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Cooking fuel preferences among Ghanaian Households: An empirical analysis

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ABSTRACT

This paper investigated the key factors influencing the choice of cooking fuels in Ghana. Results from the study indicated that education, income, urban location and access to infrastructure were the key factors influencing household's choice of the main cooking fuels (fuelwood, charcoal and liquefied petroleum gas). The study also found that, in addition to household demographics and urbanization, the supply (availability) of the fuels influenced household choice for the various fuels. Increase in household income was likely to increase the probability of choosing modern fuel (liquefied petroleum gas and electricity) relative to solid (crop residue and fuelwood) and transition fuel (kerosene and charcoal). I therefore proposed that poverty reduction policies, provision of education and modern infrastructure, as well as provision of reliable supply of modern fuels should be part of the policy framework in promoting the use of modern fuels in Ghana, especially for urban dwellers, while for rural dwellers the focus should be on how to efficiently use traditional fuels in a more environmentally friendly and sustainable way.

Introduction

In most developing countries, fuelwood is the major energy source for the household (mainly for cooking), irrespective of the health implications that this source of energy can potentially involve, especially when used indoors. It is estimated that over 2.5 billion people in the developing world depend on biomass as their primary energy source for cooking (IEA, 2006). Air pollution is increasingly becoming a major contributing factor for poor health in the world, especially respiratory diseases, of which "dirty fuel"[1] is one of the major contributing factors. For instance a study by World Health Organization (WHO, 2009) indicates that the burden of diseases attributable to indoor smoke from solid fuels for developing countries is about 1.94 million premature deaths per year. The health consequences of using dirty fuels in homes cannot be overemphasized as it contributes massively to indoor air pollution, which has both direct and indirect health consequences, which women and children are the most exposed in society.

Besides the health concerns from the high usage of "dirty fuels", especially fuelwood, there are economic consequences such as loss of productivity, either due to poor health as a result of polluted air, or time spent in gathering fuelwood at the expense of working or studying. The loss of economic opportunities via the use of fuelwood falls heavily once again on women and children, as they are responsible for gathering fuelwood for the household in most developing countries. Biomass collection is also one of the factors that contribute to deforestation in developing countries, especially near cities and major roads (Heltberg, 2001).

The proportion of households in developing countries using biomass energy (especially fuelwood) is very high compared to rich-industrialized countries. According to Bonjeur et al. (2013) solid fuel use is most prevalent in Africa and South East Asia where more than 60% of the households cook with solid fuels. For instance, in some urban cities such as Ouagadougou, 70% of the households use fuelwood as the main cooking fuel (Ouedraogo, 2006) and it is similar in the case of Ghana.

Switching to modern fuels therefore provides many potential benefits such as less time required for cooking and cleaning pots. It also increases the productivity of the poor as it allows them to redirect labor and land resources from fuelwood collection and production to activities that generate income (Heltberg, 2004). Switching into modern fuels also improves the welfare of women by providing them with the opportunity to engage in income-earning activities as a consequence of the efficiency and reduced time required for cooking.

Despite the disadvantages outlined above in the use of biomass fuels, such as fuelwood, it is still the major cooking fuel in Ghana. In 1990 approximately 69% of Ghanaian households used fuelwood as the main cooking fuel, and this figure decreased to 57.8% in 2005 (Ghana statistical service report, 2008). The reduction in 2005 indicates a remarkable

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[1] Dirty fuel in this paper refers to biomass fuels, especially cow dung, crop residue and fuelwood, Charcoal on the other hand is in this paper classified as a transition (partial) fuel in the sense that it is not as dirty as fuelwood, but not as clean as liquefied petroleum gas (LPG). Kerosene is also classified as a transition fuel in this paper. Modern fuels or "clean fuel" refers to LPG and electricity.

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progress as a result of the efforts made by the government of Ghana with the support of the United Nations Development Program (UNDP) to promote the use of modern fuels in Ghanaian households, especially liquefied petroleum gas (LPG). Various policies have been undertaken, including the national LPG promotion Program[2] and the West African Gas Pipeline (WAGP) project to aid the supply of LPG from Nigeria. Despite the efforts made by the Ghanaian government over the years, the percentage of households using fuelwood in Ghana is still very high. Within the same period (1990–2005), LPG usage increased from 0.8% in 1990 to 6.4% in 2005, and that of electricity also increased from 0.5% in 1990 to 1.1% in 2005. Irrespective of the progress made over the years to influence households to switch to modern fuels, fuelwood and charcoal are still the preferred household fuel choices for cooking in Ghana. It is therefore important to understand the main factors influencing household preferences regarding cooking fuels in order to develop appropriate policies to aid the penetration of "clean" fuels in Ghana as principal cooking fuels.

In this study, fuels are classified into three groups; modern, transition and solid fuels (traditional fuel). This classification is based on the so-called energy ladder hypothesis.[3] The energy ladder hypothesis states that at a low level of income, households tend to consume fuels that is at the bottom of the ladder and regarded as "dirty" such as biomass fuel. As income level rises, households tend to move up the ladder by replacing biomass fuels with "transition" fuels such as kerosene and further to "modern" fuels such as LPG and electricity as income rises still further. Given this classification it will be possible to investigate the energy ladder hypothesis and its relevance in the case of Ghana.

