solid fuels, with respect to expenditure.

Table 2. Multinomial Logit Estimates of Choice of Solid, Non-solid, and a Mix of Solid and Non-solid Fuels

Variables	**(1) Solid fuels**	**(2) Mix of solid and non-solid fuels**
Price of wood (deflated)	0.008 (1.59)	0.013 (2.54)**
Price of charcoal (deflated)	-0.507 (0.64)	0.541 (0.66)
Price of kerosene (deflated)	9.915 (6.97)***	4.492 (3.01)***
Price of electricity (deflated)	1.517 (0.68)	3.351 (1.45)
Family size	0.410 (4.18)***	0.238 (2.85)***
Family size squared	-0.023 (3.21)***	-0.013 (2.10)**
Proportion of women in household	0.117 (0.34)	-0.179 (0.59)
Max. education of a household member (1 if secondary education)	-0.701 (4.46)***	-0.392 (2.71)***

Variables	(1) Solid fuels	(2) Mix of solid and non-solid fuels
Max. education of a household member (1 if post-secondary education)	-1.252 (6.64)***	-0.702 (4.45)***
Sex of household head (1 if male)	-0.471 (3.17)***	-0.337 (2.63)***
Age of household head	0.017 (3.32)***	0.004 (0.85)
Expenditure per month (deflated)	-0.001 (4.24)***	-0.000 (0.99)
Year 2004 (1 if yes, else 0)	-2.894 (5.33)***	-1.596 (2.90)***
Addis Ababa X Year 2000+	-3.246 (8.57)***	-3.080 (7.82)***
Addis Ababa X Year 2004+	-4.084 (9.65)***	-3.158 (7.40)***
Constant	-14.615 (7.24)***	-8.176 (4.14)***
Observations	2125	2125
Wald Chi2(26)	286***	

Robust z statistics are in parentheses.

* significant at 10%; ** significant at 5%; *** significant at 1%

+ X is used to indicate multiplication as this represents interaction between the two variables.

The reference (omitted) category is households that use non-solid fuels as their main fuel .

The results also indicate the roles of time and location. In particular, households were more likely to have non-solid fuels as their main fuel in 2004, compared to 2000, suggesting a shift towards non-solid fuels over time. Moreover, the negative and significant coefficients for the interactions between the dummy for the Addis Ababa site and the survey years suggest that households in Addis Ababa were more likely to choose non-solid fuels both in 2000 and 2004. This is perhaps due to several factors, including better access to electricity and kerosene, better awareness, and learning from others.

3.3.2 Random effects logit estimates of the decision to use a fuel type

Random effects logit estimates of the decision to use electricity, kerosene, charcoal, and wood are presented in table 3. The significance of the estimated ρ-coefficient for kerosene and wood indicates the appropriateness of using random effects logit as opposed to pooled logit.

Negative and statistically significant coefficients of own prices in the regressions for charcoal and kerosene indicate the decrease in the likelihood that these fuel types would be selected as their prices rose. However, the coefficients of own prices of wood and electricity were not significant. The cross-price coefficients generally suggest substitutability between the fuel types, except the one for charcoal and electricity which suggests complementarity.

Households with more members were more likely to use charcoal and wood and less likely to use kerosene. Households with a larger proportion of women were more likely to use charcoal, but it did not affect the choice of the other three fuel types.

The likelihood that households used non-solid fuels (electricity and kerosene) is higher if the household had a member with secondary or post-secondary education, the effect for the latter being stronger. Moreover, the likelihood that such households used wood as fuel is also less. This suggests the importance of opportunity cost of time for collection and also awareness about the possible negative effects of fuels (such as wood or biomass combustion on health). We also found that households with female heads were more likely to use wood, while those with older heads were more likely to use wood and charcoal and less likely to use kerosene.