There are several studies in the literature that have studied household energy use patterns in developing countries, but most of the studies are based on descriptive statistics. Few of the studies actually based their analysis on econometric methods to try and understand causal factors influencing household energy choice, energy demand or both. Econometric studies on this topic can be grouped essentially into three based on the focus of the study, a group that focus on different energy sources (Hosier and Dowd, 1987; Reddy and Reddy, 1994; Masera et al., 2000; Barnes et al., 2002; Heltberg, 2004,2005; Ouedraogo, 2006 and Farsi and Filippini, 2007), a group that concentrate on household energy demand (Cuthbert and Dufournaud, 1998; Heltberg et al., 2000; Chambwera and Folmer, 2007) and a group that consider both choice and demand for household energy (Barnes et al., 2005 and Gupta and Köhlin, 2006)

In the literature, high cost of equipment and the high price of modern fuels, among other factors, are cited as the main constraints to the adoption of modern fuels. Furthermore, Leach (1987) states that income, cost of appliances, relative fuel prices and the availability of commercial fuels are the most important variables influencing household fuel preferences in South Asia. Soussan (1988) found that, both multiple fuels and fuel switching were common in poor households due to specific budgeting strategy. Reviewing a larger number of energy surveys, Leach and Gowan (1987) found that income, household size, climate, cultural factors and cost of appliances were the key demand-side variables influencing fuel choice. In cases of insecure energy supplies, fuel security rather than fuel switching dominates in the household energy plan (O'Keefe and Munslow, 1989). Other works that based their analysis on the energy ladder model include, Hosier and Dowd (1987), Reddy and Reddy (1994), Barnes et al. (2002), Heltberg (2004), Gupta and Köhlin (2006) and Ouedraogo, 2006. Contrary to the energy ladder model, Masera et al. (2000) found that in rural Mexico, fuel switching is actually a step toward "multiple fuel cooking" or "fuel stacking" for both fuelwood and LPG.

The aim of this paper is to determine the key factors that induce the choice between modern, solid and transition fuels, and to investigate the energy ladder hypothesis. Given the benefits of switching to modern fuels, and the challenges that high dependence on the use of biomass fuel poses on poverty alleviation Program such as the United Nations millennium development Program, it is imperative to have a clear understanding of the key variables that influence household decisions regarding the choice of cooking fuel. This will help in the designing of the appropriate policies towards efficient and sustainable cooking energy consumption. To reach the objectives I will adopt a multinomial probit regression (MNP)[4] approach to try to answer the question relating to the factors that determine the choice of a particular group of fuels (modern, solid, and transition). I will also decompose the groups into their specific fuels and investigate the factors influencing the probability of choosing each of the three main cooking fuels in Ghana (fuelwood, LPG and charcoal).

In the literature, to the best of my knowledge, the only published work on Ghana in the area of household cooking fuel is that of Heltberg (2004) and Akpalu et al. (2011). Heltberg (2004) studied eight developing countries (Ghana as one of the countries). In the paper, Heltberg used the 1998/99 survey data for each of the countries. I argue that a lot has happened since then, especially in the area of energy policy aimed at increasing LPG penetration in the domestic fuel mix from the 0.8% in 1989 to 50% by 2020. Therefore, by using new data, new light will be shed on the possible progress made, and we can also assess the impact of the availability/non-availability of the fuels on the fuel-choice process. In addition, the 2004/05 survey is more extensive in terms of coverage (increase in the number of households and additional variables such as availability of the fuels) than the 1998/99 survey, and will contribute to the literature on Ghana as the factors influencing choice of fuels are context-specific. Akpalu et al. on the other hand studied the extent to which preference matter regarding four cooking fuels (fuelwood, charcoal, kerosene and LPG), which is a different focus in comparison to that of this study. Besides, they also used the 1998/99 survey data that did not capture the second phase of the LPG promotion program (Rural LPG Challenge program) that was launched in 2004.The rest of the paper is organised as follows; section 2 contains the theoretical considerations and econometric model, section 3 presents the data. The results of the study are presented in section 4, in section 5, I present the conclusion of the study and ideas for future work.

The model

In this section, I will outline the theoretical model for household fuel demand and consequently the indirect utility function that will be used in the empirical section. The theoretical model for household demand for cooking fuels can be derived from the household utility maximisation principle. Assume that household utility depends on food consumption (C) and on the consumption of other goods and services (OG). The utility function can then be expressed as;

$$U = u(C, OG). \tag{1}$$

Further, assume that food consumption is a function of cooking fuel (F) and groceries (G), conditional on the cooking technology:

$$C = c\left(F_j, G\right), \quad j = type/alternatives \ \ of \ \ cooking \ \ fuel. \tag{2}$$

[2] This program includes expanding the capacity of the Tema oil refinery in the production of LPG to increase domestic supply, instituting the uniform petroleum price fund (UPPF) that uses sales from petrol to cross-subsidize LPG and providing financial incentives for LPG sales occurring in places more than 200km from Tema refinery.

[3] The reason for using only energy ladder model relative to the competing alternative "fuel-stack" model is due to the nature of the data at hand. In the survey, no question was asked on possible second and third fuel used by the household for cooking and as a result, the data limit the model choice for the analysis to the energy ladder model.

[4] Other econometric approaches used in the literature on this topic include Tobit model (appropriate for censored data) and the two-step selection type of model approaches (Lee, 1983; Dubin and McFadden, 1984, and Dahl, 2002). The Tobit model is more applicable in cases where there is an issue of censoring in the data, while the selection type of models deals with issues of selection in the data. Both approaches require that the dependent variable for the main model to be a non-factor variable and therefore not applicable for the data used in my study.

Substituting Eq. (2) into Eq. (1) results in a household utility function that has cooking fuel as one of its arguments via food consumption:

$$U = u\left[c\left(F_j, G\right), OG\right]. \tag{3}$$

The utility function, as expressed in Eq. (3), permits cooking fuel to enter the household utility function indirectly via food consumption. The optimization problem for the household is therefore formulated as follows;

$$\begin{aligned}&\max_{F,G,OG} u\left[c\left(F_j, G\right), OG\right]\\ &st \quad P_{F,j}F_j + P_G G + OG \leq Y\end{aligned} \tag{4}$$

where $P_{F,j}$ and P_G correspond to the price for cooking fuel and price of groceries, respectively and Y is the household income. The price of other goods and services is normalized to 1.The solution to the above maximization problem gives the household demand for cooking fuel expressed as:

$$Q_j = q\left(P_{F,j}, P_G, Y\right). \tag{5}$$

Since the demand function in Eq. (5) is homogeneous of degree 0 in prices and income, one can express fuel price as relative to the price of groceries by dividing $P_{F,j}$ by P_G. Incorporating the relative price modification, Eq. (5) becomes:

$$Q_j = q\left(P^r_{F,j}, Y\right), \quad \text{where} \quad P^r_{F,j} = \frac{P_{F,j}}{P_G}. \tag{6}$$

The demand equation, as expressed in Eq. (6), is further augmented with a vector of household characteristics, Z, in addition to availability of the fuels A. The variables A and Z act as demand shifters. The augmented demand equation for fuel j can then be expressed as:

$$Q_j = q\left(P^r_{F,j}, Y; A, Z\right). \tag{7}$$

From the fuel demand function, the indirect utility function becomes:

$$V_j = v\left(Q_j\right) = v\left(P^r_{F,j}, Y; A, Z\right). \tag{8}$$

Econometric model

Suppose a representative household i faces j alternatives of cooking fuels (where $j = 1, 2, 3$), and that the indirect utility derived from each of the j alternatives is defined by V_{ij}. The indirect utility function is broken down into an observed part, $x_i'\beta_j$ and an unobserved part ε_{ij}, where x_i is a vector of all the variables in Eq. (8). The indirect utility for alternative j for household i can then be expressed as:

$$V_{ij} = x_i'\beta_j + \varepsilon_{ij}. \tag{9}$$

The unobserved part, ε_{ij}, is assumed to be jointly normally distributed with $\varepsilon \sim N[0,\sum]$.The probability that household i chooses the first alternative is now:

$$\begin{aligned}P_{i1} &= pr\left(\varepsilon_{i2} - \varepsilon_{i1} < x_i'\beta_1 - x_i'\beta_2 \quad \text{and} \quad \varepsilon_{i3} - \varepsilon_{i1} < x_i'\beta_1 - x_i'\beta_3\right)\\ &= pr\left[\dot{\varepsilon}_{i,21} < x_i'(\beta_1 - \beta_2) \quad \text{and} \quad \dot{\varepsilon}_{i,31} < x_i'(\beta_1 - \beta_2)\right]\end{aligned} \tag{10}$$

where $\dot{\varepsilon}_{i,21} = \varepsilon_{i2} - \varepsilon_{i1}$ and $\dot{\varepsilon}_{i,31} = \varepsilon_{i3} - \varepsilon_{i1}$. Similar expressions can be obtained for P_{i2} and P_{i3}. It is assumed that ε_{ij} has a joint normal density function defined as $f(\varepsilon_{ij}) = f(\varepsilon_{i1}, \varepsilon_{i2}, \varepsilon_{i3})$, and let y_{ij} denote a discrete choice outcome variable that takes a value 1 if household i chooses fuel j and 0 otherwise. The cumulative probability for the choice of the first alternative fuel by household i can now be expressed as:

$$P_{i1} = \text{pr}[y_i = 1] = \int_{-\infty}^{\dot{V}_{i,12}} \int_{-\infty}^{\dot{V}_{i,13}} f\left(\dot{\varepsilon}_{i,21}, \dot{\varepsilon}_{i,31}\right) d\dot{\varepsilon}_{i,21} d\dot{\varepsilon}_{i,31} \tag{11}$$

where $\dot{V}_{i,12} = x_i'(\beta_1 - \beta_2)$ and $\dot{V}_{i,13} = x_i'(\beta_1 - \beta_3)$, the expression in Eq. (11) is specific to the first fuel. In a more general case, the choice probability for household i choosing alternative j is given by $P_{ij} = pr[y_i = j] = m_j(x_i'\beta_j)$. Where $m_j(x_i'\beta_j)$ takes a similar expression as in Eq. (11). The log likelihood function for a sample of N independent households with J alternatives can then be expressed as:

$$\ell = Ln \ L = \sum_{i=1}^{N} \sum_{j=1}^{J} y_{ij} Ln\left(\hat{P}_{ij}\right) \tag{12}$$

where $\hat{P}_{ij}$ is estimated via a similar expression as in Eq. (11) using simulation methods and substituted into the log likelihood function, which is then maximised to obtain the parametric estimates for the β ' s.

Data

The data set for this paper is the fifth round of the Ghana living standards survey (GLSS 5, 2005/06) conducted in the year 2005/06. The sample consists of 8687 households of which 8262 contain information regarding household energy use. In this paper the analysis is based on the 8262 households as the focus of the paper is on household choice of cooking fuel. The sample frame for the GLSS 5 was defined as the population living within private households in Ghana and was divided into two units, the primary and secondary sampling units. The primary sampling unit was defined as the census enumerated areas (EAs), and the household within each EA constituted the secondary sampling unit. The EAs were first stratified into the ten administrative regions in Ghana, based on proportional allocations using the population in each of the regions as the basis for the allocation. Furthermore, each EA in each region was further subdivided according to rural and urban area of location. In order to achieve a reliable and comprehensive coverage, the Ghana statistical service (GSS) adopted a two-stage stratified random sampling design, where 550 EAs were considered at the first stage of sampling. In the second stage of sampling, 15 households per EA were considered. Combining both stages of sampling resulted in an overall sample size of 8700 households nationwide. In the end, however, 8687 households were successfully interviewed representing a 99.85 % response rate.