Table 3. Random Effects Logit Estimates of the Decision to Use a Fuel Type

Variables	(1) Electricity	(2) Kerosene	(3) Charcoal	(4) Wood
Wood price (log)	0.958 (3.88)***	0.713 (2.82)***	0.124 (0.53)	0.628 (1.52)
Charcoal price (log)	-1.973 (2.06)**	-0.997 (0.99)	-2.622 (2.55)**	-6.370 (3.19)***
Kerosene price (log)	7.957 (4.22)***	-13.397 (6.93)***	8.638 (4.95)***	16.875 (5.22)***
Electricity price (log)	-1.750 (0.88)	3.366 (1.71)*	-3.333 (1.66)*	-5.239 (1.53)
Family size (log)	0.106 (0.88)	-0.468 (3.16)***	0.219 (2.06)**	1.074 (6.30)***
Percentage of women in household	0.128 (0.44)	0.014 (0.04)	0.648 (2.54)**	0.372 (0.98)
Max. education of a household member (1 if secondary education)	0.139 (1.06)	0.413 (2.66)***	-0.115 (0.97)	-0.488 (2.73)***
Max. education of a household member (1 if post-secondary education)	0.272 (1.80)*	0.520 (2.93)***	0.016 (0.12)	-1.020 (5.00)***
Sex of household head (1 if male)	-0.083 (0.67)	0.102 (0.70)	-0.151 (1.40)	-0.321 (1.98)**

Variables	(1) Electricity	(2) Kerosene	(3) Charcoal	(4) Wood
Age of household head (log)	0.095 (0.48)	-0.473 (2.01)**	-0.282 (1.61)	0.898 (3.37)***
Expenditure per month (log)	0.476 (5.54)***	0.754 (7.22)***	0.522 (6.89)***	-0.261 (2.42)**
Year 2004	0.953 (2.48)**	2.376 (5.78)***	-1.635 (4.30)***	-3.223 (4.73)***
Addis Ababa*Year 2000	0.599 (2.30)**	1.652 (5.89)***	-0.280 (1.09)	-1.697 (3.94)***
Addis Ababa*Year 2004	-0.051 (0.17)	2.722 (9.10)***	-0.344 (1.36)	-1.874 (4.48)***
Constant	-9.073 (5.60)***	-0.151 (0.09)	-2.397 (1.75)*	-3.028 (1.37)
Rho	0.02	0.17***	0.02	0.4***
Observations	2137	2137	2137	2137
Number of hhid	1590	1590	1590	1590
Wald Chi2(14)	401***	341***	139***	171***

Absolute value of z statistics are in parentheses.
* significant at 10%; ** significant at 5%; *** significant at 1%
The dependent variable is 1 if the household used the fuel type, and 0 if not.

3.3.3 Random effects estimates of the determinants of quantity of fuel consumed

Table 4 presents the factors that determine the quantity of each of the four fuel types consumed by the households in the sample. We used random effects in the estimation to take into account unobserved effects. Since only those households that consumed the fuel type considered are included in the estimation, we used an inverse Mills ratio to account for possible sample selection bias in the estimation. Standard errors are bootstrapped.

The coefficients of own prices, which can be interpreted as own-price elasticities, were insignificant for kerosene and charcoal and had the unexpected sign when they were significant for electricity and wood. Possible explanations for this include the facts that prices of kerosene and electricity are controlled, and perhaps access and availability of supply are more important

Table 4. Random Effects Estimates of the Determinants of Quantity of Fuel Demanded

Variables	(1) Electricity	(2) Kerosene	(3) Charcoal	(4) Wood
Wood price (log)	0.188	0.240	-0.306	0.111
	(0.82)	(2.14)**	(2.58)***	(1.66)*
Charcoal price (log)	0.251	1.444	0.494	-1.364
	(0.42)	(3.54)***	(0.68)	(3.51)***
Kerosene price (log)	5.134	-0.147	0.751	2.521
	(2.94)***	(0.10)	(0.32)	(2.77)***
Electricity price (log)	1.921	0.189	-2.411	0.615
	(2.01)**	(0.20)	(1.98)**	(1.08)
Family size (log)	0.167	0.138	-0.009	0.090
	(2.56)**	(3.18)***	(0.08)	(0.85)
Proportion of women in household	0.149	0.076	-0.058	-0.213
	(1.17)	(0.95)	(0.20)	(1.92)*
Max. education of a household member (1 if secondary education)	0.268	0.021	0.058	-0.056
	(3.86)***	(0.37)	(0.68)	(1.01)
Max. education of a house-hold member (1 if post-secondary education)	0.524	0.131	-0.020	-0.081
	(6.18)***	(2.22)**	(0.21)	(0.88)
Sex of household head (1 if male)	-0.030	0.020	0.179	-0.084
	(0.55)	(0.61)	(2.12)**	(1.59)
Age of household head (log)	0.041	-0.037	-0.074	0.216
	(0.47)	(0.58)	(0.56)	(2.00)**
Household expenditure per month (log)	0.530	0.255	0.259	0.158
	(5.39)***	(5.54)***	(1.58)	(3.39)***
Year 2004	0.350	-0.209	-0.060	-0.213
	(0.91)	(0.76)	(0.13)	(1.18)
Addis Ababa Year 2000	0.704	-0.173	-0.460	0.169
	(3.71)***	(1.31)	(2.39)**	(0.87)
Addis Ababa Year 2004	0.075	-0.264	-0.539	-0.121
	(0.70)	(1.35)	(2.62)***	(0.52)
Inverse Mill's ratio	0.770	-0.337	-1.771	-0.208
	(1.02)	(1.08)	(1.62)	(0.48)
Constant	-4.028	-1.540	3.477	1.054
	(1.77)*	(2.63)***	(2.00)**	(1.55)
Observations	1462	1496	1380	1408
Number of households	1228	1165	1158	1141