Based on the survey design outlined above, in-depth data was collected on the following key variables; household income, consumption, expenditure, education, energy use for cooking, demographic characteristics, and type of housing. The data set therefore contains information on household living characteristics such as education, employment, main fuel for lighting, household location, income, and availability of the various cooking fuels. There is also information on whether the "household head" is a female or a male, age of the household head, size of the household. The education variable has three levels; basic, secondary and tertiary (university education). In addition, there is information on whether the household is located in a rural or urban area and the main source of lighting for the household. The latter can serve as a proxy for the level of access to modern infrastructure, although it may be correlated with household income and fuel expenditure.

The data set also contains information on the main fuel sources used by each of the households. This cover fuels such as crop residue, fuelwood, charcoal, kerosene, liquefied petroleum gas (LPG), and electricity. For each of the fuels, the information in the data set only refers to choice of fuel, not the quantity. Therefore, our analysis is restricted to discrete choices and probabilities related to the choice of these fuels.

The GLSS data set is the main source of information for energy sector reforms in Ghana due to the information it contains. It allows for the identification of the major fuel use among households, the identification of major sources of fuel for the poor and rich households, as well as a comparison across the whole country in order to assess how well the country is doing in its energy reforms. A drawback of the GLSS data is that they do not contain information regarding energy prices, which limits the analysis. Other purposes of energy use in the household are not captured either, and it does not allow for analysis related to fuel stacking (combining different fuels to satisfy household cooking needs), which is a common feature especially among urban households in developing countries. A list of the variables in the data set and their definitions are provided in Table A in the appendix.

In the sample data, fuelwood is the most used cooking fuel in Ghana (57.6%), followed by charcoal (30.0%), LPG (9.3%), crop residue (2.2%), kerosene (0.6%), and electricity (0.3%). The details are presented in Table 1. Irrespective of the various policies implemented over the years to promote a switch from fuelwood use into modern fuels, fuelwood still remains the dominant choice of fuel for cooking. There are many factors that could explain the slow response to government policy targeting switching from fuelwood into modern fuels. According to the energy ladder hypothesis, a major factor for moving up the ladder is that of income and therefore low levels of income could be one of the reasons for fuelwood still being the dominant cooking fuel in Ghana. Other factors include luck of proper education on the health impact and the consequent opportunity cost associated with poor health in the use of fuelwood (especially indoor), the relatively high unit cost of modern fuels and cooking stoves appropriate for the use of modern fuels, and the supply of modern fuels.

Results

The empirical strategy for the study was as follows: I first ran a MNP model to determine the factors that influenced household choice for each of the three groups of fuels; modern, solid and transition fuel. Secondly, I broke down the group of fuels into their respective constituent fuels and analysed the choice process for each of the three main cooking fuels in Ghana (fuelwood, LPG and charcoal) in order to obtain a clear picture of the choice process for these specific fuels.

Factors influencing choice for modern, solid and transition fuels among Ghanaian households

I applied a MNP regression model to determine the factors influencing the choice for modern, solid and transition fuels, controlling for fuel supply (availability of the fuels). The choice of MNP model was due to its ability to relax the IIA (Independence of Irrelevant Alternatives) property. The IIA property states that the relative probabilities of choosing between two alternatives is unaffected by the presence of additional alternatives. Given the data set it was very unlikely that this property would hold. For instance, it was very likely that presence of modern fuel would have an impact on the probability of choosing between solid and transition fuel. The estimated marginal effects are presented in Table 2. Modern fuel in this paper referred to LPG and electricity, solid fuels on the other hand comprised crop residue and fuelwood, whereas transition fuel referred to kerosene and charcoal.[5] In Table 2, I only reported the marginal effects, as the estimated β ' s were difficult to interpret directly (the β ' s are reported in Table B in the Appendix). The results from Table 2 indicated that all the marginal effects were significant, except age of household head, availability of kerosene and charcoal that were not significant in influencing the choice probability for modern fuel at the 5% significance level. Whereas for solid fuel, all the marginal effects were significant except the availability of LPG, while for transition fuel, the results indicated that the availability of kerosene, secondary and tertiary education were the variables that did not significantly influence the choice probabilities. The marginal effects for an explanatory variable could be interpreted as an increase (if sign was positive) or a decrease (if sign was negative) in the adoption probability for a given fuel, for example, the estimated marginal effect for household size was −0.6 for modern fuel. The interpretation of the value (−0.6) is as follows; increases in household size, decreased the adoption probability for modern fuel by 0.6%, implying that a large household was less likely to adopt modern fuel as a cooking fuel in relation to a small household.

The results indicated that income was a significant factor in determining the probability of choosing modern, transition and solid fuels. For instance, income increased the adoption probability for modern fuel by 2.6%, while it decreased the adoption probability for solid and transition fuels by 1.4% and 1.2%, respectively. The implication of this was that, the higher the household income, the more likely it was that it would choose modern fuel in relation to both solid and transition fuels. The choice of modern fuel as the main cooking fuel therefore displayed characteristics of a normal good while that of solid and transition fuel displayed those of an inferior good. The negative income effect for both solid and transition fuel and the positive effect for modern fuel also appeared to validate the energy ladder hypothesis, since at higher income levels, households tended to increase their probability in choosing modern fuels as postulated by the energy ladder hypothesis.

The results also indicated that household characteristics such as household size, male head and age had significant influence on the choice probability for modern, transition and solid fuels. Whereas household size and male head had a negative effect on the choice probabilities for both modern and transition fuels, it had a positive effect in the choice probability for solid fuel. Age of the household head only had significant impact on the probability of choosing both solid and transition fuel, it was positive for solid fuel and negative for transition fuel. In the case of modern fuel, both household size and male head decreased the adoption probability by 0.6% and 1.7%, while they increased the adoption probability for solid fuel by 1.4% and 4.8%, respectively.

The results also showed that education was a significant determinant on the choice of fuel. All the three levels of education had a significant positive effect on the choice probability of modern fuel. The estimated marginal effects on basic, secondary and tertiary levels of education indicated an increase in the choice probability for modern fuel by 5.2%, 11.9% and 15%, respectively. Each of the three levels of education on the other hand had a negative effect on the choice of solid fuel. A household head with a basic level of education decreased the adoption probability for solid fuel by 7.6, while with a tertiary level of education, the adoption probability for solid fuel decreased by 17.8%. The implication of this was that when the head of the household head was educated, the likelihood of choosing modern fuel increased. In the case of transition fuel, only basic education had a significant (positive) effect on the choice probability, implying that a higher level of

Table 1
Main cooking energy sources and their percentages.

Main energy source	Frequency	Percentage
Crop residue/sawdust	185	2.24
Fuelwood	4762	57.64
Charcoal	2477	29.98
Kerosene	49	0.59
LPG (gas)	766	9.27
Electricity	23	0.28
Total	8262	100.00

[5] This classification is based on the energy ladder hypothesis that considers kerosene and charcoal as transition fuels, while crop residue and fuelwood are at the bottom of the ladder. LPG and electricity are at the top of the ladder.

education beyond the basic level had no effect on the adoption probability for transition fuel. In general, education appeared to increase the probability of choosing both modern and transition fuels, but decreased the probability of choosing solid fuel. One possible explanation for this was that, education tended to inform the households about the opportunity cost associated with using solid fuels such as the health cost, storage cost, and cost of time. When the opportunity cost was taken into consideration, the solid fuel was likely to be an expensive alternative compared to modern or transition fuel.

The results as presented in Table 2 also revealed that the availability of the various cooking fuels significantly influenced the choice of cooking fuel. Specifically, both the availability of LPG and fuelwood had a significant impact on the choice of modern fuel. Whereas the availability of LPG increased the choice probability for LPG, the availability of fuelwood on the other hand decreased the probability of choosing LPG. In the case of solid fuel, the availability of kerosene, charcoal and fuelwood had a significant positive, negative and positive effect on the choice probability, respectively. The result also identified the availability of LPG, charcoal and fuelwood to have a significant negative, positive and positive effect, respectively on the choice probability for transition fuel.

Access to modern infrastructure (electricity) was also a significant factor and it decreased the choice probability for solid fuel by 15.1% but increased the choice probability for modern and transition fuels by 6.2% and 8.9%, respectively. The implication of this result was that a well-developed infrastructure that aided the use of modern fuels such as electrification, availability of LPG stations, accessible road network connecting production and delivery points for LPG and the easy accessibility of such infrastructure was likely to promote the use of modern fuels, especially LPG. In summary, the results suggested that for any energy policy in Ghana to be successful, especially policy targeting promoting the use of modern fuels, provision of good education and access to modern infrastructure should be important parts of the policy mix. Besides, the policy mix should also include measures that would lead to reliable supply of modern fuels, especially LPG supply and the affordability of these fuels via poverty reduction measures.

The theoretical model indicated that the relative price of fuel was an important variable in the indirect utility function for the household regarding the choice of fuel, but in the empirical results, this variable was omitted due to lack of data. A potential effect of the omission was the bias it created for the estimated coefficients for the variables included in the model. However, as shown in Wooldridge (2002, pp.470) this bias did not carry over to the marginal effects in probit models, and since my interest was in obtaining the relative (marginal) effects of the explanatory variables, the omitted variable bias did not have serious consequences for my analysis. Furthermore, there was also a concern about near perfect dependence among some of the independent variable, especially between income and the education variable. The collinearity diagnostic test (presented in Appendix, Table D1) however indicated that multicollinerity was not a serious issue, based on the fact that the variance inflation factor (VIF) values for each of the variables was less than 10 (the rule of thumb threshold for possible near perfect collinearity). Moreover the correlation matrix also indicated no sign of serious muliticollinearity issues among the regressors (results of the correlation matrix is also reported in Appendix, Table D2).

Factors influencing the choice of the three main cooking fuels in Ghana

The focus in this section was to get a clear understanding of the factors that influenced the choice of the three main cooking fuels (fuelwood, charcoal and LPG) within the groups that have been analysed so far. The choice of the above three fuels was because they were major fuels in each of three groups of fuels (modern, solid and transition), for instance LPG was the major modern cooking fuel in Ghana, while fuelwood and charcoal were the major solid and transition fuels, respectively. The rational for analysing the individual fuels was to avoid the aggregation problem in order to assess the major fuels in each group. This is because it was

Table 2
Marginal effects for choice of modern, solid and transition cooking fuels in Ghana.