Z statistics are in parentheses.
* significant at 10%; ** significant at 5%; *** significant at 1%

under such conditions than prices. Moreover, we considered a single price per city for wood and charcoal, while in reality households within a city face quite different prices.[5]

Households with more members consumed more electricity and kerosene, but wood and charcoal consumption did not depend on family size. The proportion of women in the household did not influence quantity of fuel demand, except for wood where a reduction in quantity demanded was observed for households with more women. We do not have a good explanation for this. Households with a member that had post-secondary education consumed more electricity and kerosene, and a similar result holds for electricity consumption where household members had only secondary education. This suggests the importance of awareness about the negative effects of wood and charcoal on health, as well as the opportunity cost of time (at least in the case of wood, which had to be collected by some of the households). Charcoal consumption was higher in male-headed households, perhaps reflecting better access to larger quantities of charcoal, since males tend to be more mobile than females in general. Older household heads were more likely to use wood, perhaps reflecting the role of habit—it is more difficult for older people to change if they grew up with wood as their main fuel and with much more limited access to other fuels, such as electricity.

Households increased consumption of each fuel type as their total expenditure increased, a result that is statistically significant for all fuel types, except charcoal. This suggests that in our sample even consumption of traditional fuels, such as wood, increased as total household expenditure rose. Hence wood was not an inferior good as suggested in the literature—particularly by the energy-ladder hypothesis. This could be for various reasons: for example, households consumed different fuels (including traditional fuels) even at higher income levels due to preferences, taste, dependability of supply, and cooking and consumption habits, among others.

After controlling for other factors, we found that households in Addis Ababa consumed more electricity and less charcoal, compared to the other six cities, in both 2000 and 2004, although the results for electricity consumption in 2004 were not precise.

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[5] The data we obtained on prices of fuels from the Central Statistical Authority is not detailed for each of the survey years.

4. Conclusion

This paper used panel data collected in the years 2000 and 2004 from seven major cities of Ethiopia to analyze household fuel choice. While previous studies that looked into fuel stacking used data mainly from rural areas in Latin America and Asia, this study provides evidence from major cities in sub-Saharan Africa. We found support for more recent arguments in the literature that households do not switch to cleaner fuels as their incomes rise. Households, even in urban areas—such as those in major cities of Ethiopia—tend to increase the number of fuels they use as their incomes rise instead of completely switching from the consumption of traditional fuels (such as wood) to modern ones (such as kerosene and electricity). We found that fuel types such as wood are not inferior, as opposed to the energy-ladder hypothesis. Thus, households tend to switch to a multiple fuel-use strategy (fuel stacking) as their incomes rise, perhaps, because of a number of factors, including preferences, taste, dependability of supply, cost, cooking and consumption habits, and availability of technology.

The results of this study have important policy implications because they suggest the need to also focus on such factors in policy design. At least for households in poor developing countries, such as those in Ethiopia, perhaps more attention should be paid to these factors and less to those implied by the energy ladder hypothesis, such as income. For example, these results are important for implementation of the United Nations Millennium Project, which recommends halving the number of households that use traditional biomass for cooking by 2015, which involves about 1.3 billion people switching to other fuels. We suggest that more studies be conducted to examine these issues to find out how important they are for smaller towns in Ethiopia and for other countries.

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