	Modern fuels *Marginal effect*	Solid fuels *Marginal effect*	Transition fuels *Marginal effect*
hhsize	-0.6^{***}	1.4^{***}	-0.7^{***}
	(0.000)	(0.000)	(0.001)
Male head	-1.7^{**}	4.8^{***}	-3.1^{***}
	(0.005)	(0.000)	(0.001)
Age	−0.0	0.2^{***}	-0.2^{***}
	(0.756)	(0.000)	(0.000)
Log income	2.6^{***}	-1.4^{***}	-1.2^{***}
	(0.000)	(0.000)	(0.001)
Basic educ.	5.2^{***}	-7.6^{***}	2.4^{*}
	(0.000)	(0.000)	(0.017)
Secondary educ.	11.9^{***}	-14.4^{***}	2.5
	(0.000)	(0.000)	(0.081)
Tertiary educ.	15.0^{***}	-17.8^{***}	2.8
	(0.000)	(0.000)	(0.221)
Av. of LPG	15.7^{***}	−4.7	-9.9^{***}
	(0.000)	(0.134)	(0.001)
Av. of kerosene	−4.2	6.7^{**}	−2.5
	(0.050)	(0.014)	(0.421)
Av. of Charcoal	−1.9	-25.6^{***}	27.4^{***}
	(0.385)	(0.000)	(0.000)
Av. of Fuelwood	-3.4^{*}	18.0^{***}	14.6^{***}
	(0.016)	(0.000)	(0.000)
Urban	5.7^{***}	-28.0^{***}	22.3^{***}
	(0.000)	(0.000)	(0.000)
Electricity	6.2^{***}	-15.1^{***}	8.9^{***}
	(0.000)	(0.000)	(0.000)
Sample size (N)	8262		
LR Chisq.	3563.6^{***}		
Log likelihood	−4204.3		

Note: The estimates are obtained using MNP regression with kerosene and charcoal as the reference case. Where * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.The marginal effects are multiplied by 100 to convert in to percentages. Av. Stand for availability.

Table 3
Marginal effects for choice of LPG, fuelwood and charcoal in Ghana (MNP).

	LPG *Marginal effect*	Fuelwood *Marginal effect*	Charcoal *Marginal effect*
Hhsize	-0.6^{***}	1.2^{***}	-0.6^{**}
	(0.000)	(0.000)	(0.003)
Male head	-1.9^{**}	3.4^{***}	-3.5^{***}
	(0.001)	(0.000)	(0.000)
Age	−0.0	0.1^{***}	-0.2^{***}
	(0.889)	(0.000)	(0.000)
Log income	2.6^{***}	0.0	-1.3^{***}
	(0.000)	(0.771)	(0.000)
Basic educ.	4.9^{***}	-5.8^{***}	2.8^{**}
	(0.000)	(0.000)	(0.007)
Secondary	11.6^{***}	-15.1^{***}	1.9
	(0.000)	(0.000)	(0.194)
Tertiary educ.	14.6^{***}	-19.2^{***}	1.2
	(0.000)	(0.000)	(0.587)
Av. of LPG	14.2^{***}	-7.7^{*}	-12.1^{***}
	(0.000)	(0.025)	(0.000)
Av. of kerosene	−4.7	10.0^{**}	−4.4
	(0.026)	(0.001)	(0.172)
Av. of charcoal	−2.2	-29.5^{***}	27.4^{***}
	(0.301)	(0.000)	(0.000)
Av. of Fuelwood	−2.1	20.5^{***}	-13.6^{***}
	(0.117)	(0.000)	(0.000)
Urban	5.8^{***}	-29.0^{***}	22.5^{***}
	(0.000)	(0.000)	(0.000)
Electricity	6.1^{***}	-14.3^{***}	9.2^{***}
	(0.000)	(0.000)	(0.000)
Sample size (N)	8262		
LR Chisq.	3615.4^{***}		
Log-likelihood	−5238.2		

Note: *p*-values are in parentheses where * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, Av. denote availability.

likely that, irrespective of the fact that each of the fuels in a particular group shared common characteristics, households did not necessarily view them as the same, and might therefore prefer one fuel in the same group over the other, for instance LPG over electricity, or vice versa.

The estimated result for the three main cooking fuels is in Table 3 while the estimated β ' s are reported in Table C in the Appendix, where other fuels (electricity, kerosene and crop residue) is used as the reference fuel for the MNP estimation. The marginal effects showed that household size and male head had a significant negative influence on the adoption probability for LPG. Income and education, on the other hand, had a positive effect on the probability of choosing LPG. Households located in urban areas were more likely to choose LPG as the main cooking fuel than those located in rural areas. A possible explanation for the positive urban effect was that, the opportunity cost of using fuelwood was very high due to the lack of cheaply available fuelwood in urban areas and lack of space for storing fuelwood.

Consistent with previous studies, the results indicated that households with access to modern infrastructure had a higher choice probability for LPG as the main cooking fuel than households without access. The same results were found in Barnes et al. (2005) and Heltberg (2004, 2005). The results also indicated that the availability of LPG significantly increased the probability of choosing LPG, similar to the results in Gupta and Köhlin (2006), while the availability of kerosene significantly reduced the choice of LPG as a cooking fuel. With regard to the availability of both charcoal and fuelwood, I found no significant influence of these two on the choice of LPG.

In the case of fuelwood, the results revealed that the availability of each of the fuels (charcoal, fuelwood, kerosene and LPG) had a significant impact on the probability of choosing fuelwood. As expected, the availability of fuelwood increased the probability of choosing fuelwood, and this was also true for the availability of kerosene. On the other hand, the availability of both LPG and charcoal decreased the choice probability for fuelwood by 7.7% and 29.5%, respectively. Head of the household with education, urban location and access to infrastructure decreased the likelihood of using fuelwood for cooking. The reason for the negative impact of access to modern infrastructure on the choice of fuelwood was not very clear. Heltberg (2004) found similar result and suggested that, it could be because having electricity provided the basic infrastructure for easy adoption of modern fuels such as LPG, and therefore influenced the choice of cooking fuel away from traditional fuels such as fuelwood. Income did not have a significant impact on the choice probability for fuelwood, contrary to my a priori expectation.

Furthermore, the results showed that the availability of each of the fuels had a significant impact on the probability of choosing charcoal, except that of kerosene. Whereas age, male head and income decreased the adoption probability for charcoal by 0.2%, 3.5% and 1.3%, respectively, they increased the choice probability in the case of fuelwood, except income that was insignificant. Unlike the case of fuelwood and LPG, where each of the three levels of education had a significant effect on the choice probabilities, in the case of charcoal only basic education had a significant effect. Whereas household head with basic education increased the probability of using charcoal by 2.8% as the main cooking fuel, those with either secondary or tertiary levels of education had no significant effect. An interesting finding was that, whereas a male head of household reduced the choice probability for both LPG and charcoal, it increased the probability of choosing fuelwood. This was because in most Ghanaian households, women did most of the cooking, and hence most of the burden in collecting and the use of fuelwood fell on the woman. This simply meant that the male head preferred the cheaper fuel, fuelwood, since his opportunity cost for using fuelwood was low.

Conclusion

In this paper, I have analysed the factors responsible for the choice of modern, transition, and solid cooking fuels in Ghanaian households. I also broke down the fuel groups into their respective constituents and analysed the factors influencing the choice of each of the main cooking fuels (fuelwood, LPG and charcoal). The results from the study identified household characteristics in addition to the availability of the various fuels as significant factors that influenced the choice probabilities for modern, transition and solid fuels. In the case of modern fuels, the results showed that education, availability of LPG, access to modern infrastructure, household location, and income were the key factors that influenced the choice of this fuel. Whereas in the case of solid fuel, the results identified household location, education, access to modern infrastructure, male head, and availability of kerosene, fuelwood, and charcoal, as the key factors influencing the choice of solid fuel for cooking.

The results therefore supported policies that could increase the supply of modern fuels such as LPG, to promote the use of such clean fuels in Ghana. It would be important to emphasise that increasing the supply of modern fuels alone would not be enough to encourage households (especially poor households) to increase their use of modern fuels. Supply of these fuels would have to be complimented with efforts in educating households on the opportunity cost associated with using fuelwood, for example the dangers of using dirty fuels. Maybe more importantly, the monetary cost associated with the use of modern fuels must reduce significantly. The costs included not only the price of the fuels, but also the capital cost of stoves that were needed for modern fuels, as well as the cost of handling and storing the fuels. Finally, the results also identified household location and access to modern infrastructure as important factors determining the choice of cooking fuel, in the sense that households in urban areas with access to modern fuels tended to choose modern fuels, such as LPG, over traditional fuels. This does not imply a complete switch from traditional fuels to modern fuels but rather modern fuels become the dominant energy source for daily cooking needs, while traditional fuels such as fuelwood could still be used less frequently for particular services (such as for baking and cooking traditional staple food). The implication of this is that, policy targeting increasing access to modern fuels, for instance increasing the availability of modern fuels, provision of infrastructure that allow easy access to modern fuels, reduction in the cost of using and storing modern fuels should rather focus more on urban dwellers as it is this group that the response to this type of policy is likely to have a lager effect. While at the rural areas, the policy goal should rather target increasing the efficiency in the use of traditional fuels, for instance, efficient cooking stoves and well processing of fuelwood that allow efficient burning with less smoke and also education on the health effects of indoor smoke and the need to have good ventilation in cooking areas(kitchen). The policy should also include tree planting program to ensure sustainability of fuelwood as a cooking fuel for rural dwellers as the transition process for people in the rural areas towards modern fuels is likely to be very slow.

The result should however be interpreted with some caution, as there may have been other important variables that we could not control for in this study. For example, differences in relative fuel prices, unit cost of cooking equipment, and awareness about health effects varied between households (which the education variable may not adequately capture). These and other factors could shed further light on the key factors influencing choice of fuel. For future work, it would be important to investigate these factors further in a panel framework, and furthermore, it would be interesting to investigate the factors that influence a switch between fuels by households. This would obviously be a significant contribution to this topic on Ghana.

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Appendix

Table A
List of variables and definitions.

Variables	Type of variable
Sex of household head	Dummy (Male = 1, Female = 0)
Age of household head	Continuous
Log annual household income	Continuous
Household size (HHS)	Continuous
Basic education	Dummy (Basic = 1,No formal education = 0)
Secondary education	Dummy (Secondary = 1,No formal education = 0)
Tertiary education	Dummy (Tertiary = 1,No formal education = 0)
Urban location	Dummy (urban = 1, rural = 0)
Electricity as the main lightening	Dummy (electricity = 1, Others = 0)
Charcoal	Dummy (charcoal = 1, Others = 0)
Fuelwood	Dummy (fuelwood = 1,others = 0)
LPG	Dummy (lpg = 1, others = 0)
Modern fuel	Dummy (LPG or electricity = 1, others = 0)
Transition fuel	Dummy (Kerosene or Charcoal = 1, others = 0)
Solid fuel	Dummy (Crop residue or fuelwood = 1, others = 0)
Availability of LPG	Dummy (yes = 1, no = 0)
Availability of kerosene	Dummy (yes = 1, no = 0)
Availability of charcoal	Dummy (yes = 1, no = 0)
Availability of fuelwood	Dummy (yes = 1, no = 0)

Table B
Estimated β ' s for modern and solid fuels from multinomial probit model.

Variables	Solid β ' s	*P*-value	Modern fuel β ' s	*P*-value
hhsize	0.0885^{***}	(0.000)	-0.0604^{**}	(0.003)
Male head	0.318^{***}	(0.000)	-0.146	(0.077)
Age	0.0113^{***}	(0.000)	0.002	(0.472)
Log income	-0.0533^{*}	(0.020)	0.340^{***}	(0.000)
Basic education	-0.462^{***}	(0.000)	0.578^{***}	(0.000)
Secondary educ.	-0.840^{***}	(0.000)	1.393^{***}	(0.000)
Tertiary education	-1.028^{***}	(0.000)	1.757^{***}	(0.000)
Av. of LPG	-0.0746	(0.739)	1.951^{***}	(0.000)
Av. of kerosene	0.416^{*}	(0.034)	-0.464	(0.113)
Av. of charcoal	-1.904^{***}	(0.000)	-0.723^{*}	(0.013)
Av. of fuelwood	1.254^{***}	(0.000)	-0.141	(0.452)
Urban	-1.946^{***}	(0.000)	0.288^{**}	(0.005)
Electric	-0.990^{***}	(0.000)	0.589^{***}	(0.000)
Intercept	1.900^{***}	(0.000)	-7.600^{***}	(0.000)
Sample size (N)	8262			

Table C
Estimated β ' s for LPG, Fuelwood and Charcoal from multinomial probit model.

Variables	LPG β ' s	*P*-value	Fuelwood β ' s	*P*-value	Charcoal β ' s	*P*-value
hhsize	-0.118^{***}	(0.000)	0.0197	(0.255)	-0.0552^{**}	(0.004)
Male head	-0.729^{***}	(0.000)	-0.272^{**}	(0.005)	-0.566^{***}	(0.000)
Age	-0.008^{*}	(0.013)	-0.001	(0.660)	-0.011^{***}	(0.000)
Log income	0.584^{***}	(0.000)	0.243^{***}	(0.000)	0.250^{***}	(0.000)
Basic educ.	1.158^{***}	(0.000)	0.215^{*}	(0.044)	0.614^{***}	(0.000)
Secondary edu	1.458^{***}	(0.000)	-0.671^{***}	(0.000)	0.0848	(0.567)
Tertiary educ.	1.587^{***}	(0.000)	-1.081^{***}	(0.000)	-0.175	(0.424)
Av. of LPG	0.768^{**}	(0.003)	-1.211^{***}	(0.000)	-1.206^{***}	(0.000)
Av. of kerosene	-0.664	(0.075)	0.396	(0.137)	-0.172	(0.547)
Av. of charcoal	-0.343	(0.370)	-1.464^{***}	(0.000)	0.446	(0.148)
Av. of fuelwood	0.168	(0.510)	1.343^{***}	(0.000)	0.171	(0.410)
Urban	1.356^{***}	(0.000)	-0.802^{***}	(0.000)	1.084^{***}	(0.000)
Electric	1.355^{***}	(0.000)	-0.141	(0.153)	0.791^{***}	(0.000)
Intercept	-9.853^{***}	(0.000)	-1.212^{*}	(0.012)	-2.388^{***}	(0.000)
Sample size (N)	8262					

Table D1
Collinearity diagnostics.

Variable	VIF	Tolerance
hhsize	1.56	0.6411
Male head	1.16	0.8643
Age	1.09	0.9173
Log income	1.24	0.8035
Basic educ.	1.29	0.7766
Secondary edu	1.32	0.7585
Tertiary educ.	1.16	0.8586
Av. of LPG	1.28	0.7830
Av. of kerosene	5.27	0.1897
Av. of charcoal	5.66	0.1768
Av. of fuelwood	2.53	0.3947
Urban	1.56	0.6429
Electric	1.58	0.6341
Total (mean)	2.05	

Table D2
Correlation matrix.

e(V)	hhsize	Malehead	Age	Lincome	Basic	Second	Tertiary	LPG	Kerosene	Charcoal	Fuelwood	Urban	Electric
hhsize	1.000												
Malehead	−0.212	1.000											
Agehead	−0.122	0.115	1.000										
Lincome	−0.228	−0.067	0.004	1.000									
Basic	0.098	−0.166	0.148	−0.122	1.000								
Second	0.085	−0.149	0.120	−0.137	0.362	1.000							
Tertiary	0.071	−0.120	0.004	−0.190	0.249	0.223	1.000						
LPG	0.000	0.008	0.046	−0.008	−0.010	−0.093	−0.071	1.000					
Kerosup	0.208	−0.028	−0.052	−0.005	0.006	0.002	0.014	−0.102	1.000				
Charsup	0.008	0.018	0.061	0.045	−0.019	0.006	0.001	−0.158	−0.693	1.000			
Fuelwood	0.033	−0.004	−0.050	−0.003	0.019	−0.005	−0.010	0.132	−0.200	−0.359	1.000		
Urban	0.075	0.094	−0.007	−0.068	−0.105	−0.163	−0.090	−0.048	0.029	−0.091	0.096	1.000	
Electric	0.038	0.086	0.001	−0.117	−0.186	−0.172	−0.132	−0.050	0.048	−0.045	0.022	−0.428	1.000

Note: Lincome, LPG, kerosene, charcoal and fuelwood represent log income, availability of LPG, kerosene, charcoal and fuelwood, respectively, while basic, second and tertiary denotes basic, secondary and tertiary education levels, respectively.

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